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FOR

1897.

(INCORPORATED 1881.)

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ERRATA.

Page 116, line 6, for "side," read "*sides*,"
„ 141, line 7, for "vigorous," read "*rigorous*."
„ 158, line 19, for "Dilbi's," read "*Dilbis*."
„ 170, line 28, for "Murri," read "*Bya*."
„ 176, line 11, for "atfached," read "attached."
„ 212, Fig. 17, the right-hand guy from the top of the nearest pole is not shown in the zincotype.
Abstract of Proceedings—Page xxix., line 2, for "and" read "*on*."

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1891	P 1	Grimshaw, James Walter, M. Inst. C.E., M. I. Mech. E., &c., Australian Club, Sydney.
1892		Gundlach, Louis Richard, A.M.I.C.E., Whistler-street, Manly.
1877		Gurney, T. T., M.A. *Cantab.*, Professor of Mathematics, Sydney University, p. r. 'Barham,' Forbes-street, Darlinghurst.
1891	P 1	Guthrie, Frederick B., F.C.S., Department of Agriculture, Sydney; p. r. 'Westella,' Wonga-street, Burwood.
1897		Gould, Hon. Albert John, M.L.A., Minister of Justice, Sydney.
1880		Halligan, Gerald H., C.E., 'Riversleigh, Hunter's Hill.
1892		Halloran, Henry Ferdinand, L.S., Scott's Chambers, 94 Pitt-st.
1887	P 5	Hamlet, William M., F.C.S., F.I.C., Member of the Society of Public Analysts; Government Analyst, Box 16, P.O. George-street, North.
1882		Hankins, George Thomas, M.R.C.S. *Eng.*, 'St. Ronans,' Allison Road, Randwick.
1891		Hanly, Charles, L.S., Resident Engineer, Roads and Bridges Office, Crookwell.
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.
1877	P 15	‡Hargrave, Lawrence, J.P., Stanwell Park, Clifton.
1884		Haswell, William Aitcheson, M.A., D. Sc., F.R.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r. St. Vigeans, Darling Point.
1896		Hay, Alexander, Coolangatta, N.S.W. and Australian Club.
1890		Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, M. Inst. C.E. Assoc. M. Can. Soc. C.E., Assoc. M. Am. Soc. C.E., M.M. & C.E., L.S., 'Fontenoy,' Ocean-street, Woollahra.
1876		Heaton, J. Henniker, M.P., St. Stephen's Club, Westminster, London.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1893		Henderson, John, C.E.
1884		Henson, Joshua B., C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1891		Hickson, Robert, M. Inst. C.E., Under Secretary, Public Works Department, p.r. 'The Pines,' Bondi.
1876	P 2	Hirst, George D., 377 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, Elizabeth-st. Ashfield.

Elected		
1891		Hood, Alexander Jarvie, M.B., Mast. Surg. *Glas.*, 219 Macquarie-street, City.
1892		Hodgson, Charles George, 157 Macquarie-street.
1891	P 1	Houghton, Thos. Harry, M.I.C.E., M.I.M.E., 12 Spring-street.
1879		Houison, Andrew, B.A., M.B., C.M. *Edin.*, 47 Phillip-street.
1891	P 1	How, William F., M. Inst. C.E., M. I. Mech. E., Wh. Sc., Mutual Life Buildings, George-street.
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., F. R. Met. Soc., Second Meteorological Assistant, Sydney Observatory.
1891		Hutchinson, William, M. inst. C.E., Supervising Engineer, Railway Construction Branch, Public Works Department, Bogan Gate.
1891		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 157 Liverpool-street, Hyde Park.
1884		Jenkins, Edward Johnstone, M.A., M.D. *Oxon.*, M.R.C.P., M.R.C.S. L.S.A. *Lond.*, 213 Macquarie-street, North.
1879		Johnson, James W., Norwich Chambers, Hunter-street.
1887		Jones, George Mander, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 'Viwa,' Burlington Road, Homebush.
1874		Jones, James, 'Miltonia,' Randwick.
1879		Jones, John Trevor, C.E., 'Tremayne,' North Shore.
1884		Jones, Llewellyn Charles Russell, M.L.A., Solicitor, Sydney Chambers, 130 Pitt-street.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park, p.r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Caer Idris,' Ashfield.
1875	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.
1883		Kater, The Hon. H. E., M.L.C., 'Cheverells,' Elizabeth Bay Rd.
1873		Keele, Thomas William, M. Inst. C.E., District Engineer, Harbours and Rivers Department, Ballina, Richmond River.
1877		Keep, John, Broughton Hall, Leichhardt.
1884		Kendall, Theodore M., B.A., L.R.C.P., L.R.C.S. *Lond.*, L.M., 28 College-street, Hyde Park.
1894		Kelly, Walter MacDonnell, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 265 Elizabeth-street.
1887		Kent, Harry C., Bell's Chambers, 129 Pitt-street.
1892	P 2	Kiddle, Hugh Charles, F. R. Met. Soc., Public School, Seven Oaks, Smithtown, Macleay River.
1891		King, Christopher Watkins, A.M.I.C.E., L.S., Roads and Bridges Branch, Public Works Department, Sydney.
1874		King, The Hon. Philip G., M.L.C., 'Banksia,' William-street, Double Bay.
1896		King, Kelso, 'Glenhurst,' Darling Point.
1892		Kirkcaldie, David, Commissioner, New South Wales Government Railways, Sydney.

Elected		
1878		Knaggs, Samuel T., M.D., *Aberdeen*, F.R.C.S. *Irel.*, 5 Lyons' Terrace, Hyde Park.
1881	P 7	Knibbs, G. H., F.R.A.S., Lecturer in Surveying, University of Sydney ; p.r. 'Avoca House,' Denison Road, Petersham. *Hon Secretary.*
1877		Knox, Edward W., J.P., 'Fiona,' Bellevue Hill, Double Bay.
1875		Knox, The Hon. Edward, M.L.C., O'Connell-street.
1877		Kopsch, G., 'Saxonia,' Boulevard, Petersham.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral.
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1872	P 46	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F.R.S.; Assoc. Roy. Sch. Mines *Lond.*; F.C.S., F.G.S. F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.*; Mem. Phy. Soc. *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France*; Cor. Mem. Edin. Geol. Soc.; Roy. Soc. *Tas.*; Roy. Soc. *Queensland*; Senckenberg Institute, *Frankfurt*; Society d' Acclimat. *Mauritius*; Hon. Mem. Roy. Soc. *Vict.*; N. Z. Institute; K. Leop. Carol. Acad. *Halle a/s*; Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point.
1881		Lloyd, Lancelot T., 'Eurotah,' William-street, East.
1890	P 2	Loir, Adrien.
1887		Long, Alfred Parry, Registrar General, Elizabeth-street.
1878		Low, Hamilton, 32 Cavendish-street, Petersham.
1897		Low, John S., Business Manager, The United Australian Exploration, Ltd., Equitable Buildings, George-street.
1887		MacAllister, John F., M.B., B.S. *Melb.*, 'Ewhurst,' Stanmore Road, Stanmore.
1892		MacCarthy, Charles W., M.D., F.R.C.S. *Irel.*, 223 Elizabeth-street, Hyde Park.
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1874		M'Cutcheon, John Warner, Assayer to the Sydney Branch of the Royal Mint.
1892		McDonagh, John M., B.A., M.D., M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street, North.
1897		MacDonald, C. A., C.E., 63 Pitt-street.
1878		MacDonald, Ebenezer, 'Kamilaroi,' Darling Point.
1886		MacDonald, John A., M. Inst. C.E., M. Inst. M.E., M. Am. Soc. C.E.
1868		MacDonnell, William J., F.R.A.S., c/o Mr. W. C. Goddard, Norwich Chambers, Hunter-street.
1877		MacDonnell, Samuel, Union Bank Chambers, 68½ Pitt-street.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Hospital for Insane, Gladesville.
1891		McKay, Robert Thomas, L.S.

Elected		
1893		McKay, William J. Stewart, B. Sc., M.B., Ch. M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. Charles Kinnaird, M.L.C., M.B., C.M. *Glas.*, 183 Liverpool-street, Hyde Park.
1872		Mackenzie, John, F.G.S., Athenæum Club, Sydney.
1876		Mackenzie, Rev. P. F., The Manse, Johnston-st., Annandale.
1880	P 5	M'Kinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst. C.E., Chief Engineer for Water Conservation, Athenæum Club, Castlereagh-street.
1876		MacLaurin, The Hon. Henry Norman, M.L.C., M.A., M.D. *Edin.*, L.R.C.S. *Edin.*, LL.D. Univ. *St. Andrews*, 155 Macquarie-st.
1894		McMillan, William, M.L.A., 'St. Kilda,' Allison-st., Randwick.
1882	P 1	Madsen, Hans. F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 6	Maiden, Joseph H., F.L.S., Director, Botanic Gardens, Sydney. *Hon. Secretary.*
1878		Maitland, Duncan Mearns, District Surveyor, Armidale.
1873		Makin, G. E., Market Square, Berrima.
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1877		Mann, John F., 'Kerepunu,' Neutral Bay.
1879		Manning, Frederic Norton, M.D. Univ. *St. And.*, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Hunter's Hill.
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1897		Marden, John, B.A., M.A., LL.B. Univ. *Melb.*, LL.D. Univ. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1879		Matthews, Robert Chr., Sheridan-street, Gundagai.
1875	P 5	Mathews, Robert Hamilton, L.S., Cor. Mem. Anthrop. Inst. Gt. Brit. and Irel.; Cor. Mem. Roy. Geogr. Soc. Aust, Queensland, 'Carcuron,' Hassall-street, Parramatta.
1888		Megginson, A. M., M.B., C.M. *Edin.*, 159 Liverpool-street.
1896	P 3	Merfield, Charles J., F.R.A.S., Railway Construction Branch, Public Works Department, p.r. 'Rose Moor,' Arthur-st., Marrickville.
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, Hospital for Insane, Newcastle.
1873		Milford, F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 3 Clarendon Terrace, 295 Elizabeth-street.
1882		Milson, James, 'Elamang,' North Shore.
1889	P 3	Mingaye, John C. H., F.C.S., M.A.I.M.E., Assayer and Analyst to the Department of Mines, Sydney.
1892		Mollison, James Smith, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Department of Public Works, Sydney.
1856	P 7	Moore, Charles, F.L.S., Australian Club, p.r. 4 Queen-street, Woollahra. *Vice-President.*
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1877	P 1	Morris, William, Fel. Fac. Phys. and Surg. *Glas.*, F.R.M.S. *Lond.*, 5 Bligh-street.
1882		Moss, Sydney, 'Kaloola,' Kiribilli Point, North Shore.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1888		Mullins, George Lane, M.A., M.D. Trin. Coll. *Dub.*, M.D. *Syd.*, F.R.M.S. *Lond.*, No. 293 Elizabeth-street.
1887		Munro, William John, M.B., C.M. *Edin.*, M.R.C.S. *Eng.*, 112 Glebe Road, Glebe.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.

JOURNAL AND PROCEEDIGNS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE OPINIONS EXPRESSED THEREIN

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ANNIVERSARY ADDRESS.

By J. H. MAIDEN, F.L.S.,

Government Botanist and Director of the Botanic Gardens, Sydney.

[*Delivered to the Royal Society of N. S. Wales, May 5, 1897.*]

IN delivering before you the Presidential Address, on the Seventy-sixth Anniversary of our Society, I propose to arrange what I have to say under three heads, and I set out these heads, and their sub-heads, in the following manner :—

Part I. HISTORY OF THE SOCIETY DURING THE PAST YEAR :—

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Part I.—History of the Society during the past year.—1. Roll of Members—The number of members on the roll on the 30th of April, 1896, was four hundred and nine. Thirty new members were elected, but the Society lost by death seven members and by resignation twelve, leaving the total number on the roll on the 30th April, 1897, four hundred and twenty.

2. Obituary.—The following is a list of the members who have died since the last Annual Meeting :—

Honorary Member :

Mueller, Baron Ferdinand von K.C.M.G., M.D., F.R.S., elected 1875.

Ordinary Members :

Chambers, Dr. Thomas ; elected 1882.
Eldred, Capt. W. H. ; elected 1876.
Garvan, J. P., M.L.A.; elected 1877.
Gill, Rev. W. Wyatt, B.A., LL.D. ; elected 1884.
Nicholls, W. H.; elected 1895.
Sahl, Carl L.; elected 1875.
Styles, G. M. ; elected 1883.

I propose to make allusion to the life-work of Baron von Mueller under Part III. of my address.

Dr. THOMAS CHAMBERS was sixty-seven years old at the time of his death, which took place on the 24th August. He was a native of Yorkshire, and in the year 1858 became a Member of the Royal College of Surgeons, England; in 1867 a Fellow of the Royal College of Surgeons, Edinburgh, and in 1875 a Fellow of the Royal College of Physicians, Edinburgh. He became Senior Physician in the Chelsea Hospital for Women, as he took a great interest in, and during his whole life made a study of, the diseases of women. In 1882 Dr. Chambers was compelled by ill-health to relinquish an extensive London practice and seek the more congenial climate of New South Wales, and in his adopted country lived a highly useful and successful life. For some years he was lecturer on midwifery and the diseases of women at the Sydney University; and he was recognised as one of the greatest gynæcological authorities in Australasia. He was an Hon. Physician of Prince Alfred Hospital, and in 1892 was Hon. Treasurer of of the Intercolonial Medical Congress held in Sydney. The deceased gentleman had also occupied the position of President of the New South Wales Branch of the British Medical Association, a society in which he always showed considerable interest.

The death of Captain WILLIAM HENRY ELDRED, occurred on the 17th January. He was in his seventy-eighth year, and had ably fulfilled the duties incumbent upon him as Consul-General for Chili, though of late he had not figured very prominently in public. A genial and hospitable man, he will be chiefly remembered amongst us for the interest he took in acclimatisation matters, particularly referring to plants, spending much time and energy in the reciprocal introduction of plants of Chili and New South Wales.

By the death of J. P. GARVAN on the 25th November, the Colony has lost a good man and a distinguished citizen. Mr. Garvan was born at Cappa, County Limerick, on 2nd May, 1843, and while still a child was brought to Australia. He was educated

at the Sydney Grammar School, and received systematic legal training, although he never became a solicitor. He had considerable experience in the management of mining companies, and his organising ability was also shown in the City Mutual Fire Insurance Company, the Citizens' Life Assurance Company, and other institutions founded and managed by him. He was a member of Parliament for many years and a Treasurer of the Colony.

Of recent years no member more regularly attended our monthly meetings than did the Rev. W. WYATT GILL, B.A., LL.D., a man of much charm of manner, and one whose depth of knowledge was only equalled by his willingness to impart it. He was one of the pioneer missionaries of the London Missionary Society in the South Seas, and died on the 11th November last. His experience of the South Sea mission field extended over about half a century, and his LL.D. degree was conferred in recognition of his work of seeing through the press a translation of the Bible in the Rarotongan language. Rarotonga was for many years the field of his missionary labours, and Dr. Gill's knowledge of the dialect was singularly accurate and ample. He was the author of several books on folk lore in the South Seas, and a contributor of numerous papers on ethnology and kindred subjects to many scientific and literary institutions. These led him into communion with several eminent students on the subject of ethnology, notably Professor Max Müller. For several years Dr. Gill was associated with Dr. Chalmers in New Guinea, which was the last scene of his missionary labours. His long experience of the natives of the South Seas led him to be regarded as one of the highest authorities upon the languages, customs, and history of those peoples, and his contributions in this respect to the subject of ethnology are considered to be of unique value, in so far as they have rescued from oblivion what might otherwise have been now quite irrecoverable. Mr. C. Silvester Horne, in his story of the London Missionary Society, tells of Mr. Gill landing at Savage Island in 1846, after several futile attempts had been made by other missionaries, and inducing the natives to promise protection to a Samoan

teacher. "Dr. Gill can claim," writes Mr. Horne, elsewhere, "to have taken out to the Pacific the first complete Bible issued by the Bible Society. He himself was responsible for a revised reference Bible for Rarotonga." Dr. Gill's "Myths and Songs from the South Pacific" has especially had a very wide circulation.

I have also to chronicle the death of another old member, Herr CARL LUDWIG SAHL, German Consul for New South Wales, who died in March last. Herr Sahl was an old resident of Sydney, having arrived here twenty-five years ago. He left Germany at the age of thirteen, and was for some years a resident of Fiji, where he owned considerable property, and he acquired an interest in some plantations on the islands. He was senior partner in the firm of Rabone, Feez, & Co., general merchants, having risen from the position of clerk in the firm's employ. He was one of the oldest members of the German Club, Phillip-street, and last year was elected president. Twelve months ago he was decorated by the German Government with the order of the Red Eagle, a decoration awarded for distinction in the Civil Service. Herr Sahl was well known and highly esteemed by his countrymen in Sydney and by a wide circle of English acquaintances as a cultured and courteous gentleman.

3. PAPERS READ IN 1896.—During the past year the Society held eight meetings at which the average attendance of members was thirty-six, and of visitors 4·5. The following papers were read:

1. President's Address, by Prof. T. W. Edgeworth David, B.A., F.G.S.
2. On periodicity of good and bad seasons, by H. C. Russell, B.A., C.M.G., F.R.S.
3. The 'Mika' or 'Kulpi' operation of the Australian Aboriginals by Prof. T. P. Anderson Stuart, M.D.
4. Note on the absorption of water by the gluten of different wheats, by F. B. Guthrie, F.C.S.
5. On Aromadendrin or Aromadendric acid from the turbid group of eucalyptus kinos, by H. G. Smith, F.C.S.
6. On the cellular kite, by Lawrence Hargrave.

7. Note on a method of separating colloids from crystalloids by filtration, by C. J. Martin, D.Sc., M.B.
8. An explanation of the marked difference in the effects produced by subcutaneous and intravenous injection of the venom of Australian snakes, by C. J. Martin, D.Sc., M.B.
9. On the occurrence of a submerged forest, with remains of the Dugong, at Shea's Creek near Sydney, by R. Etheridge, Junr., Professor T. W. Edgeworth David, B.A., F.G.S., and J. W. Grimshaw, M. Inst. C.E.
10. Note on recent determinations of the viscosity of water by the efflux method, by G. H. Knibbs, F.R.A.S., L.S.
11. On the constituents of the 'Silky Oak,' *Grevillea robusta*, R.Br., and the presence of butyric acid therein, by Henry G. Smith, F.C.S.
12. Current Papers, No. 2, by H. C. Russell, B.A., C.M.G., F.R.S.
13. Additional remarks concerning Aboriginal Bora held at Gundabloui in 1894, by R. H. Mathews, L.S.
14. On the occurrence of precious stones in New South Wales and the deposits in which they are found, by Rev. J. Milne Curran.
15. Sill structure and fossils in eruptive rocks in New South Wales, by Professor T. W. Edgeworth David, B.A., F.G.S.
16. On the presence of a true manna on a 'Blue Grass,' *Andropogon annulatus*, Forsk., by R. T. Baker, F.L.S., and Henry G. Smith, F.C.S.
17. The rigorous theory of the determination of the meridian line by altazimuth solar observations, by G. H. Knibbs, F.R.A.S., L.S.
18. The notable hailstorm of 17 November, 1896, in parts of parish of Gordon, by E. Du Faur, F.R.G.S.

4. Sectional Meetings.—The *Engineering Section* held eight meetings at which the following papers were read and discussed :—

1. Annual Address to the Engineering Section, by Professor W. H. Warren, Wh. Sc., M. Inst. C.E.
2. The machinery employed for artificial refrigeration and ice making, by Norman Selfe, M. Inst. C.E., M.I.M.E., &c.

3. Water conservation surveys of New South Wales, by H. G. McKinney, M. Inst. C.E.
4. Lift Bridge over the Murray at Swan Hill, by Percy Allan, Assoc. M. Inst. C.E., Assoc. M. Am. Soc. C.E.
5. Centrifugal pump dredging in New South Wales, by A. B. Portus, Assoc. M. Inst. C.E.
6. The present position of the theory of the steam engine, by S. H. Barraclough, B.E., M.M.E.

The average attendance of members and visitors was twenty-three.

The *Medical Section* held a special general meeting in the Physics Lecture Room of the University of Sydney (by kind permission of the Senate) when Prof. Threlfall, M.A., gave a lecture-demonstration upon "The 'x' rays of Röntgen and their practical application."

Three ordinary bi-monthly meetings were also held in the Society's Hall, when the following papers were read :—

1. Some experiences of Skull and Head injuries with their results during a lengthy practice in Sydney, by Dr. F. Milford.
2. Human Fallibility and its relation to accidents on Railway and by Sea, by Dr. S. T. Knaggs.
3. Osteitis Deformans, by Dr. S. Jamieson.
4. Cardiac Thrombosis, by Drs. C. J. Martin and G. E. Rennie.

5. Reception —A 'Reception' to the members of the Society was held at the Society's House on the 18th June, 1896, at 8 p.m., as a house-warming on the occasion of the Society taking possession of its recently enlarged and newly decorated premises. About three hundred guests were present, including the Honorary President, His Excellency the Governor, Lady Hampden, the Hon. Dorothy Brand and Capt. Ferguson, A.D.C., the Minister for Lands, and the Minister for Justice.

6. Financial Position.—From perusal of the Hon. Treasurer's Financial Statement, it will be seen that the Society has paid its way and has carried forward a balance of £14 6s. 11d.

7. Society's Premises.—All expenses in connection with the purchase of fourteen feet of land, the extension of and alterations to the Society's premises, together with the necessary furniture and fittings have been met, but this has necessitated a loan on mortgage of £1,400 at 4½%, and a further loan of £376 7s. 9d. from the Clarke Memorial Fund bearing interest at the current Savings Bank rates.

It may interest members to learn the extent and arrangement of the accommodation which has been secured to us by the much needed alterations in the Society's premises to which allusion has been made. *Basement:* Large room for meetings 40′ × 23′ 6″, book room 15′ 5″ × 23′ 6″, pamphlet room 15′ × 23′ 5″, lavatory 15′ 9″ × 12′ 7″, vestibule 26′ 6″ × 12′ 7″, yard (including latrines, &c.) 34′ 9″ × 13′ 5″. *Ground Floor:* Large hall 53′ 6″ + gallery 8′ = 61′ 6″ × 24′ 9″, library and reading room 15′ 3″ × 24′ 10″, hat and cloak room 7′ 10″ × 17′, office 18′ 4″ × 13′. *First Floor:* Council room 24′ 10″ × 15′ 7″, book room 18′ 4″ × 13′. *Second Floor:* Housekeeper's quarters.

8. Library.—The amount expended upon the Library during the past year was £235 15s. 4d. viz.: for books and periodicals £199 16s. 4d. for binding £86 15s. 5d., and for new cedar book-case &c., £35 19s.

9. Exchanges.—Last year we exchanged our Journal with four hundred kindred societies, receiving in return three hundred and seventy-three volumes, one thousand four hundred and five parts, fifty-nine reports, one hundred and eighty-two pamphlets, seventeen hydrographic charts, thirty-eight meteorological charts, and two engravings, a total of two thousand and seventy-six publications. The following Institutions have been added to the exchange list :—Institution of Surveyors New South Wales, Sydney ; Royal Academy of Belles Lettres, History, and Antiquities, Stockholm.

10. Original Researches.—In response to the offer of the Society's Medal and a grant of £25 for the best original paper on the following subjects :—

Series XV.—*To be sent in not later than 1st May, 1896.*

No. 49—On the origin of Multiple Hydatids in man.

No. 50—On the occurrence of Precious Stones in New South Wales with a description of the deposits in which they are found.

No. 51—On the effect of the Australian Climate on the Physical Development of the Australian-born Population.

No paper was sent in on subject No. 49 ; two were sent in on No. 50, and four on No. 51. The Council resolved that no prize be awarded to any of the writers of the papers on subject No. 51.

At the meeting held September 30, the Council awarded the prize of £25 and the Society's medal to the writer of the following paper :—"On the occurrence of Precious Stones in New South Wales with a description of the deposits in which they are found," by "Tourmaline"—Rev. J. Milne Curran.

The list of subjects now offered for prizes is as follows :—

The Royal Society of New South Wales offers its Medal and £25 for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon each of the subjects, Nos. 52 to 54 inclusive ; and for Nos. 55 and 56 the Society offers its Medal and £10 10s.

Series XVI.—*To be sent in not later than 1st May, 1897.*

No. 52—On the Embryology and Development of the Echidna or Platypus.

No. 53—The Chemical Composition of the Products from the so-called Kerosene Shale of New South Walss.

No. 54—On the Mode of Occurrence, Chemical Composition, and Origin of Artesian Water in N. S. Wales.

Series XVII.—*To be sent in not later than 1st May, 1898.*

No. 55—On the Iron-ore deposits of New South Wales.

Series XVIII.—*To be sent in not later than 1st May, 1899.*

No. 56—On the life history of the Australasian Teredo, and of other species of Australasian wood-eating Marine Invertebrata, and on the means of protecting timber from their attack.

Part II.—Progress of Science in New South Wales during the past year.—Before proceeding to a review of work already done, let me draw attention to the forthcoming meeting of the Australasian Association for the Advancement of Science, to be held in Sydney in January next. It will be an event of high importance, particularly to Australian scientific men. The meeting will take place ten years after the first meeting of the Association in Sydney, which deserves strong support, if only for the reason that it has done so much to bring the scientific workers of Australasia together for both intellectual and social intercourse. If our large centres of population were more numerous, and the distances between them not so great, there is no doubt that more frequent meetings of this character would be welcomed.

The organization is in full working order for the forthcoming Sydney campaign, and Presidents and Secretaries of Sections have been appointed. I would recommend all of our members who are not yet in possession of information as to the preliminary details of the meeting to apply to Prof. Liversidge, LL.D., F.R.S., the Permanent Hon. Secretary, and now President elect, at the Sydney University.

1. Physiology.—In the physiological laboratory of the University of Sydney, in addition to various other works in progress, a new contrast phenomenon has been observed and worked out by Professor T. P. Anderson Stuart, and an account of the same will be published shortly.

In this department of science, we in Sydney have to deplore the loss of a distinguished worker. Our loss is Melbourne's gain, and I trust that Dr. C. J. Martin may occasionally favour us with the results of work carried out by him. During the past year Dr. Martin completed his investigation into the action of the well-known Darling pea *(Swainsona galegifolia)* on sheep. The report is in the hands of the Department of Agriculture, and many of us look forward to perusal of it. The operation of the plant is slow, but it eventually, if consumed for over one month, occasions degeneration of nerve fibres near their destinations

(peripheral neuritis), and consequently interference with both sensation and movement. This effect Dr. Martin produced himself upon sheep fed under his direction. The same condition exists in so called "pea-eaters" and explains all their symptoms.

Let me remind you of the wide field for research in regard to the physiological effects produced, or capable of being produced, by the active principles of Australian plants.

Dr. Martin also completed and published last year an account of his molecular filter for filtering off large molecules from smaller ones,[1] and a paper on the separation of the two poisonous proteids of snake venom by the apparatus.[2]

2. Zoology.—For an account of the work done in this domain in New South Wales one will naturally turn to the publications of the Linnean Society of New South Wales. At the same time, even at the risk of a little repetition, perhaps I may be permitted to invite attention to some points of local zoological research of interest.

Australian Museum.—The very serious discovery having been made that white ants had nearly destroyed the roof-framing of an entire hall and the floor of another, interfered greatly with the labours of the scientific staff. The Local Committee of the "Funafuti Coral Reef Boring Expedition, of the Royal Society of London," in charge of Professor Sollas, LL.D., F.R.S., having offered to allow one of the officers of the Museum to accompany the expedition, Mr. Charles Hedley was selected for the purpose, and left Sydney with the expedition in H.M.S. "Penguin," Captain Mostyn Field, R.N., on 1st May, and after a residence on the island for two and a half months, returned to Sydney on 22nd August. During his stay on Funafuti he succeeded in amassing an interest-

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[1] A rapid method of separating colloids from crystalloids in solutions containing both.--*Journ. Physiol.*, Vol. xx., (Nos. 4 and 5, Oct. 19) 1896, p. 364; see also *Journ. Roy. Soc. N.S.W.*, Vol. xxx., p. 147, (Aug. 1896).

[2] An explanation of the marked difference in the effects produced by subcutaneous and intravenous injection of the venom of Australian snakes.—*Journ. Roy. Soc. N.S.W. loc. cit.*

ing collection, particularly of invertebrate and ethnological objects, together with much valuable scientific information, and although no other collecting expeditions have been organised, some of the members of the Museum staff have, at various times, been able to collect specimens, many of which are of value to the Museum. The Curator, Mr. R. Etheridge, junr., had an opportunity of visiting the Wombeyan and Yaralumla Caves and other places in the interior, from which he procured much interesting material. The most important event of the year was the investigation by the staff, of Mr. Hedley's collection, still going on. The publication of their results form Memoir III.,[1] of which parts i. and ii. have appeared, part iii. is printed, and part iv. well advanced in MS.

Professor W. A. Haswell of the Sydney University has been chiefly engaged during the year in finishing his share of Parker and Haswell's "Zoology" shortly to be published by Macmillan, and seeing it through the press. He has, however, been able to work out a portion of the material he has had by him for some time relating to the development of the Port Jackson shark, and has a paper ready for publication giving an account of the stages prior to the formation of the mesoderm and notochord. The work on zoology already alluded to will be of considerable importance to students of the subject, and particularly to Australasian students, because of the special local knowledge and experience of the authors. In this work, in each of the major divisions or phyla of the animal kingdom one or several examples are fully described and illustrated. Then follows a brief statement of the general characteristics of the phylum, with a sketch of its classification and an indication of the systematic position of the example. The description of the latter, is in this way, brought into relation with what follows—viz., an account of the general organisation, embryology, ethology, distribution and affinities of the whole group. A general account of the structure and physiology of animals forms an introductory chapter, and chapters on the history of zoology,

[1] The Atoll of Funafuti, Ellice Group: its Zoology, Botany, Ethnology and general structure, based on collections made by Mr. Charles Hedley.

the philosophy of zoology, and the distribution of animals close the book. About three hundred of the illustrations are from original drawings by the authors.

Mr. J. P. Hill, Demonstrator of Biology in the Sydney University has, since the middle of the past year, been engaged in working up the details of the placentation of the bandicoot. The fortunate acquisition of important earlier and later stages since the announcement of the occurrence of an allantoic placenta in this marsupial, has enabled him to work out the main details of its development, and to give a fairly complete acccount of the entire placentation phenomena. Interesting facts have been brought to light regarding the mode of parturition, and a detailed examination has been made of the female urino-genital organs. These results are now almost ready for publication. Important material has also been collected for a further study of the development of the platypus, and also of the wallaby. He has reported on the collection of enteropneusta brought back by Mr. Charles Hedley from the Atoll of Funafuti, in the Memoirs now in course of publication by the Australian Museum.

During the first half of 1896 Professor J. T. Wilson was constantly engaged with Mr. J. P. Hill in writing up the results of their joint investigations upon the development of the marsupial dentition. These results have just now appeared in the *Q. J. of Micros. Sci.* For the rest of 1896 his time was mainly occupied with departmental work.

Mr. A. H. S. Lucas, M.A., B.Sc., Head-Master of Newington College, has found time for some important work, the results of which are mainly published outside the Colony. The titles of his papers are :—(In conjunction with C. Frost, F.L.S.) 1. Description of a new species of *Ablepharus* from Victoria, with critical notes on two other Australian lizards.—*(Proc. L.S., N.S.W.*, Vol. XXI., part iii.); 2. Description of two new species of lizards from Central Australia, (includes a new genus of snake-like lizard).—*(Proc. R.S., Vic.*, Vol. IX., New Series); 3. The lizards of New Zealand.—*Trans. N. Z. Inst.*, to be published this year, read last

July). 4. On some facts in the geographical distribution of land and freshwater vertebrates in Victoria.—(*Proc. R.S., Vic.*, Vol. IX., New Series).

My predecessor announced, in his presidential address, the death of Mr. A. S. Olliff, a leading New South Wales entomologist, and now I have to chronicle the death of Mr. F. A. A. Skuse, cut off in early manhood like Mr. Olliff, whom he succeeded at the Australian Museum, and like him, a trained entomologist, one who had done excellent work, and one who, it was hoped, had a life of usefulness before him. Our scientific men are too few in number for us not to feel deeply the loss of two able men, so full of promise.

The work of Mr. W. W. Froggatt, our Government Entomologist, for the past year has been mainly published in the Proceedings of the Linnean Society of New South Wales, viz., papers entitled "On the bag-shelters of Lepidopterous larvæ of the genus Teara"; "The entomology of Grass-Trees(*Xanthorrhœa*)"; and "Australian Termitidæ, part ii." Mr. Froggatt also published an important paper on honey ants.[1]

Marine Biological Laboratory and Public Aquarium.—A scheme which was discussed some years ago for the establishment of a Public Aquarium in Port Jackson, with, in association with it, tanks for experiments on fish culture, and a Biological Station or laboratory for investigations in marine biology, has lain dormant of late. But when the Fisheries Bill, now before Parliament, becomes law, the conditions ought to be more favourable for the establishment of such an institution. The Director of Fisheries, for whose appointment the bill provides, will assuredly demand that facilities such as would be provided in the way suggested, should be afforded, in order to enable him to make any sound improvements in the state of the fisheries of the Colony. Such a composite institution as that suggested, if placed in a conveniently accessible position, say in the Domain, would undoubtedly be a

1 Report (Zoology) of the Horn Expedition to Central Australia, 1896, pp. 385 - 92, pl. 27, figs. 1 – 13.

highly popular one, and at the same time might be expected to prove of substantial value both to science and to the fishing industries.

Coral-bores.—The subject of coral reefs has been prominent during the past year. A brief visit was paid to the Great Australian Barrier Reef by Prof. Agassiz last winter, and though his work was brought to an abrupt termination through unfavourable weather, Australian students will await with interest the observation and conclusions of one so profoundly versed in the coral deposits of another hemisphere. More closely connected with ourselves was an expedition, first announced to you in the Presidential Address of 1895, the departure of which was described by my predecessor at our last anniversary. Professor Sollas, the leader appointed by the Royal Society Committee for investigating coral reefs by boring and sounding, was with his party safely conveyed to the atoll of Funafuti by H.M.S. "Penguin." The tale of his repeated efforts and ill success in penetrating the atoll by means of the diamond drill is told by himself in a report to the Royal Society.[1] It appears that the substance of an atoll had been assumed to be compact and homogeneous rock, whereas the diamond drill revealed it as chambered with subterraneous caverns full of loose foraminiferal sand. The mechanism in the hands of the expedition not having been selected for such a contingency, was unable to reach to any considerable depth, and the boring was of necessity abandoned.

So successful however, was the alternate method of inquiry—by sounding,—that, although not allowing a demonstration as absolute as a handful of ash in a boring tube would afford, it has yet given us a probable clue to the structure of an atoll. Unconnected with other members of the Archipelago, springing alone from the abyssal floor of the Pacific, Funafuti towers upwards in a cone, from a base thirty miles in diameter to a height of 12,000 feet. Such a cone cannot be mistaken for aught but a volcano, and its outlines accord with those of giants like Mount Etna or

[1] *Nature*, Feb. 18, 1897.

Mauna Loa. At about one hundred and forty fathoms from the surface, an abrupt change in the declivity of the slope occurs, for at this point a wall-like rampart rises on all sides of the atoll. "It is difficult," says Prof. Sollas, "to resist the impression that it is the upper one hundred and forty fathoms which represents the true coral reef." It will of course be obvious to you that Prof. Sollas' interpretation of the contour of Funafuti as a volcanic cone crowned with a coral cap some eight hundred feet thick (less if the reef advanced on a coral talus), calls for no great amount of subsidence.

During the stay of the boring party the fauna, flora, and ethnology of Funafuti were studied by Mr. Hedley, who accompanied Prof. Sollas as naturalist. Mr. Hedley made excellent use of his time, and the results of his personal observations, and of his own work and that of other specialists on his collections, form the subjects of several parts of a memoir which have already been issued by the Australian Museum.

Though unfruitful in the principal object, the voyage of the "Penguin" has advanced the study of the subject along other lines. Her surveys have suggested to Admiral Wharton an original and brilliant hypothesis on the origin of atolls.[1] The fact that all atolls stood on the same level was advanced by Darwin as a convincing proof of his theory of subsidence. A satisfactory explanation of the uniformity of level without invoking subsidence is offered by the Hydrographer, who points out that submarine volcanoes void chiefly ash and such loose matter, that at the close of an eruption such a pile is first denuded by aerial agencies to the sea level, and then by marine forces to whatever depth wave action extends. Proofs are advanced to show that submarine erosion cuts deeper than is generally supposed. The flat top of the volcanic peak thus ground down he considers as the lagoon floor of the future atoll around whose rim the coral ring grows up.

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[1] *Nature*, Feb. 25, 1897.

3. GEOLOGY.—In the Geological Department and School of Mines at the University of Sydney, research work has during the past year been directed chiefly to the radiolarian jaspers, cherts, and claystones of the Bingara, Barraba, Tamworth, and Jenolan Caves Districts. The results of these investigations by Professor David and the third year University students have already been communicated to the Linnean Society of New South Wales, and they prove that a large proportion of the Devonian rocks of New South Wales are composed of shells of Radiolaria.

An examination with Mr. W. E. Abbott of the "Burning Mountain" near Wingen, showed that there was conclusive evidence that the coal seam in which the fire is seated belongs to the Greta coal measures. There is proof that it has been burning for probably about one thousand years. The results of the study of the "Submerged Forest" at Shea's Creek, and of the Sills at Tamworth have already been communicated to this Society. A recent examination of a considerable area in South Australia, classed previously as Pre-Cambrian, has convinced Professor David and Mr. Walter Howchin that the rocks are of Lower Cambrian Age, as remains of *Archæocyathinæ* are abundant in a certain bed of limestone in this group. This will necessitate a complete re-classification of the older rocks of South Australia.

In connection with the School of Mines' students (or perhaps, to speak more correctly, students of the Department of Mining Engineering), at the University, it is a matter for congratulation both to Professor David and to Professor Warren, that Mr. J. A. Watt, M.A., B.Sc., has lately been appointed Geological Surveyor on the Staff of the Department of Mines in this Colony; Mr. T. Blatchford, B.A., has obtained a similar appointment in West Australia, and Mr. E. S. Simpson, B.E., has received the position of Assayer and Analyst to the Geological Survey of the same colony.

During 1896 a large amount of routine work was done by the officers of the Geological Survey of New South Wales. Mr. Pittman, the Government Geologist, made an examination of the gold and diamond bearing deposit at Kangaloon; what appears

to be a volcanic neck occurs there, but no diamonds have as yet been found in the volcanic breccia. The examination of the Triassic artesian basin was continued. In company with Prof. David, several examinations were made of portions of the southern coalfields. The presence of mud springs and Lower Cretaceous rocks at Coolibah was noted. A considerable portion of Mr. Pittman's time was also taken up in connection with the work of the Royal Commission (of which he was a member), on the heating of coal cargoes.

Mr. J. E. Carne, Geological Surveyor, examined the country between Port Macquarie and Cape Hawke, and added Triassic to the formations formerly mapped in that district. During the greater part of the year Mr. Carne was engaged in an examination of the country along the Victorian border. He has added considerably to our knowledge of those parts, and has succeeded in obtaining palæontological evidence to prove that both the Lower Silurian and Devonian series occur there, a fact that was not known before. He has also made a long report on the Pambula goldfield, where there is a large development of felsites, in some places nodular, and rhyolites.

Mr. J. B. Jaquet, Geological Surveyor, made many examinations of mines, and reports of great economic value. In the Kosciusko region he was unable to discover any traces of glacial action.

Under the active supervision of Mr. Card, Mineralogist and Curator of the Geological and Mining Museum, great progress has been made in the arrangement, etc. of the Departmental Museum, which contains a unique collection of the colony's minerals, rocks, and fossils.

Large collections of Upper Silurian and Siluro-Devonian fossils from the Yass-Murrumbidgee districts have been made. These contain much new and valuable material, and have been worked at by Mr. W. S. Dun, Librarian and Assistant Palæontologist of the Survey.

The Rev. J. M. Curran was engaged during the early part of the year on the gems and precious stones of the colony, and the results of his observations will appear in the coming volume of this Society. Mr. Curran has also continued his observations on the Mount Kosciusko Plateau, and notes additional evidence to support his conclusion (already made known through the Linnean Society), that (1) there is no evidence of glacial action in the valleys at the base of Mount Kosciusko; (2) there is absolutely no evidence of any extensive Post-Tertiary glaciation on the Kosciusko Plateau. During a tour in the Cretaceous area of the north-west of the colony, the same gentleman found evidence to show that in the *north-west, as well as at Coonamble*, the artesian water is derived from Triassic rather than from Cretaceous beds. Mr. Curran was by good fortune on Salisbury Downs in September last, when an artesian supply was tapped at a depth of 1,700 feet, and amongst the debris brought to the surface by the first rush of water was a well preserved specimen of *Taeniopteris*, together with a number of fragmentary impressions of the same fern, and this may be taken as conclusive evidence of the water-bearing beds being Triassic and not Cretaceous. This discovery is an important contribution to Australian geology.

4. Chemistry and Metallurgy.—The work done by Mr. W. M. Hamlet, the Government Analyst, although essentially of a scientific nature, largely consists of routine work; it embraces such items as the following which were analysed, examined, and reported on during the past year:—drugs, chemicals, articles of food and drink, condiments, cosmetics, antiseptics, disinfectants, textile fabrics. such as cloth, silk, cotton, blanketing, paints, fuels, dyes, soap, sealing wax, patent medicines, sewage effluents, bitumen and building materials. Investigations have also been made on the subjects of air-pollution, water supply and sewage disposal. Mr. Hamlet's opportunities for research during the past year have been seriously diminished through having to remove his laboratory to other premises pending the erection of the Board of Health building, a floor of which will be set apart for his impor-

tant investigations. His accommodation promises to be so improved that I hope his taking possession of his new laboratory will be synchronous with the commencement of a long period of important research work.

The work of Mr. F. B. Guthrie, Chemist to the Department of Agriculture, has progressed during the past year, and there is no doubt that, under his direction, the new chemical research laboratory at the Bathurst Experiment Farm will produce results highly important to agriculturists. The establishment of laboratories at the different experiment farms will enable researches to be conducted where suitable material and conditions are available, and must result in great benefit to the colony. Mr. Guthrie's routine work has included advice on all matters connected with agricultural chemistry, the best methods of treatment of soils and most suitable crops, based on chemical examination of the different soils; analyses of fertilizers, feeding-stuffs, beet roots, and farm and dairy produce generally. The routine work occupies the time of the laboratory staff pretty fully, and special investigations have to be carried out when time permits, and as during the year, in addition to the departmental work, Mr. Guthrie undertook the duties of Acting Professor of Chemistry at the University during Professor Liversidge's absence on leave, this spare time was necessarily reduced to a minimum. In addition, towards the end of the year, arrangements had to be made for removing the laboratory to new premises, and work was consequently entirely suspended for a time.

The investigations in wheat, commenced in 1895, were continued during the year, a large number of additional wheats being examined, and particularly a number of carefully selected cross-bred wheats grown with the special object of improving the class of grain grown in the colony. An investigation was undertaken with the object of determining the cause of the different power of absorbing water which is possessed by the flour from different wheats, the result of which was communicated in a paper read before our Society during the past year. The work done in this

connection has been largely instrumental in modifying the views previously held as to the suitability or otherwise for milling of different wheats, and enabled the Rust in Wheat Conference which met in Melbourne in 1896, and to whom Mr. Guthrie communicated his results, to recommend as good milling wheats certain varieties of grain which have been found to be rust-resistant. These wheats were formerly considered less suitable for milling than those usually grown, but the result of the above investigation has been to clear away a great deal of previously existing prejudice, and, as a matter of fact, these wheats are now being more extensively grown and with most encouraging results.

The examination of the wines and timbers of the colony has also been continued. Further results on the first of these subjects have been published during the year in the *Agricultural Gazette*, and the results of the examination of a number of New South Wales timbers, which has proved a more lengthy task than was anticipated, are now being revised ready for publication. Another investigation, the results of which should shortly be ready for publication, is one into the chemical action of lime upon the soil, undertaken with the view of ascertaining exactly what chemical changes in the state of the plant food are brought about by the addition of lime.

In the laboratory for agricultural chemistry at Bathurst it is proposed to undertake almost purely research work. Amongst the more important lines of work which will be there taken in hand are:—First, investigations into the nitrifying organisms of the soil, with special reference to conditions prevailing in New South Wales. Secondly, examination by means of pot-experiments, of the action of fertilizers on different crops.

The chemical investigations undertaken during the year by Mr. H. G. Smith, Mineralogist of the Technological Museum, have been of an important character. The chemistry of the new substance "Aromadendrin," isolated from a kino belonging to the turbid group of Eucalyptus kinos, was brought under the notice of this Society in a paper read in August. A paper

was also submitted to the Society of Chemical Industry, and read before the Yorkshire Section of that Society, on the Dyeing Properties of Aromadendrin and of Eucalyptus kinos; by subsequent investigation aromadendrin has been found to be a true mordant dyestuff like quercetin or maclurin, thus differentiating it from catechin, which is not a true colouring matter. The chemistry of our Eucalyptus trees has thus been considerably advanced during the year. The investigation of the sap of *Grevillea robusta* has probably determined the origin of the deposit of succinate of aluminium (as far as the acid is concerned), previously described from this tree before the Society. The investigation of a manna on grass from Northern Queensland, containing a large quantity of mannite, was undertaken; this is the first record of material of this character thus occurring, and the results have been presented to this Society.

The recent establishment of the Government Metallurgical Works at Clyde, near Parramatta, is of considerable practical and scientific importance. The works are under the direction of Mr. James Taylor, the Government Metallurgist. They are regularly working, and a steady stream of ores from all parts of the colony is being received. As the works are for experimental purposes as well as educational, Mr. Taylor does not expect to reach finality in regard to them. At present he is not yet running the cyanide and chlorination processes, but the necessary plant is being erected and it will be shortly in operation.

Mr. J. C. H. Mingaye, Analyst and Assayer, is also at work in his new laboratory at Clyde, and has made a large number of assays and analyses of New South Wales minerals during the past year, in addition to some original research.

5. Astronomy and Meteorology.—The past year has not been a favourable one for astronomical work at the Sydney Observatory owing to the dry weather, which always brings a hazy sky, unfavourable to telescope work. The regular observations have been kept up with the transit instrument and the large equatorial; the latter is now devoted to a re-examination of double stars discovered

in this observatory; all double star measures up to end of 1896 have been published, and the next volume of meridian observations is now ready for the printer. Photographic work suffers more from drought haze than ordinary telescope work, because the hazy sky reflects the city light and produces fog on the plates. Mr. Russell has, however, obtained three hundred and sixty-eight star photographs, with exposures of from thirty to forty-five minutes; these are for the chart of the heavens, and the comparatively long exposures limit the number of plates which can be taken.

As regards Meteorological work, the volume for 1895 has been published and that for 1896 is ready for the printer. It contains a series of six outline maps of New South Wales, (1890 to 1895 inclusive), in which the rainfalls of all parts of the colony are compared with the average, and the result given as a percentage; this proves to be the best method yet tried for estimating the value of the annual rainfall. The series has been carried back to 1880 for publication in the 1896 volume. Another series of diagrams, shewing the monthly distribution of rain with special reference to agriculture, in the various parts of the colony, is in course of preparation; some of them are ready for the 1896 volume. The number of volunteer observers in the country is rapidly increasing, and every square degree of the colony now contains three or more observers, some as many as ten. Amongst the recording instruments at the Observatory a long felt want has been supplied, viz., an extremely sensitive recording thermometer, which shows every ripple of change in the temperature wave even to a quarter of a degree, and shows very clearly that the atmosphere, even when there is not a cloud in the sky, is often made up of portions which are not equally heated. If a large cloud passes over the sun, or a shower of rain comes, the fact is duly recorded by the new thermometer.

Besides the work of the Sydney Observatory, Mr. John Tebbutt has a record of important work during the year, carried on at his Observatory, the Peninsula, Windsor, New South Wales. The work which Mr. Tebbutt has done since the close of last May

comprises the usual routine work for determining the local time, and determinations of the positions of Perrine's Comet of November 1896, together with observations of occultations of stars by the moon, and of the phenomena of Jupiter's satellites. Mr. Tebbutt has during the same period published a number of papers on astronomical subjects in the Royal Astronomical Society's Monthly Notices, the Journal of the British Astronomical Association, and the Astronomische Nachrichten.

We have also a band of astronomical observers who form the New South Wales Branch of the British Astronomical Association, the following particulars concerning which may be acceptable:— The inaugural meeting of the branch was held in Sydney on 30th January, 1895, and at the second annual meeting held in March last, seventy-five members were reported on the roll, and the finances in a flourishing condition. The objects of the association are (1) the association of observers, especially the possessors of small telescopes, for mutual help, and their organisation in the work of astronomical observation; (2) the circulation of current astronomical information; and (3) the encouragement of a popular interest in astronomy. During the past two years Mr. John Tebbutt, F.R.A.S., was president, and during the present session Mr. G. H. Knibbs, F.R.A.S., occupies that position. The section to determine the colours of the southern stars finished during the past year their survey of all stars to the fifth magnitude, situated between 20° south and the southern celestial pole. Several interesting drawings of Mars and Jupiter were made, and paths of many meteors noted by various members. Monthly meetings are held at which papers by the members are read and discussed, and photographs of the most characteristic celestial objects obtained at the leading observatories are projected on a screen and explained.

6. Physics.—Professor Threlfall has during the year 1896-97 been wholly engaged in the Physical Laboratory of the Sydney University in an experimental study of the losses of electric energy which ensue when a dielectric is carried round a cycle of electrification. The investigation was extended to a great many dielectrics.

The general result was to show that real hysteresial losses always occur, and that the properties of a particular sample are perfectly definite in this respect, though different samples of the same dielectric may have widely different properties. Since the commencement of the year he has had the advantage of Miss Martin's assistance, and an investigation similar to the foregoing, but referring to the magnetic properties of substances like sulphur, bismuth, etc., is nearly completed. Professor Threlfall has also devoted much time to the phenomenon of the electrolytic deposition of metals, with the object of ascertaining the cause of the difference in the nature of the deposits which occur under varying circumstances. So far the results of this investigation have been entirely negative.

In hydrodynamics Mr. G. H. Knibbs, Lecturer in Surveying in the Sydney University, has continued, in the Engineering Laboratory, his examination of the determination of the viscosity constant for water. He has shewn that the corrections for end conditions used in even the most recent evaluations require amendment. The very extended results available have now been entirely re-reduced from the original data, and exhaustively compared, the more rigorous corrections being applied throughout. Mr. Knibbs concludes that the discrepancies between the results of different investigators are not satisfactorily accounted for by merely dimensional differences in the apparatus used, and if a higher order of precision is sought, it will be necessary to consider the sources of the discrepancies. In geodetical astronomy Mr. Knibbs has fully discussed the method of determining the direction of the astronomical meridian by means of solar observations, and has obtained expressions for the errors of the methods usually employed. The series of tables supplied in his paper greatly facilitate the discussion and reduction of such observations.

7. Engineering and Public Works.—Our Engineering Section is one of which we as a Society are justly proud, and the papers of the Section published in our Journal by no means represent the whole of the scientific work dealt with at the monthly meet-

ings of the Section. Following are some notes on recent work accomplished, or in progress, by some of our local engineers.

In the Engineering Laboratory of the University of Sydney, Professor Warren has been engaged in investigations on the strength and elasticity of materials. He has devised an apparatus for testing the strength and elasticity of metals at various temperatures, and is at present using this apparatus for testing copper. A large number of experiments have been made to test the strength of the various methods used for staying locomotive fireboxes. A special machine is in course of construction for testing the vibrating strength of materials in which the stresses alternate between tension and an equal compression. This is considered to be an improvement on the Wöhler and Bauschinger machines, as it enables ordinary bars, prepared as in tension specimens, to be rotated in the machine under stresses produced with a constant bending movement. It is also proposed to use the machine for investigating the change in the so called elastic limit, when subjected to alternating stresses. A series of experiments is also in progress on the strength and elasticity of beams, and columns of brickwork and concrete. Numerous appliances have been added for making minute measurements of strains and for drawing autographic diagrams, while experiments are also in progress to ascertain the flow of water through orifices and canals.

Railway Survey and Construction Work since May 1896.—Following is a brief outline of the work carried out by Mr. Henry Deane, Engineer-in-Chief for Railways, our in-coming President, during the past year :—Trial survey work done has been as under—Condobolin to Broken Hill, completed during the year two hundred and ninety-four miles out of a total of three hundred and seventy-three and a-half miles ; Woolabra to Collarendabri, completed eighty and three-quarter miles ; Singleton to Jerry's Plains, completed twenty-three miles ; Galong to Burrowa, completed seventeen and three-quarter miles ; Moree to Inverell, south route, completed thirty-three and a-half miles ; Belmore to Liverpool with alternative junction at Cabramatta, completed

fourteen miles; Coolamon to Ariah, completed forty-one and three-quarter miles; Grong Grong to Ariah, completed twenty-four and a-quarter miles. The following are in progress: Glen Innes to South Grafton (amended route), Liverpool to Mulgoa and Koorawatha to Wyalong. The following lines have been permanently staked for construction: Tamworth to Manilla, twenty-eight and three-quarter miles; Nevertire to Warren, twelve and a-quarter miles; Railway connection with Darling Island; deviations between Hill Top and Mittagong, Great Southern Railway, seven and a-quarter miles; Berrigan to Finley, thirteen and three-quarter miles. The construction of the following lines has been completed during the year, and they have been opened for traffic: Jerilderie to Berrigan twenty-one and three-quarter miles; Parkes to Bogan Gate twenty-three and a-half miles; Narrabri to Moree sixty-three miles; Locksley deviation,[1] G.W.R. three and a-quarter miles; Dargan's Creek deviation,[1] G.W.R. three miles; line now under construction, Bogan Gate to Condobolin, forty miles. The following additional deviations have been executed under the direction of the Railway Commissioners, deviations between Faulconbridge and Wentworth Falls,[1] G.W.R. three miles; Moss Vale and Exeter deviation,[1] G.S.R., one and three-quarter miles; Katoomba deviation,[1] G.W.R., one and three-quarter miles; Blackheath and Mount Victoria deviation,[1] G.W.R., one mile.

Tramways.—The following is a statement of work done in connection with tramways. The construction of the permanent way of the Mosman's Bay Electric Tramway, Sydney, was commenced in June 1896, and the line was completed and opened for traffic on the 1st March, 1897. The length of line is one and a-half miles, with sharp curves and steep grades, and since being opened for traffic has worked satisfactorily. The generator is placed in the power-house at Ridge-street, North Sydney, being driven by belts off the main cable engines. An accumulator-house is situated at Spit Road, which contains two hundred and fifteen cells,

[1] To improve grades and curves on existing lines; information supplied by Mr. Firth, Engineer for Existing Lines.

together with a motor-booster ; the line is worked on the overhead trolley system, in the design of which simplicity and unobtrusiveness were specially considered. No trouble has been experienced in working, although, owing to the sharp curves, great care had to be exercised in carrying out the overhead work. Approval for the construction of the Willoughby (Sydney) Electric Tramway was given on the 16th December, 1896, when it was decided to convert that portion of the Cable Tramway beyond the Power House at Ridge-street, North Sydney to electric traction, a distance of sixty chains, thence to Victoria Avenue, Willoughby; length of line two miles forty-five chains. This work is at present being carried out. The generator will be driven off the main engines in the power house at Ridge-street, and an accumulator house containing two hundred and fifteen cells erected on a piece of land situated about midway between the power house and the terminus of the line. The overhead work will be of the same type as that used on the Mosman's Bay Electric Tramway, and which has worked so successfully.

Approval for the construction of an Electric Tramway from the terminus of the Ocean-street (Sydney) Cable Tramway to Rose Bay was given on 19th January 1897 ; the length of the line is one mile twenty chains. Preparations are now being made for the carrying out of the work. The generators, of which there are two, will be driven off the main cable engines at Rushcutter's Bay, as a means of using some of the surplus power, these engines having proved to be even more economical in working than was expected. The overhead construction will be similar to that which will be used on the George-street Tramway with the exception of the poles, which will be of tallow-wood. A battery of storage cells will be erected in the engine room at Rushcutter's Bay, and advantage will be taken of lighting the power and car house at Rushcutter's Bay by electricity. Arrangements have also been made by which the pumps in connection with the Double Bay low-level sewerage will be worked by electric motors driven off the Rose Bay Tramway.

Instructions have been given for the construction of the George-street and Harris-street Electric Tramway, recommended by the Standing Committee for Public Works on May 8th, 1896, and assented to by Parliament on the 14th September, 1896. The length of the line from the eastern side of the Circular Quay to Harris-street, Pyrmont, near the intersection of John-street, is three miles twenty chains of double track. Several contracts have already been let, and the site for the power and car house fixed, which will eventually become the Central Station when the conversion scheme in connection with existing steam tramways is carried out. The overhead construction will be of neat appearance, embodying all the latest improvements, the wires being carried on ornamental poles. Special attention has been paid to the permanent way, a new type of rail having been specially designed, and which has since been adopted as the standard rail for all future tramway work. The rails will be bonded with the Edison-Brown Plastic Bond, which has proved to be the best preventitive of electrolysis. The rails throughout will be laid on concrete, and the entire surface of the streets wood-blocked. The power and car house arrangements will be very complete and economical in working. The site chosen, which is between Mary Ann and William Henry-streets, Ultimo, and adjoining the railway, is a very convenient one. Considerable attention has been given to a scheme to connect the tramway systems of Sydney and North Sydney by means of a sub-aqueous tunnel. The length of the line, double track, would be one mile thirty-two chains, of which one and a quarter miles are in tunnel. This, with other schemes, was subsequently the subject of enquiry by a Select Committee.

Harbours and Rivers.—Tweed River.—On the Tweed River about five and a quarter miles of stone walls for the training of the river have been constructed, and the channel deepened by means of sand pump dredging, the material raised being discharged on shore at the back of the walls, thus reclaiming land and deepening the channel by the same operation.

Richmond River.—The internal works at the Richmond River, consisting of training walls along the northern and southern shores, and the walls for regulating and guiding the waters of North Creek, are now completed, and the two breakwaters partially constructed, there remaining to be done about one hundred and thirty feet and eight hundred and forty feet respectively to arrive at the points to which it is proposed to carry them in the first instance. The whole of the stone now being used in these works is obtained from Riley's Hill, about eighteen miles distant, whence it is conveyed to the entrance in punts. A canal, about sixty feet wide, two and a quarter miles long, and carrying from six to eight feet of water at low tide, has been excavated along the course of Fishery Creek, and through the low lying land at the back of the town of Ballina to North Creek.

Clarence River.—The principal work carried out on the Clarence River has been the construction of the southern and part of the northern training walls. The former is a half tide wall over two and a half miles long, extending from the eastern end of Freeburn Island to the Heads, the greater length of which has been constructed with stone tipped from a timber staging on piles; the northern wall extending across the North Spit, is about half a mile long. These walls were completed in 1896 and have been very effective in deepening the channel, there being from thirty to fifty feet of water at low tide. Preparations are now being made for the construction of a wall about 7,600 feet long, extending down stream from the eastern end of Goodwood Island; also the continuation of the northern training wall along the shore line at Ballina. The stone for these walls will be obtained at Green Point quarry, about four miles distant, whence it will be brought by rail to Freeburn Island and punted across to the works.

Bellinger River, &c.—Training walls are also in course of construction at the Bellinger and Nambucca River entrances, the lengths completed being 4,010 feet and eight hundred and fifty feet respectively. Tenders have also been invited for a similar wall at the Hastings River.

Macleay River.—In 1893 a flood having broken through the narrow strip of land between Spencer's Creek and the Ocean, at a point about one and three-quarter miles north of the South West Rocks, thereby forming a navigable channel, a scheme was prepared for fixing the entrance at this place instead of at the Heads some five miles distant. The work done up to the present consists in straightening up the channel by dredging, protecting the slopes of bank with stone, and constructing a portion of the southern training wall.

Trial Bay.—The breakwater at Trial Bay, which when completed will enclose an area of about five hundred and fifty acres to form a harbour of refuge, has now been extended from the shore to a distance of five hundred and eighty-three feet, the apparently slow progress being due to the great depth of water in which the breakwater is being constructed, and to the height above water which, owing to the exposed position, it was found necessary to raise the top. Blocks of granite up to thirty tons in weight are being used in the construction of this breakwater.

Manning River.—The work done at the Manning River has been the construction of portion of the wall on the northern and north-western side of the entrance, the total length constructed being 2,070 feet. As the scouring action at the tip head was causing a considerable deepening of the water, thereby necessitating the use of a much larger quantity of stone in the wall, the bottom was coated with a layer of stone deposited from a punt, and extending to about 200 feet in advance of the tip, which has effectually prevented any further deepening.

Newcastle Harbour.—Owing to the necessity for an increased depth of water at the entrance to Newcastle Harbour, it was determined to extend the northern breakwater and construct a guide wall at the southern side of the entrance, commencing near the eastern end of Newcastle Wharf. Most of the preliminary work in connection with the construction of these works, such as the opening up of quarry, constructing railway lines, gantries,

cranes, etc., has now been done, and the depositing of stone will shortly be commenced.

The dredging plant in use by the department consists of fourteen dredges, fourteen grab bucket dredges, eight suction dredges, five combined grab and suction dredges, twenty-one tugs, and ninety punts, employment being found on these for about three hundred and fifty men, and the cost of working amounting to about £75,000 per annum.

The use of sand pump or suction dredges some six or seven years ago had had the effect of reducing, by about half, the average cost per ton of material raised, and of increasing very largely the total yearly output. Indeed, so successful and economical have they proved, that it was considered advisable to convert a number of the grab dredges into combined grab and suction dredges. Five of these have already been altered, and two others will shortly be ready for work. The grab has been retained on these dredges for dealing with stiff material which could not be pumped, lifting snags, etc., but most of the material met with, where these dredges are worked, is of a soft nature and easily lifted and discharged by the pump. In reclamation works, at the heads of bays, behind river training walls, etc., the suction dredges have been found very economical, for not only the material at the site but that raised by ladder and grab dredges working in the neighbourhood is utilised for reclaiming, the latter being brought alongside in punts, dumped and pumped ashore through flexible jointed pipes to where required, up to a distance of from 2,500 to 3,000 feet, at a cost of about a quarter of the older system.

The following shows the areas in Sydney Harbour which have been wholly or partially reclaimed in this way:—Rozelle Bay (Johnstone's Creek), forty-eight acres, partly reclaimed; Rozelle Bay (White's Creek), twenty-seven acres; White Bay, twelve and a half acres, complete; Snail's Bay, five and a half acres, complete; Neutral Bay, seven and a half acres, complete; Careening Cove, three and three quarter acres, complete; Callan Park, five and a half acres, complete; Long Cove, fifty-eight acres, partly

reclaimed ; Homebush Bay, three hundred and sixty-one acres, partly reclaimed ; Tarban Creek, eight acres, complete ; Sewerage Farm, Parramatta, forty-one acres, partly reclaimed.

Sydney Water Supply.—Following are some notes on the service reservoir in the Centennial Park, Sydney :—Length five hundred and eighteen feet, breadth three hundred and twenty feet, depth of water twenty-one feet ; capacity 18,000,000 gallons. Site, soft sandstone, much fissured and traversed by clay bands, overlain by blown sand. Walls, brickwork in cement mortar faced with double pressed bricks. Floor, concrete rendered with cement mortar. Roof, coke concrete, groined arches six inches thick at crown, supported by brick columns twenty feet by twenty feet apart, capped with cast iron skewbacks. As it is intended that the roof of this reservoir shall be used as a recreation ground, and will, therefore, be subjected to unequal loading, the columns will be connected throughout to each other, and to the walls, with wrought iron tie-rods, which will be protected from rust by a thick asphaltic covering. The roof will be covered with a layer of sand and turfed. It will be surrounded by a dwarf stone wall and ornamental cast iron railing with hollow cast iron pillars at intervals. At the centre will be a pavilion forming an entrance shaft and ventilation tower. The air will be taken in through the hollow railing pillars and escape at the central tower, causing a thorough circulation throughout the reservoir. Roof lights are provided for inspection and cleansing purposes. The reservoir will be divided by a central concrete wall, and each compartment provided with inlet, outlet, and scour pipes. Alternative designs were prepared for roofing the reservoir with Monier arches, and with coke concrete groined arches, and when tested in the open market, the latter proved the more economical.

Bridges.—Tenders were received during 1896 for one hundred and forty works, comprising high and low level timber beam bridges, truss bridges, concrete and stone bridges, punts, and miscellaneous works. A considerable item in the expenditure of the Branch consists in the renewal of old timber bridges which are

reported from time to time to be decayed beyond repair. Many of these structures have been in existence from twenty-five to thirty years, and some even longer still, a fact which speaks well for the lasting qualities of our hardwood timbers ; and it is anticipated, with the modern type of structures which are now being erected, and with the increased care now bestowed on the selection of the timber employed, that even better results will be obtained in the future. Among the old bridges which are now in process of being renewed are the Berrima bridge, an old truss bridge on masonry piers (built thirty-six years back), the superstructure of which is now being replaced by truss spans of the latest standard type, and the old truss bridge over the Kangaroo River, on the road Moss Vale to Nowra, in place of which a new suspension bridge is being built in one span of two hundred and fifty-two feet, with steel wire rope cables, and a timber stiffening truss.

During the year new bridges were completed at Inverell and Wallis Creek, Maitland, in place of the old structures at those places. The former consists of three one hundred and ten feet truss spans of a similar type to those recently designed for the new Wagga Wagga bridge, and this type is also being employed in the large timber truss bridges at Morpeth and Albury, which are now in course of construction. Wallis Creek bridge is a substantial structure on the road between East and West Maitland, formed of steel girders carrying a tarred metal deck.

The Swan Hill bridge over the Murray River, was also opened for traffic during the year, being the third of the steel lift bridges which have been erected over that river within the past seven years at the joint expense of the two colonies of Victoria and New South Wales, the work having been designed and carried out in each case by the Public Works Department of New South Wales. Swan Hill bridge consists of two ninety feet timber truss spans, with timber beam approaches and a steel lift span of fifty-eight feet four inches, centres of piers giving fifty feet five inches clear waterway, and thirty feet seven inches clear headway above the highest known flood-level when the span is raised to its full height.

The lift span is formed of two steel Warren girders, carrying a timber deck, the total weight of the span being about thirty-four tons. This is counterbalanced by four cast iron balance boxes filled with lead, which are connected to the span at each corner, and work over large rope wheels fixed in the top of wrought iron braced towers. The lift span differs from its predecessors in that the span is worked from the deck level instead of from a platform at the top of the towers; and with the new arrangement of the shafting and gearing one man can open the span in five and a half minutes, through the full height of the lift, which is twenty-five feet in this case, as against twenty-one feet in previous bridges of the same type. The metal work for Swan Hill bridge was manufactured in Melbourne, and the whole of the timber, with trifling exceptions, obtained from the northern rivers of New South Wales.

Among the miscellaneous works carried out during the year was the wood blocking of portions of the Circular Quay near the P. & O. Wharf, in which blackbutt, tallow-wood and red mahogany blocks were used, laid in sections, to allow of the relative wear under traffic being observed and compared. At the present time the Branch is engaged upon a number of important works, including new bridges over the Tweed River at Murwillumbah, Paterson River at Dunmore, Queanbeyan River at Queanbeyan, Stone Quarry Creek at Picton, and the Macleay River at Kempsey. The design for Kempsey bridge includes four one hundred and fifty-three feet timber truss spans of a new design; these will be the largest spans in the colony constructed wholly of timber.

For the above information (other than that referring to railway and tramway matters), I am indebted to Mr. R. R. P. Hickson, M. Inst. C.E., Under Secretary for Public Works and Commissioner for Roads, and to Mr. Cecil Darley, M. Inst. C.E., Engineer-in-Chief for Public Works.

8. Public Health.—In giving some account of the work of the Board of Health and of its scientific staff, during the past year, it is only proper for me to point out that duties connected

with the re-organisation of his department have prevented Dr. Ashburton Thompson, the new President, from giving the same attention, during the past year, to original investigation in matters pertaining to Public Health, that he has undertaken in past years. The most important event connected with the public health during the past year was the successful passage of a Public Health Act. Such a measure had for many years been demanded by the public, and formally advocated by successive premiers; the late Sir Henry Parkes indeed went a step further than that, and actually introduced a measure in 1886, which, however, was never debated; and it remained for the present premier, the Hon. George Reid to place a new and short Public Health Act on the statute book. The act is framed to allow the fullest measure of local self-government in this respect, and at the same time gives the Board of Health effective powers of control; it provides for appointment of medical officers of health, for the notification of infectious diseases, for controlling the adulteration of food, and for dealing with unwholesome dwellings, which may be either condemned or put into habitable condition as may be possible; it requires registrars of deaths to enter the cause of death in their registers, and to distinguish between uncertified and certified deaths—points which have been carefully attended to for many years past by departmental arrangement but which are now for the first time directed by law; it furnishes what is expected to prove a direct and speedy means of dealing with nuisances; and it amends one or two existing acts in rather important respects. At the same time, while the constitution of the Board of Health remained unchanged in quality its numbers were reduced, and it was decided that for the future the President should be a civil servant, wholly employed in discharge of his functions in that capacity, and also as the Chief Medical Officer of the Government.

During the year foundations of a new building for use of the Health Department were laid; this is now rapidly approaching completion, and it will afford accommodation for the clerical and professional staff of the Health Department on the ground floor;

the first floor will be entirely occupied with the laboratories of the Government Analyst; the second floor will be occupied with a commodious and well equipped bacteriological laboratory; while in the basement, which, owing to conformation of the site is at the ground-level at the rear of the building, will be conducted business connected with hospital accommodation for the sick poor, public vaccination, and some other matters administered by the Chief Medical Officer. At the same time the staff is gradually being improved and added to in important respects; and in the course of a year or two there is every reason to hope that the colony will at length be found furnished with a Public Health Department capable of safeguarding the prosperity of the people in important respects, and competent to perform its proper functions.

During the year the usual routine examinations of specimens from diseased animals were continued in the Biological Laboratory of the Board of Health, by Dr. Frank Tidswell, bacteriologist to the department, being mostly diagnostic examinations for anthrax, tuberculosis, etc. Some preliminary observations were made on the disease of pigs known to butchers as "pig quinsy," which tend to show that the malady in question is a form of septicæmia. This diagnosis is provisional only, pending the elucidation of details. Observations made on a form of ulceration of the cornea of the eye in cattle suggest that in most instances the affliction is of traumatic origin. The examinations of bovine tumours were continued, the growths specially examined being from the orbit of bullocks. The results show that the tumours are sometimes true cancer of the form known as epithelioma. Occasional bacteriological examinations of the water supplied to Sydney furnished further evidence of its microbic purity. Samples of water from wells yielded abundant crops of bacteria, not always of a harmless type. The most important work undertaken in the laboratory was the histo-pathological examination of the organs of lepers deceased during the year. Detailed descriptions were published in the report of the Health Department on Leprosy in New South Wales, for the year 1895. The report is illustrated by

some beautifully executed photomicrographs, and forms a very valuable contribution to the study of leprosy.

Part III.—Some Botanical Matters.—

1. Botanical Workers.—*a. The late Baron von Mueller.*—My year of presidential office has been sadly memorable through the death of Baron von Mueller. For nearly half a century this distinguished man had continued to elucidate the structure and classification of Australian plants. In 1897, with our luxurious steamships and express-trains, our stores, and well-furnished larders under hospitable roofs extending over the greater part of the continent, our *Flora Australiensis*, *Fragmenta*, and *Census*, not to mention piles of botanical literature less frequently referred to, it is difficult to entirely enter into the circumstances of the young German botanist who stepped forth into the wilds, bent on conquest far more glorious than that of Napoleon, whom we style "the Great,"—just fifty years ago. Mueller was a member of the most distinguished trio of explorer-botanists who have made Australia the principal field of their labours, and association with Robert Brown and Allan Cunningham is high honour indeed. These three men were practically contemporaneous with the century which is fast drawing to a close; they are the three bright stars around which the lesser lights revolve.

Geographical and botanical exploration have gone hand in hand on this continent, all modern expeditions having had botanical collectors attached to them; moreover, the pioneers of pastoral and mining settlement have ever shown their willingness to send specimens to elucidate the plants of their districts. There are now but few tracts of Australian soil which have not been geographically explored; the result is that there does not appear to be scope for another explorer-botanist of the first rank. In other words, present and future botanists must win their spurs in a different way. But in hinting that Australia has been well explored botanically, I do not wish to be misunderstood. There are plenty of imperfectly explored regions awaiting attention. I

can conceive few ways in which the public funds could be better applied than by defraying or subsidising. the cost of journeys of Australian botanists to regions that could be readily indicated. And while such explorations could not result in such abundance of new material as Mueller and his predecessors obtained on their journeys, yet many plants still remain to be discovered, and many problems pertaining to variation and geographical distribution, and even more important botanical matters, remain to be solved. Just as in the early gold-digging days alluvial very frequently gave valuable results with comparatively little labour, so now claims are reduced in area and worked deeper. And in this laborious working of small areas many prizes have been won, and remain to be won.

I do not wish to push my comparison too far, certainly not so far as to let it be inferred for a moment that the labours of Mueller have been anything but arduous. Only his earlier contemporaries can recount the troubles and dangers the Baron passed through in his early days. Days, weeks, and even months has he passed alone in the wilds of Australia—in the inhospitable ranges of the Victorian-New South Wales Alps, to wit. He took a slender supply of poor food, and his only companion was a pack-horse. I suppose his insatiable fondness for a cup of tea dates from the time he used to boil his billy in the fastnesses of the Southern Alps. Loneliness I am sure he did not feel, for how can a man feel lonely when new plants present themselves everywhere to his delighted gaze. On one occasion one of these mountain streams rose rapidly, Mueller's scanty supply of food was washed away, and he himself climbed into a tree to pass the night and to await events. He also went on very short commons on some of his other trips.

His Victorian explorations in the early days were as follows: In 1853 he explored the Australian Alps from the Victorian side, see his First General Report on the Vegetation of the Colony, dated September 1853. During 1854 he examined the Grampians and the adjacent ranges; thence to the Darling, and along the

Murray. During this year he made a more extended exploration of the Australian Alps, as detailed in his Second General Report dated October 1854. His other explorations were under the leadership of A. C. Gregory in 1856 to explore North-western and Northern Australia for traces of Leichhardt, journeying from the Victorian River overland to the Dawson, and botanical expeditions of an exploratory character to Western Australia in 1867 and 1877 respectively, the former trip being from King George's Sound to the Stirling Range, and the latter to the Shark's Bay district.

The mere recounting of the Baron's works would take up more time than can be allowed on the present occasion, but I may invite attention to some of the principal ones. His share in the preparation of the *Flora Australiensis* is gracefully told by the great Bentham in the Preface to Volume I. of that work. The *Fragmenta Phytographiæ Australiæ*, consisting of eleven octavo volumes of say, two hundred pages each, written in Latin, forms an invaluable supplement to the Flora, while the *Systematic Census of Australian Plants*, of which two editions have appeared, is indispensable to the student, being a cyclopædia of notes on geographical distribution, references to descriptions of species, etc. "Eucalyptographia" with descriptions and illustrations of one hundred species of Eucalypts, is sufficient of itself to make the reputation of any man, and is the standard work on the subject. It is one of a series of valuable quartos dealing with various natural orders, each work containing carefully drawn figures, with abundant detail. Such companion works (differing only from "Eucalyptographia" in the absence of descriptive accounts of each plant), are the "Iconography of Acacias and Cognate Genera," "Iconography of Australian Salsolaceous Plants," "Descriptions and Illustrations of the Myoporinous Plants of Australia," and "Iconography of Candolleaceous Plants" (only one decade issued). The "Plants indigenous to Victoria," in two folio volumes, with beautiful lithograph illustrations, was issued in the sixties, and forms his principal work devoted exclusively to plants of the

colony from which he obtained his official position. It forms the basis, (at all events as far as the illustrations are concerned), of certain of his minor works on Victorian plants. Then we have the "Select Extra-tropical Plants," a compendium of information in regard to plants (chiefly economic) worth cultivating, and one which has been translated into several languages.

The Baron did not by any means strictly confine himself to the vegetation of Australia and Tasmania. Plants from New Zealand and adjacent islands, from the New Hebrides, Samoa, and other Polynesian islands, and particularly New Guinea, all engaged his attention, and form the subjects of valuable papers.

I believe that no complete list of Mueller's works exists, and I have on another occasion made the suggestion that such a list (with bibliographic annotations), would form a very appropriate memorial of him. The list should be in strict chronological order, with a botanically classified supplement. Such a list would find a place on the work-table of every student of Australian plants, and would go far to keep his memory green. The value of such a publication would be greatly enhanced if there were added to it reprints of some of his papers in obscure or rare serials; at present they are lost to most of us.

It has been suggested that a memorial of the Baron should be the publication of an eighth or supplementary volume of the *Flora Australiensis*. The work could contain a steel engraving of the Baron's portrait, and some account of his life. Other suggestions for perpetuation of the memory of the Baron have been made, and are doubtless under consideration of the Victorian scientific societies. Those of us in New South Wales who are interested in a memorial of the great man await the decision of Melbourne, —the city in which he practically spent the whole of his Australian life.

Of honours he received many. His Fellowship of the Royal Society of London dates from 1861; a year or two ago he was elected a Corresponding Member of the Institute of France. The King of Wurtemburg created him a Baron in 1871 in recognition

of his eminence as a scientific man, and in 1879 Her Majesty made him a Knight Commander of the Order of St. Michael and St. George. His lesser distinctions (many of them very honourable), form a very long catalogue.

The story of the Baron's life has already been outlined in several publications, and I may refer you to those noted at foot.[1] I may mention that he was born at Rostock in Northern Germany in 1825, and emigrated to South Australia in 1847. Already a trained pharmacist, he obtained employment of this nature in Adelaide, but very shortly made his way to Victoria, of which colony he was made Government Botanist in 1852. This office was conjoined with the Directorship of the Botanic Gardens of Melbourne in 1857, and the offices were again separated in 1873, the Baron remaining Government Botanist of Victoria until his death on the 10th October last.

No man knew the Baron more intimately than Mr. J. G. Luehmann, his assistant for twenty-eight years and now his successor. I lately asked Mr. Luehmann what he considered the Baron's strongest or most evident point as a botanist. He at once replied,—"His marvellous memory for the forms of plants." The Baron had a remarkable power of "spotting" a new plant, and hence, when large parcels came to him, he could rapidly run through them and lay on one side, with an almost unerring instinct, the new forms; and having made this preliminary selection, his descriptions of new species were rapidly proceeded with. I have given a few notes on his personal characteristics in the *Agricultural Gazette* for November last, and most accounts of his life work refer to such matters.

I enjoyed the personal friendship of the Baron for fifteen years. Sometimes I criticised his nomenclature, and other botanical

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1 *Victorian Naturalist*, Oct. 1896; *Chemist and Druggist of Australasia*, Nov. 1896; Melbourne *Argus*, 12th Oct., 1896; *Sydney Mail*, 17th Oct., 1896; *Brisbane Observer*, 20th Oct., 1896; *Agricultural Journal of Cape Colony*, 26th Nov., 1896; *Gardeners' Chronicle*, *Pharm. Journ.*, and *Chemist and Druggist*, all of 17th Oct., 1896. *Nature*, 22nd October, 1896.

matters to his face, but always respectfully, for I never lost sight of the intellectual greatness of the man. At the recent commemoration of the University of Sydney, I was struck with a quotation by His Excellency the Governor, from Burke, who, referring to George Townshend, said, "He had no failings which were not owing to a noble cause; to an ardent, generous, perhaps an immoderate passion for fame—a passion which is the instinct of all great souls." I would apply these eloquent words to the memory of Ferdinand von Mueller.

b. Other Workers.—Mr. J. G. Luehmann has been definitely placed in charge of the National Herbarium of Melbourne with the title of Curator. It is a matter for congratulation that a man so familiar with this fine herbarium should have been appointed to succeed Baron von Mueller in charge of it. This National Herbarium comes under the ministerial control of the Chief Secretary of Victoria, and it is also a matter of congratulation that Mr. C. A. Topp, M.A., the Under Secretary of that department, is also a botanist, and takes a keen interest in the welfare of the herbarium. Besides the plants of his own colony, Mr. Luehmann has been giving special attention to those of Western Australia, of which he has already described several new species.

Professor Ralph Tate's absence in Europe during the past year has of necessity caused his botanical work to be temporarily laid aside.

Mr. F. M. Bailey, the veteran Colonial Botanist of Queensland, has been as actively as ever engaged in the work of his department. In addition to the valuable botany bulletins bearing his name, he is far advanced in the preparation of a Flora of Queensland, which cannot but enhance his already high reputation. During the year the Botany Bulletins he published for the Queensland Department of Agriculture were Nos. 13 and 14; he also published a paper on Queensland grasses for a pamphlet on dairying, for distribution in England. He has now in the press a Bulletin on Fresh-water Algæ, which will be larger than either

of the two former ones, and also a second and enlarged edition of his "Companion to Queensland Student of Plant Life and Botany Abridged."

Steady work has been carried on at the Technological Museum of Sydney during the year. Mr. R. T. Baker has published in the Proceedings of the Linnean Society of N. S. Wales a flora of the Rylstone and Goulburn River districts, a part of the colony hitherto but little known to botanists. The geographical range of many species has been extended, and several new species have been discovered, seven of which have already been described, viz.: *Acacia Muelleriana*, *Helichrysum tesselatum*, *H. brevidecurrens*, *Daviesia recurvata*, *Isopogon Dawsoni*, *Prostanthera discolor*, *P. stricta*. Mr. R. T. Baker is an indefatigable worker, and he and his colleague, Mr. H. G. Smith, have collaborated in a paper read before this Society on the occurrence of a true Manna on a grass, *Andropogon annulatus*.

2. AGRICULTURE.—*a. Green Manuring and cognate matters.*—Let me allude, if only for a few moments, to the especial necessity for nitrogen in our soils, and to the room for experiment and research, in this direction, in New South Wales. In many parts of our colony we have not the advantage, (from an agricultural point of view), of severe frosts, which break up the soil to a fine tilth. On the other hand, our sub-tropical rains beat down the surface and render it comparatively impervious. Such consolidated soils do not properly perform their functions, an open soil being necessary, amongst other things, to ensure free access of atmospheric nitrogen, which may be fixed by the tubercle-bacteria of leguminous plants. Free access of air is also of importance in providing the conditions favourable to the growth of the nitrifying organisms of the soil. The consolidation of the soil referred to is, however, to some extent counteracted by the roots of Leguminosæ, for many of them are deep-rooted, and their ramifications cause æration of the soil, while their decomposition adds humus to it.

We cannot entirely follow the precedents of other countries in regard to the particular plants to be selected as nitrifying agents,

but must experiment for ourselves. In the first place, as far as I know, but little has been done in regard to the examination of indigenous Australian leguminous plants for root-tubercles. Dr. T. L. Bancroft has published a note[1] on the subject. We require bulky growing plants of rapid growth which are capable of assimilating large quantities of nitrogen from the air, and which rapidly disintegrate when ploughed under as "green manure." In this respect, also, we are at a disadvantage in comparison with northern climes; our vegetation is, as a rule, more fibrous, and our soil is less continuously moist, and thus rapid disintegration is hindered. The subject in its many bearings is of great practical importance, and perhaps our various experiment farms may take up the matter on an even larger scale than they have hitherto done.

Nor must we lose sight of the great value of many leguminous plants as fodders; they are thus of double utility. While testing our native species we require to experiment with as large a variety as possible of exotic Leguminosæ, not forgetting that we have numerous climates, so that if one species will not flourish in a district, it is possible it may do so in another. In addition to work in this direction undertaken in Government establishments I must not omit reference to the researches of Mr. W. Farrer of Queanbeyan, who has, at his own expense, introduced many Leguminosæ for his experimental plots. The colony is extensive, and there is room for many more experimenters.

I would invite attention to a recent paper by Dr. Bernard Dyer,[2] on this subject, which gives an excellent resumé of work in this field, particularly that of Dr. Schultz of Lupitz, Saxony, who has, in the course of forty years, converted an estate of poor soil (manured with dung procured elsewhere), into one producing valuable crops.

"The basis of this transformation has been the culture of leguminous green crops, notably lupines, with the aid of mineral manures—lime,

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1 "Note on bacterial diseases of the roots of the Leguminosæ." *Proc. Linn. Soc., N.S.W.*, [2] VIII., 51, (1893).

2 "Green Manuring."—*Journ. Roy. Agric. Soc.*, VII., 773, (1896).

potash, and phosphates—without the use of nitrogen; the mineral manures being usually applied, not to the leguminous crops themselves, but to the non-leguminous crops with which they were alternated. To decide what are the best catch crops or green crops to be used for this purpose of green manuring, and to trace out the causes of their good effects, has been the life work of this celebrated agriculturist."—*(Op. cit.)*

Incidentally, one might suggest experiments with lupins as a manurial crop in this colony.

In the excellent article on "Manures and Manuring," by Mr. F. B. Guthrie, Chemist to the Department of Agriculture which is published in the "*Farmer's and Fruit Growers' Guide*," recently issued by the Department, will be found a resumé of work connected with the inoculation of the soil by pure cultures of nitrogen-fixing organisms. Hellriegel and Wilfarth's work in this direction reads like a romance, and I only wish that time and the occasion permitted me to dwell longer upon the subject.

b. Some work of the Department of Agriculture.—I would like to invite your attention, for a few moments, to some of the work which has been undertaken by our Department of Agriculture, for I have not time to enumerate all its agencies. Among these are Experiment Farms for sub-tropical products at Wollongbar, Richmond River, at Bathurst for miscellaneous farming, at Bomen near Wagga Wagga, where wheat and fruit growing are the specialties, and at Richmond where the Hawkesbury Agricultural College has its headquarters. The last institution is presided over by Mr. J. L. Thompson as Principal, and it is of considerable magnitude. I will proceed to give some account of it and also of its aims and objects.

The college opened in March 1891 with twenty-five students, there now being ninety in residence, whilst more than three hundred have already availed themselves of the facilities offered. Commencing with 3,500 acres of poor bush land, 2,000 acres have been cleared; there are fifty acres under orchard and vineyard, four hundred acres under general crops, and ten acres devoted to experimental work. Every branch of a farmer's life is taught. Young men are trained in general farming and all the operations

necessary to the sowing, cultivating and harvesting of crops, orchard work in all branches, drying of fruit, wine making, treatment for insect pests and disease, growing of vegetables, and packing of fruit; general dairy, pig, bee, and poultry work; engine-driving, carpentering and blacksmithing.

The aim of the institution is to give a thorough grounding in all matters likely to be of use to the agriculturist of the future; it is clearly recognised that methods must be improved, and that practical farming to be successful must be carried out on scientific lines. Lectures are given, these with practical work occupying alternate days, on principles of agriculture, chemistry, botany, and vegetable pathology, insect pests of the farm, and numerous other subjects calculated to help the students to a thorough knowledge of the scientific principles underlying their work. The regular course lasts two years, after which special courses may be taken by the student. The college is in the seventh year of its existence, and there is no doubt that it will become more and more useful as time goes on. If anything is necessary to prove its utility, it may be noted that growers are becoming more and more interested in its work, and that results abundantly testify in favour of careful and thorough, as opposed to careless, work. Time will not allow of full details as to the past year's work, but it must suffice to say that by means of ensilage cows are kept in milk all the year round, while the ordinary products, fruit, cheese, etc., have brought the highest market prices when any surplus has been disposed of. By means of careful rotation the two main seasons give each its crop. The experimental work becomes more and more conclusive that proper rotation, constant cultivation, careful selection of seed, application of appropriate manures, attention to insect and fungus pests, and strict attention to details, pays handsomely for the extra cost, the crops being better, heavier, and cleaner, whilst cultivation properly carried out tends to minimise the drawbacks experienced in our variable climate.

Students at the college benefit by the accumulated knowledge of the world in farming matters. Everything is done that can

be thought of to improve the methods of work and the information conveyed to students. The opportunity is *there;* it rests with the young men themselves whether the country is to benefit or otherwise. A new departure has been recently made; the senior student of 1896 has been selected to undertake a course of study at one of the leading American colleges; on his return the information gained will be made use of in a practical way. Such travelling scholarships are highly to be commended, and, provided the scholar is capable and receptive, he should be able to impart much that is valuable on his return.

I had the pleasure, a few months ago, of carefully examining the work at the Murrumbidgee Experiment Farm at Bomen near Wagga Wagga, an institution second only in importance to the Hawkesbury Agricultural College. It is not necessary for me to enter into detail in regard to the farm, as such particulars will be found in the *Agricultural Gazette*, but I think it is only right that, addressing as I am a body of scientific men, I should draw your attention to the highly scientific work in regard to the selection of wheats proceeding at Bomen. This work is carried on jointly by Dr. Cobb, the Vegetable Pathologist to the Department, and Mr. George Valder, the manager of the farm. Much pioneer work in this direction has been already done. Hundreds of kinds of wheats have been planted under varying methods of cultivation, have been harvested, and the grain subjected to milling and other tests, and while still in the ear observations have been systematically carried on in regard to the period of ripening, tendency to shell etc. In fine, the question of wheat cultivation and examination of the grain has been attacked in very many directions. Farmers have been shown that the heavier sowing is not necessarily followed by the heavier crop, even when other conditions are identical. The claims of various kinds of wheats to certain reputed characteristics have been investigated, and the wheats are classified in regard to yield per acre, weight per bushel, earliness or the reverse, capability of resisting rust, and so on. This farm is distributing "stud wheats" in limited quantities to farmers

at fixed prices, and the demand for these is so great that it is expected that in a few years the institution will be almost self-supporting. If the distribution of improved wheats raises the yield of the colony but one bushel per acre, what a grand achievment that would be! And the quality of the wheat is being improved at the same time, becoming more rust resistant, and of improved value for milling purposes. I am afraid I must leave this fascinating subject, as further discussion of it is perhaps more appropriate to an Agricultural Society than to a Royal Society for the promotion of science in general. I would, however, that agricultural societies would not entirely devote their energies to displays of stock, products and manufactures; it might be advantageous to their members to discuss agricultural matters, introduced by lectures or papers, and important subject-matter for many a meeting could be supplied by recounting the aims, methods, and results of the various agencies for the advancement of rural pursuits by the Department of Agriculture of New South Wales.

c. Mr. W. Farrer's work with Wheats.—Besides this wheat-selection work of the Department of Agriculture, Mr. W. Farrer of Lambrigg, Tharwa, continues his work with this cereal; this he has carried on at his own expense for many years. The system Mr. Farrer is following is that of cross-breeding between selected distinct varieties, followed by selection from the resulting numerous types, of such as appear to possess, in the highest degree, the qualities which are valuable, not only to the farmer, but to the miller, baker, and consumer as well,—to the two latter especially. Mr. Farrer is paying attention more particularly to the nutritive value of the grain, and resistance to rust, in his experiments, without neglecting such important matters as productiveness, earliness of maturity and strength of straw. He is aiming to make the good qualities of his wheats normal and stable qualities of new varieties. Such new varieties as he makes in this manner he is in the habit of distributing, before they are quite firmly fixed, to the Agricultural Departments of the different colonies,

Mo. Bot. Garden,
1898.

in order that further selection may allow strains to be fixed in their new homes, and suitable for their special conditions.

d. Testing of Seeds.—This is a subject upon which I again propose to touch, but the matter is worthy of special emphasis in connection with agriculture. I hope that, before the lapse of many years, we shall have a Seed-control Station in connection with our Department of Agriculture, where agricultural seeds may be tested as to name, germinating power and purity. The germinating power of seeds is of course of paramount importance to the farmer. Not only do seeds vary considerably in the length of time they may be safely kept before sowing, but there is often much variability in seeds in the same parcel through admixture, and other causes. I cannot do justice to this subject on the present occasion, but I venture to refer members to two excellent papers, which will well repay perusal.[1] Hardy less valuable is a paper by another author[2] belonging to the same department, where homely appliances for the testing of seeds are described.

It has long beeen a matter of surprise to me that seed-testing is so little practised by farmers. Of course, as regards the more difficult points that present themselves in these investigations, the farmer would do well to appeal to the Department of Agriculture for help, but, as a rule, with very little practice, and with appliances to be found in every household, he can test the germinating power of most seeds as well as anybody. And if the citizen whose purchases of seeds are limited to those required for the horticulture of a suburban garden, were to adopt a similar plan, much heart-burning would be saved, and the precautions of seedsmen for the supply and distribution of good seed would be promptly increased.

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[1] (1) "Seed Control: its aims, methods and benefits," by Gilbert H. Hicks.—*(U.S. Depart. of Agriculture)*—Read before Massachusetts Hort. Soc., Feb. 8, 1896. Boston, Rockwell and Churchill; pp. 28. And (2) "Pure Seed Investigation," by the same author, reprinted from the *Year-book of the U.S. Department of Agriculture for 1894*. The same botanist is author of Circular No. 6, Division of Botany of the same Department, entitled "Standards of the purity and vitality of Agricultural Seeds."

[2] A. J. Pieters—"Testing Seeds at Home," Reprinted from *Year-book U.S. Depart. of Agriculture, 1895.*

3. FORESTRY, ETC.—*a. Arboretum.*—The colony does not at the present time possess a single arboretum of the first class. Our climates and soils are so numerous that it would be desirable to have arboretums in several districts, but even one arboretum in a suitable situation could be made of high educational value. We possess a number of collections of trees (the Botanic Gardens in Sydney being especially rich in species), but no real garden of trees. To possess its maximum value for the people of this colony an arboretum would require to be at no great distance from Sydney, but, in such a case, it would be almost necessary to have a small branch establishment in one of the colder regions of the colony. The present time is inopportune to suggest fresh expenditure, but perhaps it might be possible to set apart a considerable area (say two hundred acres), of Crown Lands in a suitable situation within forty or fifty miles of Sydney. It might be possible to establish within this area a Forestry School, where young men might receive education in forestry matters under conditions as they exist in the colony, and if the site of the arboretum were at no great distance from a natural forest, the educational advantages would be greater still.

b. Danger of planting inferior species.—Whether plantations are made by the Government or by private persons, the importance of planting only useful species cannot be overestimated. I have seen plantations in Australia which should now be revenue-producing, but the timber has no known use, and forms inferior fuel. It is, in fact, unsaleable. In re-afforestation operations, by means of our indigenous trees, it is necessary to emphasise this point very distinctly. This brings me to the seed-question. The selection of suitable seed is not by any means a matter resting solely with the seedsmen. Customers (official bodies and individuals), ask distinctly for seed of species which we know to be inferior. The reason of this is in some cases owing to the fact that through the confusion of botanical writers in regard to the merits of trees of the especially difficult genus Eucalyptus, species have received praise which is really not due to them, and planters, observing these

favourable remarks, have placed their orders accordingly. The lesson to be learnt is that grave responsibility attaches to the man who, through imperfect information, praises the virtues of a tree. The tendency to speak in superlatives as to the excellencies of our native vegetation is growing, and should be restrained, as a man who is deceived by glowing accounts of our trees is apt to underrate them when the reaction takes place.

I think I am right in asserting that very few of our landowners have cultivated any considerable number of trees for timber. In the northern hemisphere this practice is well established, and it is a matter well worthy of consideration, by many of our country people, to what extent the planting of trees will afford profitable employment for capital and land.

c. Industry of Seed-collecting.—Most of the forest seeds collected in this colony are those of Eucalypts, trees difficult to discriminate. But that does not in any way justify collectors in supplying mixed seed, or seed with misleading names. I feel indignant as evidence is furnished to me of the carelessness of suppliers of indigenous seeds. If a man desires to learn the names of his seeds, dozens of botanists will help him without fee or reward. So that ignorance can be no man's excuse in this matter, and a man who supplies named seed of whose origin he is ignorant or careless, is a delinquent of a peculiarly despicable kind, one whose wickedness can only be found out after the lapse of years, when perhaps reasonable hopes have been blasted. I would like to see the purveyors of false seed subjected to the penalties of a draconian law. Human nature is much the same everywhere, and our people are not greater delinquents in this respect than are those of other lands, but I have personal experience in these matters when I say that the disastrous effects of the distribution of ill-named or bad seed are comparable, as regards agriculture, forestry, and horticulture, to droughts and pests. Planters of all kinds have quite enough discouragements of an unavoidable character without being saddled with others absolutely within human control.

For my own part I am doing all I can to establish a seed-control station, at all events for indigenous seeds. I am the officially appointed buyer of Australian seeds for two countries, and have many opportunities of influencing purchases by public bodies and private citizens. I am doing all I can to encourage technical education in seed-collecting, and shall not rest until a buyer is able to procure his seeds under some reasonable guarantee. I have used plain language, but I feel strongly in the matter, and feel that I am doing right in addressing a body of men the extent of whose influence in educating the community cannot readily be exaggerated.

d. Supply of good timbers not unlimited.—The demand for our timbers has been so active during the last few years, and fashion has set in almost exclusively for a very few species, that a word of caution is necessary, particularly in regard to the timbers referred to. We have large quantities of excellent timber,—there is no doubt of that, but not so much that we can afford to cut recklessly, and neglect conservation of young growths. We must not forget that the giant trees, the monarchs of our forests, which have yielded large quantities of high-class timber, are being rapidly cut out. They have been maturing their timber through the ages, practically uninterfered with by the aboriginal lord of the soil, and are no more to be replaced than can the nuggets which man can do nothing to produce; he simply reaps a harvest which he has not sown. The cutting out of forest without replanting or conservation of young forest growths is simply living upon capital, and, continuing the metaphor, we should seriously ask ourselves if we are establishing an adequate sinking fund.

e. Forest-thinning.—This is a matter of considerable practical importance to us in this colony. It is a subject which requires to be approached with a spirit of respect and caution, as it involves pitfalls. Because a man can thin out lettuces or verbenas it does not follow that he can undertake forest thinning successfully. And the greater caution is required because the effects require

time for development; we might possibly pay a man for work of this kind when it would have been sounder policy to pay him the same sum for inaction. I hardly know a forestry operation requiring greater skill on the part of the overseer than that of thinning. Work of this kind can with difficulty be directed from a distance, and empiricism in dealing with a natural forest must be done away with as far as possible. If we had a natural forest on an absolutely level plain, with conditions of drainage everywhere similar, soil and subsoil alike in every respect, the winds and moisture precisely similar in their effects over the entire area, then we could decree that the ultimate thinnings should leave the trees so many feet apart, which result could be attained either at once, or by so many intermediate thinnings. But such conditions nowhere exist, and each patch of forest requires the individual consideration of the operator. The local conditions require careful study in every instance, for the too abrupt alteration of the conditions under which a tree is living, by ill-advised clearing in its immediate vicinity, may do a tree harm rather than good, may retard its growth even if it does not induce actual disease. Careless thinning may cause trees to be bark-bound, to send out lateral branches, instead of forming a straight bole free from knots, and may have injurious effects in other ways. I am quite aware that it is difficult to secure the services of men who are capable of carrying out such work satisfactorily. Men should remember that the taking down of a number of trees in thinning operations is different in character to the removal of a number of stone or iron columns, and those entrusted with such operations must have a knowledge of the physiology of plant growth, and shrewd common sense to decide, under all the varying conditions of a specific locality, what is the best action to take, —how to vary, in different parts of the same forest, the degree of thinning.

One rule in forest-thinning should be borne in mind (*i.e.*, where merchantable timber and not merely landscape effects are in view) viz., the necessity for keeping the ground shaded as much as possible,

as exposure to the direct rays of the sun and the beating effects of the rain, alike diminish the productivity of the forest. Some valuable correspondence (although written with European and Indian conditions in view), on "What constitutes a thinning," has, during the last few months, appeared in the "Indian Forester"[1] a journal which is not so well known in these colonies as its merits deserve.

f. Ringbarking.—There is a vast field for enquiry into the best methods of destroying tree-growth. It is a matter of everyday knowledge that trees are sacrificed unnecessarily, but, when it is decided what trees are to be destroyed, there is frequently serious trouble owing to the suckering of certain species, (or the ground being taken possession of by others whose seeds have been lying dormant in the ground). The result, from whatever cause, is that ground is taken possession of by scrubby growths which have frequently become well nigh impenetrable, and instead of ring-barking having resulted in an increased growth of grass, the reverse has been the case. So diverse are local conditions that it is impossible to prescribe with exactness the time for destroying trees in every district.

If it be thoroughly understood that trees of different species do not perform their various functions connected with rest and growth, simultaneously, and that our seasons are exceedingly irregular compared with those of Europe, on the recorded experience of which many of us rely, perhaps too much, we shall have learned a good deal. And let it be further noted that we have a good deal of pioneer investigation to do yet,—in other words, that when a man asks us the best time to ringbark a certain tree, we have frequently no precedent to offer him. Because Stringbark was successfully ringbarked at Bandaloo in September 1889, it does not follow that Box may be successfully ringbarked at the same or any other place in September 1897. If we could prepare a column of statistics in this way, just as we record physical con-

[1] Mussoorie, India.—Official Organ of the Forest School, Dehra Dun. 15 rupees per annum.

stants, what a boon it would be! No, we must approach this subject, the importance of which is still of such magnitude to New South Wales, that outsiders can scarcely understand, in another way. We must consider the tree as a living organism, and give some attention to the physiology of tree-growth.

The first thing is to ascertain when the sap is "up" (to use a rather loose phrase the meaning of which is, however, well understood), evidence of which is shown by the facility with which the bark strips, and also by the formation of leaves, to be noted at a distance by their greater greenness. (In Australia we have of course mainly to deal with non-deciduous trees, but nevertheless it is usually an easy matter for a careful observer to note the extent to which the formation of a new growth of leaves has extended, or whether the tree is at rest). For an account of the physiology of the processes connected with sap-movement I must refer to the text-books. But I may remind you that starch is contained in the sap of trees, or a substance from which starch is obtained. This starch is separated from the sap and is stored up, during the period of active growth, in the wood, and especially in the root wood, ready for the formation of buds, (usually leaf-buds), which buds usually burst in the spring, but the season of bursting forth is exceedingly variable in this colony with various trees, as I have already hinted. Every forester, every man concerned in the procuring of timber, and every pastoralist, should make and preserve records of the periods of "flushes" of leaves on each of the various kinds of trees in his own district.

Now many trees, if the bark be injured, or ringbarked, have the power of developing the latent buds which exist under the bark, which buds are developed by means of the store of starchy matter which we have already referred to as existing in the root-wood (and in the stump). In other words we have "suckers," those curses of the forester and pastoralist. If information be desired as to the relative degrees of suckering of our forest trees attention may be invited to an article[1] dealing with the subject.

1 "Notes on Ringbarking and Sapping," (based on foresters' reports). —*Agric. Gazette of N.S.W.*, v., 14, (January 1894).

The liability of Box (*Eucalyptus hemiphloia*, etc.) to sucker has passed into a bye-word. So here, as pointed out by Farrer and others, many years ago, we have, I think, the key to the problem of ringbarking. If a tree is to be rung, see that the work is done properly, right through the cambium layer all round. Then see that it is cut at a period when the particular kind of tree operated upon has little or no starch or bud-sustaining material left in its roots. In other words, see that it is cut off from its base of supplies. Consequently, it may be bad practice to set a man to indiscriminately ringbark an area. Ringbarking is, in fact, an operation requiring scientific direction, and no land-owner should turn a number of axe-men into his property to ring-bark without very cautiously directing their operations.

It is a pity that the operation of ringbarking should be more difficult than is usually supposed, but we cannot contravene nature's laws without taking the consequences. A favourite saying of Sir Andrew Clark to a patient, was "Remember that Nature never forgives." If a land-owner will pay no heed to the science of ringbarking, his pocket will suffer; if a public official directs or sanctions ringbarking at an improper season, I would endeavour to teach him better, and if he proved incapable or unwilling to learn, I would replace him. If ringbarking were conducted on proper lines, that alone would justify the existence of a forestry department, for it would result in enormous saving to private citizens, and to that great land-owner, —the State. Here we have another potent reason for the technical education of the forestry staff.

g. Noxious Scrub and Prickly-pear.—I believe that the key to the effective destruction of noxious scrub, such as the Brigalow scrub, which devastates thousands of acres, and the Prickly-pear, (*Opuntia*), the eradication (or rather partial or non-eradication), of which has given rise to a permanent colonial industry, will be found in what I have said on the subject of ringbarking. We in fact take a mean advantage of plant-life. We cut the plant's head off at a period, carefully ascertained by the study of local

conditions, when it is unable to grow a new one. I would like to see measured areas of brigalow scrub cut on the principles I have indicated, and compared with scrub on adjacent land. I have no fear of the result, but scrub-cutting carried out carelessly or indiscriminately is just another name for pruning, and will probably result in a fine healthy crop of suckers which will require treatment at a greatly enhanced cost.

Did time permit, I would like to dwell on the subject of "weed-killers," a matter to us in Australia of national importance, however strange it may sound to European ears. I look upon weed-killers as only of very partial application, as they often merely scotch the weed, leaving its vitality practically unimpaired. With some weeds, under special circumstances, some (very few) weed-killers may be made to do useful work in the hands of carefully directed men. In any case weed-killers ought only to be paid for by bills having a currency of one, two or three years, provision being made to return the bills to drawer in the very probable event of the weed-killer not doing its work.

I think that weed-killers, where large weeds, such as prickly-pear, sweet-briar, etc., are concerned, should be placed in the same category as mattocks and picks; they are simply to be used as a means for destroying the plant at a period when it can no longer draw upon its accumulated nutritive store, its starchy capital in fact.

4. Australian Timbers.—*a. School of Timber-research.*—There is a vast field for research in the histology of colonial timbers. Very little has been done in this direction, and the work is interesting and full of promise of valuable results. How to get the work done is the difficulty, and it is not easy to make suggestions. Some of us have been spasmodically engaged in the work for a number of years, but it is work unsuited to the attention of men with many other claims on their time, and endeavour might perhaps be made to interest young University graduates in the matter. Students of biology should be well grounded in histology if they

make use of their opportunities, and no doubt Professor Haswell would help his old students who might seek his advice. Many fine illustrations of the microscopic structure of exotic woods have been published, and the student could give his first attention to these, many of the timbers to which they refer being readily available. As regards colonial timbers, the fine collection of the Technological Museum would be available. Material inducements to enter on the study might perhaps be made by recognising it in some way by the University (say as part of a post-graduate course), or perhaps the medal of our Society might be awarded for good work in this direction.

b. Wood-paving.—A good deal of attention has been recently devoted in the press to the evergreen subject of wood-paving. And it is pleasant to observe that every epidemic of letter-writing to the newspapers on this matter, shows that the writers have become better informed on the subject. At present it does not appear to be necessary that those who lay down paving of this character should possess much acquaintance with the timbers themselves, which is a matter for regret, although the diagnosis of Eucalyptus timbers is admittedly difficult. At present, even in Australia we see roadways made of timbers which have been felled practically all the year round, and timbers of different kinds mixed in the same stretch of roadway. The matter is already receiving the attention of the Engineering Section of this Society, and it is well worthy the attention of scientific men. Our health and our pockets are alike concerned, for the sanitary character of a roadway depends not only upon the nature of the material, but upon the way it is laid, and our pockets suffer in the improper depletion of certain kinds of timber, and through anything which prevents the maximum life of the roadway being obtained.

c. Special Uses of Australian Timbers.—This is a field in regard to which practical men may benefit themselves and the community at the same time. Many of our native woods have been recommended for specific uses. Can those recommendations be endorsed? The great majority of our native timbers have been put to no

other use than as fuel. It is in the highest degree improbable that our timbers, so varied in texture, colour and properties are unsuitable for many purposes. If not, what are those special purposes? The uses of wood are infinite, and this enquiry, while not of a high scientific character, is certainly work of great importance.

5. Botanical Teaching in New South Wales.—*a. The present state of Botanical Instruction in this Colony.*—I think I am correct in saying that there are few institutions in the colony in which botany is practically taught. As regards schools, whether the subject is taken up or not depends upon the inclination of the individual teacher. It is recognised in the local examinations of the University as an optional subject. In the University itself, it is taught as part of the Biology course. The great objection with which one is met in advocating wider teaching in botany is the already (in the opinion of some), overcrowded list of subjects taught in many schools. But, bearing in mind the primary meaning and object of education,—the "leading out" of the faculties, it does seem a matter for regret that a place is not found for a subject like botany, which is so well adapted for securing the end in view. In country schools the plants of the district may be made of never-ending interest to the scholars, and they could be taught to observe, with objects ever at hand. In towns there need rarely be insurmountable difficulty in obtaining a fresh supply of leaves and flowers to illustrate a practical discourse. I would not press on children, at too early a stage, anything in the shape of a course of structural and systematic botany. Rather, I would take a few well-known plants, bring out a few points of structure, and illustrate their uses wherever possible. In like manner, in teaching a child chemistry, I would show him a series of experiments, in order that he might see the kind of apparatus employed and the class of effects produced, that he might, in short feel himself in an atmosphere of chemistry, and so imbibe a love of it, before being put to the more serious work of systematic study of the science. But where shall we get the teachers? Well, it does

not require that a teacher shall have a very profound knowledge of the subject before he can give a very interesting (and sound) practical lesson to children in botany. If teachers would not mistrust their own powers in this respect, they would find their own knowledge would grow, for by a kind of inductive action between teachers and taught, teachers would find their own knowledge develop, and they could proceed to broader views of the subject.

As intellectual discipline, the science of botany possesses merit of a high order, while it has the advantage of causing its votaries to wander in the fresh, pure air of the fields and woods, never without companions although apparently alone, and last, though surely not least, the refining effect of a love of plant-life must never be overlooked. And if the subject be encouraged in the elementary schools, its more ample recognition in higher schools and colleges, and by the University, will follow as a matter of course.

b. An Institution for Botanical Research.—We lack an institution to do for the botanical student what the chemical laboratory does for the chemical student. By use of the term laboratory, I do not wish to be misunderstood; I mean an institution where the student may pursue botanical enquiries with facilities for reference to abundant fresh and growing material. The need of such an institution has been felt in London, and I would refer to an interesting scheme recently propounded by Mr. W. Martindale.[1] As far as New South Wales is concerned, an institution of this character must obviously be in close touch with the Botanic Gardens at Sydney, for no scheme of botanical instruction can be complete without practical demonstrations with living plants. I am not prepared with a working scheme, and will content myself at present with a few suggestions. A house in the vicinity of the Gardens could be set apart for students. None of them would

[1] On the desirability of establishing an institute for the testing of botany in the Royal Botanic Gardens" (London), by W. Martindale.—*Pharm. Journ.* [4] IV., 203, (6th March, 1897).

be in residence, and the rooms could be fitted up with the appliances usually found in a herbarium and botanical museum, special apparatus and fittings for special work being of course provided as required. Intending students would require to give evidence of their fitness to conduct research, and a room, or part of a room, would be put at the disposal of each for a period, such period being capable of extension if found desirable. Students might be nominated by the University,—special students who, having graduated, desire to take up a special line of botanical research; medical and pharmaceutical students could be nominated by the Medical School of the University and by the Pharmaceutical Society; the Department of Public Instruction might nominate teachers as students during the whole or part of their vacation; students and cadets from the Technical College and Technological Museum might be nominated; the Department of Mines and Agriculture might nominate forests cadets, students at agricultural colleges and experiment farms, inspectors of prickly-pear and other weeds. Every encouragement could be given to other students to take up practical work in connection with the physiology and morphology of plants, and to work at problems of classification. A student would bring such books and apparatus as he could afford, and as regards the rest, he could have ready access to the Public Library and the library of the Botanic Gardens, to a fine collection of growing plants and a very fair herbarium, and to the various conveniences for study (hot-houses, frames, ponds, tanks, etc.) which a generously equipped botanical establishment might supply. For my own part, I desire to see the educational opportunities which the Gardens afford exercised to their fullest extent, subject only to necessary safeguards for the safety of the public collections, and to non-interference with the discipline of the staff. I quite think it would be possible to carry out some such scheme as I have outlined, without interfering with the ordinary work of the Gardens.

c. Education of Foresters.—Our foresters are some of the best abused men in the service, but, if only for the reason that they

have the oversight of part of the assets of the colony worth a very large sum of money, we should do all we can to encourage them and further their welfare. Some of the men in our forest service are, to my personal knowledge, excellent men for the positions they hold, but this is owing to the men themselves, and not to the method by which they have been trained. Just as the administrators of the public school system of this colony find it necessary to train, from the beginning, most of their teaching staff, so, I think it would be also a wise policy for the State to train foresters for its own service. If the whole, or the majority of the forestry posts were awarded to trainees of the State, the State would find competition to undergo courses of training keen, and better men would probably find their way into the service.

Some knowledge of the botany of Australian plants (particularly trees) should be insisted upon, in addition to the botany of exotic plants usually exclusively taught in Australia itself, together with knowledge of the physiology of plants, for unless a forester possesses such knowledge, his treatment of his tree-charges must of necessity be empirical. Apprenticeship for one or two years of forestry cadets in the Botanic Gardens and Parks would be very desirable, in order that the operations and discipline of such establishments might be familiar to them. In fact I would insist on such training, and with stringent provisions for the prompt termination of a course in any case in which a student did not appear to profit by the instruction provided.

6. A Plea for a Botanical Survey.—The desirability of a botanical survey for the Colony is so obvious, that I require only to touch upon a few points which suggest themselves, because of our special circumstances and environments. In the first place, we are frequently asked where this or that plant, or a supply of its product, may be obtained in quantity, and sometimes we can only indicate the locality in general terms. The establishment of a botanical survey need not involve the expenditure of a large sum of money, but rather the organization and control of existing agencies which may subserve the grand object in view. I feel

sure that in country districts there are hundreds, nay, even thousands of private citizens, and officials such as engineers, surveyors, mining, land and forest officers, school teachers, postmasters, and many others, who would give voluntary aid to the furtherance of a botanical survey. Many would, in their spare moments, gladly supply information and collect specimens if they knew what would be acceptable. But while the work must be largely voluntary, it need be none the less systematic. I have conducted an informal botanical survey on my own account for many years, but my correspondents, although many, do not represent the whole of the colony, and their work has been necessarily of a fitful and unorganised character.

In time to come we shall not only have geological and mining surveyors, but also agricultural and forestry surveyors. I use the word surveyor (as regards agriculture, forestry, etc.), not so much in the sense it bears as applied to a land-surveyor, for a man may be able to furnish valuable information suitable for a botanical and agricultural survey, and yet be incapable of using a theodolite. To summarise, I would use the term "botanical survey" as correlative to geological survey, and it would include observations applicable to :—

a. Pure Botany.
b. Agriculture.
c. Forestry.
d. Horticulture.

Let us touch upon these heads in a little detail.

a. Pure Botany.—An obvious advantage to the systematist would be that material from a wider area would be available, and thus he would be better able to define the limitations of species and varieties than he is at present. How frequently we have to deplore the one-sided description of a species, often prepared from one specimen, from one locality, in ignorance perhaps of the amount of variation the same plant undergoes a very short distance away. A botanical survey will above all things secure thoroughness ; its action will be comparable to that of the wide-

spreading net which sweeps a large area, while our present spasmodic efforts in the same direction may be compared to those of the patient and stationary angler who must fain be content with a bite here and a bite there. The acquisition of more complete material in many orders will lead to the employment of specialists; many of our local botanists who take up the subject broadly, will probably specialise on certain genera and orders. Nor, under an improved arrangement, will any orders or groups of plants be ignored, as some practically are at present. The head-quarters of the Botanical Survey will be practically a Botanical Clearing-house, waste and duplication will be minimised, and no man who desires material for research need go unsatisfied. I may, perhaps, draw special attention to the desirability of additional botanists and collectors in New South Wales giving attention to fungi (particularly micro-fungi), mosses and sea-weeds.

Local Floras.—A properly organised botanical survey would supersede the special preparation of local floras, or rather, the local botanist would have his task limited to the filling in of blanks in well defined geographical or geological areas. I have nothing but praise to bestow upon the outlines of local floras already published for districts of New South Wales, but their authors would be the first to admit that their observations are incomplete, and lack their full educational value for the reason that they had to work upon imperfectly defined areas. We have much to learn in regard to the range of plants with respect to geological formations. The admirable coloured geological map issued by our Geological Survey is of the greatest service to botanical collectors collecting with the above object in view.

Flowering Periods of Australian Plants.—A botanical survey might also take cognizance of such matters as the flowering periods of indigenous plants, information which would be desirable, on the practical side, as indicating when fruits and seeds might be probably available.

b. Agriculture.—The subject of Agriculture is so important that it might either have a survey to itself, or the facts having a

special bearing on the subject might be collated by themselves. Of course in dealing with this subject the indigenous plants are, on the whole, of inferior importance to exotic ones. The crops we raise are practically all exotics; at the same time we must never lose sight of the possibilities of our indigenous fodder-plants, for instance. The character of the indigenous vegetation is a valuable guide to the agriculturist who desires to break up fresh soil, therefore a botanical survey should be in a position to furnish him with the information. Not that any sensible man would buy land without looking at it previously; at the same time a farmer is usually a poor man, and, whether he is or not, we should endeavour to supply all information which will facilitate settlement. The Department of Agriculture is already in possession of a vast amount of information in regard to the suitability or otherwise, of different districts and small areas, for the cultivation of various plants,—an Agricultural Survey would systematise such information and render it more readily available to the public. The establishment by the department of model farms in different parts of the colony, will, besides teaching improved methods of farming, furnish the colony with many of the agricultural data requisite for a complete agricultural survey.

The survey will also take cognizance of weeds, of the areas affected by the noxious species, of the spread of such plants, of various methods for weed-eradication and their results, and all matters which will assist in the framing of laws and regulations for coping with these pests.

The Botanical Survey should be in intimate touch with the Geological Survey, as we require to know, amongst other things, the character of soils and sub-soils, and various matters connected with the retentiveness of the soil for water, natural water-supplies etc. This information will supplement that of the Chemist of the Department of Agriculture on the chemistry and physical properties of soils. As regards the desirability of co-operation with the Entomologists of the colony, I have only to state the case to commend it to consideration, as plant and insect life are indissolubly connected.

c. Forestry.—We have much to learn in regard to the geographical distribution of even our principal forest trees; much more then, is there scope for enquiry in regard to the distribution of those of less frequent occurrence. The matter is of importance from a utilitarian point of view, because of the fact that be a timber ever so desirable, it cannot be utilized commercially unless a continuous supply be available, and to obtain supplies we must know the localities of its occurrence not merely in general terms. The value of a botanical survey would be most immediately felt in regard to our forests. We could by the aid of it take stock, as it were, of our possessions, of our standing timber, and prepare a scheme for scientific conservation. A general statement to an outsider as to the vastness of our timber supplies is at once met by the plain questions,—Where are each of your timber-trees found, of what size are they, and in what abundance?

Measurements of Trees.—One of the matters to which attention would be given by a botanical survey would be that of ascertaining the heights and trunk-diameters of various kinds of trees, different observations being made in regard to the same species in different districts. In this way a ready index would be obtained as to the climates and soils in which various species flourish best. Notes would also be taken of the sizes of abnormally large trees. These are of course becoming rapidly fewer ever since the advent of the white man. If the identity of individual trees be noted, either by marks on or near the trees themselves in the forest, or on the maps, it would be easy to prepare records of the rates of growth of our Australian trees, a matter of considerable economic importance, and of some scientific interest, but in regard to which we possess very few data at present.

Rate of Growth of Forest Trees.—This is a forestry matter which might well engage the attention of a Botanical Survey. We have a few scattered notes on the growth of indigenous trees,[1] but no enquiry of this nature, on a large scale has, to my know-

[1] For example, *Agric. Gazette N.S.W.*, VII., 504, (August 1896).

ledge, been yet attempted. The ascertainment of the rate of growth of exotic trees in various districts is also of great practical importance, and the data are often more readily available than is the case with indigenous trees, as, since as a rule they have been planted by man, approximate dates of planting are often ascertainable.

Natural Re-afforestation.—A phase of the forest question that is not often enquired into is the conversion of grazing land into forest growth since European settlement. It is a well ascertained fact that, since the advent of the white man, a growth of trees, more or less dense, has, without artificial planting, taken possession of grass land. Enquiry might be made into the circumstances of each case, for opinions are by no means unanimous as to the cause of these forest growths. The reason of this change is attributed to the overstocking of country, the stock eating down the grass, so that bush-fires, (which formerly consumed the seedlings of forest-trees), are now less frequent, and devastate smaller areas of country, than they used to do. In some cases there is no doubt that stock aid in the propagation of trees by trampling the seeds into the ground, and even manuring the ground, thus preventing the seed being washed away by rain. At the same time one must not lose sight of the fact that stock have important influence on the formation of natural forest growths, as they eat out (particularly when grass is scarce), many young trees.

d. Horticulture.—Many of our plants are well worthy of cultivation for ornamental and other purposes. The merits of but few are known to horticulturists, so that there is room for much enquiry.[1] Some desirable plants are sparingly distributed; in regard to these we require full data as to localities, with particulars as to soil, aspect, etc., and particularly the season for maturing seeds.

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1 See "Some New South Wales Plants Worth Cultivating for Shade, Ornamental, and other Purposes."—*Agric. Gazette N.S.W.*, VII., 341, (June 1896).

County and Parish Maps.—As the results come in, they will, after checking, be carefully entered by a draughtsman-clerk (many of whom already possess knowledge of plant names), in the county and parish maps. The county maps will serve for more general records, the parish maps for those in more detail. To accompany each map, or group of maps, registers could be attached, where information could be recorded which is unsuitable for (either on account of its bulk, or for other reasons), the maps themselves. Such registers could have printed columns and head lines; thus expense could be saved and neatness and uniformity secured.

Such is a crude outline of my views on a subject which I venture to submit to your consideration. India has for many years enjoyed the advantages of a botanical survey, and I trust that no great time will elapse before we have a properly organised Botanical Survey of New South Wales.

On the CRYSTALLINE STRUCTURE of GOLD and PLATINUM NUGGETS and GOLD INGOTS.

By A. Liversidge, LL.D., F.R.S.,

Professor of Chemistry in the University of Sydney.

[With Plates I.–XVI.]

[*Read before the Royal Society of N. S. Wales, October 3, 1894.*]

A preliminary account of the subject of this paper were communicated in 1894 to the Royal Society of N. S. Wales, and the sections of some nuggets were exhibited then and later on, but the publication of the paper has been deferred until now, pending the preparation of the illustrations; a brief notice from the proceedings of the Society was also published in the Chemical News in 1894.[1]

In a paper read before the Royal Society of N. S. Wales in 1893,[2] I discussed the origin of gold nuggets and reviewed the theories which had been put forward to account for their formation. One explanation of their origin is that they have been formed *in situ* in the gravels and alluvial deposits in which they are found, and that starting with a nucleus they were gradually increased in size by the successive deposits of gold from solution, *i.e.*, that they were built up of superimposed coatings and were analogous in structure to an onion. In that paper I gave various reasons to show that this explanation is not justified; after its publication I obtained specimens of gold nuggets, which were ground down or sliced through so as to obtain sections; these sections were then polished and etched by means of suitable

[1] It has been arranged that this paper should be published simultaneously in the Journal of the Chemical Society, London.—A.L., Sydney, July, 1897.

[2] On the Origin of Gold Nuggets.—Journ. Roy. Soc. N.S.W., 1893; Chemical News, Vols. xlix. and l., 1894.

solvents, such as chlorine water, aqua regia, a solution of potassium cyanide or by a mixture of sodium chloride solution and nitric acid; the last was found to be the most convenient because the strong solution of salt dissolved off the coating of silver chloride which was usually formed, and which prevented the action of the solvent from being properly watched.

As a result of this treatment it was invariably found that the nugget did not present any traces of concentric coatings, but that the gold was always more or less crystallised, and in some cases the crystals were very large and with well defined boundaries; in fact the etched surfaces closely resembled those obtained from sections of many metallic meteorites, except in the form of the crystals—this structure is clearly seen in the illustrations to this paper.

Some of the nuggets also showed cavities and enclosures of quartz, ferric hydroxide and argillaceous matter, although in many cases none was visible on the rolled surface of the nugget, the non-appearance of the impurities on the surface being due to the soft gold having been usually beaten down, by rolling and attrition, in such a way as to cover over and hide the enclosures or render them less conspicuous.

It was found also that many nuggets when heated strongly in a bunsen burner became blistered, and that these blisters burst with a sharp report sometimes accompanied by the projection of small pieces of gold; they also gave off gases or vapours, which issued under considerable pressure and forced out the bunsen flame into little blow-pipe-like jets. It was thought that these phenomena might be due to the presence of enclosed gases under pressure, but when the nuggets showing these blisters or blebs were immersed in a solvent and the walls of the blebs slowly dissolved away, there was no escape of gas.

Subsequent investigations showed that the nuggets yielded but very small quantities of permanent gas, when examined at a high temperature in vacuo for occluded gases, and it was found that the vapour given off was mainly that of water mixed with some

sulphur dioxide and air. The water vapour was probably derived from the hydrous oxide of iron and argillaceous matter enclosed in the nuggets, and the sulphur dioxide from pyrites or other sulphur containing minerals.

The nuggets examined came from various parts of Australia and differed considerably in purity; the purer ones usually presented a much better marked crystalline structure—this is well shown in the specimens from West Australia. *Plate* 1 reproduces a photograph of a nugget from Coolgardie, W.A., enlarged two diameters so as to render the external details clearer. The somewhat rounded and worn points show traces of crystalline form, probably that of the octohedron and its derivatives. On the whole the nuggets from West Australia which I have seen did not possess such a worn and rounded appearance as that usually presented by large nuggets from other localities, and I am inclined to think that they are less water worn on account of the greater dryness of that region. The weight of this nugget was 9·94 oz. Troy, and the Mint assay was gold ·8900, silver ·105.

The assays given in this paper are those of the average of the parcel of gold from which the nugget was selected, the assays of the individual nuggets and of portions of the nuggets have yet to be made. It is intended to cut out crystals from the sections and examine them separately to see if there is any difference in their composition. Some of the crystals are much more deeply etched than others, that this is the case can be seen from the photographs, which by no means give all the details.

The external depressions of this and other West Australian nuggets contained a little clay, which under the microscope showed the presence of a few spangles of gold and some small particles of quartz with sharp edges and conchoidal fractures. One small fragment of galena was also detected. Internally the nugget was practically free from foreign matter. *Plate* 2 is from a photograph of an etched section of the nugget taken very near the median plane. *Plate* 3 shows the other side of the same section but more deeply etched. A few minute cavities can be

seen in the crystals, but the nugget was remarkably free from impurities, the dark parts are due to the way in which the light has been reflected from the surfaces of the crystals. Crystals which appear black in the photograph in one position, appear white or half-tone in another position. The whole of the surface was, of course, of a brilliant gold colour.

When *Plate* 3 was taken this nugget had been by successive filings and etchings reduced to about $\frac{1}{8}$ inch in thickness.

The three preceding plates and No. 14 have been reproduced in collotype so as to permit of examination with a magnifying glass, the rest of the photographs have been reproduced by process blocks for the sake of economy, with unfortunately the loss of many details. None of the photographs or reproductions have been touched up or the effects heightened in any way.

In *Plate* 4, there is a section of another nugget from Coolgardie, enlarged three diameters; this nugget weighed 2·96 oz. Troy, and was picked out of a large parcel of some hundreds of ounces mainly composed of nuggets from two to five ounces in weight, all of which were only sub-rolled or water worn, and many pieces showed traces of external crystal planes.

On etching this section with chlorine water its surface became thickly coated with silver chloride; some of the crystals were much more rapidly etched than others—the lines of contact of the crystals were also deeply etched. Unless there be a difference in composition or of structure, the differential action of the solvent is difficult to account for; in the case of meteorites we know that the characteristic Widmannstatt figures are largely due to a difference in composition.

Freshly cut and thoroughly dried fragments of this nugget when strongly heated gave off water and sulphur dioxide, the latter probably due to the presence of a little iron sulphide, and it emitted an empyreumatic or nitrogenous odour similar to that which I have often found to be given off by rock crystal, many

minerals and rocks. No explosions, however, occurred and no blebs were formed.

The section of a nugget from Orange, New South Wales, reproduced in *Plate* 5, on heating to incipient redness in a bunsen, gave perhaps, the sharpest explosions and the largest blebs of any. The weight of this nugget was 1·08 oz. Troy, and the Mint assay of the parcel from which it was obtained gave gold ·9345, silver ·0600. No foreign matter was visible in the section until it had been etched, when it was found to be studded with minute grains of quartz and a little oxide of iron; the crystalline structure is on a much smaller scale than that of the West Australian nuggets. The blebs and the cavities left by them are well shown, and *Plate* 6 shows the cavities left after the bleb-walls had been dissolved away.

As already stated, no gas was observed to escape from the blebs when the walls were dissolved away by chlorine water, hence the blisters were not due to imprisoned liquid carbon dioxide or other similar substance, but apparently to water or to a hydrated substance such as iron oxide.

Although the process block shows the structure of this section fairly well, yet some of the detail is lost, and nothing is seen of certain long and straight well defined lines meeting at angles of about 70°; these lines are clearly visible in the section itself, they reflect light very brilliantly and appear to be the edges of crystals.

A nugget from Nerrigundah, New South Wales, also showed these long straight brilliant and sharply defined edges; in both cases they were seen on the exterior of the nugget as well as in the section. Assay = ·9805 gold and ·010 silver.

On *Plate* 5 there is also the etched section of a nugget from Adelong, New South Wales, weighing ·4 oz. Troy, Mint assay of parcel = ·9275 gold and ·0650 silver. This section showed the presence of much iron oxide and a minutely crystalline structure. On heating only minute blebs were formed.

On *Plate* 6 there is also the section of a nugget from Queensland which shows the gold in the form of veins enclosing much ferru-

ginous matter; the lighter coloured parts are the gold. Weight ·7 oz. Troy; assay ·8795 gold and ·1150 silver. Externally this nugget showed a foliated structure and the presence of ferruginous matter.

The first figure on *Plate* 7, is the section of a gold nugget from Wellington, New South Wales, weight ·99 oz. Troy, Mint assay of parcel, gold ·9335, silver ·0600. Externally this nugget seemed to be massive gold, but the section showed the presence of much ferruginous matter; the bending and welding over of the gold thus enclosing the impurity is well shown by the photograph.

The three following New South Wales specimens also show much enclosed ferruginous matter, and a minutely crystalline structure.

The next specimen on *Plate* 7 represents a section of particularly bright gold from Peak Hill, this weighed ·92 oz. Troy, Mint assay =gold ·9790, silver ·0100. No visible impurity was present, the black and dark parts are crystals of gold; from the large size of the crystals this nugget looks as if it had belonged to a much larger piece, but not necessarily so. The crystal sections have a satiny sheen, not visible in the illustration, as if made up of thin plates. The interpenetration of the crystals is well shown. This nugget is purer than usual and such gold generally yields larger crystals, this is the case also with ingot gold.

The nugget from Parkes, New South Wales, *Plate* 8, shows a different structure to any of the preceding; it is minutely crystallised and contains rounded enclosures of iron oxide. Weight 5·4 oz. Assay = ·9265 gold.

Sections of many other nuggets were made and photographed, but as they did not differ materially from those described herein they are not figured. A nugget from Hill End, New South Wales, showed under a one inch objective a small cavity lined with quartz crystals. In others the cavities were lined with minute crystals of gold.

Platinum Nugget.

The section of a nugget of platinum weighing thirty-six grammes, sp. gr. 15·87 was also prepared, polished and etched by

aqua regia, *Plate* 9. The structure was found to be much more granular than that of the gold nuggets, and the mass readily disintegrated into particles of from 1 to 2 mm. in diameter and possessing a crystallised appearance with octahedral markings.

Between many of the granules there were films of a pale buff-coloured non-metallic mineral, which requires further examination. The nugget was evidently impure and requires to be analysed.

Copper Nuggets.

Some nuggets of native copper were sliced and etched, although they presented a crystaline structure it was not well marked. I hope to shortly procure some silver nuggets for examination.

Artificial Nuggets and Ingots.

Next attempts were made to prepare artificial nuggets by electrolytic deposition; around wires, fairly thick masses were obtained, the sections of these showed well defined rings and traces of crystalline structure; the rings or successive coats were clearly due to changes in the strength of the current and of the solution. Masses of fused gold were also cut, polished and etched, and in all cases a strongly marked crystalline structure was visible.

In *Plate* 10 is shown the cross section through the centre of an ingot of gold weighing 1,400 oz. and assaying 1,000, *i.e.*, it was nominally pure gold. The crystals are seen to be very large and well defined and radiating out from the sides, which were in contact with the ingot mould, in well-defined curves. The horizontal lines may be due to the action of the planing tool by which the ingot was cut, the tool marks were filed and polished away completely, but doubtless the pressure of the tool set up stresses and molecular changes, and the effects of these become apparent in the process of etching; the shearing strain must have been considerable, for it required a nominal four-horse power engine to work the tool when making the vertical groove or cut, although the cutting edge was quite narrow.

The next, *Plate* 11, shows the base of the ingot after etching; before etching no crystalline structure was apparent.

In *Plate* 12 is shown the structure brought out on etching an internal horizontal section of the ingot cut parallel with the top and base through the plane A.B. *Plate* 10, in this also the groove-like lines seem to be due to the stress of the planing tool. This horizontal section was made by planing away the top of the ingot down to the median line A.B.

Next a large ingot, weighing 1,203 ounces, of standard gold coinage alloy (22 carat or 11 gold to 1 of copper), was cut through, polished and etched; this impure gold, as might be expected, showed a much smaller crystalline structure (*Plate* 13), and the crystals only radiate inwards a short way. This particular specimen was etched for me by Mr. McCutcheon, Assayer to the Sydney Mint, as it was found inconvenient to have such large masses of gold carried between the Mint and the University laboratory. It will be noticed that the striæ caused by the cutting tool, (if they be due to that in the softer and purer ingot) are not visible in this harder alloy. Although only two ingots are figured and described, several other smaller ones were made and examined, with similar results.

The next, *Plate* 14, is a collotype of, nominally pure and standard gold fillets, of the thickness of a sovereign; the crystalline structure is preserved in spite of the rolling and annealing which they have undergone, and in the case of the purer gold, some of the crystals are etched so deeply as to throw the others up into such high relief as to yield well defined shadows. It is noticeable too, that the large longitudinal crystals (elongated by the rolling process) are crossed, practically at right angles, by other smaller but well defined crystalline striæ. Enlarged two diameters.

Plate 15 represents an etched rolled fillet of Mount Morgan gold, assaying 1,000, and supplied to me by the late Dr. Leibius of the Sydney Mint, as a specimen of the purest gold he had ever made. In this the crystals are still larger. Enlarged two diameters.

A plate of copper was thickly coated with gold electrolytically and etched but only a minute crystalline structure was obtained.

A fillet of nominally pure silver presented a minutely crystalline structure, quite unlike the gold fillets.

I had hoped to obtain and examine a specimen of "brittle" gold from the Sydney Mint, but none happened to be produced at the time, as its crystalline structure would be of interest and it might perhaps afford information which would be of use.

For comparison an ingot of tin was etched by nitro-hydrochloric acid, with the result shown in *Plate* 16; the ingot weighed about 20 lbs., only a small part of its surface is shown in the plate.

The well known moiré-métallique structure became visible immediately on moistening with the acid; the etching was continued until about one-quarter inch in depth had been dissolved away, the outlines of the crystals apparently underwent no change, and the surface remained quite smooth, *i.e.*, none of the crystals were dissolved away more quickly than the others, and no grooves were eaten out along their edges. The gold nuggets, ingots and fillets behaved quite differently, that is, grooves were eaten out at the junctions of the gold crystals, and some were sunken below the others so that the etched surfaces of the gold could be printed from, and the differences of level seen and felt, nothing of the kind happened with the tin ingot.

I have much pleasure in acknowledging the very great assistance I have received from the Deputy Master and the officers of the Sydney Mint in specially preparing and slicing the heavy ingots of gold for me, and for their cordial coöperation generally.

Conclusion.

A great deal requires to be done to complete this investigation, but as far as it goes it proves that gold nuggets do not show that they have been built up of concentric coatings round a nucleus, but that they possess a well marked internal crystalline structure and that they usually enclose foreign substances, also that a similar crystalline structure is shown by gold which has been fused; I do

not, however, think that native gold has necessarily been in a fused condition, on the contrary I think it has been deposited from solution and usually within veins or pockets in rocks, although if it had been deposited round nuclei, it might still have possessed the crystalline structure which has been described and figured in this paper.

A CONTRIBUTION TO THE STUDY OF OXYGEN AT LOW PRESSURES.

By R. THRELFALL, M.A., Professor of Physics in the University of Sydney, and FLORENCE MARTIN.

[*Read before the Royal Society of N. S. Wales, June 2, 1897.*]

WHEN a mass of oxygen is enclosed in a tube and the mercury pressure on it continuously diminished, it is found that at about 0·7 mm., and over a certain range of lower pressures, the gas appears to undergo a change of condition. The phenomenon may be described in the words of Bohr, its discoverer,[1] "A given mass of oxygen is enclosed in a tube and the mercury adjusted so as to give rise to a pressure rather less than 0·7 mm. If the volume of the gas is now reduced by raising the pressure, say to 0·8 mm., it is noted that this pressure will not remain constant; but varies more or less with lapse of time. In three to five hours the pressure will fall by some 12% of its initial value (the volume being constant). After five hours the pressure was found to have attained its steady value, so far as observations extending over twenty-four to thirty-six hours could determine."

This curious behaviour of oxygen was also noted by Baly and Ramsay,[2] who observed that at a pressure of about 0·75 mm.

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[1] Wied. Ann. 27, p. 475. [2] Phil. Mag., 38, p. 324, 1894.

oxygen becomes unstable as to its pressure volume relation, and that the equilibrium condition is not attained until after seventy-eight hours rest. The slightest change of pressure or volume then upsets the equilibrium, and time has again to elapse before a steady state is attained. It appears likely either that the oxygen forms an allotropic modification, or that it forms some compound with mercury or other material present and with which it is in contact.

It will be noted that according to Bohr, the volume of the gas tends to increase below 0·7 mm. indicating that the molecules of oxygen are partly split up. In this case, therefore, it would be reasonable to infer an increase of oxydising power, and it is possibly to this cause that the soiling of the fall tubes of Sprengel pumps is to be attributed. It appears worth while therefore to try to arrange some chemical test capable of showing the presence of active oxygen.

The two following test solutions were found to satisfy the conditions, though one was more sensitive than the other. One condition of course is that the test solution must not have a vapour pressure comparable with 0·7 mm. The first indicator tried was a solution of indigo in pure sulphuric acid. This is bleached by ozone, but experiment showed that the reaction does not afford a very delicate test of the presence of that gas. Another solution was therefore tried, consisting of potassium iodide and starch dissolved in glycerin. The glycerin was carefully dried at a temperature of 260° C. When cool, some of it was mixed with a small quantity of powdered potassium iodide. A very small quantity of starch was added to the remainder of the glycerin, which was then slowly heated till the starch was quite dissolved and the liquid again became transparent. When cold, this portion was mixed with the potassium iodide solution—a solution so prepared is not affected by ordinary oxygen, but one bubble of the gas which has passed through an ozone tube turns it bright yellow, and three bubbles give it a dark blue, almost black colour. This seemed sufficiently sensitive, and was accordingly adopted. Of course the starch is not absolutely necessary,

iodine being liberated in large enough quantities to colour the solution, but it was considered to be of some advantage to use it as an additional verification. Oxygen was prepared and purified in the usual manner, and stored in a gas holder.

On leaving the gas holder, the gas passed through (1) a system of purifying tubes containing *(a)* nitrate of silver, *(b)* solid potash, *(c)* sulphuric acid, *(d)* phosphorus pentoxide, (2) a wash-bottle containing a small quantity of the potassium iodide solution, (3) an ozoniser by which the oxygen could, when required, be ozonised without altering any of the apparatus.

Two diagonal glass taps, in series, allowed the purified gas to pass into the exhausted part of the apparatus. This consisted of a glass tube about 0·2 cm. in diameter and 0·30 cm. long, to which was fixed a mercury pressure gauge of the U type, 0·1 cm. in diameter. In order to prevent a possible loss of active oxygen through the action of the mercury in the gauge, the latter was connected to the exhausted space by a capillary connection.

The exhausted tube was connected through a small wash-bottle with a Fleuss pump, the wash-bottle containing a small quantity of the sensitive solution. A similar wash-bottle, containing the same solution, was arranged to stand close to the bottle through which the gas was passed in order to enable colour comparisons to be made. All the apparatus was, practically speaking, either fused together or had joints protected by paraffin and mercury, the use of india-rubber being of course inadmissible. The Fleuss pump was worked by an electric motor, and the taps were adjusted until a steady stream of oxygen could be passed through the apparatus at a pressure of about 0·25 mm. of mercury.

The apparatus, after having been made entirely air-tight, was filled with oxygen and exhausted several times; a steady stream of oxygen, at atmospheric pressure, was then run through it for an hour in order to get rid of traces of air. It was then exhausted and kept at a constant pressure of nearly 0·25 mm., (never less than 0·1, nor greater than 0·4 mm.) with the oxygen bubbles coming through at the rate of twenty per minute. Each

bubble of oxygen on reaching the exhausted tube was therefore reduced in pressure over the range of instability. After six hours, no change having taken place in the potassium iodide solution, the apparatus was filled with oxygen at atmospheric pressure and left for several hours. This experiment was repeated during three days, that is to say the oxygen was passing through the apparatus at a pressure of 0.25 mm. for 17·5 hours altogether. At the end of this time, no trace of the ozone reaction being observable, it was considered advisable to ascertain whether if a very small proportion of the oxygen passing through had become converted into ozone—so minute a quantity, at so low a pressure, would affect the test solution. With this object, the wires of the ozoniser were now joined up, and it was found that in one minute a faint yellow colouring of the solution, slight but distinctly visible, occurred. Evidently, therefore, twenty bubbles of electrically ozonised oxygen produce more effect than 21,000 bubbles of oxygen which has been simply subjected to the effects of low pressure. And even if the experiment described above is not considered to prove, with sufficient conclusiveness, that low pressure alone has no power to cause the formation of ozone in oxygen, it must at least be admitted that the ozone so formed is less than $\frac{1}{1000}$ of the quantity produced by an ozoniser in the ordinary way in the same volume of oxygen, and as this can scarcely exceed 5% of the whole volume, the ozone formed by lowering the pressure cannot be so much as ·005% of the volume of oxygen present.

We must not neglect to state that our curiosity in this matter was stimulated to the experimenting point by a letter from our friend, Mr. W. Sutherland, of Melbourne, who considered, on grounds based on the kinetic theory of gases, that allotropic oxygen of some kind would most likely be found at about the pressure we employed. The soiling of Sprengel pumps, however, as well as the experiments of Baly and Ramsay, had previously led us, independently, to infer the possibility of a production of active oxygen under the conditions we have mentioned.

DETERMINATION OF THE ORBIT ELEMENTS OF COMET *f* 1896 (*PERRINE*).

By C. J. MERFIELD, F.R.A.S.

[*Read before the Royal Society of N.S. Wales, June 2, 1897.*]

THE object of this short paper is to present the Society with a detailed account of the calculation of the orbit elements of Comet *f* 1896, which the author has discussed with the best data available.

This comet, which was discovered by Mr. Perrine of the Lick Observatory, California, on November 2, 1896, was observed by various European and American Observatories from the time of discovery until about the 20th of December of the same year. Owing to the comet's position in space, it was lost to view during the latter part of December 1896, also during January 1897. After the perehelion passage 1897 February 8, the comet, which was receding from the earth before this date, again approached our planet, and would be well placed for southern observers.

During the evening, 1897 February 22, Mr. J. Tebbutt, F.R.A.S. of Windsor, was successful in obtaining an observation of this apparition. From this date and until 1897 April 27, the author has been supplied with about thirty observations taken by that gentleman. The comet, which did not attain to the brilliancy expected, has been faint and difficult to observe, so that Mr. Tebbutt was forced to abstain from further observation after the 27th April.

Preparatory to this discussion, approximate orbit elements were computed from observations taken by Mr. Tebbutt on the 5th, 10th and 15th of the month of March 1897, with the following result :

$$T = 1897 \text{ Feb. } 8{\cdot}168615 \text{ G.M.T.}$$

$$\left.\begin{aligned} \omega &= 172^\circ\ 25'\ 1''{\cdot}14 \\ \Omega &= 86^\circ\ 29'\ 10''{\cdot}82 \\ \iota &= 146^\circ\ 11'\ 3''{\cdot}78 \end{aligned}\right\} \text{Mean equinox 1897}$$

$$\text{Log } q = 0{\cdot}0263786$$

These elements agreed fairly well with those computed by Dr. Knopf, and published in the *Astronomische Nachrichten* 3394, that is if ten minutes of arc be applied by addition to the longitude of the ascending node, as there published. The computation of the co-ordinates of the comet showed that this correction was necessary to make the given figures consistent, the error being evidently a typographical one.

The elements agreeing so well, the author decided to adopt the ephemeris, computed by him from Dr. Knopf's elements, in comparing the various observations for the purpose of obtaining normal places.

The first normal place was constructed by comparing with the computed ephemeris ten observations from several European observatories, taken between the dates 1896 November 26, and 1896 December 4. These observations were culled from the *Astronomische Nachrichten*, *Comptes Rendus de l'Academie*, and the notes of the Royal Astronomical Society.

Consulting the table, denoted by the Roman numeral (I.), there will be found a complete list of observatories, the observations of which have been employed in constructing the first normal. After reducing the times to the meridian of Greenwich, they have been corrected for aberration of light, and tabulated in column three as the day and fraction of the year 1896. The residuals, after comparing the observed co-ordinates with the computed ephemeris, are given in columns four and five.

The second normal place was computed from observations, taken by Mr. Tebbutt, between the dates 1897 March 5 and 1897 March 15, some eight observations being compared in a similar manner as in the construction of the first normal. (See Table II.)

In the construction of these normal places, the means of the residuals have been applied to the right ascension (α), and the declination (δ), taken from the computed ephemeris corresponding to the mean of the times.

These two normals were computed, anticipating that observations would be obtained during the month of June 1897, but as previously mentioned this was impossible.

To complete the necessary data, an observation has been employed, that was taken by Mr. Tebbutt on the date 1897 April 19·89 Greenwich mean time, this position being adopted, as the astronomer noted that the star, from which the differential measure was taken, is a good one.

Table I.

Place.	Mean Time at Place 1896.				Day of the year 1896 Greenwich Mean Time.	*o* − *c*	
						Δ α	Δ δ
	d.	h.	m.	s.		+ s.	− ″
Hamburg ...	Nov. 26	5	54	29	330·20820	1·04	10·55
,,	,, 28	5	44	33	332·20116	0·98	7·53
,,	,, 28	5	44	33	332·20116	1·07	5·33
Bordeaux ...	,, 29	6	0	8	333·24107	0·79	4·38
Dresden ...	,, 29	7	8	51	333·24920	0·73	9·34
Greenwich	,, 29	7	22	12	333·29660	1·08	8·56
,,	,, 30	6	9	59	334·24639	0·76	4·63
Hamburg ...	Decr. 2	5	56	25	336·20913	1·03	2·43
Dresden ...	,, 2	6	45	40	336·23290	0·98	5·84
Bordeaux ...	,, 3	5	39	46	337·22666	0·88	4·54
	10 observations				334·0	+0·93	−6·31

Table II.

Greenwich Mean Time 1897.				Day of the Year 1897.	*o* − *c*	
					Δ α 2	Δ δ 2
	d.	h.	m.	s.	− s.	+ ″
March	5	6	9	47·5	63·24871	2·05	2·07
,,	5	6	9	47·5	63·24871	2·00	2·27
,,	7	6	17	31·5	65·25434	2·71	4·96
,,	10	6	11	34·5	68·25059	3·21	11·62
,,	12	6	5	30·5	70·24664	3·25	13·68
,,	13	6	19	4·5	71·25619	4·12	12·81
,,	13	6	19	4·5	71·25619	3·95	14·81
,,	14	6	19	49·5	72·25684	4·32	16·55
8 observations					68·0	−3·20	+9·85

First Normal.—Corresponding to the three hundred and thirty-fourth day of the year 1896, the right ascension and declination

computed with Dr. Knopf's elements equal

	h.	m.	s.
α_c =	19	53	50·44
δ_c = +	6°	53′	58″·8

these co-ordinates are referred to the beginning of the year 1897.

Applying to each the mean residuals found in Table I., we obtain

	h.	m.	s.
α_o =	19	53	51·37
δ_o = +	6°	53′	52″·5

Second Normal.—The residuals, that have been applied to the computed right ascension and declination for the second normal, are found in Table II., the computed co-ordinates being for the sixty-eighth day of the year 1897 thus—

	h.	m.	s.
α_c =	19	42	58·91
δ_c = −	35°	10′	33″·0

	h.	m.	s.
α_o =	19	42	55·71
δ_o = −	35°	10′	23″·2

Third Place.—After applying the correction for parallax to Mr. Tebbutt's observation, taken on the date 1897 April 19·89, also referring the co-ordinates to the beginning of the year, and correcting the time for the aberration of light, the result is as follows—

		h.	m.	s.
1897 April 19·8875 G.M.T.	α_o =	10	22	35·60
	δ_o = −	66°	15′	49″·46

Collecting together the separate results we have

t	α_o h.	m.	s.	δ_o °	′	″
1896 Nov. 30·0	19	53	51·37	+ 6	53	52·5
1897 March 10·0	19	42	55·71	− 35	10	23·2
1897 April 19·8875	10	22	35·60	− 66	15	49·5

These co-ordinates are referred to the mean equinox of 1897.

Adopting the ecliptic of 1897, as the fundamental plane, the above co-ordinates are changed into longitude and latitude by the usual formulæ for the purpose. A better check on this calcula-

tion, than that usually supplied by most writers, is given by the following—

$$\cos \propto \cos \delta = \cos \lambda \cos \beta.$$

The latitude of the sun has been considered, by applying a correction to the latitudes of the comet, computed from the formula

$$d\beta = -\frac{RL \cos \beta}{\Delta}$$

in which R denotes the radius vector of the earth, L the latitude of the sun, and Δ the distance of the comet from the earth. These corrections being applied, the various formulæ used in the solution of the problem are somewhat simplified.

The longitudes of the sun, also the radii vectores of the earth have been interpolated from the American Ephemeris and Nautical Almanac for the given dates, the longitudes being referred to the same plane.

The comet's mean anomalies and radii vectores, together with the logarithm of the distance from the earth at the first date, have been computed with Dr. Knopf's elements, and are to be considered as approximate quantities.

The complete data employed in the discussion are therefore as follow—

$t = 0{\cdot}0$	$\lambda =$	302°	8′	55·26″	$\beta +$	27°	13′	39·73″
$t_2 = 100{\cdot}0$	$\lambda_2 =$	291	25	1·48	$\beta_2 -$	13	36	54·64
$t_3 = 140{\cdot}8875$	$\lambda_3 =$	210	2	21·72	$\beta_3 -$	64	56	12·90

$\odot =$	248°	50′	28·26″	Log. $R = 9{\cdot}9937815$
$\odot_2 =$	350	12	17·90	„ $R_2 = 9{\cdot}9972915$
$\odot_3 =$	30	32	0·73	„ $R_3 = 0{\cdot}0022991$

Approximate Values.

$v =$	−68°	7′	59″	Log. $r = 0{\cdot}1897610$
$v_2 =$	+35	34	7	„ $r_2 = 0{\cdot}0687598$
$v_3 =$	+68	29	50	„ $r_3 = 0{\cdot}1916340$

Log. $\Delta = 0{\cdot}2617790$

In obtaining the ratio of the curtate distances of the comet, the complete expression for the purpose has been employed, thus—

$$M = M' \frac{n}{n'} - M'' \left(\frac{n}{n'} - \frac{N}{N'} \right) \frac{R}{\rho}$$

The usual equations have been adopted in finding M' and M''; the ratio n/n' of the parabolic sectors, also the quantity ρ have been computed with the values of v, r and Δ, as given in the data.

All available checks were applied during the calculation, and upon the completion of the work, it was found that the adopted ratio "M" required so small a correction that a recomputation was not necessary. The computer being guided to the following:

Elements.

$T = 1897$ Feb. 8·08155 G.M.T.

$\omega = 172° 17' 38''·75$
$\Omega = 86° 28' 31''·40$ } Mean equinox 1897
$\iota = 146° 8' 44''·28$

Log q 0·0263356

Middle Place.

$c - o$

$\text{Cos } \beta_2 \Delta \lambda_2 = -3''·3 \quad . \quad \Delta \beta_2 = +1''·2$

Equations for the Co-ordinates of the Comet.

$x = [9·9196857]\ r \sin (176° 32' 9''·16 + v).$
$y = [9·9796499]\ r \sin (278° 38' 23''·66 + v).$
$z = [9·8002836]\ r \sin (211° 16' 58''·43 + v).$

The comparison of the computed middle place with the observed, shews a small difference, which may be accounted for by the departure of the true orbit from the parabolic form, and the uncertainty of the star places. Under these circumstances a further refinement seemed unnecessary, so that it was not thought advisable to proceed with another approximation; the above elements would be very little altered by so doing.

In conclusion, the author desires to express his thanks to Mr. J. Tebbutt, F.R.A.S., of Windsor, for his kindness in communicating copies of his observations, and for the courtesy uniformly extended to him.

APPARATUS FOR ASCERTAINING THE MINUTE STRAINS WHICH OCCUR IN MATERIALS WHEN STRESSED WITHIN THE ELASTIC LIMIT.

By W. H. WARREN, Wh. Sc., M. Am. Soc. C.E., M. Inst. C.E.,
Challis Professor of Engineering, University of Sydney.

[*Read before the Royal Society of N. S. Wales, July 7, 1897.*]

THE coefficient of elasticity is usually defined as the ratio of the stress to the strain which it produces. It is necessary to know the coefficient of elasticity whenever it is desired to calculate the deformation or strain produced by a given load or stress, or to calculate the stress from an observed deformation. Such calculations are of frequent occurrence in connection with the design of structures and machinery.

The deformations produced by the stresses under normal working conditions are exceedingly minute, and require very delicate instruments to measure them accurately. This remark is especially true in connection with the determination of the elastic constants for stone, concrete, and cements, where a stress of one ton per square inch may produce a compression of only one hundred thousandth part of an inch ($\frac{1}{100000}''$) per inch, in which case the coefficient of elasticity would be expressed as 100000, the units of stress being tons per square inch. In the case of a certain kind of sandstone, for example, Prof. Bauschinger obtained a coefficient of 240,000 with the same units in compression. So that a stress of one ton per square inch on this sandstone would produce a compressive strain of one two hundred and forty thousandth of an inch.

In the case of metals the deformations produced by stresses are much larger, and the elastic coefficients correspondingly smaller, so that their accurate determination is more easily accomplished. But even in this case it is necessary to be able to measure strains

as small as one ten thousandth of an inch, and for the determination of the true elastic limit the error in the measurements must not exceed one hundred thousandth of an inch.

The apparatus which has been hitherto in use in the Engineering Laboratory for the measurement of small strains consists of various arrangements of levers or micrometers. The most delicate of these are, *a*, the Lever Extensometer designed by Prof. Kennedy; *b*, the Richle-Yale Extensometer.

Prof. Kennedy's Extensometer consists of a light frame attached to the test piece, and carrying a light lever multiplying the strain a hundred times, and giving the mean strain produced on each side of the test piece. The scale is divided into tenths of an inch, but it is possible to record one-tenth of these divisions, in which case the readings are taken to one ten thousandth part of an inch.

The Richle-Yale Extensometer consists of a light frame attached to the test piece, and carrying two screw-micrometers which measure the extension or compression of the bar on each side to one ten thousandth part of an inch. An electric battery and bell are attached to enable contacts to be made with the micrometers, with greater accuracy.

Professor Martens' Mirror Apparatus is far more delicate than either of the foregoing, and has recently been made for the Engineering Laboratory by Mr. Edward Böhme, instrument maker to the Royal Mechanical Technical Experimental Station Charlottenburg, Berlin. It is represented in the accompanying sketches, Fig. 1 – 4, and consists of two small prisms *k k* which are held in firm contact with the test piece and the distance pieces *d d* by means of a steel wire spring, the action of which is indicated by the arrows *s s*. Each prism is provided with a stem *a*, which carries a small mirror *m* held in the frame *f f* rotating freely about the stem, and is held in position by means of a spring *e*. At *b* is a capstan screw for the adjustment of the mirror which is held against its point by a small spring not shown in the sketch. At a definite distance from the test piece are two stands side by

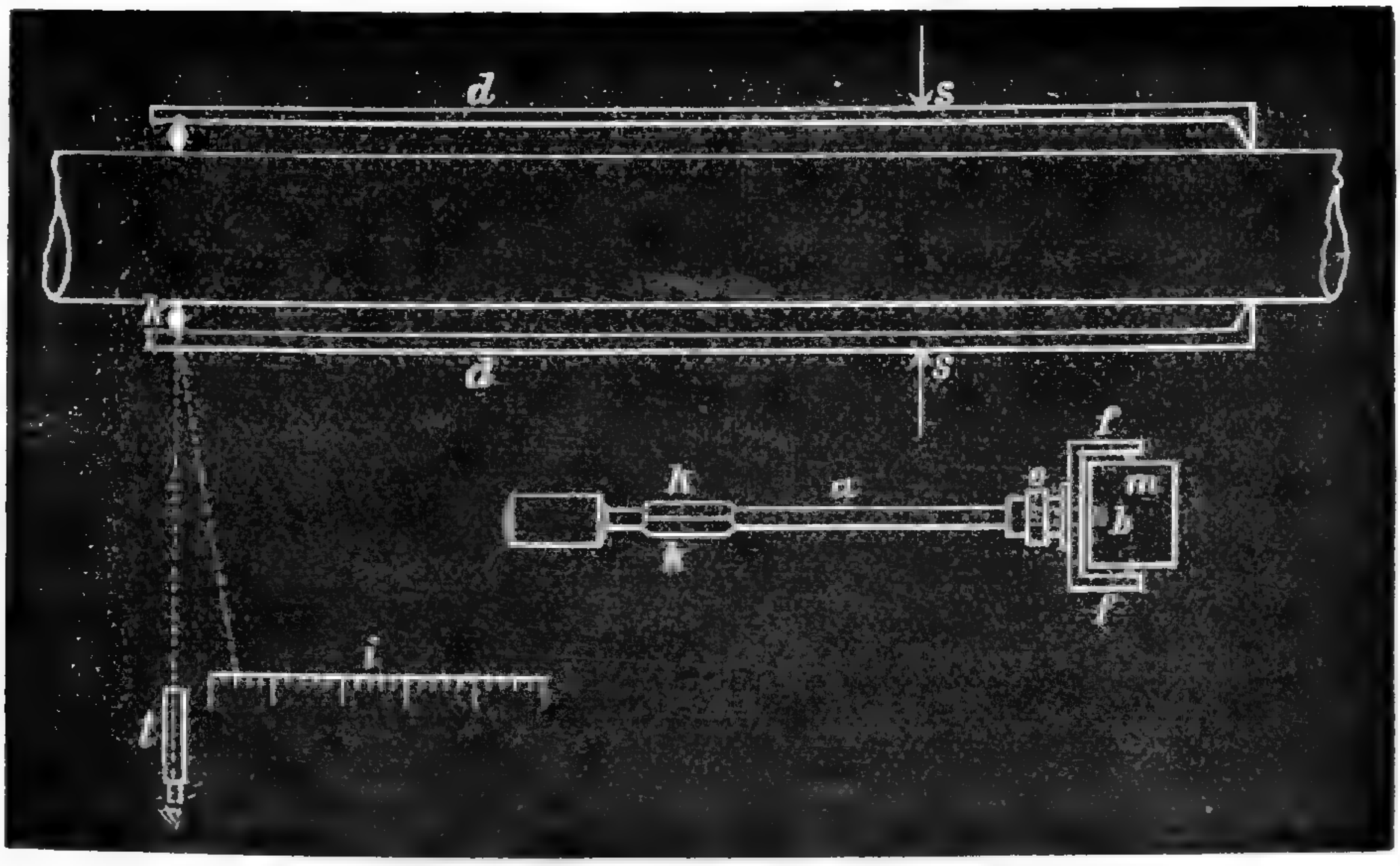

Fig. 1.

side, each carrying a telescope t with adjusting appliances and a scale i which is divided into millimeters. The scale is seen clearly in the telescope reflected by the mirror, and as the mirror rotates slowly in consequence of the elongation of the test pieces, the image of the scale moves in the focus of the telescope and defines the tangents of the double angle through which the prisms, and consequently the mirror, has revolved. The proportion between the elongation of the specimen and the reading of the scales is determined as follows :—

Let r denote the width of the prisms, and R the distance between the scales and the mirror. Then if U be the elongation we have approximately—

$$U = \frac{r}{2R}$$

The mean width of the prisms in the apparatus shown is 4·5402 millimeters, and R is made 1135 millimeters

$$\therefore \quad U = \frac{1}{500}$$

Now since differences of $\frac{1}{10}$ of a millimeter can be easily defined on the scale, the extension corresponding with this reading is $\frac{1}{5000}$ of a millimeter, and the total of both readings with $\frac{1}{10000}$ of a millimeter, so that this apparatus is capable of showing elongations

as small as one two hundred and fifty thousandth of an inch. It has the advantage also of not being influenced by the temperature of the body of the observer to anything approaching the same extent as with micrometer readings, and is probably the most accurate apparatus yet designed for measuring the small deformations which occur within the elastic limit of materials.

The apparatus is illustrated in Figs. 2, 3, and 4,[1] which show its application to the testing of a mild steel bar, and a cube of concrete.

The following table gives a series of readings taken with the apparatus for a round specimen of mild steel :—

Diameter of test piece in millimeters.	Length over which the Elongations were taken in mm.	Load in tons.	Readings of Scale.		Mean Readings $\frac{1}{10000}$ mm.	Differences.	Remarks.
			Left $\frac{1}{5000}$ mm.	Right $\frac{1}{5000}$ mm.			
20	200	0·25	0	0	0	0	
		1·00	80	88	168	168	
		2·00	120	200	306	228	
		3·00	299	323	622	266	
		4·00	411	441	852	230	
		5·00	530	551	1081	229	
		6·00	649	660	1309	228	
		7·00	758	779	1537	228	
		8·00	872	894	1766	229	
							—Limit of elasticity.
		9·00	995	1009	2004	238	
		10·00	1140	1130	2270	266	
		10·25	—Yield point				
		16·50	—Breaking Load.				

Mr. Böhme has also made a pair of Roller Extensometers for the Engineering Laboratory, which will be used for ascertaining the deflections of beams, and compression of columns. This extensometer consists of a dial divided into five hundred parts and a rotating index, which has an angular displacement proportional to the deformation of the test piece. One revolution corresponds with one centimeter deformation, so that readings are taken to ($\frac{1}{500}$ mm.) one-fiftieth part of a millimeter, or one thousand two

[1] The letters in these figures refer to Mr. G. H. Knibbs' paper on the same subject, following on.

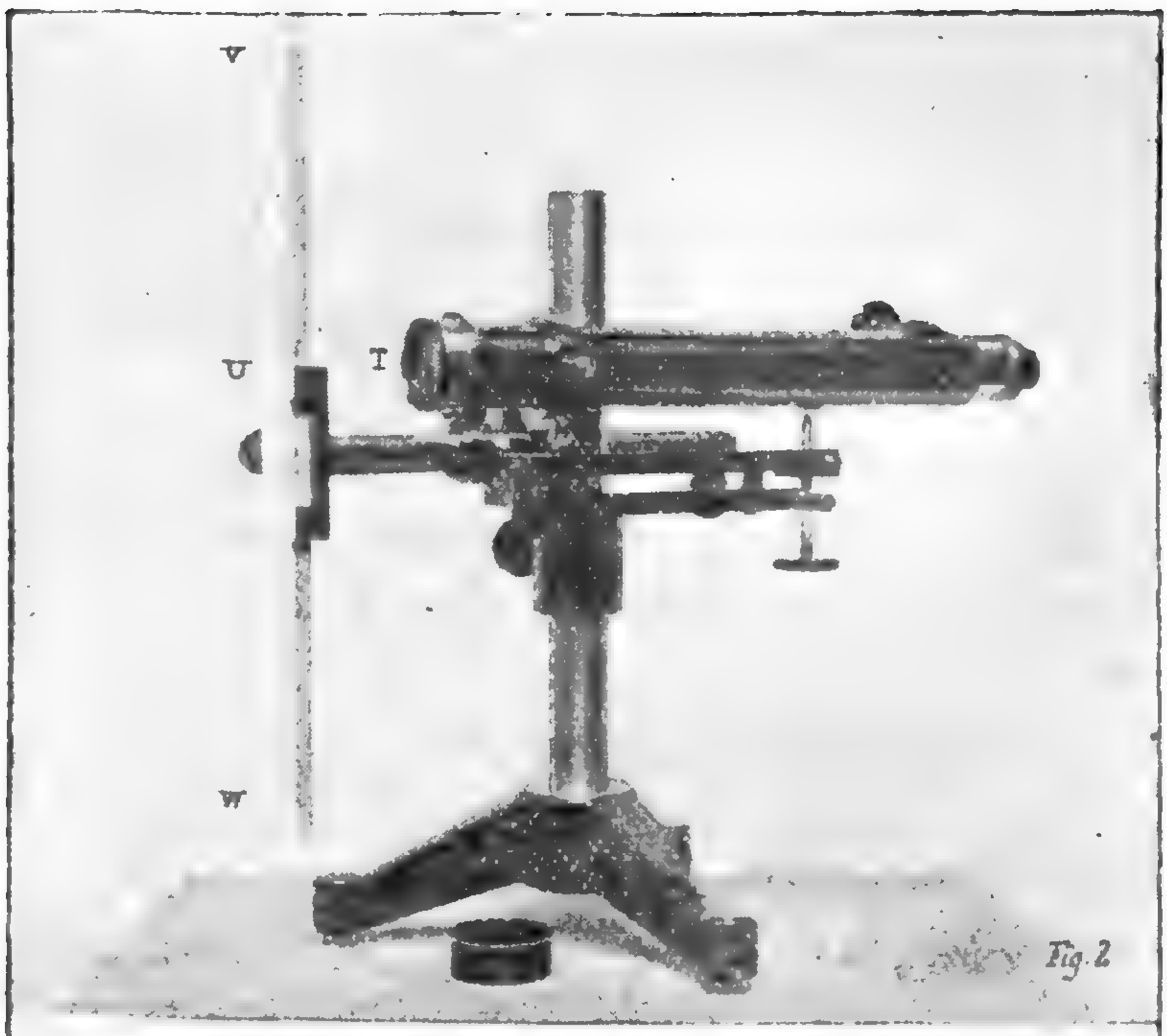

Fig. 2

Fig. 3

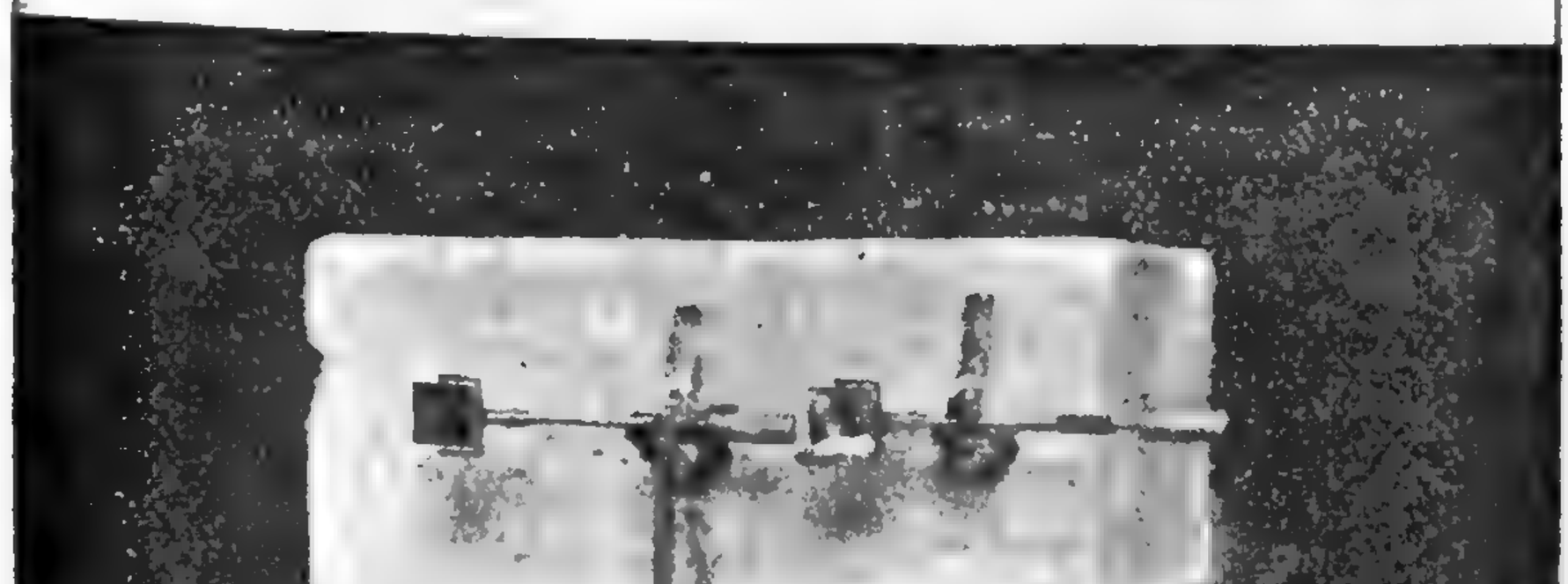

Fig 4

hundred and fiftieth part of an inch; there is no difficulty in subdividing the divisions on the dial if desired, in order to read in $\frac{1}{100}$ mm. The writer has just used one of the instruments in determining the elastic deflections of some rails for Western Australia, and he proposes to use it in connection with a series of tests of brickwork and concrete columns.

The THEORY of the REFLECTING EXTENSOMETER of Prof. MARTENS.

By G. H. Knibbs, F.R.A.S.,

Lecturer in Surveying, University of Sydney.

[*Read before the Royal Society of N. S. Wales, August 4, 1897.*]

1. Approximate theory sometimes inadequate.
2. Description of the extensometer.
3. Relation between extension and scale-reading.
4. Construction of tables of corrections to scale-reading.
5. Application of scale-reading correction.
6. Adjustment of prism perpendicular to test-piece.
7. Examination of the pivot axis of the mirror.
8. Parallelism of the rotation axis of the mirror with the knife-edges of the prism.
9. Error due to longitudinal movement of the test-piece.
10. Error from rotational movement of the test-piece.
11. Disposition of the apparatus in testing, and general.

1. *Approximate theory sometimes inadequate.*—The theory of the measurement of very small extensions by means of Professor Martens' reflecting extensometer, which was exhibited and described by Professor Warren at the last meeting of the Royal Society, leaves little to be desired, when the extensions do not exceed the limits contemplated in that description, that is, when they are extremely small as compared with the distances between the knife-edges of the rotated prism carrying the mirror. And

although the formula given for finding the extension from the scale readings is, as Professor Warren indicates, but approximate, it is nevertheless as regards precision fairly satisfactory within those defined limits.

Instruments constructed on the same principle may however, be made serviceable with larger extensions than those which Professor Warren had in view, but in such cases the theory of the instrument requires further development. And moreover, for the higher readings of the scale in the instrument exhibited, the approximate theory is not quite adequate, for its error, though absolutely, is not relatively small, and may be entirely eliminated. I propose therefore to consider the more rigorous theory of the instrument, and to illustrate it by applications to the extensometer referred to, which, I may here say, Professor Warren has very courteously placed at my disposal for the purpose in view.

2. *Description of the Extensometer.*—The following brief description of this instrument will be necessary in order to admit of the discussion of its theory being properly elucidated. The knife-edge F, see Fig. 1, of a small steel prism FG, lozenge-

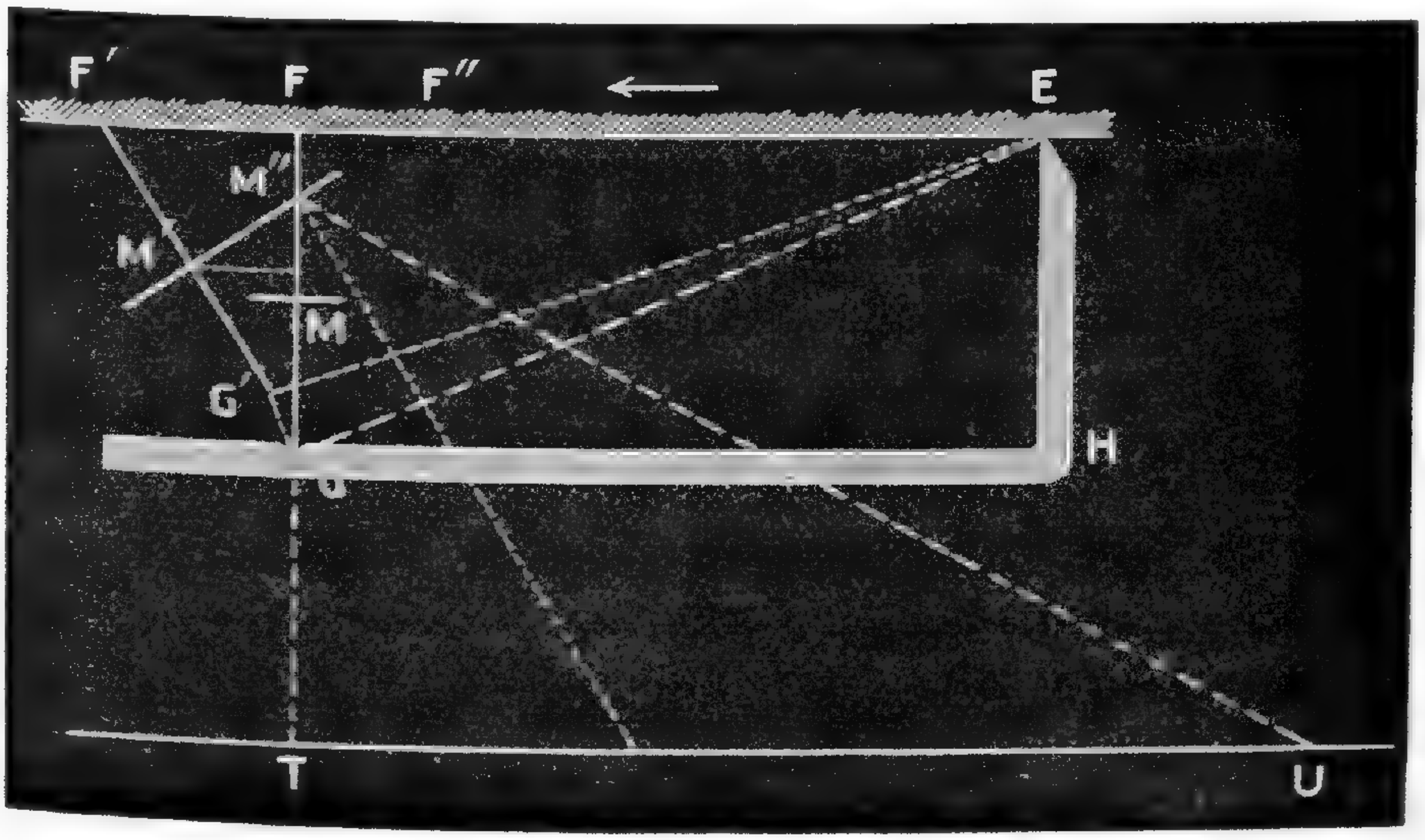

Fig. 1.

shaped in transverse section, is held against a specimen of material EF—the elongation or compression of which under stress is to be measured—by means of a small contact piece GHE, about 2 or

3 mm. in thickness, about 9 mm. in breadth, and from 30 to 200 mm. in length, suitably held in position. Usually there is a contact piece symmetrically placed on each side of the specimen, both being held in place by means of a simple spring clamp, as shewn in Fig. 3 illustrating Professor Warren's paper. The other knife-edge G of the prism rests in a groove in the contact piece. Attached to the prism is a mirror M, which can be rotated on its pivots PP' by means of a screw C not shewn, working against a slight spring A, and by means of this mirror a scale TUV, is read, the reading being determined by the way in which the sight line of the telescope T meets the plane of the mirror.[1] On the application of the stress to the specimen, the prism, and consequently the mirror attached to it, are rotated; the result being that the scale reading is altered. The difference of these readings is the datum from which may be deduced the amount which the knife-edge F has shifted, that is the amount of extension or compression which the applied stress has produced. The scale, an ordinary millimetre scale with black lines on a white ground, is set approximately perpendicular to the sight line of the telescope, and can be rotated in that plane through any angle. The telescope is of short focus; has an objective of 28·5 mm. clear aperture; its focal limits are 5030 and 868 mm., the conjugate focus at the greater limit being about 256 mm., and at the less about 348 mm.[2] The ocular of the telescope is an ordinary Ramsden or positive, of considerable magnifying power; the cross-wire diaphragm is susceptible of slight rotatory adjustment, so that the wires may be set horizontally or vertically. By means of slow motion screws the telescope can be moved either horizontally or vertically through small arcs. Other features of the instrument will be referred to when dealing with the question of its adjustments and use.

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[1] See Figures 2, 3, and 4, Professor Warren's paper.

[2] The distances are only roughly measured. The relation $\frac{1}{5}\frac{1}{0}\frac{1}{3}\frac{1}{0} + \frac{1}{2}\frac{1}{5}\frac{1}{6} = \frac{1}{8}\frac{1}{6}\frac{1}{8} + \frac{1}{3}\frac{1}{4}\frac{1}{8}$ should hold good. The results are ·00411 and ·00403, the accordance is evidently satisfactorily.

3. *Relation between extension and scale-reading.*—Let one terminal of the apparatus be supposed fixed on the test specimen *E* Fig. 1; and on the application of the stress *S*, the other terminal viz., the knife-edge *F*, also touching the test piece, to move from *F* to *F'*, that is through the distance *e*, which is therefore the extension due to the stress. For simplicity also, let the knife-edges *EG* of the rotated prism, be supposed to move from the position of adjustment, that is from a line perpendicular to the test piece, and to take up the position *F'G'* in consequence of the extension *e*. It is obvious that as the point *E* moves toward *F'*, the point *G* will move in the arc of a circle whose centre is *E*. Then since $EG = EG'$—the distance between the knife-edge *G* and the point *E* being, as indicated, invariable—we shall have, *E* denoting the length *EF* of the test piece, the extension of which is to be determined, *l* the distance between the knife-edges, and ω the angle of rotation of the line joining them,

$$E + e = l \sin \omega + \sqrt{(E^2 + l^2 - l^2 \cos^2 \omega)}$$

which by expansion and transposition gives

$$e = l \sin \omega \left(1 + \frac{l}{2E} \sin \omega - \frac{l^3}{8E^3} \sin^3 \omega + \text{etc.}\right) \ldots\ldots (1)$$

The final term can never be greater than one hundred-thousandth, hence it may be at once rejected, and the expression thus reduced accurately denotes the relation between the extension *e* and the rotation of the prism.

If the knife-edge occupy the position *F''*, Fig. 1, instead of *F'*, we may regard *FF''* as negative, as also the rotation angle ω: in other words, if the point *F* move toward *F''* it is a minus extension, or a *compression* instead of an elongation. In such a case the formula still holds good, *e* and $\sin \omega$ are negative, and the term in $l/2E$ is numerically subtractive from unity, instead of additive as in the preceding case. The formula may therefore be regarded as quite general.

If the scale *TU* be supposed parallel to the test piece,[1] that is, if it be parallel to *FF'* Fig. 1, and if the distance between the scale

[1] The more general case is stated later in § 11.

and the mirror M before rotation, be denoted by L; then the distance L' to the point $M,''$ where the telescopic sight-line TM—assumed to be identical with FG—will strike the mirror after rotation, will be

$$L' = L \pm \frac{l}{2} (\text{vers } \omega + \sin \omega \tan \omega) \pm \frac{l^2}{E} \sin^2 \omega \tan \omega \text{—etc.....(2)}$$

the minus sign being taken when the contact piece GHE is on the opposite side of the test specimen, the mirror however, facing as in the illustration Fig. 1.

A little consideration will shew that in any case, the term in l^2 can never be sensible, because neither the measurement of the distance L, nor the reading of the scale can even approximately attain to the order of precision involving its retention. Hence it, and all higher terms may be rejected. Again, for the same reasons, the circular functions enclosed within the brackets may be written as $\frac{3}{2} \sin^2$, $\frac{3}{2} \text{arc}^2$, or $\frac{3}{2} \tan^2$, without involving sensible error. Reducing the above expression in the manner indicated, and multiplying by $\tan 2\omega$, so as to obtain the distance TU, which is the difference R of the scale readings before and after the stress is is applied; we have

$$R = L \tan 2\omega \left(1 \pm \frac{3\,l}{4\,L} \tan^2 \omega\right) \text{.....(3)}$$

an equation which accurately defines the relation between the reading of the scale and the original distance of the mirror therefrom, in terms of the prism rotation. Remembering that powers of ω higher than the second may, when multiplied by a small factor like l/E or l/L, be certainly rejected as insensible, we get from these equations expressing the values of e and R, viz. from (1) and (3), after some slight reduction,

$$\frac{e}{R} = \frac{l}{2L} \frac{\cos 2\omega}{\cos \omega} \left(1 + \frac{l}{2E} \sin \omega \pm \frac{3}{4} \frac{l}{L} \tan^2 \omega\right) \text{.....(4)}$$

Similarly for a negative reading of the scale, we may simply regard R and ω as negative and leave the signs unchanged.

When ω is so small that its cosine may be taken as unity, and its sine as zero, this equation is reduced to the approximate formula given by Professor Warren, viz.,

$$\frac{e}{R} = \frac{l}{2L} \text{ approximately.....(4a)}$$

which may be employed whenever the extension or compression is very small, and when therefore R is very small in relation to L. When however R is not relatively small, the approximate formula is clearly unsatisfactory, since it is easily shewn that

$$\frac{\cos 2\omega}{\cos \omega} = 1 - \frac{3R^2}{8L'^2} + \frac{31R^4}{128L'^4} - \text{ etc.....(5)}$$

L' being the actual distance from the scale to that point on the mirror where the sight line meets it, see (2).

This last equation indicates in a general way the order of the error committed in accepting the approximate formula. Although the value of ω is not directly afforded by the instrument, but has to be derived from R and L', little is gained by the expansion in a series of convergent terms, because in extreme cases the convergence is not sufficiently rapid. The most convenient method of dealing with equation (4), is to find a correction x to be applied to the reading R, such that the corrected reading R' will be

$$R' = R + x..... (6),$$

and so that we shall have with precision

$$\frac{e}{R'} = \frac{l}{2L} .....(7)$$

x will of course be a variable correction, to be obtained with the arguments R and E, from a table of double entry constructed for the lengths L; for positive values of ω it will be generally negative. Then with this corrected reading, the convenient relation expressed by formula (7) may be used rigorously.

4. *Construction of tables of corrections to scale-readings.*—In order to construct tables of corrections, the dimensions of the extensometer apparatus must be taken into account. The contact bars[1] EHG, Fig. 1, supplied with the apparatus, and which determine the length E the extension of which is required, are of the following reputed lengths, viz., 30, 50, 100, 150, and 200 mm., in order to meet the requirements of different sizes of test piece.

[1] See also Figs. 3 and 4 of Professor Warren's paper.

In order to check the values assigned by the maker for the distances between the knife-edges of the rotation prisms, they were carefully measured by means of a Brown and Sharpe Manufacturing Company's micrometer gauge, with vernier reading. The results compare very well with those given by Böhme, the manufacturer, as the following schedule of the measurements will shew.

Distances between knife-edges.

No. 1	0·17875 in.	= 4·5402 mm.	By Böhme	4·5403 mm.
No. 2	0·17875	4·5402		4·5396
No. 3	0·17870	4·5389		4·5415
No. 4	0·17875	4·5402		4·5393
Mean		By me 4·5399		4·5402

If the mean result, say 4·5400 mm., be accepted as the true value of each prism, the greatest error arising from such an assumption will be only about one four-thousandth, which may be regarded as quite negligible. The distances 1135·0 mm., and 2270·0 mm., are respectively 250 and 500 times the width between the knife-edges, or $L = 250l$ in the first instance, and $500l$ in the second; and since the doubles of these distances lie within the focal limits of the telescope, by means of which the reflection of the scale is seen in the mirror, they are suitable as standard distances to set out between mirror and scale when placing the instrument into position for an observation. The scale, graduated in millimetres, ranges between -50 and $+500$, and is numbered 5, 4, 3,...1, 0, 1, 2,...49, 50. At the shorter standard distance, viz., 1135 mm., the maximum value of 2ω will be about $23^\circ\,46'\,30''$ —or more accurately $23^\circ\,46'\,10''$—so that ω will be about $11^\circ\,53'$. From these data the following tables of corrections, conformably to formulæ (6) and (7), have been computed by means of formula (4). The results are given to two places of decimals of a millimetre in order to facilitate the formation by interpolations of a more extended table of corrections for practical use. In the working tables, the corrections would be expressed to the nearest tenth of a millimetre, since that is the unit obtained by estimation, in reading in the mirror the reflection of the scale; and since also

the graduation of the scale itself hardly warrants any attempt to further refine the measurement.

TABLE I.

Corrections to Scale-readings, the zero being in the position of adjustment, L 1135 mm., and l 4·54 mm.

Scale Reading.	Approx. Angle. 2ω	Distance E between contacts on test piece in millimetres. 30 mm.	50 mm.	100 mm.	150 mm.	200 mm.
± 0	0°0′	·00	·00	·00	·00	·00
± 50	2·31	+ ·05 + ·12	+ ·01 + ·09	− ·01 + ·06	− ·02 + ·05	− ·03 + ·05
± 100	5·2	− ·04 + ·62	− ·09 + ·49	− ·19 + ·39	− ·22 + ·36	− ·24 + ·34
± 150	7·32	− ·23 + 1·72	− ·53 + 1·42	− ·75 + 1·20	− ·83 + 1·12	− ·86 + 1·09
± 200	10·0	− ·99 + 3·59	− 1·51 + 3·07	− 1·90 + 2·68	− 2·03 + 2·55	− 2·09 + 2·49
± 250	12·25	− 2·41 + 6·43	− 3·21 + 5·62	− 3·81 + 5·02	− 4·01 + 4·82	− 4·11 + 4·72
± 300	14·48	− 4·68 + 10·38	− 5·82 + 9·24	− 6·67 + 8·39	− 6·96 + 8·10	− 7·11 + 7·95
± 350	17·8	− 7·97 + 15·59	− 9·50 + 14·07	− 10·64 + 12·93	− 11·02 + 12·54	− 11·21 + 12·35
± 400	19·25	− 12·42 + 22·19	− 14·37 + 20·23	− 15·84 + 18·77	− 16·33 + 18·28	− 16·57 + 18·03
± 450	21·38	− 18·13 + 30·22	− 20·55 + 27·81	− 22·36 + 25·99	− 22·97 + 25·39	− 23·27 + 25·08
± 500	23·46	− 25·16 + 39·73	− 28·07 + 36·81	− 30·26 + 34·63	− 30·99 + 33·90	− 31·35 + 33·54

NOTE.—The upper signs are to be taken throughout in extension tests, the lower in compression tests; and the sign of the scale reading in relation to the sign of the correction. That is to say, a plus correction numerically reduces a minus reading.

When the mirror is on the further side of the test-piece, an extension causes a reduction instead of an increase of the distance, from the point where the sight-line meets the mirror, to the scale. That is to say MM'' instead of being positive as shewn in Fig. 1,

is negative. For this case the values of the corrections require very small alterations which amount to

$$\pm \frac{3\ l}{2\ L} \tan^2 \omega\ R \frac{\cos 2\omega}{\cos \omega} \ldots \ldots\ldots\ldots (8)$$

These very small quantities are given in the following table. They are to be *added* with their attached signs to the corrections in Table I.

TABLE II.

Secondary corrections to be applied when the mirror is on the side of the test piece remote from the telescope.

Scale-reading in millimetres		150	200	250	300	350	400	450	500
Extension Compression	mm.	0	±·01	±·02	±·03	±·05	±·07	±·09	±·12

A similar table with the argument $L = 2270 = 500l$ may also be required, as it may be sometimes convenient to use the instrument at that distance. It may be readily formed with sufficient precision from the preceding table by multiplying the upper five horizontal lines by 2 throughout, with the one exception of the angles 2ω. These must be left as they stand. This simple method of obtaining the corrections for the other length depends upon the fact that the term $\mp 3l \tan^2\omega/4L$ is really insensible throughout for the values of ω in question.

This latter distance, viz., 2270 mm. is about the maximum at which the scale may be placed from the mirror, forasmuch as at greater distances it would be beyond the focal limit of the telescope.

5. *Application of scale-reading correction.*—In order to readily obtain accurate results it is essential that the face of the scale should be at right angles to the sight-line of the telescope. Then if the zero of the scale be placed in the plane containing both this line, and as the case may require, either the vertical or else the horizontal diaphragm wire used in reading the scale, the mirror attached to the prism may be rotated until the zero of the scale seen by reflection therein becomes approximately coincident with the cross-wire; when the final adjustment to the zero exactly, may be conveniently made by means of the slow motion screw

rotating the telescope. This last fine adjustment may be regarded as not sensibly altering the indicated condition of perpendicularity as between scale and sight-line. In such a case the correction x is at once applied to the reading. For the first reading R_1 say will be 0, and to the second R_2 the correction x must be applied so that the corrected value R' is given by the equation

$$R' = R_2 + x$$

x being the tabular correction for R_2.

But if for any reason it is inconvenient to make the zero thus coincident with the plane containing the sight-line and reading-wire, then $R = R_2 - R_1$, and we must employ

$$R' = (R_2 - R_1) + x$$

x being the tabular correction for $R = R_2 - R_1$. It is perhaps hardly necessary to point out that the difference of the tabular correction must not be taken in the form $x_2 - x_1$, that is to say, the total correction is not the difference of the corrections for the two readings. In the preceding observations it is of course assumed that the initial position of the line FG is vertical to the test-piece EF Fig. 1.

When two scales are read and give different results, the correction x should be for the mean of the differences of their readings, see § 11.

6. *Adjustment of the prism perpendicular to the test-piece.*—The table of corrections in § 4 indicate the necessity of starting the measurement of an elongation, or of a compression, with the prism in the position of adjustment, whenever very accurate results are desired. In Fig. 3,[1] a small bar BB' is shewn passing through the centre of a small brass cylinder forming a handle for the mirror apparatus, its length being 30 mm. On releasing the small screw S in this brass handle, the bar and handle may be rotated with respect to the line joining the knife-edges of the prism—*i.e.*, the line FG—and consequently may in this way be placed exactly at right angles to the knife-edges. This is conveniently effected

[1] Fig. 3 in Professor Warren's paper.

by suitably grasping the edges in grooves in two opposed positions, one with the handle *toward* the observer, the other with it *from* him, and rotating the handle till its direction remains unchanged, or is identical in either position.[1] The handle then becomes a director, by means of which the prism can be set perpendicularly to the test specimen. This setting can be done with care to about 0·1 in the 30 mm., which is equivalent to $11\frac{1}{2}'$: with the most ordinary care there is no difficulty in setting to 0·2 mm. in the distance mentioned is to 23′. By means of the column of values of 2ω in Table I. it is easy to evaluate the uncertainty in the result, due to the uncertainty of this adjustment. For example, suppose the uncertainty in setting be ± 20′ and the readings at the 1135 distance to be 0 and 400; then it is easy to see from the table that the error of reading would be roughly about ·7 mm. for extension, or about 1·1 mm. for compression. This indicates the importance of the adjustment when extreme precision is desired, and at the same time points out one of the limitations of the instrument. The difficulty in this respect, however, can be met by reading extensions up to 200 mm. on the scale, and then reädjusting the prism at right angles for a second series, remembering of course, that this second series are not, in terms of the original length, but of the length $E/(E+e_1)$, practically $E-e_1$ since the extension is very small in relation to the original length E.

7. *Examination of the pivot-axis of the mirror.*—In order that no error shall be introduced by rotation of the mirror about its pivots, it is necessary that the line joining them should be at right angles to the axis about which the mirror turns, and which as already pointed out, should be parallel to the two knife-edges. This may be tested as follows:—Suitably clamping the handle, so that the axis, parallel to the two knife-edges, shall be approximately coincident with the sight-line of the telescope, place the mirror face approximately at right angles to this axis or line, and rotate till the line joining the pivots is parallel to the scale. Then by a

[1] A suitable instrument designed by the author for effecting this adjustment was exhibited.

slight rotation about the pivots the scale will be seen in the field of view of the telescope, and a reading may be taken, which say is R_1. Then rotating the mirror and pivots about the axis so that the two pivots exchange positions, and the line joining them is consequently again parallel to the scale, a second reading R_2 is obtained. If then ι denote the angle between the line joining the pivots and a plane at right angles to the axis, and since ι is so small that the distinction between sine tangent and arc ceases to be significant, it is easy to see that

$$\iota = \frac{R_2 - R_1}{4L} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

L as before denoting the distance of the scale from the mirror. In this way it was found that the errors of the line joining the pivots were as follows :—

Number of Apparatus	1	2	3	4
Angular Error	$-1'$	$+2\frac{1}{2}'$	$-7'$	$+16\frac{1}{2}'$
Absolute error in 14 mm.	·004	·010	·028	·067 mm.

The plus sign, when the handle is downward and when also the observer is looking into the mirror, denotes that the standard carrying the right hand pivot is too long. The absolute error given is for the width of the mirror, viz. for 14 mm. The fact that it is nowhere 0·1 mm. is evidence of the excellence of the manufacture.

8. *Parallelism of the rotation-axis of the mirror to the knife-edges of the prism.*—When the angle ι referred to in the last section has been obtained, the relation between the rotation-axis of the mirror and the axis of the knife-edged prism may readily be found by reading the scale by reflection, say with the pivots and scale parallel to the knife-edges : then turning the knife-edges round through 180° and reading the scale again. A second similar set of readings with pivots and scale at right angles to the knife-edges is necessary to determine the defect in both planes. After allowing for the difference 4ι between the readings, the residual difference if any, D say, will furnish the required inclination γ of the axes. The formula obviously is

$$\gamma = \frac{D}{4L} \quad \ldots\ldots\ldots\ldots\ldots\ldots(10)$$

L being the distance of the scale. This examination may be made at the same time as that referred to in the previous section by a routine of readings which is sufficiently obvious, from what has been stated.

9. *Error due to longitudinal movement of test piece.*—If the scale be parallel to the test piece, and if in the application of the stress to the piece of material being tested, it be moved longitudinally only) it is evident that the correction to be applied to the reading may be determined from the absolute longitudinal movement of the point E Fig. 1. This may readily be measured by means of a small piece of millimetre scale, attached to the specimen, with a suitable pointer not subject to the motion of the specimen: this pointer may of course be the cross wires of a telescope. Let the longitudinal movement be denoted by s and reckoned positive in the direction marked by the arrow in Fig. 1, viz., in the direction EF. The the effect will be to *increase* the reading on the scale—since the distance therefrom to the point where the sight line meets the mirror is increased—by the amount $s \tan \omega \tan 2\omega$. Hence the *correction* y to the reading will be

$$y = \mp \frac{2s}{\cot^2 \omega - 1} = \mp \frac{s}{2}\left(\frac{R^2}{L'^2} - \frac{1}{4}\frac{R^4}{L'^4} + \text{etc.}\right) \ldots\ldots(11)^1$$

The lower sign is to be taken when the mirror apparatus is on the opposite side of the test piece to the telescope. For 10 mm. movement the values of this correction are the following:—

TABLE III.

Corrections for longitudinal movement of test-piece: $L = 1135$.

Scale reading in mm.	100	200	300	400	500
Correction 10 mm. shift	∓ ·04 mm.	·15	·34	·60	·85

The results indicate how little effect the absolute movement of the test-piece has, for the position of the instrument illustrated by

[1] The final formula depends on the relation $\tan \omega = \frac{1}{2} \tan 2\omega - \frac{1}{8} \tan^3 2\omega + \text{etc.}$

Fig. 1. If however the apparatus be disposed as shewn in Fig. 3 of Professor Warren's paper, that is to say, if two mirrors both facing the same way are read, the error is cancelled in forming the sum of the two results, consequently the disposition of the apparatus shewn in his illustration is to be preferred.

10. *Error from rotational movement of test-piece.*—Although test-specimens are so held that they shall not be subject to rotation, yet to the order of small quantities under consideration, they cannot be regarded as incapable of such movement. Let ρ denote a small angle of rotation of the test-piece, in the plane containing its longitudinal axis and the scale, ρ being considered positive when in the same direction as the mirror, and let z denote the scale-reading *correction* due to this movement following on the application of stress, then

$$z = \mp 2\rho L' \sec^2 2\omega = \mp 2\rho \left(L' + \frac{R^2}{L'}\right) \ldots\ldots (12)$$

the minus sign applying to the case for the mirror on the remote side of the test-piece. The following series of corrections for a rotation of 10′, equivalent to a movement of about $\frac{1}{30}$ inch in the axis of a 12 inch specimen, will give some idea of its significance.

TABLE IV.

Corrections for rotational movement of axis of test-piece: $L = 1135$.

Scale-reading	0	100	200	300	400	500 mm.
Correction 10′ rotation	∓ 6·60	6·66	6 81	7·07	7·43	7·88 mm.

As in the preceding case these corrections can be eliminated by disposing the apparatus as shewn in Fig. 3 of Prof. Warren's paper, for the variation of these corrections is not rapid.

11. *Disposition of the apparatus in testing and general.*—In order that defects in the construction of the apparatus may have no appreciable influence on the results it affords, and that the application of the scale-reading correction treated in § 4 should be rigorously accurate, it is desirable to adopt, in testing, the disposition of the apparatus hereinafter indicated.

(*a*) Arrange the contact pieces on either side of the test-piece and parallel to its axis, with the mirrors at the same end[1]—as shewn in Fig. 3 in Prof. Warren's paper—and so clamped that the stems of the mirrors shall be vertical in all directions when the test specimen is horizontal, or horizontal and parallel to one another when it is vertical.

(*b*) Set the handle-bars BB' Fig. 3, above mentioned, parallel to the longitudinal axis of the test-piece. This will fix the prisms at right angles thereto, if the handle-bars have been adjusted as described in § 6.

(*c*) Set each scale parallel to a plane, passing approximately through the pivots of the mirror, and at right angles to the stem and prism, and let the scale be also approximately parallel to the test-piece. The centre of the object lens of the telescope, and the longitudinal centre line of the scale, should lie on either side of this plane, and while being placed as near as possible to it, should be equidistant from it. This last disposition of the apparatus eliminates any errors which might arise from pivot errors.

(*d*) So arrange the zero of the scale that a plane perpendicular thereto, containing the zero line shall pass through the centre of the mirror, the stem and the prism; and let the telescopic sight-line be as nearly as possible coincident with this plane and directed to the centre of the mirror. Then by rotating the mirror about its axis and about its pivots PP' the zero of the scale may be seen, and the small adjustment thereto may be perfected by means of the slow motion screw. The scales are set in opposite ways, that is the reading runs say from left to right in one scale, from right to left in the other, this of course is not essential, nor is it necessary that the initial reading be zero; but the arrangement facilitates the application of the correction, see § 5.

The correction will *reduce* the scale reading, that is to say, the error of the scale is always one of excess, with the exception of

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[1] This is necessary so that the errors due to longitudinal movement and to rotation of the test-piece shall be eliminated.

the very small additive corrections, indicated in Table I. for the reading 50 mm., with contact pieces of 30 mm. and 50 mm.

With the corrected reading the formula (4a), of § 3, becomes absolutely exact, hence if l/L be 1/250 the extension is

$$e = \frac{1}{500} R' \ldots\ldots\ldots(13)$$

so that if we add the corrected readings by the two scales we have

$$e = \frac{1}{1000} (R'_1 + R'_2) \ldots\ldots(14),$$

that is to say, the sum of the corrected readings expresses the extension in thousandths of millimetres. Since one-tenth of a division can be estimated, the result is given to 0·0001 mm. or about 1/250000 inch. Consequentiy twice the largest correction in Table I., shews that the neglect of the exact theory can lead to a maximum error of about ·08 in 30 or 1 in 375 with the shortest contact piece, or of about 1 in 2500 with the longest. Since the larger defect would not be likely to occur, we may say generally that the error of the approximate theory is after all only of the order of about 1 in 1000 at the most. When the corrections are applied, I infer from the few opportunities I have had so far of judging, that the real error is likely to be about one division of the scale or ·001 mm.

It ought perhaps here to be added that it is more rigorously exact to apply the correction x to the mean of the readings. Hence if the mean of the differences of the readings of the scales be R_m then

$$e = \frac{1}{1000} R_m + 2x \ldots\ldots\ldots(14a)$$

It should not be forgotten that the length E, for which the extension is measured, is from the knife-edge of the prism to the edge of the contact piece. By measuring from the angle of the groove to the sharp edge of the contact piece, that is from G to E Fig. 1, E can be readily determined. Calling the distance EG, F we have

$$E = F - \frac{l^2}{2F} \text{ very approximately} \ldots\ldots(15)$$

The reductions for the five lengths of E are respectively ·343,

·206, ·103, ·069 and ·052. It is difficult to rely upon measurements of F to less than say ·05 mm., corresponding to an error of from 1 in 600 to 1 in 4000, according to the length of the contact piece. Again if the director be set to 0·2 mm. as mentioned in § 6, the prism is set to ± ·030, so that from this cause there is an uncertainty of about the same order as that arising from defective measurement of the test-piece. And further the distance of the scale from the mirror, viz. L, cannot easily be fixed to within 0·25 mm., nor can the right angle condition be very perfectly satisfied, so that here again an absolute error of the order of about one four-thousandth also exists.

It is evident from what has been educed that this Extensometer will give extremely accurate results so far as relative extensions or compressions are concerned, but the relation of these to the absolute length of the test-piece is not of the same order of accuracy. By lengthening the handle-bars, the setting of the prisms could be made more exact, and by making the grooves less deep and finishing them more carefully the value of E could be ascertained with greater accuracy. In this way, and by fixing the relations of parts of the apparatus which require to be relatively adjusted, allowing only for small adjusting movements, the absolute results can be made more nearly comparable in precision to the differential ones, in which a very high order of accuracy has been already reached, thanks to the very ingenious contrivance of Professor Martens, and the excellent workmanship of Herr Böhme.

One point remains to be noticed, viz., that the scale need not necessarily be parallel in two planes to the test-piece; hence after defining the plane in which it is important it should be carefully adjusted, I have said that it should be made merely "approximately parallel to the test-piece," see (*c*) this section. Even were the scale at right angles thereto, it is evident that the mirror rotation would be similarly registered. When however the variation caused by this rotation in the length of L, and the errors due to the shifts of the test-piece, are considered, it will be seen that the position indicated is the best.

In conclusion it may be remarked that with the aid of this extensometer, the behaviour of materials under stress may be studied with a thoroughness, that heretofore was very difficult if not practically impossible. The elasticity, solidity, plasticity and nachwirkung of materials may in the future be examined in larger specimens than have generally been used in the past. A series of exhaustive investigations in regard to these, to the effect of temperature, and to the influence of the duration of the applied stress, in determining the resultant deformations, ought to afford results valuable alike to the physicist and engineer.

THE BURBUNG, OR INITIATION CEREMONIES OF THE MURRUMBIDGEE TRIBES.

By R. H. MATHEWS, Licensed Surveyor.

[*Read before the Royal Society of N. S. Wales, July 7, 1897.*]

SYNOPSIS:

Introductory. The Main Camp and Burbung Ground. Gathering the Tribes. Arrival of Contingents. Daily Ceremonies at the Camp. Taking away the Boys. The Thurrawonga Camp. Ceremonies in the Bush. Return of the Boys. Finishing Ceremonies. Conclusion. Explanation of Wood Cut.

Introductory.—In two papers contributed to the Anthropological Institute of Great Britain,[1] I gave a short account of the Burbung of the northern section of the Wiradthuri tribes, who occupy the country commencing somewhere about the Barwon River, and extending southerly up the Macquarie, Castlereagh, Bogan, and other rivers, to the sources of the Lachlan, New South Wales. I also communicated a paper to the Royal Geographical Society of Australasia,[2] Queensland, on the initiation ceremonies of the tribes

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[1] "The Burbung of the Wiradthuri Tribes."—Journ. Anthrop. Inst., XXV., 295 – 318. *Ibid.*, XXVI., 272 – 285.

[2] "The Initiation Ceremonies of the Aborigines of the Upper Lachlan."—Proc. Roy. Geog. Soc. Aust., (Q.), XI., 167 – 169.

located upon the upper portion of the last named river. As previously stated,[1] the articles referred to were the first ever published describing the details of the Burbung of the Wiradthuri tribes; in short, practically nothing was known respecting this ceremony until the first of these articles appeared.

In the present paper it is proposed to deal with the southern portion of the Wiradthuri community, whose initiation ceremonies differ in many respects from those of their northern brethren. These people occupy the Murrumbidgee River from Jugiong to Hay, extending southerly to the Murray; and reaching northerly up the Lachlan River to about the effluxion of the Willandra Billabong, where they join the northern section above referred to. It will be seen therefore that the present communication, read in connection with my former papers, deals with the Burbung ceremonies of the entire Wiradthuri community, comprising the numerous tribes spread over a wide zone of country stretching from the Murray almost to the Barwon, a distance of about four hundred miles. The Wiradthuri language is the most widely spread of the aboriginal tongues of New South Wales.

On the eastward of the southern half of the Wiradthuri community are a number of adjoining tribes scattered over the coastal district of New South Wales from Two-fold Bay almost to Sydney, among whom the initiation ceremony is known as the *Bunan*, a description of which has been furnished by me to the Anthropological Society at Washington.[2] Among the tribes who adopt the *Bunan* form of initiation, there is an abbreviated ceremony termed the *Kuringal*, which has been described by my fellow worker, Mr. A. W. Howitt,[3] and is further illustrated and explained by me in a subsequent article.[4] Lying between the northern half of the Wiradthuri territory and the sea coast, the

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1 Journ. Anthrop. Inst., xxv., 295.

2 "The Bunan Ceremony of New South Wales."—American Anthropologist, ix., 327–344.

3 Journ. Anthrop. Inst., xiii., 432–459.

4 Journ. Anthrop. Inst., xxv., 316, 317, plate xxvii.

Darkinung tribe[1] occupied the country from the Hunter River southerly to about Sydney or Botany Bay, and reaching westerly to the Wiradthuri boundary.

Adjoining the Wiradthuri on the north are the numerous tribes of the great Kamilaroi community, who occupy a wide tract of fertile country reaching from the Upper Hunter River in New South Wales to somewhere beyond the Queensland boundary, embracing the region watered by the Namoi, Gwydir, Macintyre, Barwon, and subordinate rivers. Comprehensive descriptions of the *Bora*, or initiation ceremonies of these tribes are contained in papers communicated by me to the Anthropological Institute of Great Britain,[2] and the Royal Society of Victoria.[3]

To the east of the Kamilaroi are various tribes spread over the table-land of New England and the country situated between there and the Pacific Ocean, comprising the districts watered by the following large rivers and their numerous affluents:—the Hunter, Manning, Macleay and Clarence. In these tribes the initiation ceremonies are of the *Keeparra* type, of a highly interesting character, and are described with some fulness of detail in my papers published by the Anthropological Institute of Great Britain,[4] and by the Royal Society of Victoria.[5] The *Keeparra* type contains some abnormal or modified forms, which in some cases so much alter the character of the ceremony that they are called by a different name.[6] These are only a probationary form of initiation, and the youths who enter the ranks in this manner

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[1] "The Burbung of the Darkinung Tribe."—Proc. Roy. Soc. Victoria, x., N.S., 1–12.

[2] "The Bora or Initiation Ceremonies of the Kamilaroi Tribe."—Journ. Anthrop. Inst., xxiv., 411–427. *Ibid.*, xxv., 318–339.

[3] "The Bora of the Kamilaroi Tribes,"—Proc. Roy. Soc. Victoria, ix., N.S., 137–173.

[4] "The Keeparra Ceremony of Initiation."—Journ. Anthrop. Inst., xxvi., 320–338.

[5] "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, ix., N.S., 120–136.

[6] "The Dhalgai Ceremony."—Journ. Anthrop. Inst., xxvi., 338–340.

have subsequently to attend the fuller ceremonial of the *Keeparra*. Among the tribes inhabiting the country between the Clarence River and Point Danger, including the area watered by the Richmond and other rivers, the initiation ceremonies are known as the *Wandarral*, which I have described in a paper contributed to the Royal Society of Victoria.[1]

It will be seen, therefore, in the various papers contributed to different learned institutions, on the Bora, the Burbung, the Bunan, the Keeparra, the Wandarral, and the subsidiary ceremonies connected with them, that I have given tolerably comprehensive descriptions of the types of initiation ceremonies practised by a number of large and important tribes occupying about three fourths of the total surface of New South Wales, and reaching some distance into Queensland. This vast extent of country is comprised approximately within the following limits, namely, from Twofold Bay westerly to Moulamein in the county of Wakool; thence northerly to Barringun in the county of Culgoa; thence easterly to the Pacific Ocean, and thence by the sea coast back to the starting point at Twofold Bay. A reference to the map of New South Wales will enable the reader more thoroughly to understand this description.

The Main Camp and Burbung Ground.—The site for the celebration of the Burbung ceremonies is usually chosen in some part of the tribal territory where water and fuel are plentiful, and where there is a sufficient supply of game to meet the food requirements of all the tribes who are expected to be present from other districts. The people who belong to the district in which the Burbung is to take place, whom I shall call the local tribe, are of course the first to arrive on the ground and erect their camp. The other tribes who arrive later, take up their position around the camp of the local mob, each in the direction of the district they have come from.

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1 "The Wandarral of the Clarence and Richmond River Tribes."—Proc. Roy. Soc. Victoria, x., N.S., 29 - 42.

During the time that the other tribes are assembling, the local mob are busy preparing the ground. A suitable site is selected close to the camp, where a large ring called the *būrbŭng*, about twenty-five yards in diameter, is marked out, and cleared of all timber and grass. The surface of this is levelled, and is surrounded by a wall[1] about a foot high, composed partly of the loose earth scraped from within, and partly of soil scraped off the surface for several yards outside the ring.

The Burbung ground described in the following pages has not been used for upwards of twenty years, and that is why I have chosen it, because all the works connected with it are on a more extensive scale than Burbung grounds of more recent times. It is situated between twenty-five and thirty chains easterly from the eastern boundary of Portion No. 11 of seventy-eight acres, in the Parish of Waddi, county of Boyd, New South Wales.

The large ring, *(burbung)* was about three hundred yards from the left bank of the Murrumbidgee River. Its boundary, which was composed of a raised earthen embankment, is still distinguishable, and measures twenty-five yards in one direction, by twenty-three yards in the other. In the southern wall of this circle an opening about three feet wide was left as an entrance, from which a pathway, called *dharambil* or *mooroo*, now grown over with grass, led away in a direction bearing S. 5° W. for a distance of fifty-five and a-half chains,[2] to a cleared circular space called the *Budtha Goonang* or *Goombo*. This space was not surrounded by an embankment like the Burbung ring, but the loose soil scraped off its surface in levelling it formed a sort of boundary around it.

Within this boundary were four heaps of earth about two feet high. These mounds were oblong in shape, three of them

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[1] In one instance I saw a Burbung ring defined by a nick cut in the ground around its boundary. The nick or groove was three inches deep and four inches wide, cut out with tomahawks or sharp sticks.—Journ. Anthrop. Inst., xxv., 299.

[2] The goombo was a little under seventeen chains from the Burbung at Bulgeraga Creek,—Journ. Anthrop. Inst., xxv., 299.

being nine feet long and four feet broad; the remaining one, which was opposite to where the *mooroo* or track entered, being ten feet by five feet. These mounds were built up by first laying on the ground a number of pine logs, about five or six feet in length, and covering them over with loose earth. These four mounds formed a quadrilateral, the side of which were nine, eleven, twelve, and eleven yards respectively. Approximately in the centre of this quadrilateral, a log of wood, with a fork on the upper end, was inserted perpendicularly in the ground, projecting above the surface about two and a half feet.[1] About six yards beyond the goombo a fence composed of forks and boughs was erected, about twenty yards long and four or five feet high, known by the native name of *gareel* or *gheerang*.

The pathway, *mooroo*, from the Burbung to the Goombo passed over a black soil flat very lightly timbered, for the first half mile, and then entered a scrub of pine, box and undergrowth. At this point some saplings were bent over the track so as to form a kind of arch. From this point to the Goombo, a distance of fifteen chains, was higher ground, and consisted of a reddish sandy clay, well suited for carving or raising figures on its surface. At the time of my visit all the figures on the ground had disappeared, and most of the marked trees had been rooted out and burnt, owing to the occupation of the country by the white people. Fortunately the ground for a few chains around the goombo had not been interfered with.

I was accompanied by some of the old black-fellows who had attended the last Burbung held here, from whom I obtained the following description of it. On both sides of the pathway between the archway referred to and the Goombo, numerous devices and figures were formed on the ground. The outlines of some of them

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[1] In the Burbung ground at Bulgeraga Creek, there were two inverted stumps of saplings inserted in the ground at the goombo, which were smeared with human blood.—Journ. Anthrop. Inst., xxv., 301. See also "The Burbung of the Darkinung Tribes."—Proc. Roy. Soc. Victoria, x., N.S., 2.

were defined by a groove cut into the turf by means of flat sticks sharpened at one end to form a kind of spade; others were composed of the loose earth heaped up so as to resemble the horizontal image of the required object.

Amongst these drawings on the ground were the following: a large figure of Baiamai and the imprint of a gigantic human hand;[1] a kangaroo; a mallee hen's nest; a canoe with a paddle beside it; a spear, boomerang, waddy and tomahawk. Interspersed amongst these drawings were masses of *yammunyamun* or *yowan* patterns,[2] always met with on Wiradthuri and Kamilaroi initiation grounds. In a forked branch of one of the trees, twenty or thirty feet from the ground, an imitation of an eagle-hawk's nest[3] was formed of twigs and sticks.

On one side of the path, not far from the goombo, an image of Dhurramoolun was formed of mud or clay about four or five feet high, having only one leg. In order to give it greater stability, this mud figure was propped against a tree. Between this image and the goombo was a fire *(woongonyalbil)*. It was kindled on top of a low heap of earth built up for the purpose, and any of the men who happened to be near it replenished the fuel when required.

An incident occurred in connection with the last gathering which took place on this Burbung ground, which is of considerable interest, inasmuch as it shows the course pursued by the natives when any unforseen event occurs to make it necessary to abandon the Burbung ground during the progress of the ceremonies. On that occasion very heavy rains had fallen on the sources of the Murrumbidgee River, causing a flood, which spread over all the low lands around the camp, and filled the watercourse (see sketch) between the Burbung ring and the Goombo. All the tribes present then shifted from their quarters near the Burbung, and went about six miles farther down the river to a place where there was some high dry ground, and erected a new camp.

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[1] Journ. Anthrop. Inst., Lond., xxv., 300.
[2] *Loc. cit.*, xxv., 302. [3] *Loc. cit.*, xxv., 300.

Instead of preparing another Burbung ground like the one they had been obliged to abandon, they selected a clear space of well grassed land near the camp, and formed a ring about seventy feet in diameter by binding the tops of the grass together around its boundary, but the grass growing within the ring was not cleared away. On the following morning the people mustered around this grass ring *(ngyendool)*, and the whole of the procedure in taking away the novices was the same as described farther on in this paper.

Gathering the Tribes.—The headman of the tribe whose turn it is to muster the people for the Burbung, and who may be called the initiator, sends a messenger, accompanied perhaps by another man, to one of the neighbouring tribes in which he has some relatives or friends. A message stick, *(dharral)*, on which some symbols were carved, would be handed to the messenger, and their meaning explained to him. This stick would have a long string, made of opossum fir, twisted around it. The purport of this message would be something to the effect that the sender knew of a place in his country, *(ngoorumbang)*, where there were plenty of kangaroos, birds, iguanas, and other game. The bearer of the message on arrival near the men's camp in the tribe to which he was sent, would sit down, and some of them would go to him. He would then be conducted to the *ngooloobul*, or private meeting place of the men, and introduced to the headmen of the tribe, to whom he would hand the message stick, and deliver the oral message which he had received with it. The headman would understand by his friend reporting that he knew of a place where there was plenty of game, that he was ready to gather the tribes into his hunting grounds, for the purpose of initiating their boys, if they were agreeable to his doing so.

A consultation is held among the men present as to the time that would be most convenient for them to accept the invitation. They then give the messenger several tails *(burran)*, some bunches of feathers, and a bunch of grass tied up, for distribution among the initiator and his friends. The messenger is then sent back to

his own people, and on his return he would hand the bunch of grass[1] to the headman, a tail to one of the other headmen, a bunch of feathers to another, and so on. The bunch of grass conveys the meaning that the party sending it is agreeable to the proposal, and that he wishes the initiator to proceed with the preparation of the ground. On receiving this reply, the camp would be removed next day to the place where it was proposed to hold the Burbung, and the men would commence making the ring and other parts of the sacred ground.

The initiator would then send another messenger to the same tribe to which the first messenger was sent. On this occasion the messenger, who would have another man with him to keep him company, would be furnished with a bull-roarer, *(mudjeegang)*[2] and several tails *(dhullaboolga)*. On the arrival of this messenger at the camp he was directed to summon, he would be conducted to the *ngooloobul*, where he would hand the bull-roarer to the headman, and the tails would be distributed to the men to whom they had been sent by the Initiator. The time and place of holding the Burbung would also be stated at this meeting. In the course of a short time after the arrival of this messenger, all the men would pull small green bushes, and having taken one of these in each hand, would start away from the ngooloobul in a serpentine line, their headman in the lead, and would run into the women's camp, uttering gutteral noises like "birr! wah!" as they went. They would then form into a group in a clear space and dance round,[3] calling out the names of places in their ngoorumbang, after which they would throw down their bushes and break up, and walk away to their camps.

After the evening meal the young men would paint themselves and get up a corroboree in honour of the arrival of the messenger.

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[1] If the tribe to whom this invitation was sent had not approved of holding a Burbung at that time, or were for other reasons prevented from accepting it, they would not give the messenger a bunch of grass to carry back with him, and this would be understood by the initiator as an end of the matter for the present, and nothing more would be done.

[2] Journ. Anthrop. Inst., xxv., 303. [3] *Loc. cit.*, 304.

At the conclusion of this corroboree, one of the single men, who had gone away unobserved by the women, would sound the bull-roarer within hearing of the camp. The procession of the men, and the noise of the bull-roarer, are done for the purpose of making the women aware that a message has been received to attend a Burbung. The mothers of the boys who are old enough to be initiated are glad to hear this announcement, because their sons will be admitted to the rank of men of the tribe.

In the course of a few days—or if the time were short, perhaps the next day—after receipt of the message, the tribe would make a start towards the place where the Burbung was to be held.[1] On the journey thither, wherever the tribe camped at night a corroboree would be danced by the men, after which the bull-roarer would be sounded in the proximity of the camp. This journey would be performed by easy stages on account of the women and children and aged people having to accompany the rest. The entry of this mob into the main camp will be described under the heading "*Arrival of Contingents.*"

This is the only tribe which will be summoned directly by the local man, whom I have designated the initiator of the proceedings. There are now two mobs assembled on the Burbung ground,—the tribe of the initiator and that of the headman who sent the bunch of grass. It is now the turn of the latter to summon the next tribe, which he does by sending out a messenger bearing a bull-roarer and a few tails to the headman of some tribe in the community in which he may have friends or relatives. This messenger would be one of his own men, but a man of the other tribe may go with him to keep him company. The headman of this third tribe adopts a similar course in summoning a fourth tribe; and this procedure will be followed until all the tribes whom they wish to be present are gathered at the Burbung camp.

Arrival of Contingents.—When a tribe gets within a day's journey, or perhaps a less distance, of the Burbung camp, the

[1] Journ. Anthrop. Inst., xxv., 304.

men and women paint themselves in whatever style is customary among them, and decorate their hair with feathers. In the tribes I am referring to, the painting consisted of stripes and daubs of pipeclay on the limbs and upper parts of the bodies, and on the face. The boys *(eeramooroong)*, who are to be initiated are painted red all over their bodies. On coming in sight of the main camp the men disencumber themselves of their rugs and other effects, leaving them in charge of the women. A shout is now given, and on this being answered from the camp, all the men form into single file and march on in a serpentine line, each man being about a yard behind the man in front of him.

The headman is in the lead holding the lower end of a spear in his left hand, the other end of the spear pointing outward from his left shoulder. Instead of a single spear he may have several in a bundle. On the side of the spear, close to the end which he holds in his hand is tied the bullroarer *(mudjeegang)*, which had been sent to him by the messenger.[1] The bullroarer is wrapped in a piece of the skin of some small animal, and in order to conceal it from observation, the man carries a small bush in the same hand. In his right hand he carries another small bushy bough, which he shakes at every few steps.

Each of the other men who are following have also spears and boughs exactly like the leader, but no bullroarer. The probationers, who will be referred to presently, carry a bough only. The messenger who has escorted the tribe is in the procession, a short distance behind the headman. On the left hand side of this sinuous cortege, but near the rear, the novices who are to be initiated, belonging to this tribe, and their mothers, are marching along. Each mother and her novice would march abreast of one of their male relatives in this procession. The other women of

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[1] On the Lower Murrumbidgee, the *mudjeegang* is attached to the upper end of the spear, and has small bushes fastened around it. Among the Macquarie and Bogan River tribes, the *mudjeegang* is fastened to the lower end of the spear, and a *burran* to the upper end.—Journ. Anthrop. Inst., Lond., xxv., 305.

the tribe, together with the children and perhaps some of the infirm old men, would remain at the place where the men had left their superfluous effects.

As soon as the men of the local tribe hear the shout of the strangers approaching, they proceed to the ring, accompanied by the men belonging to all the contingents who have previously arrived at the Burbung camp.[1] They all sit down near the ring, on the side opposite to that from which the new tribe are coming, and commence beating their boomerangs together.

When the men of the new mob reach the Burbung ring, they run in single file once round the outside of it, and then enter it through the opening in the embankment, and march round inside until all the men are within the circle. The novices, painted red all over, with their mothers halt a short distance from it, and do not enter with the men, but go back and join the other women of their own tribe.

All, or nearly all, the tribes who arrive, will have with them a greater or less number of young men who were inaugurated into the rank of manhood at the three consecutive burbungs which took place previous to the present one. On the arrival of a contingent, these probationers are mixed among the wavy line of men, each of them walking behind the man who was his guardian on the occasion of his initiation. Each probationer has a large bush, which he holds with folded arms, against the front of his body. These young fellows enter the ring with the other men, and at once proceed to the centre, where they stand in a group. The men then form a cordon round them, and call out the names of several of the chief localities in their own ngooranbang or country. After this the men walk out of the circle and throw down their boughs beside the embankment. The neophytes follow them, still carrying their boughs in the way described.

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1 "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, IX., N.S., 123. "The Bora or Initiation Ceremonies of the Kamilaroi Tribes."—Journ. Anthrop. Inst., XXV., 321.

The men of the local tribe and all those who are sitting down with them, then get up and step into the ring, dancing round and forming into a group, and call out the names of places in their respective districts. These men, who may be designated the hosts, now go away to the camp. The men of the newly arrived contingent then return to the place where they left their women and swags, and all of them march on into the main camp, and commence to erect their quarters on the side facing the direction of the district from which they have come.

After the new comers have had a short rest, they join the men of the hosts at the *ngooloobul*, or place where the initiated men meet near the camp. All the men now provide themselves with small boughs, which they carry in the right hand, and a boomerang in the other. The hosts then start in single file, walking in a winding line towards the ring, and are followed by the new arrivals, the men of each tribe keeping by themselves. When the man in the lead reaches the ring he steps over the bank and walks round near the circumference followed by the other men, until they are all within the ring, perhaps forming a spiral of several laps, if there are many men present. They now dance round several times, shouting out the names of a few places in their country. The hosts then start away along the track towards the goombo, halting at all the principal figures on the ground and on the trees, at each of which they shout in unison, and are followed by the strangers. When the hosts reach the goombo, a number of the men go and crouch down behind the bough-fence, *(gareel)*[1] mentioned in the description of the Burbung ground, with a small bush in each hand. Four of the old men skilled in magical lore *(Weearthooree)* now stand at the four heaps of earth and commence their performances. By this time the strangers have arrived at the goombo, and sit down in front of it as spectators. The men who were hidden behind the screen of boughs, now come dancing out, one after the other, waving the small bushes which they hold in their hands, and mix with their comrades.

[1] Journ. Anthrop. Inst., xxv., 306.

The men who are at the heaps of earth change places, running from heap to heap, and while doing so are exhibiting rock crystals *(goonabillang)* or other substances in their mouths. They run after the men who are gathered round them, and the latter get behind the *weearthooree* and put their hands on his shoulders, so that he cannot turn round and catch them. When these performers get tired, some of the old men belonging to the strange tribe go and take their turn standing at the heaps, and running after the men of their own tribe. When the men have had sufficient play, they go back in file along the track, clapping their hands, to the burbung, which they enter, and shout out the names of places, waterholes, totems, etc., as usual, after which they go away to their camps.

The young fellows whom I have called "Probationers," to distinguish them from the full men, go to the ngooloobul with the men of their own tribe, where each lays his large bough on the ground and sits down on it. When the men start for the ring, as described in the last paragraph, the probationers start direct from the ngooloobul to the goombo, as they are not allowed to enter the ring except on the occasion of their arrival, as stated in a previous page. The boys who were initiated at the last Burbung have now an opportunity of looking at the image of Dhurramoolun —the *yowan* on the ground, the marked trees, and all the surroundings, for they were not permitted to see any of these things at the time of their inauguration, the particulars of which will be described under the head of "*Taking away the Boys.*" When the men have finished their performances at the goombo, the probationers proceed from there to the camp, while the men return by way of the ring, as already described. The probationers left their boughs at the ngooloobul; and always when they assemble there with the men, they sit down upon the boughs. When they get too dry for use, they are replaced by fresh ones.

That night, after the evening meal is over, the young men of the local tribe, or perhaps the young men of one of the other tribes who have arrived previously, paint themselves, and dance

a corroboree on a cleared patch of ground close by, which is used for this purpose, the women belonging to their own tribe singing and beating time for them.[1] At the conclusion of this corroboree a man swings a bullroarer in the direction of the goombo, and all the men go into the Burbung carrying boomerangs, waddies and other weapons in their hands, where they dance round and call out the names of remarkable places, after which they retire to their respective camps for the night.

The foregoing description will apply to the arrival of every contingent, except the last mob who are expected to be present at the ceremonies, who make their appearance in the following manner. The painting of the men, women and novices, and their march when approaching the camp are precisely the same as on the arrival of previous contingents, but the leader of the serpentine cortege, instead of having a bullroarer, has a piece of burning bark *(weenduri boggara)*, in the hand which holds the spear, and a bush in the other. Each of the other men carry a spear and a bush, but no fire. Their entry into the ring, and subsequent proceedings, are the same as already described. After the newcomers have erected their camp, the hosts and other tribes start away to the ring and are followed by the strangers. From the ring they proceed as usual along the track towards the goombo. When the man of the new mob who is still carrying the burning bark[2] reaches the fire, he throws the bark upon it, and leaves it there. The remainder of the formalities are the same as on previous occasions.

Daily Ceremonies at the Camp.[3]—From the time of the arrival of the first tribe of visitors, until the main encampment is broken up, there are corroborees and other performances almost daily.

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[1] Journ. Anthrop. Inst., xxv., 306.

[2] Instead of the piece of smoking bark, the tribes in some parts of the country included in this paper carry a bunch of grass, which is thrown upon the fire. Every one in the camp knows, on seeing the leader carrying a firestick or a bunch of grass, that this is the last tribe which is expected to attend.

[3] Journ. Anthrop. Inst., xxv., 307 and 325.

About daylight every morning the bullroarer is sounded by one of the single men in close proximity to the camp, and when this is heard the men raise a shout.[1]

During the early part of the day the men and youths would go out hunting for the purpose of obtaining food. The women would also go out in search of such game and roots as they are in the habit of procuring. Infirm old men and women and young children would be left in the camp. By about two or three o'clock, most of the people would have returned from the bush, some coming in at one time and some at another, according to their success in the field.

About two or three hours before sun-set, the men of the local tribe, with their head-man in the lead, would proceed to the ring in a serpentine line, with a bush in each hand. Some of the men might have a boomerang in one hand and a bush in the other, or perhaps a boomerang in each hand. This would be a signal for the men of the other tribes, who would also start, and join the assemblage, the members of each tribe keeping by themselves. This procession would march round and round inside the ring until all of them had entered it. The headmen of the local tribe would then call out the names of camping places, etc., and this example would be followed by the headmen of the other contingents in succession.

All the men would then come out of the ring, and throwing down their bushes, would start away along the track towards the goombo, the local men being in the lead. A stoppage is made at the image of Dhurramoolan, the fire, and all the principal figures on the ground and on the trees, the men dancing and shouting as they come to each one.[2] On arriving at the goombo, any of the clever men, who want to display their magical powers, stand at the

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1 "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, ix., N.S., 121. "The Bunan Ceremony of N. S. Wales."—American Anthropologist, ix., 333, 334.

2 "The Bora, or Initiation Ceremonies of the Kamilaroi Tribes."—Journ. Anthrop. Inst., xxv., 323.

heaps of earth and run after the other men who race about so as to get out of their reach. On these occasions there is no detachment of men hidden behind the garreel, or screen of boughs, that formality being gone through only on the arrival of a new mob.

At the conclusion of the proceedings the men return along the track to the ring and dance round, shouting the names of camping places, waterholes or the like, in their respective districts, after which they go to their camps. At these daily performances, the probationers go direct from the camp or ngooloobul to the goombo, and are invited by the old men to take particular notice of all the performances, and of everything on the ground and trees, so that they may be able to reproduce them on future occasions. When the men start back to the ring these probationers go to the camp direct from the goombo.

Later in the evening, if it were not wet or the men too tired, the usual corroboree would be danced by the tribe whose turn it was to do so. After that the bullroarer would be sounded in the adjacent forest, which would be answered by shouts of the men, and the women singing the usual burbung songs.

At the daily meetings of the headmen at the ngooloobul, or men's council place, the kooringal, or band of strong active men, who are to perform all the pantomimic displays in the bush are picked out; and also the men who are to act as guardians to the novices are chosen at these meetings.

Pieces of bark, called *munga* or *dhoorung* are stripped from trees somewhere adjacent to the goombo, where they are kept ready for use on the morning of the final ceremony, to be described presently. These strips of bark are about two feet and a half in length, and six inches in width at one end, but tapering smaller at the other in order that they may be gripped in the hand.[1]

On the evening preceding the taking away of the novices there is the usual corroboree, and afterwards there is considerable sexual

[1] For an illustration of one of these pieces of bark, see plate xxvi., fig. 40.—Journ. Anthrop. Inst., xxv., 308 and 315.

license allowed between the men and women, whether married or single. This liberty is accorded only to those parties who would be permitted to marry each other in conformity with the tribal laws. This license would not be extended to the novices.

Taking away the Boys.—When the morning arrives on which it has been determined to take the novices away into the bush, some of the men leave the camp unobserved by the women a short time before daylight, and proceed to the goombo and light the *wcongonyalbil* fire. When the day dawns these men sound the bullroarer *(mudjeegang)* somewhere within the sacred ground. When this sound is heard in the camp, the men shout in unison and the women commence to sing and beat their rugs. All the men who have remained at the camp, pick up each a burning stick from their camp fires, and run in single file into the Burbung, the leader entering it by stepping over the embankment and is followed by all the rest. They dance round inside the ring a short time, waving their fiery sticks in the air, shouting and naming places in their ngoorumbang, after which they return to their camps, and throw the burning sticks into the fires from which they have been taken.

The women and children, all quite naked, are now mustered out of the entire camp, and are brought close to the Burbung, the women of each tribe keeping by themselves, and sit down on the side which faces in the direction of their respective districts. The mothers of the novices are in the front, close to the embankment bounding the ring, the other women being behind them. The mothers are painted on the face and chest with marks of red ochre and pipeclay, the relatives of the boys and other women being also painted.

The youths who form the subject of the ceremony are now separated from the rest, and each is taken charge of by the guardian *(goomahn)*, who has been selected for this duty. These men are the brothers actual or tribal, of the women from among whom the novices could, when old enough, obtain a wife in accordance with the tribal laws. These guardians do not for the present

take a prominent part in the proceedings, but get some of their brothers, who may be called their assistants or surrogates, to act for them until after the women have been covered up.

Each novice's female relatives, consisting perhaps of one of his sisters and a sister of the guardian, now paint him red all over his body and limbs, and ornament his hair with feathers.[1] During the progress of the painting of the novices, some of the men cut green boughs for use in covering the women presently, and a number of rugs and blankets are gathered throughout the camp for the same purpose.

The men are sitting down by themselves, in a state of nudity, a hundred yards away, and as soon as the novices are painted they are taken by their mothers towards where the men are sitting. When the men see the novices and their mothers coming, they go and meet them, and the latter run back to the camp followed by the men, who now take charge of the novices. Each group of boys is then taken by their male friends to the men belonging to a neighbouring tribe, who invest each novice with a man's attire, consisting of a belt or girdle round the waist, to which are attached four tails or kilts; a headband; and a band or armlet round each arm between the elbow and the shoulder. The group of novices are then taken back to their friends, and the men who had invested them in their regalia now take their own group of novices to the men of another tribe to have them dressed in a similar manner.

To make this matter more easily understood it may be supposed that the tribes from Hay, Narrandera, Gundagai, and Hillston are present. The novices of the Hay tribe, for example, would be invested in the garb of manhood by the Narrandera men; the Narrandera boys by the Gundagai men; the Gundagai novices would be dressed by the Hillston men; and the Hillston boys by the Hay men. That is to say, the novices belonging to one tribe

1 "The Burbung of the Wiradthuri Tribes."—Journ. Anthrop. Inst., xxv., 308. "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, ix., N.S., 124.

are always dressed in the regalia of a man by the men of one of the other tribes present at the general Burbung gathering.

When these decorations have been completed, each novice is taken by his friends into the ring, and is placed sitting down on a piece of bark laid on the embankment forming the boundary. All the novices belonging to each tribe are placed in a row on the side of the ring which is nearest their own ngoorumbang. There would therefore be as many groups of boys as there were tribes present, assuming that each tribe had brought some novices for the purpose of initiation. One of the sisters of the man who has been appointed guardian to the novice now enters the ring, and places a green leaf in the boy's mouth, after which she squirts pipe-clay out of her mouth into his face, and then retires among the other women. Each novice is treated in a similar manner by his guardian's sister.

The selection of the site to which the women will remove the camp[1] after the boys are taken away is the next business to be disposed of. Two old headmen enter the Burbung, one on each side, facing each other. One of them walks a few paces, and sticks his spear into the ground, and sitting down, says, "This would be a good place for the thurrawonga camp," at the same time mentioning the name of the locality. The other man then advances a few steps, and sticking his spear into the ground, sits down and calls out the name of another place which he thinks would be a better site for the new camp. Then the first man goes on a little way farther, and goes through the same deportment, and names another locality. Perhaps half a dozen different places may be suggested in this way, until one of them mentions the name of a place which they both approve of. Then the other old man approaches and sits down beside him, and both of them call out the name of the locality. This finally settles the matter, and the two men come out of the ring.

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1 "The Bora, or Initiation Ceremonies of the Kamilaroi Tribe."—Journ. Anthrop. Inst., Lond., xxv., 327. "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, ix., N.S., 124.

A yamstick is then stuck into the ground just outside the embankment bounding the Burbung, and a man, who may be called No. 1, catches hold of it in one hand, say his right. Another man then steps forward, and the first man lets go the yamstick, which the other man catches in his right hand—at the same time with his left hand catching hold of the right hand of the first man, who moves on to make room for him. A third man now steps up and the second man releases his hold of the yamstick, which is then caught by the right hand of No. 3, who, with his other hand catches the right hand of No. 2. Fresh men are continually added in this way until there is a complete ring of men with their hands joined all round the Burbung—the first man, No. 1, having again reached the yamstick, which he catches in his left hand.[1]

A man then runs once round this ring of men, singing as he goes, and when he gets back to the point from which he started, he hits the ground once with a nulla-nulla or piece of bark. All the men then let go their hands, and fall face downwards on the ground.[2] The man again runs once round and hits the ground as before, and all the men who are lying on the ground roll over on their backs. The man once more runs round, and strikes the ground in the same way, which is the signal for all the men to rise to their feet. They then step back from the ring, some of them going to one side and some to another, but most of them mustering near the side from which the pathway issues. Having collected their weapons, which were lying close at hand, they commence beating them together.

The old men then bend down the heads of the novices,[3] and direct them to keep their eyes cast upon the ground at their feet. The mother of each novice is brought up near the embankment, immediately behind her son, and lies down in such a position that

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[1] "The Burbung of the Darkinung Tribe."—Proc. Roy. Soc. Victoria, x., N.S., 5, 6.

[2] "The Bunan Ceremony of N. S. Wales."—American Anthropologist, ix., 335, 336.

[3] Proc. Roy. Soc. Victoria, ix., N.S., 125.

she can hold in her hand one of the tails which are attached to the sides of his girdle. The other women and children are also told to lie down, and the men cover them all over with the rugs and bushes which had been got ready for that purpose. A few of the men stand on guard with spears in their hands to see that none of the women or children attempt to remove their covering or look up. Little children who cannot speak are not covered up, but are allowed to remain standing or sitting among the women, because they are not able to report anything which they may see.

When all the necessary preparations have been made, the principal headman gives the signal, and two men approach from the direction of the goombo, sounding bullroarers, one man taking up his position on one side of the burbung, and the other man on the opposite side. Three or four other men also make their appearance, each having in his hand a piece of bark, *dhooroong*,[1] already described under the head of "*Daily Ceremonies at the Camp*." These men enter the Burbung and go round once beating the ground with the dhooroong, but not shouting, and then run away quietly towards the goombo.

It not unfrequently happens that small pieces of the bark used by the men in beating the ground, break off and remain in the ring, or rebound over the bank amongst the women. Some of the young men standing around watch for these fragments, and very carefully pick them up immediately, at the same time obliterating the imprints left on the ground where struck by the *mungas*. These precautions are taken so that the women, when they get up presently, may not be able to obtain any clue to the cause of the terrible thumping sounds produced in this manner. They are persuaded that it is caused by the trampling of the Evil Spirit when walking about taking the boys away, and that the noise made by the bullroarer is his awe-inspiring voice.

While the bullroarers are being sounded, and the men are beating the ground with the bark, the other men who are standing

1 These pieces of bark are also called *munga* and *barrung barrung*.

outside the ring keep up a shout. During this din the guardians step forward, and take the novices by the arm and lead them noiselessly away along the *dharambil* or pathway. As each novice rises to his feet, the *dhallaboolga* or tail which is held in his mother's hand separates from his girdle, and is kept by her for the present.

During the clamour produced at the ring while the novices are being taken away, some of the men pick up a few articles belonging to the women, such as dilly bags, yam sticks, or the like, and scatter them about, some of them being thrown into the ring, and others hung on saplings.[1] Burning sticks taken out of the fire at the camp are also thrown close to where the women are lying. The men who are walking about also catch hold of some of the little boys who cannot talk yet, and make a few marks of pipe-clay on their faces. Perhaps one of these little fellows is placed sitting in the fork of a tree close at hand.

When the procession of guardians and their charges have advanced along the *dharambil* and have passed through the archway, a halt is made somewhere in the vicinity of the *goombo*. The novices are placed lying down on the ground, and rugs thrown over them. During this stoppage the kooringal and other men who are to accompany the novices into the bush have time to collect their weapons and other belongings, and overtake the guardians at this place. All the men present then beat their weapons together and keep up a vociferous noise for some minutes, a bullroarer being sounded close by. The men who were using the *dhooroong* in the Burbung ring are also here, and again beat the ground. These noises can be heard by the women at the camp and will be referred to presently. After this the kooringal paint their bodies jet black with burnt grass or powdered charcoal, mixed with grease.

The Thurrawonga Camp.—In order to make the subsequent sections of this memoir more easily and thoroughly understood, it

[1] "The Bora of the Kamilaroi Tribes."—Proc. Roy. Soc. Victoria, IX., N.S., 155.

will be desirable at this stage to describe how the women and children are released from their imprisonment at the Burbung, and the removal of the camp to a new site, which may be distinguished as the "Thurrawonga Camp."

As soon as the novices and guardians are out of sight of the Burbung, the covering is taken off the women, who, on getting to their feet and seeing the boys gone and their things strewn about on the ground, chant a kind of lamentation, especially the mothers and sisters of the novices.[1] About this time they hear the shouting and other noises made by the men around the boys near the goombo. All the mothers then go to a log, or stem of a fallen tree, lying on the ground somewhere near the Burbung, half of them standing on one side and half on the other side of the log. The mothers standing on the one side then throw their yamsticks horizontally and end on, across the log, to the mothers on the other side; the latter return the yamsticks over the log in the same way. Bunches of green leaves are tied to one end of these yamsticks to make them ornamental, and the mothers sing during the performance. This throwing of the yamsticks to and fro across the log is continued until the shouting of the men near the goombo ceases, and is done for the avowed purpose of inducing the evil spirit to show clemency to their sons.

All the women and children, and a few of the old men who have been left in charge of them, then gather up their effects and start towards the locality which has been settled upon for the erection of the new camp. On arrival there the people of each tribe take up their quarters on the side facing their respective districts—the camp of the local tribe forming the initial point.

It not unfrequently happens that one of the tribes who are expected to attend the ceremonies are unable, from some cause, to reach the burbung ground before the camp is broken up, but arrive a day or two afterwards. In order that this late mob may know where to go, a messenger is sent to meet them and escort

[1] Journ. Anthrop. Inst., xxv., 330.

them to the Thurrawonga Camp, where they take up their quarters on the side next their own *ngoorumbang*.

Before leaving the burbung, the mothers of the novices provide themselves with pieces of burning bark, called *bunnang*, which they carry in their hands wherever they go. The *bunnang* consists of two pieces of bark laid together and placed in the fire till sufficiently ignited; it is then taken out, and smoulders as long as the bark lasts, when it is renewed by fresh pieces. Wherever the mothers rest to light a fire for the purpose of warming themselves or to cook their food, they cover the fire over with earth before leaving it, so that no other person may use it and so bring mischief upon their sons.

At the Thurrawonga Camp, the mothers of the novices belonging to each contingent occupy quarters by themselves a little distance from the camp of their own tribe. Every mother has a fire of her own, and no one else is permitted to use it. These separate camping places are called *dhunda*. Their sisters, or mother's sisters, or some of the elder women provide them with food, and attend to their wants generally. These women are collectively known as *yanniwa*, and none of the other women or the children are permitted to interfere with them.[1] Each mother eats the whole of the food brought to her, as it would bring evil upon her son if she gave any portion of it to the other women present. All the mothers are, however, very abstemious with their food whilst their sons are away.

The tails, *dhallaboolga*, retained in the hands of the mothers on the morning their sons were taken from them, are fastened to the upper ends of spears, and these weapons are stuck into the ground beside the quarters of the mothers to whom they belong. Every morning and evening the mothers pick up their spears and run, quite naked, a distance of about a hundred yards towards the part

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[1] "The Bunan Ceremony of N. S. Wales."—American Anthropologist, IX., 341; "The Burbung of the Darkinung Tribes."—Proc. Roy. Soc. Victoria, X., N.S., 7; "The Keeparra Ceremony of Initiation."—Journ. Anthrop. Inst., XXVI., 329.

of the district where their sons have been taken by the old men. They sing and shout and wave the spears with the tails attached, in that direction, and then run back to their own camp, inserting the spears in the ground as before. Their yamsticks, with the bushes attached, are also kept stuck in the ground in a similar manner. If one of these spears or yamsticks should fall or be accidently knocked down, it is considered a bad omen, forewarning danger to the son of the owner of the weapon.

Every man or woman who has been out hunting during the day is met by one or more of the mothers on returning to the camp. They run towards the new arrival as he approaches, and wave the spear with the *dhallaboolga* attached to it, quite close to his face, and then run back to the *dhunda*.

Some of the old men remain at the new camp to see that all the tribal customs are strictly carried out. Communication is kept up between them and the men who are out with the novices; and the day the latter are notified to return, a bough yard, called *thurrawonga* or *cudthalderry* is erected a short distance from the camp, towards the quarters in which the *ngoorang* is situated.[1] This yard is semi-oval in shape, being about forty feet across the open end, and about twenty-five feet from there to the back wall The walls of this enclosure, which are five or six feet high, are built of saplings, forks, and bushes, placed close together, so as to form a dense screen. One or more narrow openings, arched over the top with boughs, are left in the convex end, through which the contingent from the bush will enter on their arrival, as described farther on. Around each side, within this partial enclosure, a platform is erected by placing sheets of bark on top of logs laid around for the purpose.

About nightfall, all the women, accompanied by such of the men as may be in the camp, proceed to the thurrawonga, inside of which the men light a fire. The mothers of the novices are painted with marks of pipeclay and red ochre about the face, chest

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[1] Journ. Anthrop. Inst., Lond., xxv., 309.

and arms, and have the teeth, claws and small bones of various animals fastened in their hair and round their necks. They light a fire outside the open end of the thurrawonga, and wait there. When the kooringal and boys are heard coming, the men cover the rest of the women over with rugs and bushes, as on the previous occasion at the Burbung. The reader will understand this paragraph, when he comes to the section on "*The Return of the Boys.*"

Ceremonies in the Bush.—I must now return to where the novices were left lying on the ground, with their guardians and the kooringal around them. When the shouting and other noises have ceased, the guardians catch hold of the novices by the hands and help them to their feet, their faces being still bent towards the ground. They are not at any time permitted to put their hands on the ground for the purpose of assisting themselves to rise, but must wait until helped up by their guardians. A rug is now adjusted over each novice's head in such a manner that there is only a narrow opening left at the face, through which he can see anything to which his attention may be directed by his guardian.[1]

In the meantime a number of the kooringal have arranged themselves in a row, standing a few feet apart, with their faces towards the novices. Between each pair of these men a man is lying horizontally, his head resting on the shoulder of one of the men, and his feet on the shoulder of another. This will be made clearer by an example: Suppose A, B and C are three of the men standing in a line; another man, D, is laid horizonthlly between A and B; his head rests on A's shoulder, and he maintains that position by putting his arms round A's chest. His legs are on B's shoulder, one leg being round each side of B's neck. Another man, E, has his head on B's shoulder, and his feet on the shoulder of C, and keeps his hold of both men in the same way that D does. Perhaps a dozen men may be laid horizontally in this way,

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[1] "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, IX., N.S., 125.

and, when all is ready, the novices are told to raise their heads and look at the tableau before them, which is intended to represent a streak of black cloud resting on the shoulders of the men. The kooringal walk slowly towards the novices, and if a breeze is blowing they move gradually with its current, to convey the idea of a cloud drifting with the wind. The kooringal now let the men down off their shoulders, and all of them jump about before the boys.

The guardians now take the novices away several miles to a camp in the bush, being accompanied by some of the principal headmen, who have charge of the ceremonies, and a number of initiated men, called the *kooringal*, selected from the several tribes present at the Burbung gathering. The fathers and other relatives of the boys are also amongst the company. The blankets are kept over the heads of the novices in the manner already described, and they have to walk along with their eyes cast upon the heels of the man in front of them. All the men and boys walk along at a leisurely pace, and the latter are not permitted to speak or to gaze about them.

On arriving at the place where they intend to stay for the night, a space is cleared of sticks and other loose rubbish, and the boys, with their guardians, occupy one side of it, a little way from the men. The kooringal and other men camp round this cleared space, the men of each tribe keeping by themselves. The novices are placed lying down with the blankets on their heads as before, some of the guardians being continually with them. During the evening the kooringal play the *wyang* or night-owl. They have white rings painted with pipe clay round their eyes, and mud plastered on their posteriors, on which feathers are fastened. They file past the fire to and fro a few times imitating the owl, the novices sitting on the other side of the fire looking at them. If it is a fine night more than one pantomime may be played. When they become weary or sleepy, the boys are taken to their own quarters, and all hands retire for the night.

Some time before daylight the following morning all the people are roused out of their slumbers by the old men.[1] The men and boys are divided into a number of little mobs, each mob marching away from the *ngoorang* or main camp in different directions, for a distance of 100 or 150 yards. It is not necessary that each section should go the same distance from the ngoorang; this matter is regulated by the suitability of the ground for camping purposes. The novices, each being accompanied by his guardian, are taken away in these groups, some going with one group and some with another. Care is taken, however, that every novice is taken away from the ngoorang in the direction opposite to that in which his own country is situated. Some of the mobs would, perhaps, consist of men only, owing to their being no novices from the district located in the contrary direction. Each of the groups light a fire at their respective camping places, which are called *bŭnbŭl*, where they remain till after daylight, and have breakfast there.

After the morning meal has been disposed of, all the little mobs re-unite, and clear another corroboree ground contiguous to the one they prepared the previous evening. The kooringal then select some animal as the subject of the play, and when all is ready the novices are permitted to look at the performance. Their heads are then bent down as before, and they are taken back to their respective bŭnbŭls from which they have just come, where they remain with their guardians during the day. The novices are called *budthandooree* during their sojourn at the bŭnbŭl camps.

The kooringal then go out into the bush hunting, in order to provide food for the novices and guardians, as well as for themselves. On their return to the camp in the afternoon some of the game caught during the day is cooked and given to the novices. The bones and sinews are taken out of the meat which is prepared for them, and some of the old men go round to see that their food is dressed according to rule.

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1 "The Initiation Ceremonies of the Aborigines of the Upper Lachlan." —Proc. Roy. Geog. Soc. Aust. (Q) xi., 169.

As the young fellows are generally eager to participate in the plays enacted in the bush, they leave their women at the new camp, and start out to join the kooringal, having received directions respecting the locality from some of the old men at the camp, or perhaps some of these men escort them to the ngoorang. On the way out they paint their bodies with charcoal and grease, and on nearing the ngoorang, one of them climbs a tree and shouts in a peculiar manner, which is answered by the kooringal. The latter then gather up their weapons, and having mustered all the novices, take them to the quarter from which the man's voice has been heard, where they find the fresh arrivals, who are called *goory*, sitting down in a group, with bushes in their hands. The kooringal place the boys standing in a row looking at the new men, round whom they form a semi-circle, dancing and shaking their weapons.[1] The heads of the boys are now bent down by their guardians, and they are taken back to the bŭnbŭls—the *goory* joining the kooringal. These arrivals at the ngoorang generally take place late in the afternoon, or early in the morning.

At the close of the day all the men and boys camp at the same place as the night before, and similar pantomimic performances are indulged in. In the morning all hands are called up by the old men, and radiate away from the ngoorang as on the previous morning. On this occasion they do not go to the same place as before, but each little mob selects a fresh camp at which to light their fire and remain till morning. After breakfast another corroboree ground is cleared, at a different place to that used yesterday, and another play is performed by the kooringal. Different animals are represented each night and morning, and all the dances and performances are as usual largely composed of abominable and obscene displays, which cannot be described in a paper like the present. The kooringal renew the black paint upon their

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1 Compare with "The Wandarral of the Richmond and Clarence River Tribes."—Proc. Roy. Soc. Victoria, x., N.S., 38.

bodies day by day, and the guardians keep the novices carefully painted red.

It is not essential that the men and boys should remain at the same camp every night; they may stay one or more nights at the same place, or a fresh camping ground may be reached every night. When taking the boys from one camp to another, the rugs are kept over their heads, and they are under the vigorous surveillance of their guardians. When walking along through the bush, the kooringal and guardians are joking with each other all the time. If any of them see an iguana going up a tree, they say he is coming down; if a small bird is seen they say it is very large; if the day is cold, they remark that it is hot, and so on. At each of these statements, which is always the opposite of the truth, a shout is given, and all the men laugh. The novices are not permitted to laugh at anything that is said or done, no matter how amusing or preposterous it may be.

Human ordure[1] was given to the novices on more than one occasion during their stay in the bush. The sound of the bull-roarer would be heard in the adjacent forest shortly before sunset and some of the guardians would say to the novices, "Here comes Dhurramoolum to feed you with excrement." Preparations for this ceremony had been made during the afternoon. Small pieces of bark had been cut, about six inches square, and slightly charred in the fire, and on each of these a small portion of excrement was deposited by the old men. These pieces of bark with their contents, were now brought and placed before each novice as they sat at the camp fire, and they had to eat the ordure without a murmur in the presence of the headman. They were also compelled to drink urine collected in a coolamin for the pupose.[2]

On the third or fourth day after leaving the Burbung one of the middle front teeth of the upper jaw is taken out of each of the

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[1] "The Burbung of the Wiradthuri Tribes."—Journ. Anthrop. Inst., xxv., 312.

[2] "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, ix., N.S., 128.

novices. A clear patch of ground is selected somewhere near the camp, from the surface of which all loose rubbish and grass is removed. Along the centre of this cleared space a row of holes, about a foot long and four inches wide are dug into the ground to the depth of six or nine inches, according to the nature of the soil. The number of these holes is regulated by the number of boys to be operated upon, there being two holes for each individual. In some cases, however, where the ground is very hard, one pair of holes may be used for several boys. These holes are about a foot and a half apart, so that the boys when standing in them have their legs extended. In the bottom of each hole a layer of green leaves is strewn to keep the boys' feet off the ground.

About an hour or two before sunset the novices are brought out and placed standing with their feet in the holes, all their faces being in one direction. Each guardian now kneels down behind his novice, and puts his head between the boy's legs, which have been kept wide apart for this purpose, so that the boy rests on his guardian's neck and shoulders. The principal headman now walks along in front, and takes the rugs off the novices, at the same time shoving their heads up straight. Another man then comes behind each boy and catches him by the top of the head with one hand, and with the other holds the boy's chin to keep the mouth open. Sometimes the man holds one hand on each side of the boy's head, the fingers of one hand being on the chin. A piece of tough stick is placed across the boy's mouth to prevent his shutting it. A number of men accustomed to the work of extracting teeth are standing in front of the boys, and the headmen are walking about giving such directions as may be thought necessary.

The *modus operandi* in extracting the tooth is as follows.[1] The man who is to operate upon the boy steps up to him, and with his

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[1] Compare with descriptions of this operation given by me in "The Bunan Ceremony of N. S. Wales."—American Anthropologist, IX., 338; "The Burbung of the Darkinung Tribes."—Proc. Roy. Soc. Victoria, X., N.S., 7–8; "The Burbung of the Wiradthuri Tribes."—Journ. Anthrop. Inst., XXVI., 278–279.

finger nail pushes back the gum from the tooth to be extracted. He then puts his own lower teeth under the tooth and pulls outward and upward—the stick which is across the boy's mouth preventing him from biting the man's lip. This is done with the professed intention of loosening the tooth, and blackfellows have told me that occasionally it comes out under this treatment. If not, this is accomplished by placing one end of a narrow piece of wood or stone, called *wallung*, against the tooth, and hitting the other end with a stone or wooden mallet used as a hammer. The tooth is then taken out of the boy's mouth with the man's fingers and the gum pressed together. As each tooth is produced and held up, all the men present shout "Wir-r-r!" in unison. While the ceremony is going on, a bullroarer *(mudjeegang)* is occasionally sounded in the bush not far off. The blood flowing from the wounded gum is swallowed by the boy. The guardians now assist the novices to withdraw their feet from the holes, which are then filled up, and the surface of the ground strewn over with rubbish the same as it was before being cleared. The boys are freed from wearing the rugs over their heads from this time forth.

The novices are then conducted back to the camp and after supper they are taken a little way into the bush with the men under the pretext of looking for water to allay their thirst. When they have walked some distance, one of the men who has gone away unobserved by the boys, whistles, and calls out "I think there is water over here." The men and boys then proceed in that direction but go too far. The man then again whistles and they turn back and find him sitting down, apparently perishing from thirst, and he tells them he has not found any water. The kooringal then corroboree round him and shout.

After that they all go back to the camp, and the boys are placed lying down in their own quarters. In a short time the men pretend to quarrel among themselves about something, angry words being mutually exchanged, and the men get their weapons ready. The novices think a conflict is imminent, but after some further recriminations peace is apparently restored. A detach-

ment of the kooringal now gather round each novice in succession, as he lies in his camp, and sing Dhurramoolun's song[1] over him, beating their boomerangs together while doing so:—

Ghee′- bul, ghee-′ bul, oong- o- ga′ ga- la′- bi- an,
Bah′- wan- bah′ goo- rar′ nga- dahn′- tha bay′- an.

This chant is repeated a great many times without intermission. As the men finish singing over each novice they raise a shout, "Heh! Wah!" and when the ceremonial is concluded, both men and boys retire to rest for the night.

Next morning the whole camp is roused up as usual, and the men and boys divide into little groups, each going away in different directions as before. Two or three men are despatched to the women's camp to inform them that the kooringal and boys will return that evening. The kooringal go away a short distance out of sight of the camp, where they clear a portion of the surface of the ground of all sticks and loose rubbish. Pieces of bark, *barung barung* or *dhooroong*, similar in size and shape to those used at the Burbung when the boys were taken away are prepared ready for use. They also light one or more fires, and burn green bushes on them to make a smoke. The smoke, being charged with moisture from the green leaves, partakes somewhat of the nature of fog, and does not ascend as readily as ordinary smoke, but hangs about near the ground.

When these preparations have been made, the guardians march the novices, with their eyes cast down, towards the cleared space, telling them that Dhurramoolun is going to burn them at a big fire which he has ready, and their attention is opportunely directed to the smoke hovering around them, but they are not permitted to raise their heads.

In hilly districts, as on the Upper Murrumbidgee about Gundagai, where there is rocky country, the kooringal heat a few large stones in a fire at some place near to which the novices will be

1 "The Keeparra Ceremony of Initiation."—Journ. Anthrop. Inst., XXVI., 333; "The Bora of the Kamilaroi Tribes."—Proc. Roy. Soc. Victoria, IX., N.S., 167.

brought along. When the boys are passing, a large hot stone is started rolling past close to their feet, so that they can see it, and as it rolls along it scorches the grass. A little farther on one or two more stones may be rolled past in the same way. Other larger stones are thrown heavily on the ground or against rocks a little way off to make as much noise as possible, and terrify the novices, who are told that this is the work of Dhurramoolun. In level country where there are no rocks, as in the district around Hay, this stone rolling part of the performance is necessarily omitted.

As the guardians and novices approach the cleared space referred to, about a dozen men with the *barrung barrung* commence to beat the ground. These men, who are called *wundang*, are fantastically disguised by having small bushes, pieces of bark and grass fastened in their hair and in their belts. They are sitting in a row, and strike the ground in front of them with the barrung barrung, one after the other, making a great noise. A man is standing near each end of this row swinging a mudjeegang. The novices are brought up in front of the *wundang*, and are told to raise their heads and look. The men who are swinging the bull-roarers then place one foot on top of the other to give them the appearance of having only one leg, like their mysterious prototype, Dhurramoolun. The remainder of the men, including the relatives of the boys are standing around the cleared space.

The headmen and other armed warriors now step out with uplifted spears and tomahawks and warn the novices that if they reveal what they have just seen, or any of the secret ceremonies which have taken place in their presence in the bush, to the women or uninitiated, their own lives and those of the persons to whom they may confide the mysteries, will be required at the hands of the tribe.

Return of the Boys.—At the conclusion of the important ceremonial of showing the boys the bullroarer, they are taken back to the ngoorang, and everything is packed up, after which a start is made for the Thurrawonga camp—described in previous pages.

The kooringal engage in hunting as they journey along in order to provide something for dinner. The boys walk with their guardians, having, as before stated, been released from wearing the rugs over their heads, but are forbidden to look in any direction except straight ahead. About midway a waterhole is reached, where a halt is made, and the game caught by the way is cooked on fires lighted for the purpose. This camp is called *Bidjerigang*.

At this halting place, the men and boys have all the hair singed off their bodies, and the hair of their heads is also singed to make it shorter, after which the men go into the waterhole and wash off the black paint.[1] The guardians sit with the novices on the bank, and when the kooringal come out they mind the boys while the guardians perform their ablutions. None of the novices go into the waterhole. After this, the boys are painted with white spots on their faces, arms and chests. The guardian chews the end of a piece of tough green stick till it frays out like a kind of brush, which he dips in wet pipe clay and applies to the skin of the novice. These white spots are put on top of the red ochre with which the bodies of the novices have been kept painted during their sojourn in the *ngoorang*. All the men are painted in the way customary in their tribe, and boys and men wear their full dress.

The journey forward is then resumed, and on going some distance farther on a halt is made for the purpose of giving the boys a new name.[2] The guardians and novices stand in a row, each of the latter having a small bush in his hand. The kooringal form into a semicircle several paces in front of the row of novices, and some of the old men, who are relatives of the boys, are deputed to name them. These old men stand out by themselves in front of the kooringal, and call up a certain guardian, who steps forward, bringing his novice with him, and both of them stand in

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1 "The Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, IX., N.S., 131. "The Bora or Initiation Ceremonies of the Kamilaroi Tribe."—Journ. Anthrop. Inst., XXV., 336.

2 Journ. Anthrop. Inst., XXV., 310; *Ibid.*, XXVI., 281.

front of the semicircle—the boy shaking the bush which he carries in his hand. The old men then deliberate what name shall be given to him, and when this point has been decided, the name is called out, upon which all the men present shout "Wir-r-r!" in unison. The boy and his guardian then retire and stand on one side. Another guardian and his novice are then called out in a similar manner, and when the name has been given they also retire, and stand beside the previous pair. This procedure is repeated until all the novices have been named, and are standing in a row at a different place to that at first occupied by them—the bushes which they carried being thrown down. Some of the armed men then step out in front of the neophytes and repeat the caution as to the consequences which will ensue if they divulge any of the secret ceremonies which they have passed through in the bush.

Another start is now made towards the women's camp, and on nearing it, the men whistle and keep repeating "Bir-r! Bir-r!" and are answered by the mothers of the novices. On getting within about a hundred yards of the appointed place the guardians halt for a few minutes, and take the novices on their shoulders, and start on abreast till they get within twenty or thirty yards of the thurrawonga, where they again come to a stand. The kooringal are behind the guardians, and in the rear a bullroarer is sounded by one of the men. While the guardians are getting the boys on their shoulders,[1] a number of the kooringal file into the thurrawonga through the archway, and stand in rows along the wall to the right and left.

The guardians then enter the thurrawonga, and step up on the platform, keeping the boys on their shoulders. The mothers, who are standing near the fires, then advance, each having a spear in her hand, to the upper end of which is attached the *dhullaboolga* or tail which she took from her son's girdle the morning he left the Burbung. She raises the end of the spear towards the boy,

[1] "The Bunan Ceremony of New South Wales."—American Anthropologist, IX., 342.

who catches hold of the *dhullaboolga* and pulls it off, and then slides down from his guardian's shoulders out of sight of his mother.[1] The latter at the same time also turns her back towards her son. The same course is followed by all the mothers simultaneously, after which the covering is taken off the other women, who are lying down a few paces back from the open end of the thurrawonga, and then all the women go away back to the main camp.

The men who have charge of the proceedings at the thurrawonga then throw green bushes on the fire, which produce a dense smoke into which are gathered all the men who have been out at the ngoorang, as well as the boys, where they stand round the fire until the old men consider that they have been sufficiently fumigated. The guardians and novices camp all night in the thurrawonga, and early next morning go away into the bush to a suitable camping place, accompanied by some of the kooringal and old men. The women also remove their quarters, and go to another camp.

The men and boys stop away for a few days. It may be that they camp at the same place all the time, or perhaps a fresh camping ground is reached every night. The camp is not broken up into *bunbul* sections every morning, and the boys go out hunting with the men during the day, being now under no restrictions, except that they must eat only such food[2] as has been sanctioned by the old men.

At the end of this term of probation, the men and boys again go back to the main camp, stopping at some suitable place by the way to paint themselves, and put on their full dress. This return of the novices, which completes the process of inauguration, is called *ngoorango goorawalgaree* (bringing back to camp), and is

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1 Among the Wiradthuri tribes further to the northward, the mother of the novice squirts pipe-clay out of her mouth into his face when he is carried into the thurrawonga; and in some districts she afterwards taps him on the breast with a boomerang, or with a small narrow piece of bark, ornamented with paint for the occasion.—Journ. Anthrop. Inst., xxv., 310; *Ibid.*, xxvi., 282 and *note* 2.

2 "The Dhalgai Ceremony."—Journ. Anthrop. Inst., xxvi., 339.

also known as *minbin mumbilla*. A platform, *(goolay)*, about a foot high, composed of pieces of bark laid on logs, is erected by the men somewhere near the women's camp. The mothers of the novices, decorated as at the thurrawonga, and all the women of the tribe are present at this platform, but none of them are covered over on this occasion. Each boy's mother lays on the platform a rug or blanket, beside which she inserts her yamstick in the ground, and sits down on the other side of the platform. All the mothers then commence to sing doleful chants, because their sons will not be allowed to camp with them any more, but must now stay with the single men, and take their part as men of the tribe.

When these preparations have been made, at a given signal the guardians and novices approach, followed by some of the kooringal beating boomerangs, but the mudjeegang is not sounded. On getting near the platform each guardian points out to the boy his mother's yamstick, and directs him to sit down on the rug which is beside it.[1] The mothers, who are sitting down on the other side of the platform, immediately behind the boys, then put their arms around them for a few minutes. The guardians then catch the novices by the hand and lead them away to a camp in sight of the men's quarters, all the women at the same time returning to their respective camps. From the time the novices were taken away from the Burbung their mothers have been required to carry a piece of burning bark in their hands when travelling from place to place, but they are now released from this obligation, and these firesticks are left at the *goolay*. The next day the mothers of the novices go into a waterhole or running stream near the camp, and wash the paint off their bodies.

Finishing Ceremonies.—As soon as all the fundamental rites have been concluded, the strange tribes are eager to get back to their own districts, and generally start away the next day, or

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[1] Farther north the men and neophytes are smoked on this occasion, instead of on the return to the thurrawonga.—Journ. Anthrop. Inst., XXV., 312; *Ibid.*, XXVI., 283.

at any rate in the course of a short time. The local tribe also shift to another part of their ngoorumbang, the food supply of the present camping ground having been exhausted by the large demand made upon its animals and fruits by the tribes who have attended the ceremonies.

Each tribe takes charge of its own novices, who are kept under the control of their guardians or relatives. They are not permitted to talk or laugh loud until they reach the age at which they develop the voice of a man. They are allowed to lodge near the main camp, and may come in sight of the women, but must not speak to them. They are gradually brought nearer and nearer to the men's quarters until they eventually come right in among the single men. A white stone, (quartz crystal) called *goonabillang* or *ngullang*, is given to the neophytes by the old men. A boy must attend at least three burbungs before he is admitted to the full privileges of a tribesman.

The mother of a novice is likewise required to comply with certain tribal regulations. Any food which she collects herself, or which is given to her by others, is eaten by her alone, as it would be unpropitious and fraught with evil to her son if she were to give any food to another person, until her son acquires a man's voice.

It will be interesting to give a brief outline of the formalities connected with the disposal of the teeth of the novices. When the old man extracts a boy's tooth in the manner described in the preceding pages, he hands it to the guardian, who takes care of it until he has an opportunity of giving it to the father of the boy. Before all the people disperse, the father hands over the tooth to the headman of one of the tribes in which he may have relatives or acquaintances, who takes it away with him to his own country. This headman may send the tooth farther on to another tribe, or he may keep it amongst his own people.

After a time, which may be only of a few months duration, or it may be a much longer period, the headman who took the tooth

away sends messengers to the tribe to which the owner of the tooth belongs, stating that it will be brought back at such a time. On receipt of this message, preparations are made to meet the strange people at the time appointed. On these occasions it is the custom for each tribe to make presents to the other, which takes the form of exchange or barter. Supposing for example that there is plenty of suitable stone for making hatchets[1] and whetstones in the country belonging to one tribe, they will exchange these commodities with the men of another tribe, in whose country there may be suitable wood for making spears and other weapons. People who have coloured clays will exchange them for skins of animals not plentiful in their own country. Others will have string made of the bark of certain trees, richly coloured feathers of rare birds, reeds for making light spears, and so on, which they exchange for other articles. It may be that some of the men and women exchange exactly similar articles with the people of another tribe merely as mementos of their meeting.

At these gatherings, the hosts arrange themselves in a line, with their presents and other commodities lying on the ground near them. The visitors advance and form into a row opposite the hosts, and display their presents in a similar manner. The headman who has brought back the tooth returns it to the boy's father, who subsequently hands it over to his son. After some time it is buried in the ground.

Conclusion.—With the exception of a short paper on the Burbung of the natives of the Upper Lachlan River,[2] this is the first detailed account of the initiation ceremonies of the Wiradthuri tribes published in any of the Australian colonies. Moreover, the first account of the Burbung of these tribes which has hitherto been published in England is that contained in two short papers

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[1] See my paper on "Stone Implements used by the Aborigines."—Journ. Roy. Soc. N. S. Wales, XXVIII., 301–305, Plate 43.

[2] "The Initiation Ceremonies of the Aborigines of the Upper Lachlan."—Proc. Roy. Geog. Soc. Aust. (Q.), XI., 167–169.

communicated by me to the Anthropological Institute of Great Britain.[1]

I regret that in the present paper, as well as in the previous articles to which reference has been made, considerations of space have compelled me to omit many particulars which I would have liked to describe more fully. It will be observed that I have confined myself as much as practicable to descriptions only, without offering explanations, or submitting theories for the present. I have a mass of information bearing upon the reasons of many parts of the ceremonies and their meaning, gathered in conversations with old headmen of different tribes, which it is hoped will be found of interest to those who study the customs of aboriginal races.

Explanation of Woodcut.—Fig. 1 is a plan of the Burbung ground, showing everything in its correct position in regard to the north point, which is marked upon it. The scale is 16 chains to one inch. *a* is the Burbung circle; *b* is the *goombo*; and the dotted line from *a* to *b* is the pathway *mooroo*, leading from one to the other, a distance of 1225 yards, or about $55\frac{1}{2}$ chains—nearly three-quarters of a mile. *c* is the archway through which the men passed in going along the track; *a* to *c* is low lying level ground, with a deep, crooked watercourse running through it, which is liable to be inundated by the overflow of the water from the Murrumbidgee when that river is in a state of flood. From *c* to *b*, the path ran through scrubby land, considerably higher than the land at the Burbung. This scrub has, as stated in the text, been cleared away, and part of the land is now under cultivation. The space from *c* to *b*, enclosed by broken lines, is that which contained all the figures and carvings in the soil and on the trees, known collectively as *yowan*.

Fig. 2 shows the Burbung ring, twenty-five yards by twenty-three yards, averaging twenty-four yards in diameter; *a* is the

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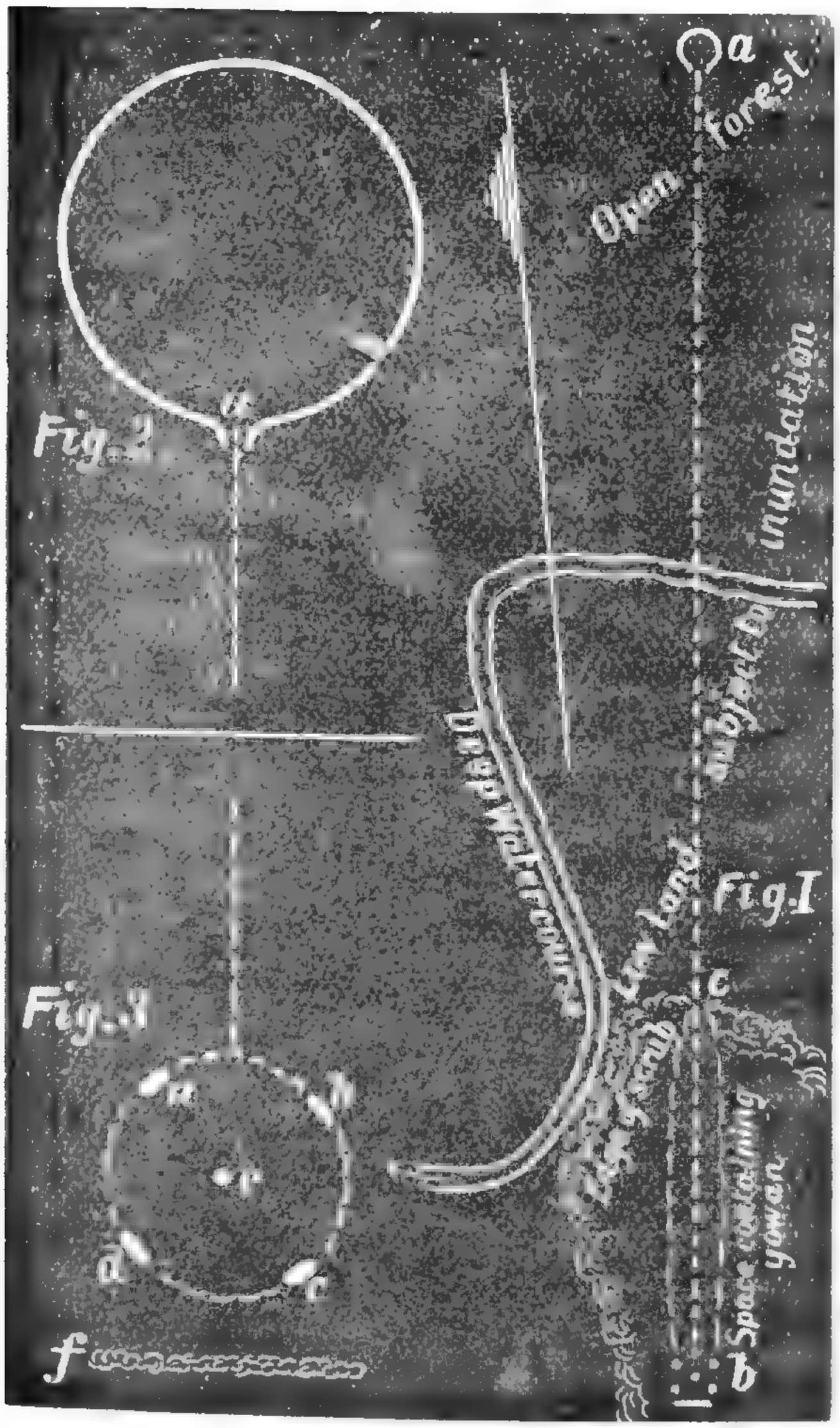
1 "The Burbung of the Wiradthuri Tribes."—Journ. Anthrop. Inst., XXV., 295 - 318. *Ibid.*, XXVI., 272 - 285.



opening in the embankment, from which the path led away towards the *goombo*. The embankment is continued outward a few feet on either side of the track where it leaves the ring. The camp of the local tribe was about one hundred yards to the north of this circle, and the other tribes were encamped adjacent, each on the side facing in the direction from which they had come. Water for camp use was obtained from the Murrumbidgee River, which was close to the camp in a north-easterly direction.

Fig. 3 is an enlarged drawing of the *goombo* or *budtha goonang* —*a*, *b*, *c*, *d*, being the four heaps of earth; *e* is the position of the forked stump;[1] *f* is the screen of boughs, *garreel*, a little way beyond the *goombo*. The dotted line is the track leading to the Burbung.

The scale of Figs. 2 and 3 is eighty feet to one inch. For complete details of all the drawings the reader is referred to the text.

[1] In Plate xxv., Diagram 3, of my description of the Burbung ground at Bulgeraga Creek, I showed the position of two wooden seats within the *goombo*. These seats were formed by digging two saplings out of the ground by the roots; the stems were then cut through about three or four feet from the base. The stumps were now carried to the *goombo*, and inserted perpendicularly in the ground, with the rooty ends upward. They were stained with human blood, and the headmen stood or sat upon them on ceremonial occasions.—Journ. Anthrop. Inst., xxv., 301, pl. xxv.

THE TOTEMIC DIVISIONS OF AUSTRALIAN TRIBES.

By R. H. Mathews, Licensed Surveyor.

[*Read before the Royal Society of N. S. Wales, July 7, 1897.*]

The first reference to the divisions of Australian tribes of which I am aware is contained in the works of Sir George Grey. In the years 1837-39, when exploring in Western Australia he found that the aborigines there were "divided into certain great families, all the members of which bear the same names. . . Each family adopts some animal or vegetable as their *kobong*, as they call it." He also noticed that "a man cannot marry a woman of his own family name, and the children always take the family name of their mother."[1] He was acquainted with the totemic divisions of the North American Indians, because he quotes from the *Archæologia Americana*, published in 1836, describing the divisions of American tribes, which was no doubt of great assistance to him in his investigations respecting similar customs among the aborigines of Australia. Sir George Grey says, "The family names are common over a great portion of the western coast, extending between four and five hundred miles in latitude."

The Rev. Wm. Ridley is the next writer on this subject. At different times between the years 1853 and 1875 he published the results of his enquiries in regard to the divisions of the Kamilaroi tribes on the Namoi and other rivers in New South Wales. Like most investigators on a new subject, which was moreover a complicated one, he arrived at some erroneous conclusions at first, but on going into the district on subsequent occasions, and pursuing his enquiries, he was enabled to correct some of his former impressions. His last work, published in 1875,[2] although incomplete

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1 Two Expeds. N. W. and W. Australia, Vol. II., pp. 225 and 228.

2 "Kamilaroi and Other Australian Languages," pp. 161 – 165.

in certain particulars, gives a tolerably good outline of the divisions of the tribes of which he treats.

Sir John Forrest, when he visited the north-west coast of Western Australia in 1878, found that the aborigines of Nichol Bay were divided into four classes, two of which intermarried with the other two, and the children followed the mother's family.[1]

In 1880, Mr. A. W. Howitt and the Rev. L. Fison published their joint work "Kamilaroi and Kurnai," in which the last named author commented upon the structure of the Kamilaroi tribes as laid down by Mr. Ridley, and also added details of similar tribal divisions in other parts of Australia. A few years later Mr. A. W Howitt contributed two papers to the Anthropological Institute on the "Class Systems of Australian Tribes," in which he included the Kamilaroi system, and described others of the same character, particulars of which had been furnished to him by correspondents in different parts of the country.[2] Besides the publications referred to, both Mr. Howitt and Mr. Fison have done much useful work in regard to some of the customs of the Australian aborigines.

Mr. Edward Palmer, in 1884, communicated a valuable paper, containing the results of his own personal observations, to the Anthropological Institute, in which amongst other native customs, he gave particulars of the names of the divisions of several tribes on the Kamilaroi basis in New South Wales and Queensland.[3] Other writers could be referred to, but my object is merely to draw the reader's attention to some of the earlier workers in this field.

In 1894 I contributed to the Royal Geographical Society of Australasia at Brisbane, a paper on the Kamilaroi divisions, in which I briefly showed how tribes of that type are organised into

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[1] Journ. Anthrop. Inst., IX., 356–357; Austsn. Assoc. Adv. Sci., II., 653–654.

[2] Journ. Anthrop. Inst., XII., 496–512; *Ibid.*, XVIII., 31–70.

[3] Journ. Anthrop. Inst., XIII., 276–347.

families, groups, and communities, with some remarks on the rules of marriage and descent established in relation to these divisions.[1] In 1896, this paper was followed by another to the Anthropological Society at Washington, U.S.A., in which I gave a short outline of the structure of the Wiradjuri system of tribal divisions and marriage laws, with the intermarriages and descent of the totems.[2] In both these papers I pointed out that our knowledge of this subject was incomplete and unsatisfactory, and drew attention to the necessity for further investigation.

Since writing the memoirs referred to, I have extended my researches, and have gathered additional information among the Kamilaroi, the Wiradjuri, and other tribes in different parts of New South Wales, which will, it is hoped, enable me to place the subject of the totemic divisions of these people, with their laws of marriage and descent, more fully before the reader than has been accomplished hitherto.

In the present article an attempt is made to dispense with the terms "class" and "sub-class," which I have always looked upon as misnomers, although in the two former papers I adopted the names given to these tribal divisions by Mr. Ridley and the other writers who followed his nomenclature. For the names thus discarded I have substituted the terms "totemic group" and "section," which it is hoped will be considered more appropriate. Another innovation which I have introduced is in making the name of the totem more important than that of the group or section. It is proposed in the following pages to deal first with the structure of the Kamilaroi totemic divisions, and then to describe the divisions which obtain among the Wiradjuri tribes in the Murrumbidgee district.

The Kamilaroi System.

At some time in the history of the ancestors of the Kamilaroi people, all the members of the community were segregated into

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1 Proc. Roy. Geog. Soc. Aust., (Q.), x., 18–34, plate i.

2 American Anthropologist, (Washington), ix., 411–416.

two groups,[1] but whether this division of the people was adopted for the purpose of imposing marriage restrictions is a debatable question, the discussion of which is beyond the scope of this short article. As every man, woman and child bore the name of an animal, or some other natural object, one moiety of the community comprising various totems, were grouped together under the collective name of Dilbi; and a corresponding variety of totems adopted the distinguishing name of Kupathin. None of the totems of the Dilbi group were included in that of the Kupathins, but entirely different totems were incorporated in each division. It is not necessary that each of the groups should have the same number of totems; and it has also been observed that some particular totem name will be borne by a considerable number of peopie, whilst the members of another totem will be numerically few.

A totem may consist of any animate or inanimate object—as animals, plants, the heavenly bodies, the elements, thunder, the seasons, etc. Among the Kamilaroi tribes the word signifying totem is *dheeh*. Names selected from the animal kingdom are far the most numerous; next come the names of plants; and after that all the other totems are more or less rare. A man's totem is supposed to watch over his welfare, and forewarn him of the designs of his enemies. If any of his friends are away in a different part of the tribal territory, and sickness or death overtakes them, or they meet with a serious accident, his totem appears in sight, by which he knows there is something wrong. A man of the kangaroo totem told me that when his mother's brother, who was absent, died, a large and remarkable kangaroo hopped past his camp at great speed.

Among the group of totems, or *dheeh*, to which the name Dilbi was applied may be mentioned the eaglehawk, black-duck, pada-melon, ground iguana, pine-tree, carbeen, bumble, pelican, bower-

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[1] I have described the Bora of these tribes in the following Journals: Journ. Anthrop. Inst., XXIV., 411–427; *Ibid.*, XXV., 318–339; Journ. Roy. Soc. N. S. Wales, XXVIII., 98–129; *Ibid.*, XXX., 211–213; Proc. Roy. Soc. Victoria, IX., N.S., 137–173.

bird, jack-ass, moon, sun, sandal-wood, bandicoot, locust, crow, porcupine, opossum, salt-bush, white cockatoo, pleiades, fish-hawk, wood-duck, ants, jew-fish, brown kangaroo, scrub-turkey, water, sparrow-hawk, bony fish, white butterfly, peewee, yellow-bellied fish, tibi-bird. The totems belonging to the Kupathin group include the following:—emu, native-bee, carpet-snake, red kangaroo, codfish, kurria, wallaroo, plain-turkey, bream, common fly, wattle-tree, native-companion, gum-tree, box-tree, centipede, brigalow, belar, goonhur, death-adder, native-cat, galah-parrot, rainbow, swan, jew-lizard, quail, coolaba, reddish butterfly, night owl, curlew, black snake, ring-tail opossum, bubbar snake, water mole, magpie.

Each group would provide the other with wives, and would theoretically stand in the mutual relationship to each other of "brothers-in-law." For example, a Dilbi man who married the sister of a Kupathin, would be related to the latter as his "sister's husband," and the Kupathin man would be related to the Dilbi bridegroom as his "wife's brother." Therefore it is evident that the Dilbi's are the brothers-in-law of the Kupathins, and the Kupathins of the Dilbi group.

With this filial relationship among a primitive people, there might also be some form of regulated sexual promiscuity between the members of certain totems in one group with a number of totems in another, which would have the effect of rendering the paternity of the individuals born in these families more or less uncertain.[1] There would, however, be no uncertainty respecting a child's maternity, and therefore it would be safe to give it the group and totem name of the mother. On the other hand, it is

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1 During the Bora ceremonies of these tribes at the present day, considerable sexual license is allowed between the men and women, whether married or single, with the condition that this privilege can only be participated in by those persons who would be entitled to marry each other in accordance with the tribal laws. It is reasonable to expect that children would occasionally be born as the result of this intercourse, the paternity of whom would be uncertain or unknown.—Proc. Roy. Soc. Victoria, IX., N.S., 153; Journ. Anthrop. Inst., XXV., 328; *Ibid.*, XXVI., 272.

quite reasonable to suppose that the children might be called after their mother, because during their infancy and tender years they are always with her, and everybody knows they are her children. If the old men married young wives, as they do at present, the latter would survive them, and consequently have charge of the children. Again, the father might be killed in a tribal war, or otherwise lose his life, leaving the family to be brought up by the mother.

Among the Kamilaroi tribes descent is always reckoned on the female side, the group and totem names of the father not being taken into consideration in this matter. For example, if a Dilbi man of a certain totem marries a women who is a Kupathin carpet-snake, the children are always Kupathin carpet-snake, the same as their mother. The children of the daughters of this marriage will also be Kupathin carpet-snake, and so on *ad infinitum*. The same rule applies to all the other Kupathin totems, and likewise to all the totems of the Dilbi group—that is, they have perpetual succession through the women of their own group.

It has been stated previously, that the Dilbi and Kupathin groups mutually supply each other with wives—the women of one group becoming the wives of the men of their own generation in the other group. As the children of both sexes take the name of their mother's group, as we have just seen, it naturally follows that the men of one group are the fathers of the men and women of the next generation in the other group, being that from which the mothers have been taken. This may be summed up in the brief statement, that the Dilbis are the fathers of the Kupathins, and *vice versa*. This paragraph will not, of course, apply to any relationship under the family regulations explained farther on.

The individuals forming the Dilbi and Kupathin groups do not collect into certain localities separate from each other, but are scattered indiscriminately throughout the whole territory—members of each group, and consequently of the totems also, being found in all the local divisions of the tribe.

In course of time a further segregation of the Kamilaroi ancestors took place. The Dilbi group was divided into two sections, called Murri and Kubbi, and the Kupathin group into two, called Ippai and Kumbo. There appears, however, to be no evidence as to whether this subdivision took place simultaneously with the separation of the community into two groups, or at a later period. The divisions into groups and sections are matters which have happened so far back in the past, that the natives of the present day have no traditions respecting them. The names assigned to the women belonging to these sections are different to those borne by the men: the sisters of Murri and Kubbi are Matha and Kubbitha respectively, and the sisters of Ippai and Kumbo are named Ippatha and Butha. These names will be understood more clearly by referring to Table A. This bisection of the original groups did not apply to the totems, who continued to be designated as Dilbi and Kupathin as before, which seems to favour the suggestion stated farther on, that the sectional divisions may have been inaugurated for the purpose of a distinctive nomenclature.

Under this second bisection of the community a Dilbi man still marries a Kupathin woman, but it becomes necessary that she shall belong to one of the sections, Ippai or Kumbo: and the name of this section is determined by the section of the Dilbi group to which he himself belongs. If he belong to the Kubbi section he must marry an Ippatha, but if he is a Murri his wife must be a Butha. Similarly, if a Kupathin man wishes to marry, and he is an Ippai, he selects a Dilbi woman of the Kubbi section, but if he is a Kumbo, he must marry a Matha.

The descent of the children under this new method of division is somewhat modified. If a Kupathin man of the section Kumbo marry a Matha eaglehawk, the children will be Dilbi eaglehawk the same as before, but they will not be Murris and Mathas like their mother. They will take the name of the other section in the Dilbi division, and be called Kubbis and Kubbithas. In examining the rules of marriage and descent as stated in this and

the preceding paragraph it becomes apparent that the old law already stated still holds good, namely, that the Kupathins are the fathers of the Dilbis, and *vice versa;* and also that the Dilbis and Kupathins reciprocally give their sisters to each other for wives.

It has been shown that Matha is the mother of Kubbitha, and *vice versa*, and it will appear farther on that Murri is the uncle of Kubbi. It is therefore possible, that the group Dilbi was divided into Matha and Kubbitha to distinguish the mothers from the daughters ; and that the terms Murri and Kubbi were adopted to provide names for the uncles and nephews of their respective generations. These remarks will equally apply to the men and women of the Ippai and Kumbo sections. Whatever may have been the origin of these divisions into groups and sections, they have the effect of preventing consanguineous marriages, by furnishing an easy test of relationship when the tribe has become so numerous or widespread that kinship could not otherwise be well determined.

Although marriages generally follow the laws above stated, there are family regulations to which I referred in my former papers on this subject,[1] under which a Dilbi man of a certain totemic family may marry a Dilbi woman of a different totem belonging to his own section, and a Kupathin man may avail himself of the same privilege. These family regulations are so widespread that they are found more or less in all the tribes of the Kamilaroi, Wiradjuri, and most of the other tribes having the Kamilaroi organisation with which I am acquainted. They were, perhaps, introduced to meet some inconvenience, arising in certain circumstances from the observance of the marriage laws already explained ; but whether their adoption preceded or followed the division of the groups into sections, or whether they were in force before the division into groups took place, is a controversial point which need not now be discussed.

[1] Proc. Roy. Geog. Soc. Aust. (Q.), x., 24 ; American Anthropologist (Washington), ix., 412.

Under the group laws it is impossible for a Dilbi or Kupathin man to marry a woman bearing the same totem name as himself, for the reason that such a totem does not exist in the division from which he is bound to select his wife. But when persons of the same group were permitted to marry each other, it became necessary to promulgate a law prohibiting marriage between individuals belonging to the same totem. All such persons are supposed to have sprung from a common ancestor, and to be connected by ties of blood. Under no circumstances, for example, can a padamelon marry a padamelon because they are considered as brother and sister, or else as "mother's brother" and "sister's daughter," according to their respective ages in the generation. If a Dilbi man wishes to marry a Dilbi woman, he must conform to the rules regulating the inter-marriage of certain totems within that group. For example, a man of a Murri padamelon family, can marry a ground iguana, but she must belong to his own section; that is, she must be a Matha. She cannot be a Kubbitha, because that is the section to which Murri's mother belongs. The same course would be followed *mutatis mutandis*, in regard to the marriage of a Kubbi, an Ippai, or a Kumbo, with a woman within their own respective sections.

These alliances may for convenience of reference be called "family marriages," a few examples of which will be given. Among the Dilbi totems who can marry each other may be enumerated the following examples:—The padamelon marries the ground iguana, or jewfish. The opossum marries the ground iguana, bandicoot, or jewfish. The ground iguana marries the opossum, padamelon, bony fish, yellow-bellied fish, or bandicoot. The jewfish marries the opossum, padamelon, or bandicoot. The bandicoot marries the jewfish, opossum, or ground iguana. The bony fish marries the ground iguana. The yellow-bellied fish marries the ground iguana.

The undermentioned Kupathin totems are amongst those who can intermarry. The emu marries the ring-tail opossum, black-snake, wallaroo, native bee, or galah. The bubbar snake marries

the red kangaroo. The bream marries the black snake, or native bee. The codfish marries the galah, red snake, red kangaroo or ring-tail opossum. The plain turkey marries the red snake, or ring-tail opossum. The black snake marries the bream, or emu. The galah marries the codfish or emu. The native bee marries the emu or bream. The red kangaroo marries the codfish, or bubbar snake. The ring-tail opossum marries the plain turkey, codfish, or emu. The red snake marries the plain turkey, or codfish. The wallaroo marries the emu.

Having given a cursory outline of the structure of the Kamilaroi totemic system, I will now pass on to illustrate the rules of marriage, descent, and relationship established in accordance with the tribal laws. The names of the divisions, showing how they intermarry, with the names of the respective divisions to which the children belong, will be readily understood by referring to Table A. The names which are affected by what I have called the "family regulations," and the descent of the children thereunder, are printed in italic, immediately under the others.

TABLE A.

A Man		Marries	Children are
Kupathin	Ippai	Kubbitha	Murri and Matha
		Ippatha	*Kumbo* and *Butha*
	Kumbo	Matha	Kubbi and Kubbitha
		Butha	*Ippai* and *Ippatha*
Dilbi	Murri	Butha	Ippai and Ippatha
		Matha	*Kubbi* and *Kubbitha*
	Kubbi	Ippatha	Kumbo and Butha
		Kubbitha	*Murri* and *Matha*

An inspection of this table shows the group and section into which a man of any given section may marry, together with the group and section to which the offspring belong. Taking the Dilbi group, it will be observed that Matha's children, no matter whether she marry a Kumbo or a Murri, are always Kubbi and Kubbitha. Her daughters, these little Kubbithas, on arriving at womanhood will marry, but it is immaterial whether their husbands are Ippais or Kubbis, their children will be Murris and Mathas.

The little Mathas will grow up to puberty, and in turn produce Kubbis and Kubbithas. It is therefore apparent that the section Matha produces Kubbitha, and Kubbitha produces Matha in the next generation, and so on continually, hence the group Dilbi has perpetual succession through the Dilbi women. Again, if Matha be of the totem padamelon, her children will be Kubbi and Kubbitha padamelons; and the little Kubbithas, on arriving at womanhood will likewise have children who will be padamelons, showing that the totems are perpetuated in precisely the same manner as the group to which they belong. If an Ippatha or a Butha had been taken for the above example, it could have been similarly demonstrated that the Kupathin group, with the totems attached to it, has perpetual succession through the Kupathin women.

It is obvious that the Dilbi totems are common to the two sections Murri and Kubbi, and are independent of the dual naming of the group. In other words, a man of the padamelon totem may be a Murri or a Kubbi, according to who his mother was, but he is always a Dilbi, the name of the group to which his totem is attached. For example, the padamelon belongs to Matha in one generation, and to her daughter Kubbitha in the next, therefore this totem must be common to these two divisions. This applies to all the Dilbi totems. In a similar manner it can be shown that any Kupathin totem is common to the Ippai and Kumbo sections, particulars of which the reader can work out for himself.

Although as before stated the name and totem of the father is not directly considered in naming the children, it is nevertheless necessary to show his important position in the genealogy. By referring to Table A it will appear that if Murri marry Butha, his children are Ippai and Ippatha; but if he select a Matha as his wife, his children will be Kubbi and Kubbitha. We find by table A that Ippai and Kubbi are the only men who can marry a Kubbitha, and as Murri is the father of these men, as just shown, it is evident that he provides husbands for the women belonging to the other section in his group. The children of these women are the grandsons of Murri, and also belong to his own

section. The application of this rule to the four divisions can be readily understood from the following table :—

Father.	Son.	Son's Wife.	Children of Son's Wife.
Murri	Ippai or Kubbi	Kubbitha	Murri and Matha
Kubbi	Kumbo or Murri	Matha	Kubbi and Kubbitha
Ippai	Murri or Kumbo	Butha	Ippai and Ippatha
Kumbo	Kubbi or Ippai	Ippatha	Kumbo and Butha

It has been stated in an earlier page that under the original group division, the Dilbis are "brothers-in-law" to the Kupathins, and conversely. This applies to the men of their own level in the generation, but on tracing the relationship of these men to the children we find that the Dilbi men are the fathers of the Kupathin boys, and the Kupathin men are the fathers of the Dilbi boys. Both these relationships also hold good under the sectional divisions. Murri and Kumbo are related to each other as brothers-in-law, and Ippai and Kubbi have the same mutual affinity. The Kubbi men are the fathers of the Kumbo boys and the Ippai men are the fathers of the Murri boys—this relationship being of course reversed in the next generation. (See table A.) Although the boys only are mentioned, children of both sexes will, of course, be understood.

Again, Murri provides wives for the young men belonging to the other section in his division. We have seen by Table A. that if he marry a Butha, his daughter is Ippatha, and if he marry a Matha his daughter is Kubbitha. Ippatha and Kubbitha are the women who are eligible for marriage with Kubbi. It is evident therefore that Murri's daughter becomes the wife of Kubbi, and Murri takes the daughter of Kubbi as his wife. In a similar manner it can be shown that Ippai marries Kumbo's daughter, and Kumbo claims the daughter of Ippai.

In those cases where a man is allowed to marry a woman within his own section, Murri is the father of Kubbi, and so on for the men of the other sections, as exemplified in Table A. Accordingly, the children of a Dilbi father are Dilbi, and a Kupathin is the

father of Kupathin children. Moreover, a Dilbi man selects a Dilbi wife, and a Kupathin marries a Kupathin. It has already been stated that a Dilbi woman is the mother of Dilbi children, and a Kupathin woman produces Kupathin children. Therefore, the group Dilbi is self-supporting, because it contains within itself the fathers and mothers—the husbands and wives—of its members, and the Kupathin group is exactly in the same position.

A man's children are not necessarily of the same group and section, or of the same totem. If a Kubbi marry two wives, which is permissible, one being, for example, Ippatha brigalow and the other Kubbitha pine, his children by the former will be Kumbo and Butha brigalow, and by the latter they will be Murri and Matha pine. In this example, the sons of one of Kubbi's wives could marry the daughters of the other, because Kumbo can marry Matha, and Murri can marry Butha. In order to prevent such a close marriage, however, every tribe has strict social customs, founded upon public opinion, which will not tolerate the union of a man with a woman whose blood relationship is considered too near.

A few remarks on the degrees of kinship existing between the members of the different divisions will be interesting. A careful study of the foregoing pages will show that the pair of sections, Murri and Kubbi, are more nearly related to each other than to the members of the other pair, Ippai and Kumbo ; and that the latter are more closely connected between themselves than with the Murri and Kubbi people. The Murri and Kubbi sections are related to each other as "mother's brother" and "sister's son," according to the generation to which they respectively belong. If Murri be the elder, he is "mother's brother" to Kubbi, and the latter is his "sister's son" ; but if Kubbi be the elder of the two this relationship is reversed. The Ippai and Kumbo sections are connected with each other in a precisely analogous manner. The importance of this family tie is shown by the fact that if a man be killed by an enemy in any way, it is his "sister's son" who is charged with the avenging of his death.

A few examples will serve to illustrate more clearly the relationship I have been endeavouring to explain. Let us take a man of the section Ippai and totem emu. All the young men of his generation who belong to the section Ippai and totem emu are reckoned his brothers. All the brothers of Ippai emu's mother will be Kumbo emus, and will stand in the relationship to him of what we call uncle, but which is expressed in the blackfellows' genealogy as "mother's brother." Moreover, these "mother's brothers" will look upon Ippai emu as their "sister's son," which is known among us as nephew. And when his sister Ippatha gets married, he will in turn become the "mother's brother" of the Kumbo boys which may be the issue of the marriage, and they will be his "sister's sons." All the emus in that locality will be Ippais and Kumbos, and will be related to each other either as uncles, brothers, or nephews, always remembering to attach to these terms the meanings above explained. This may be called the totemic or blood relationship, all the members of which are considered of the same blood and descent.

Again, all the Ippais and Kumbos scattered throughout the entire community, although of many different totems, consider themselves bound together by the broader ties of group brotherhood. Ippai emu, for example, would take a wider view, and look upon all Ippais, regardless of their totems, who belong to his own generation, as his tribal brothers, and all the elder Kumbos as his uncles, whilst he would regard the younger Kumbos as his nephews. This may be called the group or tribal relationship.

In the following examples the totems are omitted in order that these remarks may be applicable to any Ippai, and so make the relationship tribal instead of the full blood. Ippai's mother's tribal brother is a Kumbo, and will marry one of these Kubbithas, who would be the daughter of his "mother's brother," or uncle. But if Kumbo, instead of marrying a Matha, had married a Butha, which he was entitled to do, by the family regulations already described, the children would have been Ippai and Ippatha.

The Ippai whom we have taken as an example could also marry one of these Ippathas, who would likewise be the daughter of his "mother's brother"—a tribal brother being understood in both cases. So that whether Ippai marry a Kubbitha or an Ippatha she is a woman who is the daughter of his "mother's brother." Either of these women would be the cousin of Ippai, bearing in mind the wide difference between our meaning of this relationship and that of the aboriginal.

In examining the marriage laws, as stated in earlier pages, it is seen that the mother of a man's wife, and also his daughters, belong to the same section, and therefore his marriage with that section is prohibited. Neither can he marry into the section to which his mother belongs, although a woman might be found, in either case, who is in no way connected with him. Therefore the Ippai of our example cannot marry a Matha, for she is his possible daughter, and also because she is the mother, collaterally, of his wife Kubbitha. Neither can he marry a Butha, because she is his tribal mother, and the mother of his wife Ippatha, and is, moreover, his potential daughter by the last mentioned wife. (See Table A.)

The Kamilaroi type of totemic divisions extends over a large proportion of New South Wales, but as we should expect among tribes at a distance who speak other languages, the names of the divisions are different in different tracts of territory. I will conclude this part of the paper with a few brief particulars of the sectional names of three tribes in the north-eastern portion of the colony which have not hitherto been recorded.

The Anaywan tribe, occupying the New England district[1] have a totemic system which is the same in principle as the Kamilaroi, but the names of the sections are different, as will be seen by the following table :—

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[1] For an account of the initiation ceremonies of these people, see my paper on the "Burbung of the New England Tribes."—Proc. Roy. Soc. Victoria, IX., N.S., 120–136.

A Man	Marries	The Children are
Irpoong	Irrakedena	Irroong and Patyang
Marroong	Patyang	Imboong and Irrakedena
Irroong	Arrakan	Irpoong and Matyang
Imboong	Matyang	Marroong and Arrakan

Irpoong and Marroong are the equivalents of Murri and Kubbi; and Irroong and Imboong correspond to Ippai and Kumbo respectively.

On the north-east coast there are a number of tribes divided into four sections framed after the Kamilaroi type. They occupy the country from the Hunter River northerly to the Clarence, and extend from the coast inwards almost to the main dividing range, where they join the Anaywan people. These tribes comprise the people speaking the Wattung,[1] the Dhangatty, the Koombanggary, and the Bunjellung languages, with some other dialects of less importance. The names of the divisions are as follow :—

A Man	Marries.	The Children are
Kurpoong	Wirrakan	Wirroong and Wanggan
Marroong	Wanggan	Womboong and Wirrakan
Wirroong	Karragan	Kurpoong and Kooran
Womboong	Kooran	Marroong and Karragan

Both in the New England and in the coastal tribes, tabulated above, the rules of marriage and descent are precisely the same as among the four sections of the Kamilaroi already explained, and the intermarriage of certain totems within their own section also obtains among these people.

There is a group of totems common to Kurpoong and Marroong—or as they are called on New England, Irpoong and Marroong—among which may be enumerated the native bear, flying-fox,

[1] The initiatory rites of these tribes are described in my papers on "The Keeparra Ceremony of Initiation."—Journ. Anthrop. Inst., xxvi., 320 – 338; "The Dhalgai Ceremony."—*Ibid.*, 338 – 340.

plover, ground iguana, black opossum, emu, bee, native companion, yam, pelican, porcupine, perch.[1]

The Wirroong and Womboong sections—called on New England Irroong and Imboong—have the following totems amongst others: kangaroo, dingo, jew lizard, turtle, carpet snake, crow, white cockatoo, platypus, eaglehawk, locust, death-adder.

Kurpoong corresponds to Murri, Marroong to Kubbi, Wirroong to Ippai, and Womboong is synonymous with Kumbo. In comparing the above totems with those of the Kamilaroi, it is noticed that some which belong to the first pair of sections, are found inserted in the second pair of the Kamilaroi, and *vice versa*. I specially drew the attention of the blacks to this difference at the time I collected the details, but they could not give any explanation of it. I have before found that certain totems which belonged to one section in a certain district, were stated to belong to another section among a tribe occupying a different part of the country.

On the south of the Hunter River, extending thence to the Hawkesbury, we find scattered remnants of the Darkinung tribe,[2] whose territory embraces the country watered by the Colo, Macdonald and Wollombi Rivers, with their numerous tributaries. This tribe has uterine descent, and is divided into four sections, whose names correspond with those of the Kamilaroi, with the exception that Murri is called Bya[3]:—

A Man	Marries.	The Children are
Bya	Butha	Ippai and Ippatha
Kubbi	Ippatha	Kumbo and Butha
Ippai	Kubbitha	Murri and Matha
Kumbo	Matha	Kubbi and Kubbitha

1 Natives belonging to the Hastings and Manning Rivers have told me that in their tribes the children follow the totem of the father, but they take the companion, or fellow, section name to that of their mother. This will be further dealt with in another article.

2 "The Burbung of the Darkinung Tribes" is described by me in Proc. Roy. Soc. Victoria, x., N.S., 1 - 12.

3 Bya was also used instead of, or interchangeably with, Murri in all the tribes from Wollombi almost to Inverell, a distance of about two hundred and fifty miles.

The undermentioned are some of the totems attached to Bya and Kubbi :—scrub opossum, native bee, emu, bandicoot, eagle-hawk, stingaree, wallaroo. The pair of sections Ippai and Kumbo have the following totems amongst others :—grey kangaroo, diamond snake, wombat, black snake, wallaby. Among the inter-sectional or family marriages in this tribe, Kubbi bandicoot could marry Kubbitha stingaree.

The Wiradjuri System.

Some tribes of the Wiradjuri community who occupy a wide tract of country on each side of the Murrumbidgee River from about Jugiong to Hay, are divided into four sections, the names of the men and women composing which are identical with those of the Kamilaroi, with the exception that Oombi is substituted for Kumbo. The rules of marriage and descent are, however, somewhat different, thus :—Murri marries Ippatha, and the sons and daughters are Kumbos and Buthas ; Kubbi is united to Butha and their issue are Ippais and Ippathas ; Ippai takes Matha for his wife, and the children are Kubbis and Kubbithas ; Oombi is married to Kubbitha, and their offspring are Murris and Mathas respectively.[1]

Whilst travelling amongst these people for the purpose of studying their customs, I discovered a distinctive feature in the rules of descent of the totems,[2] which has not been recorded by any previous investigator. A mother possessing any given totem name produces children whose totem is different to her own. For example, Ippatha mallee-hen is the mother of Butha common fly. In the next generation Butha common fly is the mother of Ippatha mallee-hen, and so on continually. The children therefore take the section and totem name of their mother's mother. As the

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[1] The Burbung or initiation ceremonies of the Wiradjuri tribes are described by me in the following publications :—Journ. Anthrop. Inst., xxv., 295 – 318, plates xxv. – xxvii. ; *Ibid.*, xxvi., 272 – 285. Proc. Roy. Geog. Soc. Aust. (Q.), xi., 167 – 169. Journ. Roy. Soc. N.S. Wales, xxxi., 111 – 153.

[2] Among these tribes, the word *jin* means totem.

offspring belong to the section Ippai and totem mallee-hen in one generation, and to the section Oombi and totem common fly in the next, it necessarily follows that each section must have its own independent group of totems. In other words, a certain group of totems must be known by the general name of Ippai; another group must be called Kumbo; another group Murri, and another Kubbi. This is different to the Kamilaroi type, in which a group of totems is common to the pair of sections, Ippai and Kumbo, and another group to the Murri and Kubbi pair.

In the Wiradjuri tribes Murri and Ippai of the same generation stand in the mutual affinity to each other of "brothers-in-law," and the same relationship subsists between Kubbi and Oombi. Murri and Kubbi are connected reciprocally as "mother's brother" and "sister's son,"—or using our own equivalent names—as uncle and nephew, according to their place in the generation to which they belong; and Ippai and Oombi stand in the same mutual relationship. The nominal relationship subsisting between a father and his family is the same as already described in regard to the Kamilaroi.

The totemic regulations to which I referred in dealing with the Kamilaroi tribes are also found among these Wiradjuri people, by means of which a man may marry into one or more of the sections, including his own, under certain totemic restrictions, the effect of which will be seen on inspection of the following table, which shows the intermarriage and descent of four totems belonging to each of the four sections.

The wives allowed by the sectional rules, "Murri marries Ippatha," &c., are first given, followed by the women a man is permitted to marry under the family regulations before described. It is apparent by this table that one totem is always the mother of a certain distinct totem bearing a different name.

Table B.

A Man	Marries	The Children are
Murri emu	Ippatha eaglehawk	Butha grey kangaroo
	Ippatha opossum	Butha goonhur
	Matha brown snake	Kubbitha porcupine
	Kubbitha native bee	Matha ground iguana
Murri red kangaroo	Ippatha opossum	Butha goonhur
	Ippatha eaglehawk	Butha grey kangaroo
Murri brown snake	Ippatha opossum	Butha goonhur
	Ippatha eaglehawk	Butha grey kangaroo
	Matha emu	Kubbitha fly. squirrel
	Kubbitha native bee	Matha ground iguana
Murri ground iguana	Ippatha mallee-hen	Butha common fly
	Ippatha jew lizard	Butha codfish
	Butha codfish	Ippatha jew lizard
Kubbi flying squirrel	Butha goonhur	Ippatha opossum
	Butha grey kangaroo	Ippatha eaglehawk
	Butha codfish	Ippatha jew lizard
	Kubbitha porcupine	Matha brown snake
Kubbi bandicoot	Butha grey kangaroo	Ippatha eaglehawk
	Butha goonhur	Ippatha opossum
	Butha codfish	Ippatha jew lizard
	Kubbitha porcupine	Matha brown snake
Kubbi porcupine	Butha codfish	Ippatha jew lizard
	Butha grey kangaroo	Ippatha eaglehawk
	Butha goonhur [rel	Ippatha opossum
	Kubbitha flying squir-	Matha emu
	Kubbitha bandicoot	Matha red kangaroo
Kubbi native bee	Butha common fly	Ippatha mallee-hen
	Ippatha jew lizard	Butha codfish
	Matha emu	Kubbitha fly. squirrel
	Matha brownsnake	Kubbitha porcupine
Ippai mallee-hen	Matha ground iguana	Kubbitha native bee
	Kubbitha fly. squirrel	Matha emu
	Kubbitha bandicoot	Matha red kangaroo
	Butha codfish	Ippatha jew lizard

A Man	Marries	The Children are
Ippai opossum	Matha emu	Kubbitha fly. squirrel
	Matha brown snake	Kubbitha porcupine
	Matha red kangaroo	Kubbitha bandicoot
	Ippatha eaglehawk	Butha grey kangaroo
Ippai eaglehawk	Matha emu	Kubbitha fly. squirrel
	Matha brown snake	Kubbitha porcupine
	Matha red kangaroo	Kubbitha bandicoot
	Ippatha opossum	Butha goonhur
Ippai jew lizard	Matha ground iguana	Kubbitha native bee
	Kubbitha native bee	Matha ground iguana
Oombi common fly	Kubbitha native bee	Matha ground iguana
Oombi goonhur	Kubbitha bandicoot	Matha red kangaroo
	Kubbitha fly. squirrel	Matha emu
	Kubbitha porcupine	Matha brown snake
	Butha grey kangaroo	Ippatha eaglehawk
Oombi grey kangaroo	Kubbitha fly. squirrel	Matha emu
	Kubbitha bandicoot	Matha red kangaroo
	Kubbitha porcupine	Matha brown snake
	Ippatha mallee-hen	Butha common fly
	Butha goonhur	Ippatha opossum
Oombi codfish	Kubbitha porcupine	Matha brown snake
	Kubbitha fly. squirrel	Matha emu
	Kubbitha bandicoot	Matha red kangaroo

The use of this table will be better understood by giving an example. Let us take a man of the section Ippai, and totem opossum. According to the sectional marriage laws already stated, the wife of an Ippai of any totem should always be a Matha; but owing to the family regulations previously explained, he is permitted to marry certain Ippathas provided there are no disabilities arising out of nearness of kin. Moreover, in either case, his choice of a wife is regulated by his totem as well as his section name. Persons of the same totem may not marry, or have sexual intercourse with one another; and further, any pro-

miscuous intercourse between the sexes is always restricted to those individuals who are eligible for marriage.

A careful study of the table will enable us to determine what woman any given man may marry, as well as the section and totem names of his children; but of course before we can do this it must be necessary to know the section and totem names of the woman he selects as his wife. Assuming that the Ippai of our example wishes to marry, it is found by Table B. that he has the choice between, (1) Matha emu; (2) Matha brownsnake; (3) Matha red kangaroo; and (4) Ippatha eagle-hawk. If he marries No. 1, Matha emu, a reference to the table will show that the children will be Kubbi and Kubbitha flying-squirrel; if he chooses No. 2. the offspring will be Kubbi and Kubbitha porcupine; if he selects No. 3 the children will be Kubbi and Kubbitha bandicoot; and, if he marries No. 4 the issue will be Oombi and Butha grey kangaroo.

In these tribes a man may marry more than one wife, and if his wives belong to different sections and totems, this will further vary the names of his offspring. There would, in such a case, be sons and daughters of the same household who would belong to different totems, as well as to different sections. The children of a Matha are always Kubbi and Kubbitha; those of Kubbitha are Murri and Matha; those of Ippatha are Oombi and Butha; and the children of Butha are always Ippai and Ippatha. There is matriarchal descent, and in all cases the children take the totem name of their mother's mother.

The rules of marriage and descent set out in Table B. applies more particularly to the Wiradjuri tribes on the upper portion of the Murrumbidgee River, and as we go down that stream we find that the pecularity of one totem being the mother of a different one is less marked; and on going north to the Lachlan, Bogan, Macquarie, and Castlereagh Rivers, it is observed that the totems have the same descent as in the Kamilaroi tribes—that is, each totem produces itself. It may be stated here that the Wiradjuri

dialect is the most widely spread of all aboriginal tongues in New South Wales.

Conclusion.

Owing to the gradual disappearance of the aborigines before the white population and the consequent extinction of many of the totems, it is now difficult to find a native who can remember all the totem names, and he will be rather doubtful in regard to those with which he has never had any connection. Although I have exercised all possible care in trying to get reliable details respecting the intermarriage of the totems given in the tables and also in regard to the lists of totems atfached to the groups, it is possible that some mistakes may have been made; but even if such should be found to be the case, it cannot alter the general principles on which the rules of marriage and descent are based.

I wish to express my thanks to Miss Baker, daughter of Mr. W. T. Baker, Inspector of Police at Kempsey—whom I met when following up my investigations respecting the customs of the aborigines on the Macleay River some years ago—for her labours in gathering further particulars of their totemic laws, and also in defining the boundaries within which certain dialects were spoken.

Before preparing this article I requested Mr. Chas. A. Brewster a Police Trooper at Mungindi, on the Barwon River, to check a list of Kamilaroi totems tabulated by myself in that district a few years back. I also asked him to gather such additional examples of irregular or family marriages as he might consider trustworthy; and I desire to place on record the promptitude and care with which he collected information on a difficult subject.

In this article I have endeavored not to vitiate my descriptions of the tribal divisions by the incorporation of inferences derived from mere conjecture, but have left the formation of theories, and all controversial points, respecting this subject, until further particulars have been collected over a wider field. I shall feel myself sufficiently repaid for my exertions if I should be fortunate enough to induce a student here and there to continue the work of investigating and describing the totemic systems of different tribes in various parts of Australia.

On the SACCHARINE and ASTRINGENT EXUDATIONS of the "GREY GUM" *EUCALYPTUS PUNCTATA*, DC., and on a Product allied to AROMADENDRIN.

By Henry G. Smith, f.c.s., Technological Museum, Sydney.

[*Read before the Royal Society of N.S. Wales, August 4, 1897.*]

During the latter part of January 1897, I found at Belmore, near Sydney, several substances exuding from the bark of trees of the Grey Gum, *Eucalyptus punctata*, DC. The appearance of the large white patches of exudation was occasionally so marked that the trees looked as if they had been whitewashed. Closer examination shewed that a considerable inroad into the bark had been made, apparently by the larvæ of insects; from the injuries thus caused, a quantity of the several substances about to be described was found. The white material was composed of a substance sweetish in taste; the thicker portions somewhat resembled the well known Eucalyptus manna. When exuding it must have been liquid as it had run down the tree; in some instances for a considerable distance, and from continued coatings good sized tears had been formed in places. From the same trees, and at the same time, was obtained a more abundant exudation, also sweetish, much darker in colour, and which when flowing must have been even more liquid than the white substance; in some instances this had run down the trunks of the trees for seven or eight feet to the ground, and tears of a considerable thickness had accumulated in places. I succeeded in obtaining about six ounces of the more abundant darker material, as free as possible from bark and debris, the fine particles of wood and bark with which the exudation was more or less contaminated, were produced by the larva of an insect.

Around the small holes from which the white substance was exuding, were seen a great number of large ants (*Camponotus sp.*)

packed so closely that hardly any space separated them; they were feeding on the liquid as it exuded from the hole in the bark. In no instance were the ants eating the darker exudation, nor did they appear to be partial to the white when it had solidified, only one or two stray ones being near it when in that condition. The darker substance contains both tannic acid and eudesmin, which I presume is the reason why it is objectionable to them. The punctures or bores into the bark were often small, and appeared to be directly inwards towards the centre of the tree. From the same tree from which both the white and dark saccharine materials were obtained, some pure kino was also found exuding at the same time. It is remarkable that three substances differing so much in composition, should be exuding from the one tree at the same time, and I set myself the task of attempting to solve the problem. From the specimens taken from the trees, it will be seen that :—

(*a*) When the puncture has *not* penetrated entirely through the bark and a flow is set up, the exudation is quite white and consists largely of raffinose (melitose).

(*b*) When the puncture has just penetrated through the bark the exudation is contaminated with tannic acid and eudesmin, showing that eudesmin is present in the cells of the tree with the tannic acid.

(*c*) Also, that when the puncture or boring of the larva has continued into the wood of the tree, pure kino is produced, providing the sugary sap of the bark is not exuding at the same time.

This indicates that the kino is *not* obtained from the bark directly, but from the wood of the tree, and that the sap of the bark of this tree does not contain tannic acid, but consists principally of the sugar raffinose (melitose). Although tannic acid could not be detected in the white manna, yet, when the bark was boiled in water, a small quantity of tannic acid was found in the solution. In all instances it was seen that whenever kino was exuding, it was coming directly from the wood of the tree

through an opening in the bark. It is well known that in some of our Eucalyptus timbers objectionable portions are found, known as "gum veins"; these are usually seen following the annular rings, and are more or less distinct and symmetrical.

Now, why is it that there is no record of manna being obtained from any of the Eucalypts belonging to the *Renantheræ*? The kinos of this class of Eucalypts, as far as examined (always excepting *E. microcorys*), and I have examined most of them, all give a kino entirely free from either eudesmin or aromadendrin, and it appears that it is only those trees that can produce manna,[1] the kinos of which contain one or the other of these bodies. This fact is far reaching, and is being followed up as the results may be of some commercial importance.

A product allied to aromadendrin.

Although our knowledge is fairly complete as to the constituents of the exudations or kinos of the Renantheræ, yet, our information concerning the occurrence of eudesmin, aromadendrin, or like bodies in other portions of the trees belonging to this group, is somewhat meagre. Of the Eucalypts belonging to the Renantheræ I can speak definitely as yet only of *E. macrorhyncha*. I have found that the yellowish crystalline substance existing in fairly large quantities in the leaves of *E. macrorhyncha*, is in some respects allied to aromadendrin obtained from some Eucalyptus kinos, and more directly to the group of natural colouring or dyeing substances to which quercetin and morin belong. That a yellow colouring matter existed in the leaves of *E. macrorhyncha* was known as long ago as 1887, it being announced by Mr. J. H. Maiden to this Society during that year.[2]

At that time I interested myself in the preparation of a pigment from it, and obtained a yellow-lake of some promise. A water colour was obtained by precipitating an alkaline solution with baric hydrate, drying the precipitate and grinding it with gum-

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[1] *E. viminalis* and *E. Gunnii* both give turbid kinos in cold water.

[2] Proc. Roy. Soc. N. S. Wales, Vol. xxi., p. 252.

water. I submitted this pigment, thus crudely prepared, to Mr. Fletcher Watson, a well known Sydney artist, who painted a sketch, the base colour of most of the tones being this yellow-lake. The sketch he kindly presented to me, the colours are still quite fresh and bright and apparently unfaded. He was very pleased with the colour, often spoke to me about it, and in a letter to me on Nov. 18th, 1887, expressed himself as follows :—"I consider that when properly prepared it will be a most valuable pigment and supply a yellow long wanted by water colour artists, capable of producing a range of clear sober greens at present with difficulty obtained." Acting on Mr. Watson's advice I prepared some oil colour and submitted it to Mr. Samuel Brooks, who had a studio in Wentworth Court. He wrote as follows :—"The colour you submitted to me is a charming and very pure yellow. The absence of any tinge of red—so fatal to most yellows—is marked. As a glazing colour it is rich. . . I find it will mix well with any colour and many fine combinations can be produced with it."

My investigations[1] on aromadendrin, and on its dyeing properties, submitted to the Society of Chemical Industry (Nov. 1896) and the subsequent determination of its probable affinity to maclurin or morin, suggested to me by Mr. A. G. Perkin of Leeds, again directed my attention to the colouring substance contained in the leaves of this tree (*E. macrorhyncha*). This is obtained by boiling the dried and powdered leaves in a large quantity of water several times repeated, boiling for a long time and filtering through calico; on cooling a yellowish crystalline precipitate separates out. This is contaminated with a small quantity of inorganic salts, principally the alkalis, which combine with the substance as it crystallises out. By repeated crystallisation from water and alcohol the greater portion of the inorganic salts are removed, but it does not appear possible to obtain the substance absolutely pure by ordinary recrystallisation. When again dissolved in boiling water, filtering and cooling, it is obtained in yellowish microscopic hair-like

1 Proc. Roy. Soc. N. S. Wales, Vol. xxx., p. 135, 1896.

crystals exactly like aromadendrin in this respect. By decomposing with water the crystalline compound formed by hydrobromic acid in boiling acetic acid, the substance is obtained in a pure state and quite free from inorganic salts.

I have already obtained data in regard to this colouring matter which enable me to state that this substance gives every indication of being a valuable dyeing material, and probably belongs to the quercetin group of natural dyeing substances. It forms yellowish to slightly orange crystalline compounds in boiling acetic acid with mineral acids; alkalis dissolve it with a yellow to orange colour; nitric acid dissolves it very energetically to a bright crimson colour, aromadendrin becoming crimson only after a short time with this reagent: in alcoholic solution ferric chloride gives an olive-brown colour not altered by heating: the lead precipitate in alcoholic solution is yellowish to orange: it is almost insoluble in cold water and not very readily in boiling water: it is soluble in a small quantity of boiling alcohol, not readily in cold alcohol: it is practically insoluble in cold ether, and only slightly soluble in boiling ether, and it does not appear possible to remove it from an aqueous solution by ether; it differs in this respect from aromadendrin which is readily and entirely removed from aqueous solution by ether: it dyes alumina mordanted calico a bright yellow: when heated in fused alkali to 200° C. for half an hour the products of decomposition are found to be protocatechuic acid and phloroglucinol.

Many of these reactions are those of quercetin itself, and from the above results, particularly its forming crystalline compounds with mineral acids in acetic acid, and its dyeing properties, there appears little doubt but that this yellow substance is allied to quercetin. This product has perhaps great commercial possibilities because the raw material can be obtained in any quantity, and is at present unutilized, and being in the form of leaves, can be readily dried and powdered, and the dyeing material can be easily separated if required, so that tannin bodies need not interfere in any way. *E. macrorhyncha* is found over a large portion of the

colony, and it is probable that this species is not the only one in which this yellow substance exists. As my work on the Eucalypts proceeds, it appears that although well marked individual substances continually present themselves, yet, I have little doubt but that some system will be found to run through the whole of them. That there are characteristic chemical groups has long been known, but although aromadendrin, for instance, does not appear to exist as such in those trees belonging to the Renantheræ, yet this yellow substance and aromadendrin resemble each other very much in some respects. The similarity of the fine hair-like crystals from both these bodies when obtained from boiling water is most marked, yet no difference whatever between them can be detected under the microscope; they both give similar products of decomposition in fused alkali; their reactions with reagents are similar; their dyeing properties are also similar, but aromadendrin *does not give crystalline compounds with mineral acids in boiling acetic acid*, and thus according to the researches of Mr. A. G. Perkin,[1] does not belong to the quercetin group, as that reaction appears to be characteristic of the group of the natural non-nitrogenous yellow mordant dye-stuffs at present known to exist, of which quercetin forms the type.

I purpose naming this yellow crystalline substance obtained from these leaves *Myrticolorin*, as I think it is the first natural dye-stuff from our colonial Myrtaceæ which promises to have a commercial future.

1. The Saccharine Exudations.

From the results of this research we may consider that the white saccharine exudation from *E. punctata* is almost identical in composition with the ordinary and well known Eucalyptus manna, and may be considered representative of the material on which the whole of the previous investigations have been carried out. It consists very largely of the sugar raffinose or melitose, and also contains a small quantity of reducing sugars, its solution

[1] Journ. Chem. Soc., 1896, p. 1439 &c.

reducing an alkaline copper solution more readily than the ordinary white Eucalyptus manna from *E. viminalis*, etc. The only mention that I can find of manna from this tree, is, that the Rev. Dr. Woolls noticed that occasionally melitose manna dropped from *E. punctata*.[1]

Previous work on Melitose and Raffinose.

Attention was called to the peculiar saccharine substance obtained from *Eucalyptus viminalis*, and known as "manna," by Thomson[2] early in this century, and by Virey[3] in 1832. In 1843 Johnston[4] chemically examined this manna, and distinguished it from the Ornus-manna or manna of commerce. In 1855 it was further examined by Berthelot,[5] who named the sugar it contained "melitose," and who found that its aqueous solution was dextro-rotatory, and that when heated with dilute sulphuric acid it was altered into two sugars, one of which was fermentable, while the other was not; to this latter he gave the name of "eucalyn" with the formula $C_6H_{12}O_6$. It was not until 1884 that the sugar melitose (raffinose) was found existing in any other substance except the manna from the Eucalypts of Australia, although Loiseau[6] had discovered a sugar in 1876 in molasses to which he gave the name of "raffinose." Melitose (raffinose) was then found by H. Ritthausen[7] to exist in the residues from pressed cotton seeds. In 1885 B. Tollens[8] described a sugar which he had obtained from molasses, and then indicates that raffinose and melitose may be identical, although he was not satisfied on the point at that time, but expresses a doubt whether his sugar and the raffinose prepared by Loiseau from molasses were identical. In 1885 H. Ritthausen with others[9] again further describe the sugar from cotton-seed cake and prove it identical with "plus-sugar" from molasses, and also with Böhm's "gossypore,"[10] and

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[1] Eucalyptographia, art. *E. viminalis*.
[2] Organic Chemistry, Vegetables, 642. [3] Journ. de Pharm. [2] 18, 705.
[4] Mem. of the Chem. Soc. I., 159. [5] Compt. Rend. XLI., 392.
[6] Compt. Rend. LXXXII., 1058. [7] Journ. Prakt. Chem. [2] XXIX., 351.
[8] Ber. 1885, p. 26. [9] Bied. Centr. XIV., 132.
[10] Journ. Prakt. Chem. [2] XXX., 37.

Loiseau's "raffinose." The identity of raffinose with plus-sugar and gossypore was confirmed by C. Scheibler,[1] who points out some of the causes whereby different results had been obtained by different observers when working on like material. The presence of raffinose was afterwards determined in barley by C. O'Sullivan[2] who confirmed the formula previously given by Loiseau as $C_{18}H_{32}O_{16} + 5\ H_2O$, and gives the specific rotation as $[a]j + 135$. P. Rischbieth and B. Tollens[3] here undertook the careful investigation of the properties of raffinose from both molasses and cotton seed, confirmed their identity, and also made full researches into the composition of raffinose. While agreeing in the main with the formula given by Loiseau, yet, they suggest that the results would agree better if the molecule was doubled, or that the formula be $C_{36}H_{64}O_{32} + 10\ H_2O$. B. Tollens also makes at this time, a careful investigation of about 22 grams of Eucalyptus manna forwarded by Baron von Mueller. He obtained $10\frac{1}{2}$ grams of perfectly purified melitose (raffinose) from this, and he found the percentage of water to be 14·67 and the specific rotation $[a]_D + 104{\cdot}00 - 104{\cdot}44$ at 20° C. He then states that the identity of raffinose and melitose is thus proved, and that the older name "melitose" may now be applied to the sugar from all these sources. We have thus arrived at the stage when "raffinose" and "melitose" cease to exist as different sugars, and although by priority the term melitose is entitled to endure, yet, we find that it has been superseded by the more recent one of raffinose.[4] I have not been able to obtain access to all the papers referred to, but copious extracts are to be found distributed through the pages of the Journal of the Society of Chemical Industry.

Experimental.

The amount of white exudation or manna, from *E. punctata* at my disposal was small, and as it was required for permanent exhibition in the Museum, I did not consider that an exhaustive

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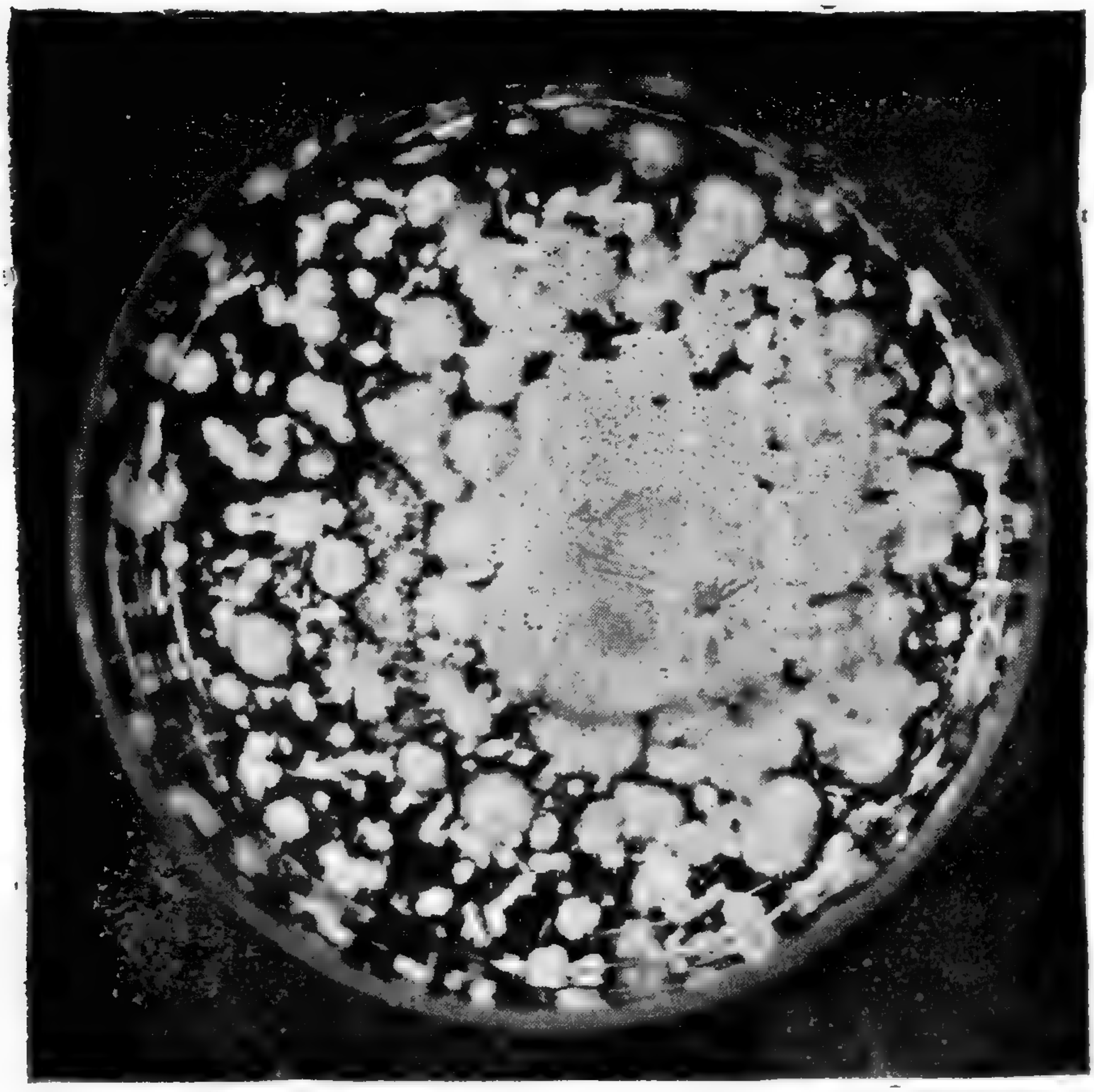
[1] Ber. XVIII., 1779. [2] Proc. Chem. Soc. XLIX., 70. [3] Ber. XVIII., 2611.
[4] Watt's Dictionary of Chemistry, Morley and Muir, IV., 557.

investigation was needed, as it differs but little from the Eucalyptus manna already worked out. The principal sugar was found to be identical in both the white and dark exudations, and as the latter was a compound of substances, its investigation might, I thought, lead to valuable results. I am not aware of any previous research on these exudations from *E. punctata*, nor on like material to this dark exudation from any of the Eucalypts.

After preliminary tests as to the best method of proceeding I adopted the following:—The material was heated with 80% alcohol, the whole of the sugary portions were thus dissolved with other substances. A rather large quantity of debris was left on filtering, consisting of fragments of bark and wood, indicating that portions of the bark had been eaten. The filtrate was evaporated to a pasty consistence, and absolute alcohol added. A whitish gelatinous precipitate was thus obtained; the very dark filtrate was set aside for further investigation, and the precipitate pressed, boiled in and washed with fresh alcohol. The precipitate was then dissolved in alcohol sufficiently dilute to dissolve the pasty mass, and set aside to crystallise. It took some days before crystals commenced to form, when they appeared in small nodular masses, which continued to increase until the material became quite granular. These crystals were washed with strong alcohol, filtered, dried on a porous slab, repeatedly crystallised and treated in the same way until the dilute alcohol ceased to be appreciably coloured when the crystals were redissolved in it. They were finally dissolved in water, alumina added, filtered, evaporated down at low heat on water-bath and allowed to crystallise, the liquid being perfectly clear and colourless. If sufficiently recrystallised from dilute alcohol, and the crystals drained on the slab repeatedly, the raffinose thus prepared, when crystallised from water, does not reduce Fehling's solution to any degree on boiling before being inverted. Although it was difficult to obtain the crystals when the solution was so impure, the sugar often taking days to crystallise, yet, as the crystals became purer they were obtained much more rapidly. The material thus obtained was

perfectly white, and crystallised in globular masses of radiating crystals, always taking that form when crystallised from water.



Raffinose crystallised from water. Obtained from the exudation of *E. punctata*. Natural size.

The determination of the water of crystallisation was found to be of some importance as by heating at different temperatures the results did not always agree. When heated to 95° C. until constant, 14·53 per cent. of water was driven off, (mean of two determinations), but when heated to 100° C. (the loss remained constant at near 15·1 per cent., four determinations on different material giving 15·13, 15·093, 15·091, 15·11); this is very near the theoretical amount required by the recognised formula for raffinose viz., $C_{18}H_{32}O_{16} + 5\ H_2O$ which requires 15·15 per cent. of water. On raising the temperature to the melting point (118° C.) the weight still remained the same. By this treatment the sugar was

not darkened, nor was any caramel odour perceptible, but some alteration had taken place, as Fehling's solution was slightly reduced on heating, although the same sugar did not do so before it was melted; on continuing the heating at the same temperature the alteration of the sugar becomes more pronounced. It appears therefore, that the sugar required to be heated to 100° C. to satisfactorily remove the whole of the water of crystallisation, and that it is not necessary to heat beyond that temperature. The different formulæ that have been assigned to raffinose or melitose by different chemists are to a certain extent partly traceable to the different percentage results of the water of crystallisation obtained by them. Ritthausen found but 13·64 per cent. of water and judged the formula to be $C_{12}H_{22}O_{11} + 3\ H_2O$, whilst Loiseau obtained 15 per cent., or corresponding to the formula $C_{18}H_{32}O_{16} + 5\ H_2O$ which is the present one given to this sugar. Berthelot[1] found that when crystallised from dilute alcohol the sugar could be obtained containing six molecules of water. Scheibler[2] has pointed out these difficulties and advises that the sugar be dried partly over sulphuric acid and completely on the water-bath. I found no difficulty in obtaining concordant results when the sugar was heated in the air bath at 98 – 100° C. until constant, reaching that temperature by slow degrees.

An aqueous solution of the pure sugar prepared as previously described, was found to be strongly dextro-rotatory and the specific rotation for a ten per cent. solution at a temperature of 20° C. was found to be $[a]_D + 104{\cdot}25$.

The melting point of the sugar also required to be carefully determined. When tested in a tube closed at the end, and heated in a liquid, the sugar from which the water of crystallisation had not been removed melted at 80° C. When slowly heated in the air bath the water is removed at 100° C., and on slowly raising the temperature the sugar melts at 118° C. (uncorrected). If the mercury rises too rapidly the melting point is irregular. When

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[1] Compt. Rend. CIX., 548. [2] Ber. *loc. cit.*

heated with nitric acid, mucic and oxalic acids were formed. When heated with dilute acids, reducing sugars were formed, only part of which were fermentable with beer-yeast when the temperature was well below 20° C. When treated with beer-yeast the sugar slowly fermented, and the temperature being kept between 20° and 30° C. the whole was destroyed after some days.

From the above result it appears certain that the sugar existing in the bark sap of *E. punctata* is raffinose, and is identical with the raffinose obtained from beetroot, and that it differs in no respect from that obtained from other Eucalypts.

I am indebted to Mr. T. Steel, F.C.S., of the Colonial Sugar Refining Company, for kindly revising the portion of this paper relating to the sugars, and also for some pure raffinose from beetroot. In its character and reactions it differs in no respect from that obtained from the exudation of *E. punctata* in its different melting points under different conditions, its percentage of water of crystallisation, its rotatory power, the form of the crystals, its reactions with acids, and also with yeast.

Determination of the uncrystallisable sugars.

The extremely dark coloured solution, being that portion first removed from the precipitated raffinose when absolute alcohol was added, as previously described, contained tannic acid, eudesmin, and some sugars. After concentration it was dissolved in water, and the eudesmin removed by agitating the aqueous solution with ether. After removal of the ethereal solution, the remainder was evaporated down, water added, and the solution placed with some well washed hide-powder, well agitated until the tannins and colouring matters (which belong to the tannins) were removed, this being completed as rapidly as possible. The hide powder was squeezed in calico and the liquid filtered through paper; the solution being then but slightly coloured, was found to be dextro-rotatory, and reduced Fehling's solution copiously, indicating that dextro-rotatory reducing sugars were present. When evaporated down it formed a sweet syrup, showing no signs of crystallisation.

After long evaporation on the water bath, under boiling, it was still a thick syrup and was hygroscopic; constant weight was obtained, however, by long heating when the loss was found to be 10·16 per cent. When heated at a higher temperature, the sugars slowly decompose, becoming very dark, and the caramel odour most pronounced, the loss when heating for half an hour at 130° C. on ·4 gram sugars being about ·01 gram for each of six determinations, the decomposition thus proceeding at an uniform rate.

When fresh beer-yeast was added to a solution of this syrup, fermentation set up at once and proceeded rapidly. After the fermentation had ceased, the solution was found to still contain a sugar that appeared to be unfermentable while the temperature was about 16° to 18° C., and the solution of which was dextro-rotatory, and that reduced Fehling's solution.

A quantitative determination of these sugars was then made with the following result:—·231 gram of the dried sugars (allowing 10·16 as the percentage of water), evolved ·0667 gram CO_2 or equivalent to ·1364 gram of fermentable sugar considered as glucose, thus leaving ·0946 gram of an unfermentable sugar at the temperature used: or, decomposed 59 per cent. and undecomposed 41 per cent. By the method of precipitation used, it is to be supposed that a small proportion of raffinose might be present, which would partly ferment, and thus prevent a correct quantitative result being obtained; but I think we may assume that the experiment shows these sugars to be present in about equal proportions, indicating that natural alteration of the raffinose had taken place corresponding to that undergone by this sugar when treated with dilute acids. It was not thought desirable to adopt chemical precipitation, so that alteration could not arise from that source.

The whole of the remaining sugars I had obtained were then treated with yeast, so that the decomposable sugar might be removed by fermentation. The remaining sugar that was unfermentable at the temperature used, was then carefully prepared for

the polarimeter, the rotatory angle taken, the solution evaporated down and allowed to absorb moisture to constant weight. From these results the specific rotation was found to be $[a]_D$ + 53·82. This sugar was a thick sweetish syrup and reduced Fehling's solution. Eucalyn is described as a syrup containing one molecule of water, and, according to Dragendorff, has a dextro-rotatory power of $[a]_r$ 65°. This sugar, therefore, obtained from this exudation, may be considered to be that previously obtained from Eucalyptus manna by inverting the melitose (raffinose) with dilute acids, and that was considered to be unfermentable, and to which Berthelot gave the name of Eucalyn.

According to C. Scheibler and H. Mittelmeier,[1] who have carried out researches on the inversion products of raffinose (or, as the authors name it melitriose) find that the inversion of this sugar by means of dilute acids takes place in two stages, in the first of which levulose and melibiose are produced, and that melibiose is the sugar previously known as eucalyn. The authors find that invertin acts upon their melitriose (raffinose) in a similar manner to dilute acids; melibiose and levulose are first formed, the former being further converted by prolonged treatment with invertin into galactose and dextrose. Loiseau[2] found that raffinose was completely fermented by the action of yeast, and Berthelot[3] also arrived at the same conclusion.

The action of beer-yeast on the uncrystallisable sugars from *E. punctata* ceased before forty-eight hours, no further action taking place during the lapse of a week, the temperature during most of that time being under 20° C. The eucalyn (melibiose) thus freed from the other sugars was separated, evaporated down, dissolved in water and some very active beer-yeast added; it was found that it slowly but entirely fermented under these conditions; the temperature requires to be above 20° C. the action appearing to entirely cease when it was as low as 18° C., but commenced again when increased to above 20° C. We thus see that the

[1] Ber. xxii., 1678 and 3118. [2] Compt. Rend. cix., 614. [3] *Loc, cit.*

whole of the sugars in this exudation are fermentable under certain conditions, and it appears that the natural alteration of raffinose is exactly the same as when artificially treated.

Ordinary Eucalyptus manna, as usually seen, is in small white opaque lumps. When in solution it reduces, to a small extent, an alkaline copper solution when heated, but when treated with acids a large quantity of reducing sugars are at once formed. As we have seen that tannic acid does not appear to exist in the sap circulating through the bark of *E. punctata*, and as other acids are absent in this manna, we naturally expect to find the product fairly pure. Ordinary Eucalyptus manna is probably derived from punctures in the bark that have not penetrated into the cells of the tree containing tannic acid. In the darker saccharine exudation from *E. punctata* we find that tannic acid is present, and this probably accounts for the presence of the reducing sugars, these being derived from the crystallisable sugar by inversion, brought about probably by the presence of the tannic acid. The tannins of the Eucalypts tend to rapidly form anhydrides; that such are present in this darker exudation is indicated by the dark colour of the material, and the fact of its removal from the solution by hide-powder. The question arises, can we account for the presence of these sugars in this exudation, to the formation of anhydrides of the tannins by elimination of the molecules of water, when in combination with raffinose in natural solutions?

The darker saccharine exudation from *E. punctata*, therefore, contains :—

Raffinose (melitose)
Tannic acid and anhydrides.
Eudesmin.
Eucalyn (melibiose)
And an easily fermentable reducing sugar.

As levulose has been stated to be one of the products of the inversion of raffinose, it would be interesting to determine definitely whether that sugar is really present in the natural exudation from *E. punctata*, and next season if sufficient material

is obtainable this may be done. These sugary exudations are so soluble in water, that a little rain is sufficient to remove them entirely from the trees, so that they can only be obtained in quantity after a period of hot, dry, weather.

2. The Astringent Exudation.

This exudation or kino was found to belong to the "turbid group" of Eucalyptus kinos, and the crystallisable substance contained in it was determined by the method previously adopted for the extraction of these new bodies from Eucalyptus kinos.[1] The ethereal solution when distilled as much as possible to dryness, did not deposit crystals, and when the residue was dissolved in absolute alcohol it was with great difficulty that crystals were obtained, the alcoholic solution standing some days before the substance crystallised out. But the crystals when obtained were large and well developed, being rhombic prisms with basal plane terminations. Although the formulæ given for eudesmin[2] were obtained from microscopic crystals, yet, now that macroscopic crystals have been obtained, the only addition is the O P plane to those previously given. The faces of the brachypinakoids are but slightly developed and are often entirely absent; minute faces of the macrodome are seen on most of the crystals. The prismatic angles are almost identically 110° and 70°. The crystals thus obtained are from 5 – 6 mm. in length. The accompanying photograph shows them the natural size.[3]

The colour reactions, melting point, and other physical characteristics determine these crystals to be "eudesmin."

Aromadendrin could not be detected in this kino, so that now we are able to divide the "turbid group" of kinos into three sub-groups, based on a chemical classification, viz.:—(*a*) those that contain aromadendrin alone, of which *E. calophylla* is a represen-

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1 Proc. Roy. Soc. N. S. Wales, 1895, p. 32, and Journ. Soc. Chem. Inst. November, 1896.

2 Proc. Roy. Soc. N. S. Wales, 1895, p. 33.

3 I am indebted to Mr. Connelly of the Technological Museum for this photograph and also for the previous one of raffinose.

"Eudesmin," natural size, from kino of *E. punctata*.

tative; (*b*) those that contain eudesmin alone, of which *E. punctata* is a type; and (*c*) those containing both eudesmin and aromadendrin of which *E. hemiphloia* is characteristic. I would here observe, that from my present knowledge, it appears to me that the presence or absence of these bodies (eudesmin and aromadendrin) in the kinos of the Eucalypts, will eventually be found to have a direct bearing upon the commercial value of their products in more ways than one. I look forward to the time when a few chemical tests of certain parts of the tree, together with examination of the anthers, cellular and other portions, will suffice for a decision as to the possibilities and products of the tree, and indicate with some certainty what the constituents of the various products will be. My colleague Mr. R. T. Baker, F.L.S., to whom I am greatly indebted for much botanical assistance in this present research, is working at this side of the question.

Besides the eudesmin, the kino of *E. punctata* contains tannic acid and its derivatives, all of which are absorbed by hide powder, no other constituent being detected. They were, therefore, determined by this method after removing eudesmin.

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The eudesmin was removed from an aqueous solution of the kino by agitating with ether, separating this, evaporating the ether, and weighing. The following is the percentage analysis of this kino

Tannic acid and its derivatives =	66·05
Eudesmin...	4·45
Moisture	16·20
Ash	0·72
Debris, (or residue) wood, bark, etc.	12·36
	99·78

The residue from the first solution of the saccharine exudation consisted largely of debris, wood, bark, etc., this was boiled with water, a small quantity of gum was obtained, also a little tannin, but no other constituent was detected likely to be of importance.

The principal results arrived at from the foregoing research are as follows:—

(*a*) That the manna is derived from the *bark* of *E. punctata.*

(*b*) That the kino is derived from the *wood* and not from the bark.

(*c*) That the principal sugar in these exudations is raffinose (melitose), and is chemically the same as that investigated from other Eucalypts and from other sources.

(*d*) That the dark saccharine exudation from this tree contains at least two other sugars besides raffinose, one readily fermentable, the other not so readily.

(*e*) That those Eucalypts not containing eudesmin etc. in their kinos do not give manna.

(*f*) That some of the Eucalypts belonging to the Renantheræ contain a yellow dye in their leaves allied to quercetin, and in some respects to aromadendrin.

(*g*) That the kino of *E. punctata* contains eudesmin but not aromadendrin.

On the ESSENTIAL OIL and the presence of a SOLID CAMPHOR or STEAROPTENE in the "SYDNEY PEPPERMINT" *EUCALYPTUS PIPERITA*, Sm.

By R. T. Baker, F.L.S., Assistant Curator, and Henry G. Smith, F.C.S., Mineralogist, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, August 4, 1897.*]

(*a*) Introductory.
(*b*) Botany of *E. piperita*.
(*c*) Description and Chemistry of the Oil.
(*d*) A new Solid Camphor.
(*e*) Probable Therapeutic Properties of the Oil.

(*a*) Introductory.

An exhaustive research is now being conducted at this Museum on Eucalyptus oils of undoubted botanical origin. Previous workers in this field of science have expressed regret at the difficulty experienced in obtaining leaves true to name, as there are few persons who can distinguish the species amongst the living trees of this most difficult genus. In our case each oil is distilled from leaves and terminal branchlets of trees selected by ourselves in the bush, and flowers, fruits, wood and bark are preserved, so that the botanical derivation is beyond dispute. The oils are also distilled at the Museum under our own supervision, and every datum connected therewith is carefully noted and recorded.

Dr. R. N. Morris, the Superintendent of Technical Education, is giving us every assistance in our researches on these oils, and we are also indebted to Mr. Owen Blacket, Lecturer in Engineering, and Mr. F. Camroux, Teacher in Applied Mechanics, for valuable help in the management and erection of the still and its appurtenances.

We have commenced our researches with what is a classical oil, viz., that of *E. piperita*, Sm., for it was from this species that the first essential oil was extracted from any tree belonging to

the genus Eucalyptus. In White's Journal of a Voyage to New South Wales, 1788, p. 226, the oil is thus referred to:—"The name of Peppermint tree has been given to this plant by Mr. White on account of the very great resemblance between the essential oil drawn from its leaves and that obtained from the Peppermint *(Mentha piperita)* which grows in England. This oil was found by Mr. White to be much more efficacious in removing all cholicky complaints than that of the English peppermint, which he attributes to its being less pungent and more aromatic. A quart of the oil has been sent by him to Mr. Wilson."

(*b*) Botany of *E. piperita.*

This species as above stated, was first described by Dr. Smith in White's Voy. N.S.W., 226, 1788, and is also referred to again in transactions of the Linnean Society, III., 286; F. v. Mueller's Frag. Ph. Aust., II., 64 and 173; DC. Prod., 217 *(E. ?acervula,* Sieb.); Eucalyptographia, F.v.M. Dec. III. In the last named work neither the fruits nor the seedling leaves are quite correctly delineated. There is another species *(E. amygdalina,* Labill.) which is widely distributed over the eastern districts of this colony, and is also known under the name of "Peppermint," we therefore think it advisable to point out some of the characteristics of the species under consideration.

In the Sydney district it is a tall tree, with a somewhat fibrous bark on the trunk and larger branches, but on the dividing range and other localities only the trunk is covered, whilst the larger and ultimate branches are quite smooth. The leaves on the seedling, unlike those of *E. amygdalina*, are alternate.

Like *E. amygdalina* it belongs to the group having reniform anthers, but its chief points of difference from that species are in the seedling and sucker foliage, and the shape of the fruits, which are almost spherical in the type, but sometimes contracted near the orifice giving it an urn-shaped conformation, whilst in the mountain form they are quite elongated. They measure from two to four lines in diameter, the pedicel varying in length from one to three lines. The orifice is thin edged, a distinctive character

that at once distinguishes it from *E. eugenioides*, Sieb., and *E. capitellata*, Sm., its allied species. The valves are not exserted.

Hab. The whole coast district and eastern mountain ranges of the Colony.

(*c*) Description and Chemistry of the Oil.

Our oil was without doubt obtained from the same variety as Dr. White's, viz., the coast or type form of *E. piperita.* As we are more directly concerned with the economic side of the question we endeavoured to carry out our distillations on lines we could recommend to the commercial world, consequently we made no attempt to collect only leaves, as it does not appear to us to be payable to treat these solely, in the face of the present market rate of labour; so we had only the ultimate branchlets with their leaves collected. These were placed in six wire baskets in a still capable of holding 200 to 250 lbs. of material, and a low pressure applied; about 80% of the oil obtained came over in about one hour and a half. Commercially we do not recommend the distillation to be continued longer than two hours.

The oil is very light in colour and had a distinct peppermint odour, which however diminishes after a few weeks. As distilled it has a specific gravity of ·9096 at 17° C., and a specific rotation of $(a)_D - 2{\cdot}97$. The levo-rotation is perhaps partly due to the presence of the terpene phellandrene, as this substance was readily detected by the usual methods, although it is not present in large quantity. The amount of Eucalyptol in the fraction boiling between 172·4° and 182·8° was found to be 24·5 per cent. using the phosphoric acid method.

The first rectification of 100 cc. of the crude oil gave the following results:—

The fraction of oil distilling between[1]	170·3 – 172·4° C.	= 19%
,, ,, ,,	172·4 – 177·6	= 40
,, ,, ,,	177·6 – 182·8	= 18
,, ,, ,,	182·8 – 193·2	= 9
,, ,, ,,	266·7 – 272·0	= 8
		94%

[1] These temperatures are corrected.

Allowing for a few drops (partly aldehydic bodies) coming over under 170·3° C. and also that portion distilling between 193·2° and 266·7° C.	=	1
Residue above 272·0° C.	=	5
		100%

The second rectification of 100 cc. of the crude oil gave the following results:—

Fraction distilling between[1]	170·3 – 172·4° C.	=	18%
,, ,, ,,	172·4 – 177·6	=	43
,, ,, ,,	177·6 – 182·8	=	18
,, ,, ,,	182·8 – 193·2	=	8
,, ,, ,,	266·7 – 272·0	=	9
Residue above 272° C.		=	4
			100%

The first three fractions entirely evaporated when placed in watch glasses; the fourth contains a small quantity of resinous bodies which prevents entire evaporation of this fraction and yet shows no signs of any crystalline body.

(*d*) A new Solid Camphor or Stearoptene.

The fifth fraction forms well marked crystals on the slow evaporation of those portions which are volatile in the air, so that we shall have little difficulty in obtaining the crystallised substance in this way, provided we do not succeed in isolating it by an easier method. It was not possible to crystallise it out from its fraction by freezing at a temperature of 10° below zero.

We were first attracted to this new substance by detecting its presence as a white crystallised body around the cork of the bottle in which the oil was placed, as well as on wooden benches on which it had been dropped. No method has so far been found to completely separate it chemically from its fraction. The best method whereby we have obtained the crystals is to saturate a large cork with the oil, when after some days the camphor crystallises out upon the surface as seen on the specimens submitted.

[1] These temperatures are corrected.

The best crystals are obtained by saturating any substance that will absorb the oil, such as a porous tile, wood, etc., but as cork is perhaps less likely to contaminate the crystals, we have used that in preference. The crystals are well developed, acicular, and polarise light, extinguishing parallel to the principal axis, and so probably are rhombic. The crystals obtained upon a porous tile appeared to be free from adhering terpenes, and were found to have a melting point of 74 – 75° C.—each of four determinations being between those degrees of temperature.

The greater part of the fraction distilling between 266·7° and 272° C. comes over between 269·9 and 272° C. Provisionally we state the melting and boiling points of this camphor at the temperatures given. We purpose naming the solid camphor from this oil "Eudesmol," in allusion to Robert Brown's name for the genus Eucalyptus.

In consideration of the fact, that the boiling point of this solid camphor is as high as 270 – 272° C., it will be seen that by any ordinary system of rectification this would remain with the residue and thus be removed from the bulk of the oil.

The therapeutic value or otherwise of this camphor must be decided before this oil can be recommended for either external or internal use. One is inclined to regard it as a rubefacient in view of the fact that other solid camphors such as menthol and thymol derived from volatile oils are so used.

(*e*) Probable Therapeutic and other Properties of the Oil.

The result of our work so far on this oil is:—

1. The yield of oil is good, being ·784 per cent. an average of four distillations on leaves with branchlets.
2. In the crude state, owing to the presence of the camphor it may very possibly be an excellent rubefacient.
3. The oil rectified below 190° C. is free from this stearoptene, and the fraction between 170° and 190° C. could, if required, be used internally, but as it contains phellandrene, and only 25%

of eucalyptol, it is not recommended for that purpose, as so many oils are obtainable exceedingly rich in eucalyptol and also free from objectionable bodies.

Of the thirteen specific oils examined by us this is the only one that so far has given a solid camphor or stearoptene, and we believe it is the first solid camphor obtained from Eucalyptus oils.

Specimens of this oil were distributed, accompanied with a request for a report on its rubefacient properties. We are pleased to state that in every instance where it has been so used the result has been highly satisfactory. Thorough investigation will be made as to the composition and properties of this camphor, and when completed the results will be submitted to this Society. We shall be glad to receive medical opinion as to the probable value of this oil for medicinal purposes.

[Added 10th Nov. 1897.]—We have since discovered that this body (Eudesmol) exists in large quantities in the oil obtained from the leaves of the "Red Stringy Bark" *Eucalyptus macrorhyncha*, F.v.M. It can be readily separated from this oil and easily purified.

OUTBURST OF SPRINGS IN TIME OF DROUGHT.

By W. E. Abbott, Wingen.

[*Read before the Royal Society of N. S. Wales, September 1, 1897.*]

The outburst of springs, and, as a consequence, the increased flow of water in creeks and rivers without apparent cause, just at the climax of a long continued and widespread drought, has occasioned a good deal of interest in New South Wales; and many theories have been offered in explanation through the press. As the phenomena were very pronounced on my own property at Wingen in May, up to which time there had been a rainfall of only about four inches, I carefully noted what was taking place, with the object of arriving at the immediate cause of the outburst, hoping by this means to be in a position to say whether it is or is not an indication of the termination of drought conditions in the area affected. I do not propose to deal with all the theories offered in explanation, but will endeavour to clear the ground by getting rid of those, which, from the position of the men by whom they have been put forward, or from other causes, have been most widely accepted; and which yet do not accord with the facts, as they have come under my own observation, both now and in former droughts, and which are well known to many people long engaged in pastoral pursuits in Australia, pursuits in which the occurrence of drought is a factor of prime importance.

First we have the explanation offered by Mr. Clement Wragge of Queensland, that the recent outburst of springs is a result of the late earthquake disturbances, having their centre in South Australia. This I think is untenable, because we who have had to suffer many droughts by which large pecuniary interests were affected, know that the increased flow of springs and creeks at some stage of a general widespread drought is almost, if not quite invariable, while earthquakes in drought or at any other time are exceptional. That this fact was probably unknown to Mr. Wragge

accounts for his having put forward an explanation which ignores well known facts.

Next we have the theory that the increased flow of water is due to barometric changes. Apart from the fact that Mr. H. C. Russell has shown that in the Bathurst and Orange districts, where the phenomena were very pronounced, there was no barometric change, it has always seemed to me that the explanation is inadequate. As far as my observations go, and I think they will be borne out by those of other observers, the increased flow invariably begins in creeks that have a drainage area of from a few hundred yards to a few miles in extent, and though it ultimately affects the larger creeks and rivers, this secondary effect is produced by the accumulated flow of the many little creeks working down gradually from the upper watershed, and does not begin in the main creeks or rivers in their lower courses.

In considering how barometric changes of pressure could produce an increased flow of water, it will be clear that there must be a high pressure at the source of the spring and a low pressure at its outlet. A low or high pressure which was the same at both could produce no effect, and as it is impossible that there could be innumerable areas of high and low pressures at distances of only a few hundred yards or a few miles apart all over the country, and continuing permanent for weeks or months, I think this explanation is disposed of. Of course it is possible that a high and a low pressure following each other across the country might effect the source of supply and outlet of a spring alternately in some cases, but even then, I think the pressures would have changed long before the effect could be transmitted from the source to the outlet.

Another explanation which has been put forward with some authority, is that the increased outflow of water is the result of the cracking of impervious dams of clay by which bodies of water had been held back in the gravels and sands of the smaller creek beds. The theory is that the long continued dry weather has caused these clay formations to crack to a point below the

water level, and so released the water dammed back, which then made its appearance as a running stream lower down. At first sight this explanation seems feasible; but to those who, having been in the habit of storing water above the surface in artificial dams made of clay, have noted what takes place in dry weather, its inadequacy is apparent. Even in a surface dam, no matter how dry the weather, and even though the dam be exposed to wind and sun for a length of time, it never cracks while there is any water on the upper side; nor is it possible that it could do so, because as long as the water remained it would be kept moist, when it cracked there would be no water to flow through. Some other explanations which have been offered, such as the action of cray-fish, supposed in extremely dry weather to undertake the sinking of artesian bores on their own account, seem to me to be too fantastic to be worth consideration.

The theory, which seems to me to cover all the facts that I have observed or seen recorded in the papers, is simple enough, but I do not claim for it any credit on the ground of originality, as I believe it is held in a vague and indefinite way by many of those who have been in a position to make a close and continuous observation of what takes place, not in one, but in many droughts, when, as stated, creeks and springs have at various times shown an increased outflow of water in the absence of rainfall. That this increased outflow of water at some stage of a general drought, of which we have heard so much lately, is not exceptional, but may be seen to a greater or less extent in every drought, is proof, I think, that it is in some way a result of what may be called drought conditions. The most notable of these is the extreme dryness of the atmosphere. For many months, sometimes extending into years over large areas of Australia, we find dry winds blowing, no dew, no rain, all vegetation parched up, and the ground cracked to a depth of many feet. Even when at the surface the ground is reduced to fine dust by the trampling of stock, at a little depth the soil is divided up by a network of cracks extending many feet downwards, and allowing evaporation to go

on freely even as far down as five or six feet, or possibly in places even still further. This I recently found to be the case when I attempted at the height of the late drought to irrigate a small area of old cultivation land shewing no surface cracks. When the water was turned on through an eight inch pipe, after spreading a few yards, it broke through the old cultivated surface and disappeared at once in cracks from three to four inches wide, without effecting the surface in any way. In a time of general or pronounced drought we do not usually have extremely hot weather, but fairly cool nights and bright clear days; anything like exceptional heat, more particularly at night, is a sure indication that the drought is but local and likely to be of short duration. A dry, clear, and not abnormally hot atmosphere, is the invariable accompaniment of a general and prolonged drought, and it is the extreme dryness of the atmosphere which I regard as the indirect cause of increased outflow of water in springs and creeks, always observed at some stage in such droughts, and so noticeable in the drought which now seems drawing to a close. To understand the apparently uncaused increase in the flow of water in many, but not in all of our creeks and springs, occurring in most cases towards the close of a general drought, it will be necessary to refer to the character of the sources from which the flow of such creeks and springs is derived in normal seasons when they are permanent.

The generally accepted theory of springs found in all books on the subject, is that on high ground there is an underground reservoir with very free openings to the surface, through which it is kept full by the rainfall. Then there is a narrow or restricted opening, not unlike a pipe line; which may be of any length, connecting this reservoir with the outlet of the spring. The reservoir being filled by rainfall much more rapidly than it is emptied by the spring, gives the spring a permanent outflow not affected by the seasons. The Prospect Water Supply with its reservoir and pipe line to Sydney is an artificial reproduction on the surface of this kind of spring, but when we come to examine the sources of

supply of the creeks and springs, which after having dried out or dwindled down in the late drought, suddenly and without apparent cause began to flow again, we find that the generally accepted theory, though applicable to some of our permanent and unvariable springs, does not apply.

The creeks and springs, of which I have carefully examined a considerable number, are fairly permanent in their flow in ordinary seasons, though many of them were not so until after the natural growth of Eucalyptus timber on the upper part of their watersheds had been ringbarked from twenty to thirty years ago. In all of them the source from which the water flowing in their channels is derived is a quantity of porous and somewhat spongy soil, of no great depth, resting on impervious strata of rock or clay, with a slope more or less steep in the direction of the creek or spring. In some cases this spongy soil is only a few hundred yards in extent, and in others a few miles; nowhere, as far as I am aware, is there any holding back of the water by an impervious bar or dam of rock or clay. In normal seasons the sponge is filled to the point of saturation by the inflow of the rainfall from the surrounding hills, and as it is held back like the water in an ordinary sponge by capillary attraction and friction, it escapes slowly at the lowest level into the channel of the creek, thus maintaining an even and regular flow from one rainfall until the next. When the country is suffering from one of our general droughts, the characteristic of which is an atmosphere of extreme dryness and an almost total absence of rainfall for many months, evaporation of course proceeds very rapidly over the whole surface of the sponge which forms the source of supply of these little creeks and springs, until at the lower levels, which are generally quite shallow, the rate of evaporation is so great as to dry it up, down to the impervious underlying strata. Then the water disappears from the creeks and the springs dry up, but all the time the water stored in the upper and thicker parts of the sponge which have not yet been dessicated, is still moving down slowly along the slopes towards the creeks or outlet of the springs. The rate of

evaporation, however, is sufficiently great to exhaust it before it reaches these channels and outlets. All at once from causes of which as yet we have no accurate knowledge, the atmospheric conditions are changed. The whole country is covered with a moist atmosphere in which evaporation almost, if not wholly, ceases. Then the conditions are reversed in the spongy sources of our creeks and springs. Evaporation having ceased, the water from the upper and thicker parts of the sponge soon works downward and resaturates the lower shallow parts and consequently reappears in the creeks and at the outlet of the dried-up springs.

This explanation seems to me to embrace all the facts covered by my observation, but whether the breaking out of springs and increased flow of water in creeks in time of drought is an indication of the near approach of its termination or not, is a matter which cannot be decided off hand. That an extremely dry atmosphere is a characteristic of drought periods, we know, but is it the cause of the drought? We also know that in a general drought which covers half or all Australia there are always small areas not suffering therefrom, and the situation of these areas vary in different droughts. For example, that Bourke, which has not suffered this time, will also escape in the next drought is very unlikely, from what we know of the past. What I would be inclined to infer is, that when the outburst of springs and increased outflow of creeks is confined to a small area of the country in a general drought, it is not an indication of a break up as small local changes are common to every drought. When however, the outflow of water covers a wide area or the whole of the drought stricken country, then it is to be regarded as the indication of the near approach of the end, since the most distinctive characteristic of a general and widespread drought—an extremely dry atmosphere —has disappeared.

THE POSSIBILITY OF SOARING IN HORIZONTAL WIND.

By Lawrence Hargrave.

[With Plate XVII.]

[*Read before the Royal Society of N. S. Wales, September 1, 1897.*]

There is a publication called the Aeronautical Annual, edited by James Means, Boston, Mass. In No. 2 and 3 of that work, Mr. Octave Chanute goes exhaustively into the question of sailing flight, and specifies every letter and article that bears on the subject. This paper may be said to take up the running where Mr. Chanute leaves off. My reasons for not writing to that periodical straight, are that publication would be delayed for many months; and the state of the art is such that at any moment some one of the many who are investigating this subject may drop on the facts stated in this paper, take out a master patent which would rule the construction of all future flying machines, and tax us all round for our good as the protectionists say, thus throwing our work back for years. I therefore, with your permission, read this paper and show the models that work as I describe, and thereby destroy the novelty of the invention for all time.

The point of doubt has been, how to account for the phenomenon of soaring in a horizontal wind. There is no difficulty in soaring if we assume an upward trend in the wind such as a cliff, building or sloping hill will produce. But when we see birds soaring in light wind and storm something beyond our knowledge is recognized as being at work.

Mr. Chanute shows the profile of a number of soaring and non-soaring bird's wings, and points out the downward projecting lobe at the front edge of the former, and also that there is a sharp curve just abaft the lobe on the under side. (*Plate* 17 fig. 1.)

A few experiments have been made at Stanwell Park to show how this affects the effective direction of the wind when soaring, with the result as I previously surmised, that it was found to create a vortex, and that the direction of the air current beneath the wing was that indicated by the arrows in (*Plate* 17, fig. 1).

The apparatus used was a small bellows, a bent piece of sheet aluminium and a candle. The centre of the vortex was found to be approximately at the centre of the curve of the fore part of the aluminium sheet (*Plate* 17, fig. 2). The candle you observe is not masked by the leading edge.

The quasi-wing was then bent like (*Plate* 17, fig. 3), and the candle flame was blown in a manner showing that in this case the vortex was elliptic. The pressure at A must be greater than at C or the candle flame would blow parallel to the blast. As a first attempt to show that the pressure at A was greater than at B, I cut a small hole at B and gummed a tissue paper valve opening towards B. I could not be certain that air was passing through it.

A portable forge was now arranged to deliver air through a two inch horizontal tin tube, and various devices were used for hanging things in front of the blast. Among others an old and rough gull's wing showed the loose feathers blowing towards the front edge (*Plate* 17, fig. 4).

When a piece of the wing was cut off and hung at eleven inches from the blast with a negative angle of about 28°, it at once began to revolve in an elliptic orbit, the feathers on the under side of the wing being ruffled back at positions A and B (*Plate* 17, fig. 5). When attempting to repeat this experiment the wing could only be made to revolve in a contrary orbit to that shown in the figure. A piece of aluminium without a bulb would only swing very slightly in the line of blast.

A piece of tin folded with a bulb at the forward edge and some pieces of down gummed on the concave side, was set at a positive angle of about 6°, the down at the bulb blew strongly in the direction of the arrow (*Plate* 17, fig. 6).

Thirty-two three-quarter inch square holes were cut in a curved piece of aluminium (*Plate* 17, fig. 7), and each hole was fitted with a tissue paper valve lifting on the curved side. When the chord of the curve was at about zero, A and B sets of valves lifted tangential to the leading edge, and C and D sets of valves were fluttering with the blast.

A level sheet of glass with a little water on it was placed in the line of blast, and the curved tin (*Plate* 17, fig. 6) standing in the water with a sprinkling of red ochre shows the vortex at a negative angle of about 30°. The tin was set at zero, but the after edge was slued round to 30° by the rotation of the vortex.

This is all very well as far as it goes, but something is wanted that would eliminate errors of direction of the wind, and some of the uncertainty as to the angles, and also to compare the curve with the plane surface. So I fixed a horizontal wire on a stand and pointed it towards the blast. A sleeve was on the wire revolving freely. On opposite sides of the sleeve I attached a bulb ended curved piece of aluminium and a piece approximately flat, with set screws to fix them at any angle with the direction of blast. There was a lead weight for balancing in the plane of rotation. There was nothing to stop the sleeve from slipping along the wire, which it did not do.

You will observe that with this apparatus if my personal equation gave any advantage to the curve it would be eliminated when the sleeve revolved 180°, and that both surfaces received a blast of equal intensity, and that placing the two surfaces on opposite side of one axis is equivalent to weighing their respective lifting powers in a pair of scales.

The plane and chord of the curve were first set at a slight positive angle (*Plate* 17, fig. 8). In this case the curve easily rotated the sleeve against the lift of the plane. There might possibly be no vortex under the curve, and the stronger rotating force might be due to the greater angle of slope of the after part of the curve.

The plane and the chord of the curve were next set parallel to the line of blast (*Plate* 17, fig. 9). In this case the lifting force opposed by the plane to the curve was nothing, although its resistance was that due to its area and the velocity of the blast, and the lift of the vortex under the curve easily overcame this.

In (*Plate* 17, fig. 10) the plane was left parallel to the blast, and the curve sloped at a negative angle, this angle was increased to at least 10° and the lift of the curve still rotated the sleeve against the resistance of the plane.

In (*Plate* 17, fig. 11) the plane was put at a positive angle of 6°, that is, 16° between the plane and the curve. The plane was now able to rotate the curve against the vortex. Figs. 12, 13, 14, 15, show the stream lines of the air when it meets a curve set at various angles.

To recapitulate, the experiments show—

1. That the profile of a soaring bird's wing and pieces of metal of a somewhat similar curve generate vortices on the concave surfaces when the chord of the curves makes a negative angle with the direction of the wind.

2. All the concave surfaces are in contact with air moving *towards* the mean direction of the wind.

3. That the mean pressure on the concave surface is higher than on the convex side.

4. That the chord of the curved metal may make a negative angle of 10° with the direction of the wind and still have a higher pressure on the concave side than on the convex.

And the direct inference is that gravity can be entirely counteracted by a volume of disturbed air moving in a horizontal direction; and that flying machines of great weight can be held suspended in a horizontal wind, and rise vertically without the expenditure of any contained motor force.

Having put matters so that anyone can easily repeat my experiments and elaborate them to the last degree of precision, we now

see why the best soaring is done in steady winds. The answer is, the bird is less liable to lose its vortices by a sudden gust and have to take a flap or two to balance itself on a fresh pair. The difference between *flying* and *soaring* is that the air in contact with the underside of the wing is moving towards the bird's head when soaring and towards the tail when flying. A soaring bird's wing is a shield dividing two currents of air moving in contrary directions. The vortex draws towards the shield and pushes it into the low pressure above the wing.

There is a very similar experiment described at pages 79, 80, of this Society's Journal for 1893, but I then failed to see the true cause of the phenomenon and thought the air currents were those shown in the flying wing (*Plate* 17, fig. 1) whereas the currents were those of the soaring wing.

Mr. Chanute says that, "Dr. Thomas Young, the great physicist, showed in 1800 that a curved S-like surface suspended horizontally by a thread advanced against an air jet impinging upon its upper surface." If this S-like surface proves to be like *Plate* 17, fig. 16, and he explains the cause to be the vortex shown therein, it is only another proof that there is nothing new under the sun. The turn-up tail is now being experimented with, as I think it provides automatic stability in a fore and aft direction.

Having experienced much of the monotonous process of repairing broken models, I have now devised and am using a method of experimenting that practically enables me to avoid all breakages. The apparatus used is well shown in Figures 17 and 18, which I think will advance the art of aërial navigation more than any amount of laboratory experiments. The two poles are twenty-four feet high and forty-eight feet apart. There is a cord between the tops of the poles, and the string of the soaring kite is tied to the middle of the cord at a sufficient height to prevent it striking the ground. I stand to leeward of the poles and start the soaring kite at a positive angle, it then flies as an ordinary kite to near the zenith. The vortex then forms under the curved

aluminium surfaces and draws the apparatus at the full stretch of the string and cord, through the 180° of arc to windward of the poles. The flag shows the wind to be horizontal, and the string that is plainly visible in the photograph shows the soaring kite pulling about 20° to windward of the zenith. The wind was blowing at twelve or fourteen miles per hour, which was inadequate to effect the best pull the affair is capable of.

Fig. 17.

The projected area of the two curved surfaces is one hundred and eighty-nine square inches, and the weight is one pound four

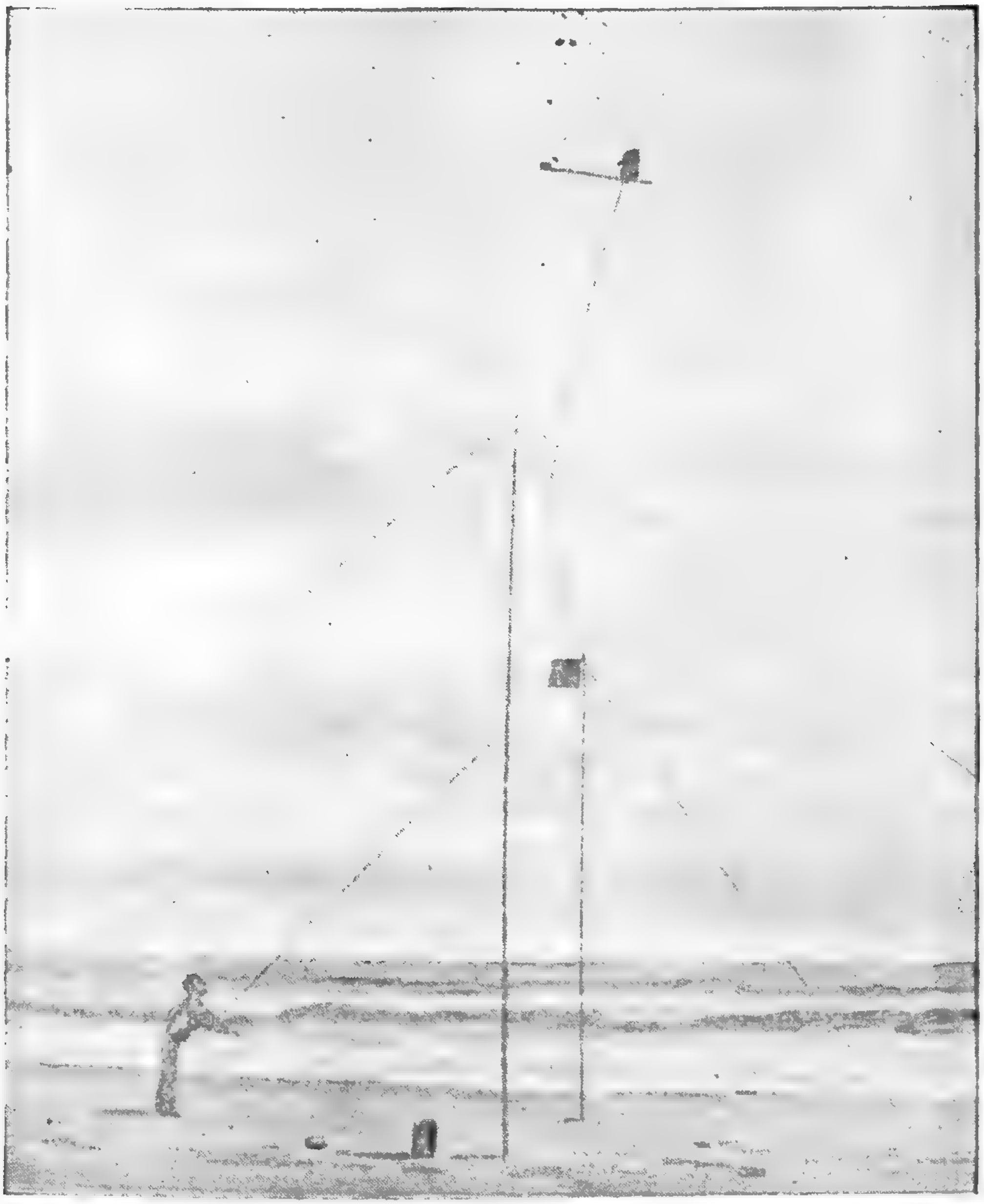

Fig. 18.

and a half ounces. The cylindrical aluminium tail is a serviceable construction. As yet I have been unable to make the kite stop when at or beyond the zenith, but the wind has been remarkably light for many weeks and few trials have taken place.

A very few trials will convince the most sceptical that if we are not soaring in moderate breezes before the end of the century it will not be from ignorance of the way to do it.

It is obvious that soaring sails for marine propulsion have a vast future before them: and it is probable that craft so rigged will make better weather with a gale in their teeth than our best screw steamers.

On a CORDIERITE-BEARING ROCK from BROKEN HILL.

By J. Collett Moulden, A.R.S.M., F.G.S.

(Communicated by E. F. Pittman, A.R.S.M.)

[*Read before the Royal Society of N. S. Wales, October 6, 1897.*]

Whilst engaged in collecting a series of rock specimens in the field, illustrative of the Broken Hill district, prior to making a number of rock-sections for microscopical investigation, I happened to come across an exposure of rock, on the rounded and weathered surfaces of which some dark, irregularly-fissured crystals were apparent. After breaking hand-specimens of this material, I recognized the mineral as cordierite, and upon testing it chemically and microscopically, found that my field observation was confirmed.

The occurrence of cordierite as a rock forming mineral, in a perfectly unaltered condition, has not, to my present personal knowledge, been yet noted in Australia, but whether it has or has not, I have ventured to hope that, from what I have subsequently discovered, viz.:—that it has a somewhat extensive development in the metamorphic rocks of this district, the matter would be sufficiently of interest to geologists in this country, to warrant my bringing it under the notice of this Society.

Cordierite—also variously known as iolite and dichroite—is a silicate of alumina, iron, and magnesia, which crystallizes in the rhombic system. It occurs as a constituent of certain granites, gneisses, and granulites—notably in the granite of Bodenmais in Bavaria. It occurs, too, as the result of contact metamorphism, and as an original secretion from the magma in certain andesites.

The clear transparent variety, found in Ceylon as rolled masses, is known as 'saphir d'eau,' and is cut and used as a gem. Where it occurs as a rock constituent, it alters somewhat easily to pinite and other ill-defined minerals, and in those forms is common in

the quartz porphyries (elvans) of the Auvergne district in France and of Cornwall, from both of which localities I have gathered specimens.

Field Occurrence.—I am not, at present, prepared to describe generally the mode of occurrence of cordierite in all of the localities around Broken Hill, in which I have been fortunate enough to find it. I propose, therefore, to take the example primarily referred to and describe it more in detail. About half a mile south-east by south from Block 14 Mine, Broken Hill, there are two parallel exposures of a granulitic rock which appear to be parallel veins. They are separated from one another by twenty-seven feet of a decomposed ferruginous schistose rock, highly quartzose, and containing also biotite and felspar. It is mostly covered with the surface soil, and where it shows at surface is of vague character. These veins strike due east and west, and are traceable for about three hundred yards in length. They appear to have a high northerly dip, as also have the other rocks close at hand, but these observations of strike and dip are purely local and are not those prevailing generally in the district, which are respectively north-east, and 70° to the north-west. One of these granulitic veins is about twenty-seven feet wide, while the other, the one nearest to Block 14, is somewhat less, about twelve feet. The rock itself is a hard, light-grey granular material, which when weathered, has a light reddish crust upon its exterior surface. It shows a tendency to concentric weathering, hence the rounded masses. These exposures are by no means prominent, and are often obscured in places by the soil.

When a freshly fractured surface of the unaltered rock is examined macroscopically, it is seen to be moderately fine in texture, and felspar, quartz, biotite, a little pyrite and cordierite are visible to the unaided eye. It breaks, when in an unweathered condition, with a smooth and somewhat conchoidal fracture. It has a specific gravity of 2·66. In some parts of it large felspar crystals are developed, and more particularly is this the case on the outer edge of the northern exposure. In conjunction with

the felspar, large crystals of cordierite have been developed, some of which measure from one and a-half to two inches in length. Right through the rock, nevertheless, cordierite occurs in greater or lesser amount, which fact becomes more apparent during the process of grinding sections for microscopical examination, for then, whilst the sections are still of moderate thickness, the mineral in transmitted light appears of a bluish or purplish-blue colour. In the finished section it is perfectly transparent and colourless, and resembles the quartz rather closely.

The cordierite, as observed in hand specimens of the rock, occurs mainly in the form of irregular grains which break with a conchoidal fracture, and have a vitreous lustre. Their hardness is 7 or a little over. Idiomorphic crystals do however occur—one in particular, on the weathered face of a boulder of the granulite, was eight sided and an inch and a-half long. I have also seen crystals of pinite, pseudomorphous after cordierite, in the more altered portions of the veins. The outer edge of the southern vein is somewhat schistose, and contains a fair amount of sillimanite in colourless thin prisms, transversely jointed in the manner so characteristic of that mineral. It is adjoined by a band of schistose amphibolite[1] similar to those commonly occurring in the neighbouring district, and which I am, after field and petrographical investigation, led to regard as a greatly altered basic intrusive rock of the gabbro type. This band is not less than twenty-nine or thirty feet in width, and it contains in places secondary quartz veinules.

The outer edge of the northern vein passes somewhat abruptly to a schistose rock containing biotite, quartz, and a good deal of sillimanite. It is upon this edge of the granulite that the larger porphyritic crystals of cordierite have been developed in conjunction with felspar. When weathered, the former appears quite dull and black with numerous irregular cracks.

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1 Memoirs Geological Survey of N. S. Wales, Geology of the Broken Hill Lode, etc.—J. B. Jacquet, A.R.S.M., F.G.S., pp. 53 - 56.

Veins of pegmatite occur not far distant, and the rocks generally in the neighbourhood are the highly metamorphic schists and gneisses, with intercalated amphibolites,[1] typical of this portion of the Barrier Ranges. Rocks of a granulitic type—both acid and basic—have been pretty extensively developed around Broken Hill, but garnet-granulite is the one most commonly met with, and cordierite-granulite the rarest, but it is quite possible that, unless the cordierite is in large crystals in the rock, the cordierite rock is not so often noticed as the garnetiferous variety is.

Cordierite may be found forming the centre of the felspar "augen" of an augen-gneiss, close to its junction with a basic eruptive rock, at a locality about three miles and a half to the east of Block 14 Mine. In that case the resemblance of the felspar knots to "eyes" is most strikingly accentuated by the cordierite forming, as it were the dark "pupils."

Petrographical Description.—I have prepared several sections of the granulite under discussion, for microscopical examination. Some of them were taken hap-hazard from flakes struck off with a hammer, others were cut, with a lapidary's slitting-disc of soft iron charged with splinters of diamond, so as to include crystals of cordierite recognisable as such in hand specimen. The rock is a perfectly compact holocrystalline-granular one, in which the minerals are allotriomorphic. Its texture is, on the whole, rather fine, almost saccharoidal in parts. Its strong coherence admits of the production of large and thin sections with ease.

The component minerals are as follows :—

Felspars—(*a.*) Orthoclase is fairly abundant throught the rock. Microcline (herewith included) is likewise abundant, and these two are the predominating felspars. The orthoclase is fairly fresh, and shows the common twinning on the Carlsbad type. The microcline shows the peculiar "cross-hatching" between crossed nicols, due to multiple twinning. In some cases, however, it presents only a series of twin lamellæ of microscopic dimensions.

[1] J. B. Jacquet, op. cit.

(*b.*) Plagioclase is present in much smaller proportion than the foregoing, and is exactly similar, save that between crossed nicols the twin lamellæ are broad and distinct. All of the felspars contain numerous inclusions of zircon, apatite, and small indeterminate colourless needles having a definite orientation.

Quartz is very abundant, and is of the ordinary granitic type. In some cases small grains form a "mosaic" area. It contains numerous fluid inclusions, in many of the smaller of which, beautiful examples of spontaneously moving bubbles are shown.

Cordierite is likewise abundant, mostly in irregular grains, though sometimes in rudely prismatic forms. The grains vary in size greatly. It is colourless and transparent in good thin sections and shows no pleochroism. It resembles quartz closely in having irregular cracks, a low refractive index, and a low index of double refraction, hence the polarization colours are low, and vary from the grey and white tones to the yellow of the first order on the Newtonian colour scale. Alteration has set in around the edges of the grains and along the cracks, giving rise to an illdefined granular clouded material of greyish-white colour, which has a fairly high index of refraction, and, in consequence, often imparts to the unaltered cordierite a false appearance of relief. Inclusions of zircon are very common, and show pleochroic haloes when the section is cut in a direction other than parallel to the basal plane of the cordierite. Biotite also occurs as an inclusion, and occurs too, as a wreath, in conjunction with chlorite, around the crystal edges in such a manner as to suggest that it arises from the alteration of the mineral. I have observed, between crossed nicols, what seems to be a complicated twin structure of lamellæ and interpenetrations, which I am rather at a loss to understand so far.

Biotite is present in varying amount in the form of wisps and plates, some of which include small zircons.

Zircon, in the form of grains and small colourless prisms, is very abundant as an accessory constituent, and nearly every crystal of cordierite contains one or more inclusions of this mineral.

Apatite in small colourless needles and stouter prisms is present to a small extent, as also is iron pyrites in rounded grains, while ilmenite either partly or wholly altered to sphene and leucoxene is somewhat more abundant. All of the essential mineral components of this rock, with the exception of biotite, polarize in low colours, and for this reason thin sections of it are not particularly striking when viewed between crossed nicols.

The felspars and quartz show strain phenomena in the form of wave extinction, and the whole appearance of the rock seems to indicate that it has suffered somewhat from the effect of natural stress. In the development of the cordierite, the rock upon the southern side of the exposures seems to have played an important part, and field observation certainly leads one to the conclusion that it has arisen as the effect of contact-metamorphism, coupled, perhaps, with the general regional metamorphism which has so profoundly influenced the rocks over the whole of this district. The rock referred to as existing upon the southern side of the exposures, is now a rather felspathic amphibolite, more or less schistose in character, and it appears to be a typical case of the common alteration which certain basic eruptive rocks—*e.g.* dykes of gabbro or pyroxene diorite—suffer when subjected to more or less intense metamorphism.

The nomenclature of rocks is in itself a "rock" upon which many of the ablest of our geologists and petrographers have split, but few, I respectfully venture to consider, after due examination, would urge any strong objection to the rock, which I have had the honour of bringing under your notice, being termed cordierite-granulite.

This photograph was taken from a thin section of the rock. The minerals represented are cordierite, quartz, felspar, biotite, and zircon. The cordierite shows in three grains—the large central one shows the false appearance of relief due to its border of more highly refracting decomposition product. It includes two zircon grains.

Microphotograph of Cordierite in the Granulite, × 32.

Objective 1½″. Eyepiece C. Light, ordinary transmitted. Actual diameter of visual field = ·090″. Dimensions (actual) of large grain of cordierite = ·079″ × ·030″. Exposure, three minutes. Light, paraffin lamp. Plate, Paget. Developer, hydroquinone-soda.

ICEBERGS IN THE SOUTHERN OCEAN, No. 2.

By H. C. Russell, B.A., C.M.G., F.R.S.

[With Plate XVIII.]

[*Read before the Royal Society of N. S. Wales, October 6, 1897.*]

The following note about recent icebergs is intended to be taken as a continuation of my first paper on this subject.[1] The reports of icebergs which follow have been collected from several sources. (*A*) from the logs which have been sent to me by the commanders and masters of sixty-two vessels trading to Sydney, without whose aid it would be impossible to carry on the work. (*B*) Some reports of ice have been taken from the *Nautical Magazine*, and (*C*) from the daily press. All of them have been collected since July 1895 when my first list closed, although a very few refer to an earlier date.

It is remarkable, and as we shall presently see, important, that during the three months following July 1895, not a single report of icebergs was received. The next month, November, two vessels, and in December five vessels reported icebergs. In January 1896 the icebergs again disappeared from the track of vessels coming to Australia, and not a single report of icebergs in January, February, March, or April 1896, reached me. May brought three reports of icebergs; June not one. Then every month to the end of the year brought reports of icebergs, and in January 1897 they came faster than ever during the six years included in these records, and twenty vessels reported ice during that month, twelve reported ice in February, and seven in March; then all the icebergs again disappeared from the track, and up to the end of September 1897 only one ship has reported ice.

[1] Journal Roy. Soc. of N.S.W., Sept. 4, 1895.

Table shewing number of ships reporting ice in each month of past six years :—

Years	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1892	—	1	3	5	5	10	2	4	3	9	2	2
1893	12	5	6	2	2	—	—	1	—	1	2	2
1894	1	2	—	—	1	1	—	—	—	1	1	—
1895	1	3	5	10	1	6	10	—	—	—	2	5
1896	—	—	—	—	3	—	3	5	1	11	17	3
1897	20	12	7	—	—	—	—	—	—			

The black bar represents no ice, and the figures give the number of ships that reported ice. Thus in January twenty ships reported ice, February twelve ships, and March seven ships ; then April, May, June, July, and August without a single report of ice.

This motion of the icebergs into and out of the track of vessels coming here seemed to me so remarkable, that I at once looked for a cause which might produce it ; and in doing so I remembered that in the latter half of 1895, the number of current papers received had been very small, and that, when I examined the weather charts, it became evident that the most marked feature of weather in Australasia was the prevalence of strong north-west winds ; and it seemed extremely probable, that these winds had forced the bottles southwards, so that they could not reach the south coast of Australia—where many of the bottles put into the sea, find a resting place—and they were in this way passed on to the eastward never to be seen again.

It seemed very probable that icebergs might also be affected by the prevalent winds. Looking again at the weather charts, I found that southerly winds had reasserted themselves in November and December 1895, and concurrently a few icebergs were seen. Referring to the tabular statement of the number of ships in each month reporting ice, it will be seen that not a single iceberg was reported during the first four months of 1896, and the weather charts shew strong and persistent north-west winds.

In July 1896 icebergs were again reported each month to the end of the year. A reference to the weather charts shewed that

concurrently southerly winds had asserted themselves. In January 1897, twenty ships reported ice, and the charts shew strong southerly winds, and during February and March icebergs and southerly winds were concurrent, but from the end of March to the end of September 1897 strong north-west winds have been prevalent, and only one ship, in September, has reported ice.

This is too short an experience to settle the question, but so far as the records go, we find that when there is a prevalence of north-west winds no ice is reported, and with southerly winds plenty of ice is reported. The fact that these icebergs are about 3000 mlies distant from Australasia where the winds were observed, must not be overlooked, and therefore the experience just given may shew an accidental relation between the position of the icebergs and the direction of winds. I do not however think so, because some years since, I investigated the winds between the Cape and Australia, and found that the atmosphere as a whole, was moving to the eastward at the rate of about five hundred miles per day, carrying storms and change of wind with it; so that a storm, in the iceberg area travels to Australia in six or seven days. The probability that the iceberg area has the same winds that we have in Australia, only a few days earlier, is very strong indeed. I have no doubt that winds of the same general character effect the two places, Australia and the iceberg area shewn on the map herewith.

We must have a longer experience before it can be considered proven. Meantime it would materially aid the proof, if any vessels sighting icebergs on a fine day with strong northerly or southerly winds, would stop the engines and watch the berg carefully for three or four hours to see if it does move with the wind. As soon as the motion with the wind is definitely determined by actual observation of the bergs, it will be possible by careful study of the winds in South Africa and Australia to forecast the positions of icebergs between Africa and Australia with some degree of exactness.

It seems unnecessary to urge upon those most interested, the importance of the experiments suggested. My investigations have convinced me that the icebergs do drift with the wind at a very appreciable rate, and there certainly are many risks, much anxiety and loss of time which might be avoided if my suggestions prove to be facts as I think they will.

THE NUMBER OF ICEBERGS.

It would be a very useful addition to the information usually put in a ship's log, if every vessel made an effort to keep count of the number of icebergs seen every day. If would be difficult and perhaps impossible to count them all, but to know how many they could count in each case with a statement, that it was only a quarter or half of those seen would be a great help to estimating the number that are actually floating about in the track of vessels which would be very useful in studying the reports. In very many logs no reference is made to the number of icebergs, no doubt because they seem to be innumerable ; but it appears from the records which came to me that in some places there are a few large icebergs, and in others the sea is almost covered by small ones.

In the following pages 7,429 icebergs are recorded, but No. 170 counted 4,500 icebergs, No. 177 saw 977 icebergs, and No. 158 reports 376, and so on. There is another point which might be added to the reports and would increase their value, and that is, the relative density of the numbers passed from day to day. For instance, the "Hebe"—log 190—passed through 1,600 miles of ice : the "Matalua" from Nov. 9 to 14th 1896, passed through ice for 1,600 miles : the "Otarama"—log 158—in November 1896 passed through ice for 1,100 miles. If in such cases it could be said there was a berg in every square mile or in every ten miles square of the ocean and so on, it would add much to the value of the record.

The following table shews the number of icebergs recorded by each vessel in the list at the end of this paper :—

List No. of Vessel.	Icebergs seen.	List No. of Vessel.	Icebergs seen.	List No. of Vessel.	Icebergs seen.	List No. of Vessel.	Icebergs seen.
124	26	150	2	176	1	202	38
125	49	151	2	177	977	203	20
126	1	152	1	178	6	204	4
127	36	153	0	179	0	205	2
128	0	154	1	180	0	206	2
129	2	155	0	181	124	207	3
130	1	156	0	182	0	208	0
131	1	157	5	183	55	209	0
132	1	158	376	184	9	210	4
133	1	159	20	185	1	211	1
134	0	160	5	186	3	212	1
135	1	161	43	187	0	213	10
136	50	162	76	188	58	214	1
137	12	163	8	189	3	215	0
138	0	164	0	190	0	216	204
139	3	165	23	191	0	217	0
140	0	166	0	192	0	218	100
141	30	167	0	193	1	219	0
142	6	168	35	194	3	220	60
143	0	169	5	195	59	221	0
144	4	170	4500	196	9	222	0
145	4	171	0	197	15	223	2
146	31	172	12	198	62	224	0
147	18	173	5	199	12	225	10
148	0	174	105	200	1	226	50
149	119	175	3	201	0	227	0
						228	0

The following table shews the number of ships that reported ice in each degree of latitude 40 to 50° inclusive, without regard to longitude. The majority is in 45°, that is in the latitude in which the safety track cuts the longitude of the densest part of the iceberg area:

Latitudes ...	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	49°	50°
No. of ships that reported ice	2	2	8	17	27	35	24	14	7	1	2	3

THE POSSIBILITY OF AVOIDING THE DANGER.

When steaming along the safety track and surrounded by an apparently unlimited icefield, it was pertinently said by the captain of one of the regular Sydney traders, that "with such

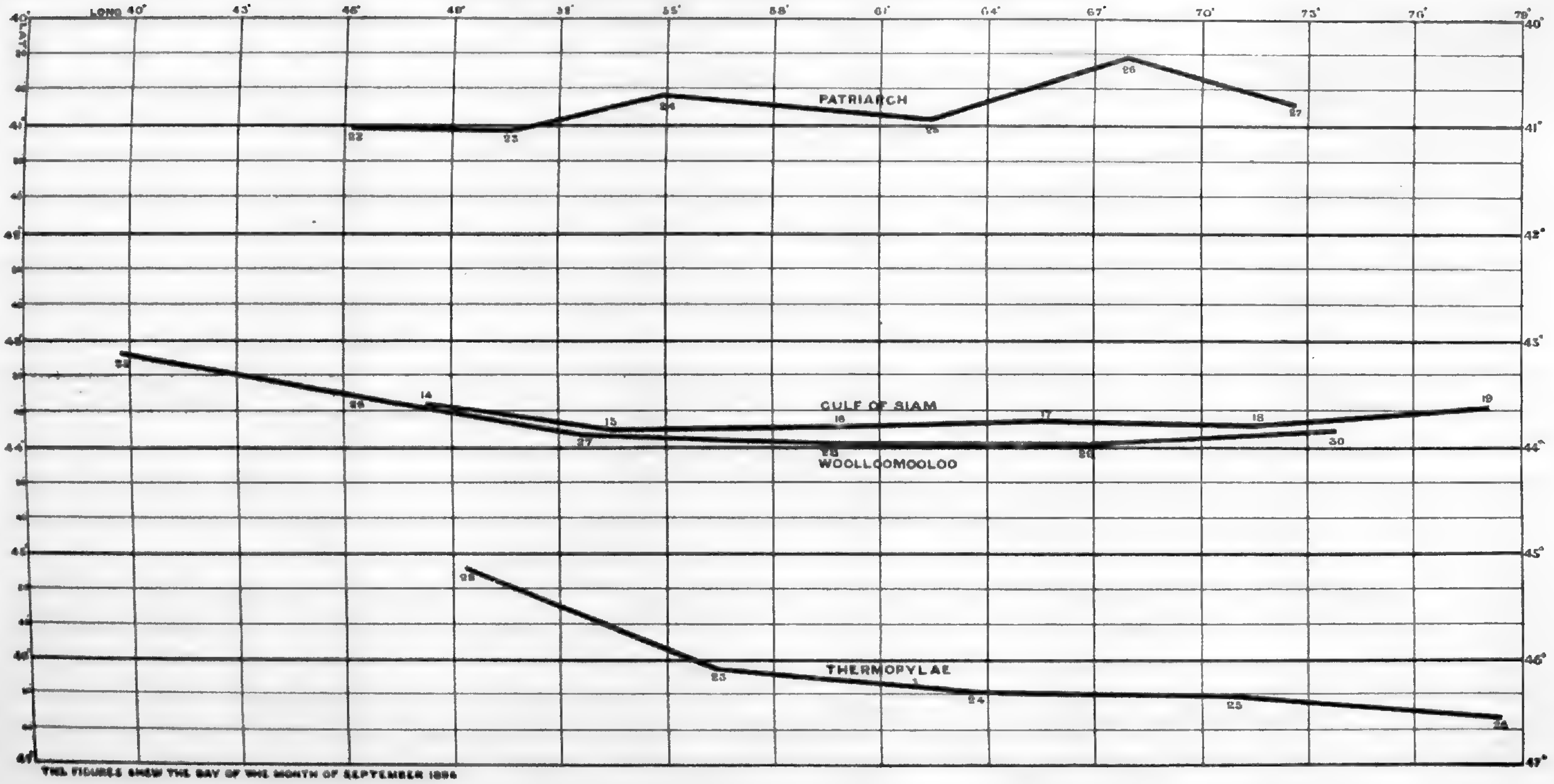
experience as ours, the reports of ships to the north of us would be interesting." It so happened, that as he spoke there were three vessels taking a course a little north of the safety track, and could he by the aid of some new telegraphy without wires have consulted their captains, the replies would have been, "Come north, in less than sixty miles you will be in open water." Had he known it then, five hours steaming would have taken the ship out of danger, and he would have wholly avoided four days and nights of great anxiety and risk to ship, passengers and crew.

I have already pointed out in this paper, the possibility, personally I would rather say the probability, that by continuing the united labours of sea-going and shore observers in regard to icebergs, it may be in the near future, possible to attempt forecasting the latitude in which icebergs will be found; and it really seems probable that electricians will ere long place in the hands of sailors, the means of consulting unseen but neighbouring vessels.

The diagram shews the track of the s.s. *Thermopylæ* in Sept. 1896, which passed through ice all the way (See report 147 in following list), also the tracks of the *Woolloomooloo*, *Gulf of Siam*, and *Patriarch*, tracks in which no ice was seen. We may turn now to the full account of the ice seen by the *Thermopylæ* in her next voyage, February 1897.

Special account of the Icebergs seen on voyage of the s.s. "Thermopylæ," Capt. A. Simpson, with attendant phenomena. (Cape Town to Melbourne) February, 1897.—About 3 p.m. on February 20th, extra special lookout being kept for icebergs, as I anticipated seeing some in this neighbourhood, a very large iceberg was observed almost right in the ship's path. Unfortunately we had only a small camera (Kodak) on board, but I decided to make the most of it, and steered the ship to pass four cables length to the south of the berg; this would make sure of being clear of any part of the iceberg that might be submerged, its position would approximately be in Lat. 45° 32′ S., Long. 46° E. Three officers were told off to take frequent and careful angular measurements, while the sea-water temperature and the dry and wet bulb ther-

DIAGRAM SHEWING TRACKS OF FOUR VESSELS



THE FIGURES SHEW THE DAY OF THE MONTH OF SEPTEMBER 1854

mometers were taken every five minutes, (that is every mile as we approached and as we receded from the berg); beyond a fluctuation of perhaps half a degree, no definite variation of temperature occurred. A mean of the angular observations gave three hundred feet high by seven hundred feet by one thousand and fifty feet as the dimensions of this berg.

In this particular part of the ocean the icebergs almost invariably have *table tops* which are corrugated and generally yellow, the colour being due to numberless birds probably resting on them at night. The top of this one being a long way above the line of spray even in a very heavy gale. Notwithstanding the long heavy swell it showed no signs of rolling or rising to the sea. The debris of broken pieces formed a line almost directly to the leeward of the berg, in fact every berg we saw had the debris drifting almost directly to the leeward of the berg. It would therefore, appear to be safer for a sailing ship or steamer, if possible, to go to the windward of an iceberg and get clear of the large pieces which are in many cases large enough to injure a vessel in case of collision. Large flocks of the blue petrel or whale bird seem to enjoy flitting about amongst the broken water around; these birds require large quantities of food, but their food must consist of animalcules which abound on the surface of the sea, as they seldom take to swimming on the water. It cannot be the scraps that go overboard from a ship that feed the hundreds of large birds now following in the wake of the ship. They seem to keep on the wing all day without being seen to pick up food of any kind.

I particularly wished to know if a ship could pass close to an iceberg with safety, as I have read so often about ships striking against the perpendicular sides, and large masses of ice falling on their decks. In every berg with a flat table top there is apparently deep water up to the perpendicular sides. The breaking sea apparently wears this perpendicular part away quickly. If in any part the water is shallow it is clearly discernible, being of a milky blue appearance. A sharp loud detonation was heard on passing this berg, but no particular attention was given to it as I

thought it might be some noise on board, but I found that these noises were continually occurring, as they were distinctly heard from several other bergs we passed fairly close to. They were also heard one evening and night proceeding from bergs that had not come within our range of vision. I also wished particularly to know how far off they could be seen at night, their colour etc. in varying atmospheres, and if they would be distinguished from breaking seas. During the next five days I had ample opportunities to find out, and do not wish another such experience. Two able seamen were placed forward, one on each bow, and a certificated officer on each side of the bridge besides myself. The watch were also alert, and as a matter of fact we saw everything that was lying in our direct track and avoided it in ample time, but I am quite certain that we must have had several close shaves. At one time sixteen bergs were in sight in the darkness, the night was starry with passing showers of rain, but with a good lookout there was no danger of collision. Of course in foggy weather they cannot be seen even in daylight, and fogs prevail on the western side of the Crozets due to the cold antarctic ice stream there.

At 4 p.m. on February 25th, during the heaviest burst of a hurricane which the ship was scudding before, it was barely possible to see beyond the length of one wave, and as the sea was a white seething mass of spindrift, we were astonished to see a high bluish mass towering up a quarter of a mile off four points on our port bow, and between it and the ship a large mass half the size of the ship above water, but completely buried in spray. This could not have been seen at night, as it was exactly like a breaking sea, Two more pieces were seen before darkness came down on us, but only for a minute or two, on our starboard side. I reduced speed to as slow as the ship could go and steer, and put my trust in Providence, and at the same time kept a good lookout. I think we could then have safely negotiated anything coming in the way, it gave us time to observe whether it was a breaking wave or a stationary piece of ice. Towards 10 p.m. the weather

continued to mend, and at our slow speed the risk was greatly reduced ; by two in the morning I was able to go ahead again full speed, no more ice being seen after this. The position of these last pieces were approximately Lat. 47° 30 S. and Long. 80° E.

From the Crozets eastwards in Lat. 46° S. the icebergs seen by me on the last four or five voyages, are apparently breaking up fast, and are weather and water worn. They lose the table top shape and are either rounded off on the ends or have high pinnacles springing up from a broad base awash by the sea. The sea temperature almost invariably rises a few degrees five hundred miles east of the Crozets, and I have several times noted quite a well defined hot stream which the ship will steam over in five or six hours in this neighbourhood. At 2 p.m on the 22nd February the sea temperature rose to 50° Fah., and continued at 49° for over seventy miles, this current undoubtedly sets the ice south which had been previously deposited by the antarctic stream into Lat. 44° and 45° S. and to the north of the Crozets. The sea is apparently not so deep to the north of Kerguelen, and I doubt very much if some of these large masses would have water enough to pass east unless they were north of Lat. 47° S.

February 21st, fine clear weather and fresh breeze prevailing, I steered for Hog Island, one of the Crozet Group, and sighted it at five in the morning, I steered within two miles of the island, and coasted along its northern and north-eastern shores. It was really a lovely sight, the beautiful autumn tints of green and yellow in the morning sunlight were similar to the views of the islands on the west coast of Scotland. Snow was lying on the top, probably about 2,000 feet above the sea. Albatrosses or molly-hawks were nesting all along amongst the grass on the lower parts of the island, while on other parts of the island penguins were sitting in thousands. There were fewer seals and sea-elephants on the beaches, than what I have observed on former visits earlier in the year, but still great numbers were on the beaches and around the ship. The hut in which the stores are placed for shipwrecked sailors seemed intact, and groups of penguins were sitting fear-

lessly alongside of it, thus showing that no human being was in the vicinity. I did not haul the ship out towards the Twelve Apostles' Rocks because I was afraid of submerged dangers. I examined the tower constructed by the survivors of the British ship "Strathmore," and observed the oars still on it, but no signal to call any attention was visible by my telescope. I then steered for Possession Island and passed abeam of the perforated rock at 12·25 p.m. Coasting along the northern shores, distant probably from one to two miles, we examined the hut containing stores in America Bay. The penguins here again, with an occasional seal were the only visitors. Snow covered the highlands, and lovely streams and waterfalls were in sight in the ravines. I did not steam so far round as Ship Cove, where another hut with stores is placed, as it means the loss of nearly one hour, and on the north-east corner of the island a field of kelp stretches a good bit off the point, thus showing that there may be rocky prominences which it would be prudent to avoid. A course was set to pass two miles off East Island on its northern side; beyond birds and seals nothing else appeared to disturb the solitude. Large masses of ice were ashore in most of the bays in nearly all the islands and in the offing great numbers of bergs appeared like a continuation of the Twelve Apostle Rocks.

We traversed over 1,500 knots, and if the weather had always been clear, we probably would never have been out of sight of ice in this long journey, we saw about three hundred bergs over fifty feet high altogether, and of course broken masses dangerous to shipping were around in all directions.

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
124	Feb. 1894	Blairmore	46 15	22 0	First ice met with, last ice seen at 51° S. 50° E.
	Oct. 1895	,, ...	48 0	25 0	First ice seen, and for four consecutive days six or seven icebergs were seen daily, which averaged from one to two miles long. Fourth day the last ice was seen at 49° 9′ S. and 60° 27′ E.; this appeared very old as it was much worn. I have made careful test of the water and I could not discover any difference in temperature.
		,, ...	50 5	34 32	
125	Jan. ,,	Primus	...	Voyage Monte Video to Sydney.	Sighted ice from two to three hundred feet high; saw eight bergs in one day, and altogether thirty or forty pieces of floe ice were passed. Exact position not given.
126	Feb. 13, ,,	Wilcannia	45 4	52 30	Sighted a small iceberg.
127	July ,,	Germanic	Sydney to Rotterdam viâ Cape Horn		Passed thirty-six large icebergs, and for eight days we were among little else but ice, between New Zealand and Cape Horn.
128	Nov. ,,	Pericles			
129	Nov. 20, ,,	Coromandel	44 0	46 0	Passed several small icebergs.
			43 0	51 0	Saw a large iceberg about three hundred feet high and one mile long; next day more ice was seen, one iceberg being two hundred feet high, and some small pieces.
130	Dec. 21, ,,	Loch Bredan ...			
131	,, 23, ,,	Culgoa	46 0	29 30	Sighted an iceberg nine hundred feet high.
			47 0	65 47	Sighted an iceberg ten miles distant south of the ship, about one hundred feet high. When nearing the Crozets so much ice was fallen in with that the course was altered to make the easting on the forty-sixth parallel.
132	,, ,,	Gulf of Martaban ...	43 0	63 40	Sighted an iceberg about fifty feet high and 250 feet long.
133	,, 31, ,,	Thistlebank...	43 0	46 0	Sighted an iceberg twelve miles off, about one hundred and fifty feet high and half a mile long.
134	,, 12, ,,	Salamanca	47 14	64 0	Fell in with a quantity of ice, some was very small, one piece was just awash.

Ref. No	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
134	Dec. 12, 1895	Salamanca	47 20	70 0	Passed through a quantity of ice, detached masses broken adrift from bergs. On the voyage homeward last year, some grand bergs were seen after rounding the Horn.
135	„ 29, „	Dartford	44 30	48 0	Passed an iceberg one hundred and fifty feet high and a quarter of a mile long.
136	May 16, 1896	Frieda Mahn ...	45 10	*9 0	Passed an iceberg seven hundred feet long and two hundred feet high.
	„ 23, „	„ ...	...	...	One iceberg five miles off, three hundred feet high and one thousand feet long; at 9 a.m. passed another about the same size and one mile distant; at 2·30 saw several icebergs and quantity of floe ice. Fell in with a dense fog and was compelled to heave the ship to, in order to avoid collision with ice. May 24th, at noon, after clearing a little, saw four large icebergs, and after this, ice was continually in sight until the 26th of May.
	„ 24, „	„ ..	...	...	
	„ 26, „	„ ...	44 40	53 10	Last ice met with, altogether more than fifty bergs seen.
137	„ 23, „	Gulf of Mexico ..	44 33	46 56	At 8 a.m. sighted ten icebergs from twenty to fifty feet high, the largest being two hundred feet long; temperature of air 46°, water 44°; they were lying from one another in a N.N.E. and S.S.W. direction.
	„ „	„ ...	44 40	47 30	At 11 a.m. passed two icebergs; temperature of air 46°, water 44°.
138	„ „	Thirlmere	40 0	...	Ran our easting between 40° S. and 42° S. Saw no ice.
139	July 17, „	Southern Cross ...	44 40	47 20	Passed a small iceberg two hundred feet high, three hundred feet long; temperature of air 42°, sea-water 39°.
	„ 18, „	„ ...	45 5	51 20	Passed an iceberg three hundred feet high and five hundred feet long; temperature of air 41°, sea 39°.

* This position is somewhat uncertain, but agrees with the period during which ice was seen, and the last longitude 53° 10′.

ICEBERGS IN THE SOUTHERN OCEAN.

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
139	July 18, 1896	Southern Cross ...	45 18	51 25	Passed an iceberg two hundred feet high, quarter mile long.
140	„ 19, „	Gulf of Bothnia ...	43 56	43 44	Passing through showers of snow.
	„ 20, „	„ ...	44 0	49 14	Passed a quantity of small ice.
	„ 21, „	„ ...	44 12	54 33	Continuous snow and sleet.
	„ 24, „	„ ..	44 20	72 29	Rain and hail showers.
141	„ „	Damascus	46 30	55 0	Passed between twenty and thirty icebergs on the run across the Southern Ocean.
	„ 24, „	„	...	...	Crozet Islands covered with snow, and twenty-six large icebergs were passed among the islands and in the close vicinity.
142	Aug. „	Kaikoura	Voyage to Tasmania viâ Cape.	54 to 70	From longitude 54 to 70° East six icebergs were met with, and much broken ice was seen in the track of vessels bound to Australia and New Zealand.
143	„ 5, „	Buteshire	45 19	55 27	From August 5 to 7, the steamer was amongst icebergs, some of which were one hundred and fifty feet high, and were surrounded by floes of small size, all most dangerous to shipping.
	„ 7, „	„	46 3	66 8	
144	„ 30, „	Carnedd Llewellyn...	45 40	58 0	Sighted three large icebergs about three miles distant, some three hundred feet high.
	„ 31, „	„ ...	...	...	Saw several large blocks, one four hundred feet long and four hundred feet high.
145	„ 5, „	Lowther Castle ...	43 3	31 19	Frequent squalls, hail and snow.
	„ 6, „	„ ...	42 52	34 43	Moderate breeze and snow.
	„ 12, „	„ ...	45 52	54 8	At 9 a.m. passed a large iceberg.
	„ 14, „	„ ...	46 32	64 30	Passed three large icebergs.
	„ 15, „	„ ...	46 36	69 15	Fresh breeze and snow squalls.
	„ 17, „	„ ...	46 44	78 14	Frequent snow squalls.
	„ 18, „	„ ...	46 47	82 30	Snow squalls.

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
145	Aug. 21, 1896	Lowther Castle ...	47 2	96 36	Heavy snow showers.
146	„ 13, „	Hawkes Bay ...	46 0	47 0	Icebergs seen.
	„ „	„ ...	46 30	47 33	At 10·30 a.m. passed one iceberg and two small pieces.
	„ „	„ ...	...	...	Passed one iceberg to northward, two hundred and ten feet high distant two and a half miles.
	„ „	„ ...	46 35	48 39	At 4·45 p.m. large iceberg to southward two hundred and twenty feet high, distant one and a half miles.
	„ „	„ ...	46 38	49 22	At 8·30 p.m. icebergs to southward.
	„ 14, „	„ ...	46 50	51 46	Five large icebergs to northward at 8 a.m.
	„ „	„ ...	46 52	52 41	At 9·30 a.m., iceberg to southward two hundred feet high; 10 a.m., ice to northward three hundred and fifteen feet high.
		„ ...	46 53	52 55	At 10·30 a.m. iceberg to southward sixty feet high, and ice to northward two hundred feet high.
	„ „	„ ...	47 51	56 40	At 4 p.m. two icebergs to southward, and one to northward.
	„ 15, „	„ ...	47 42	58 9	Eleven icebergs to southward.
		„ ...	47 47	59 29	Iceberg to southward one hundred and eighty five feet high.
	„ 16, „	„ ...	47 48	64 44	At 8·30 a.m. iceberg to southward.
		„ ...	47 48	64 59	At 10 a.m. iceberg to northward one hundred and sixty five feet high.
147	Sep. 22, „	Thermopylæ ...	45 9	49 24	At 2 p.m. passed iceberg half a mile long and six hundred and forty feet high.
		„ ...	...	...	At 8 p.m. passed large iceberg and numerous large pieces; very dangerous to shipping; snow squalls.
	„ 23, „	„ ...	46 4	56 20	At 12·30 a.m. passed large iceberg; moderate gale with heavy snow falls; 5 a.m., two large icebergs and several smaller; 6·30 a.m. another large berg and pieces 3,800 feet long, four hundred feet high, flat top and perpen-

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
					dicular sides, numerous smaller bergs; 8·20 a.m. large berg; 3·30 p.m. large berg; at 4·30 p.m. another; 6 p.m. several smaller ones; clear weather, snow squalls.
147	Sep. 24, 1896	Thermopylæ ...	46 17	63 27	Frequent snow and hail squalls; 2 p.m. iceberg three hundred and fifty feet high; 4·30 p.m. very large berg, fourteen miles distant, probably a mile long; snowing heavily at times.
	„ 25, „	„ ..	46 20	70 47	At 6·45 a.m. large iceberg twelve miles distant; 8 a.m. small berg; 9 a.m. large iceberg; 10 a.m. two more bergs; 11 a.m. large berg two miles off and numerous smaller bergs; 12·30 midnight passed the last iceberg, also a very large one. This icefield is over one thousand miles long by twenty miles broad, and in the safety track adopted by most of the steam shipping companies. The sea was very high, but did not make the larger bergs roll, and the sea broke heavily on their faces and on outlying portions.
	„ 26, „	„ ...	46 27	78 26	This was the last berg seen by us; probably as many more were near our track, but were not seen.
	„ 27, „	„ ...			Sky full of snow; squalls and snow.
	„ 28, „	„ ...			Snow and hail.

The icebergs mentioned were only the large ones over 100 feet high; the highest was 640 feet; I was very careful to get good angular measurements of those we could comfortably approach. Great disputes have arisen about the heights of these bergs in the *Nautical Magazine* and elsewhere, some having been reported in the South Atlantic 1500 feet high; seeing that these have travelled so far they must have been an exceptional size when launched from their southern home. The temperature of the sea fell to 40° Fahrenheit 12 hours before sighting the first iceberg, and a careful record of these readings, taken at least every two hours, was kept while in the neighbourhood of the ice; the lowest reading was 35·5°

Fah. at 8 p.m. on the 24th, in latitude 46° 17′ South, longitude 65° East; being dark and heavy snow squalls around, no bergs were at that time visible, but as numbers were seen before sunset, and several at sunrise, the probability is that large masses were in the vicinity. Thermometric readings of the temperature of sea water were taken about one mile apart as large icebergs were approached or left behind, for the purpose of finding out if this would be of any guide to enable ship masters to localise ice, with the result that no movement of temperature could be depended on. The thermometer fluctuated from 35° 5′ Fah., the lowest reading, to 43° Fah., the highest, taken as we passed the last berg. It may be taken for granted, however, that as soon as the sea temperature falls to 45° Fahrenheit it indicates that you have entered an Antarctic cold current, and ice may be expected at any moment, so that a vigilant lookout becomes imperative. With such experience of icebergs the reports of ships travelling to the north of us would be interesting. The heavy gales and boisterous cold weather we experienced were probably due to these great masses giving off so much cold. The sea temperature being below the average, the reports from ships travelling on a parallel to the north of us will be interesting. See diagram ot ship's track.

ICEBERGS IN THE SOUTHERN OCEAN.

Ref. No.	Date.	Ship's Name	South Lat. °	′	East Long. °	′	Remarks.
148	Oct. 11–13, 1896	Aberfoyle	44	0	42	0	Sighted large quantities of ice.
149	„ „	Tongariro	45	30	21	0	For four days the steamer was passing between large bergs and loose ice, 119 icebergs being sighted in one day; the weather during the time kept fine and clear.
			47	0	80	30	
150	„ 13, „	Jupiter	43	16	52	0	First ice met with 43° 16′ South 52° East, and last seen in 73° East. On one occasion being between two large icebergs and surrounded by a quantity of broken ice during some terrific weather.
					73	0	
151	„ „	British Isles ..	...		...		For a time in company of the barque Jupiter, and met with similar experiences.
152	„ 26, „	Aberdeen	46	30	50	0	Observed a large iceberg ashore on Hog Island; Possession Island had numerous icebergs ashore. Then a strong west-south-west gale set in with hail and snow squalls, numerous bergs were passed until in longitude 70° East and latitude 44½′ south.
		„	44	30	70	0	

ICEBERGS IN THE SOUTHERN OCEAN.

Ref. No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks
153	Oct. 29, 1896	Forth	45	0	50 78	0 0	Met with several icebergs, some of which were three hundred feet high and from one to one and a half mile long. Travelled a distance of over 1000 miles with ice in sight nearly the whole of the way.
154	„ 21, „	Kilmory	46	30	40	0	First berg sighted on October 21, and for a week large quantities of ice were in sight, the ship being 200 miles East of the Crozets before she got clear; some of the bergs were five hundred feet high and half a mile long.
155	„ „	Lismore	...		...		Met with unusual quantities of ice, while crossing the Southern Ocean, was in close proximity to some immense bergs, and at times was embayed amongst a range of spiral and dome-shaped mountains of ice.
156	„ 22, „	King Arthur ...	40	0	40	0	A large number of icebergs were fallen in with, and for three days the ship was in close proximity to these floating dangers. The weather was thick and foggy.
157	„ 22, „	Firth of Lorne ...	42	42	57	20	Sighted two large icebergs. Passed three icebergs three hundred feet high in Long. 57° E. to 60° E.
		„ ...	43	0	...		
158	Nov. 3, „	Otarama	45	33	53	51	Ice was met with in great quantities, three hundred and seventy six large icebergs and considerable quantities of small ice being passed between that date and the 7th.
	„ 7, „	„	46	52	77	30	At 1 p.m. on the 7th the ship got clear of the ice. For over eleven hundred miles the ship was amongst ice.
159	„ „	Star of Victoria ...	45	0	53	30	Sighted in all twenty icebergs.
		„ ...	45	0	67	0	Last ice seen.
160	„ 6, „	Gulf of Taranto ..	43	40	54	0	Sighted on the 6th and 7th ultimo five icebergs varying in height from one hundred to three hundred feet, and from one half to two miles in length.
	„ 7, „	„ ...	43	40	59	0	

Ref. No.	Date	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
161	Nov. 7, 1896	Narrung	44 0	...	During the long stretch across the Southern Ocean forty-three icebergs were passed at various times, the easting being run between the parallels of latitude 44 and 45° south. Longitude not given.
		,, ...	45 0	...	
162	,,	Matatua	46 0	83 0	Among ice with heavy fogs for fifteen hundred miles.
	,, 9, ,,	,, ...	45 0	51 0	Seventy-six large icebergs and great quantities of broken ice being passed up to November 14th in latitude 46° South and longitude 83° East. One berg measured four hundred and twenty feet in height.
	,, 14, ,,	,, ...	46 0	83 0	
163	,, 4, ,,	Port Melbourne ...	44 24	50 21	At 5·30 a.m. passed a large iceberg. At 6 p.m. passed three huge icebergs and several broken pieces.
	,, 5, ,,	,, ...	45 0	56 58	During forenoon snow squalls passing over. Passing several icebergs and broken pieces in the evening.
	,, 6, ,,	,, ...	44 52	63 27	During forenoon snow squalls; 4·30 p.m. passed two large icebergs; 10·30 p.m. passed iceberg.
	,, 7, ,,	,, ...	43 59	70 13	At 9 a.m. passed a high-pointed iceberg close at hand. Several large bergs were passed estimated at eighty to five hundred feet high, and from a quarter to one mile in length; the first was sighted at 5·30 a.m. on November 4 in 44·20° South and 48·50° East, and thence to 44° south and 71° East the vessel was seldom clear of bergs of various sizes, the last being passed at 9·30 a.m. on the 7th; the last one seen was reckoned to be eight hundred feet high and five hundred yards long; this was the only one with pinnacles; all the others had flat tops as if melting away as they reached the warmer waters of the tropics.

Ref No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks.
164	Nov. 12, 1896	Loch Bredan ...	45	0	52	0	First ice seen on 12th, next day the vessel was surrounded with bergs of all sizes.
		,, ...	44	0	..		The vessel passed ice for a week after that date between latitude 44° and 45° south.
165	,, 25, ,,	Australasian ...	45	30	54	15	From 5 p.m. to 8 p.m. passed twelve icebergs of various sizes between these positions.
			45	15	55	0	
	,, 26, ,,	,, ...	44	55	58	45	At 7 a.m. passed two icebergs.
			44	32	61	38	At 6 p.m. passed an iceberg.
			44	36	62	42	At 10 p.m. passed three small bergs.
	,, 27, ,,	,, ...	44	30	64	5	At 2 30 a.m. passed an iceberg.
			44	0	67	0	From 3 p.m. to 3·30 p.m. passed three large icebergs and one small iceberg. Twenty-three bergs in all were passed, five being only a few feet above water.
166	,, ,,	St. Mary's Bay ...	43	0	...		Sighted icebergs in about 43° E. Longitude not given.
167	,, 28, ,,	Buckingham ..	44	30	75	50	An iceberg one hundred and seventy feet high was seen, and for several days bergs were in sight three or four miles distant.
168	,, ,,	Castor ...	...		50 to 90		While crossing the Southern Ocean the ship was constantly in sight of ice for 40°, the last in 90° East. In one day between thirty and forty bergs were seen from two hundred to three hundred feet high.
169	,, 29, ,,	Stassfurt	44	27	67	46	Two immense bergs were passed, one being close to the vessel, they were estimated at about seventy feet in height and eight hundred feet in length; another two hundred and fifty feet high and one mile long.
	,, 30, ,,	,, ...	44	18	68	43	A very large berg and a quantity of field ice were passed, and for the three following days many more bergs of various dimensions were met with.

Ref. No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks
169	Dec. 1, 1896	Stassfurt	45	15	78	56	Passed her last berg.
170	Nov. „	Pakeha .	44	0	37	17	First ice met; during the time a tremendous quantity of broken ice was met with, and as many as 4500 bergs were counted, ranging from twenty feet to four hundred and fifty feet in height. The ice was in dangerous proximity to the ship, and on one occasion had the engines stopped for three hours. Fell in with the same ice as the s.s. "Stassfurt." Got clear of the ice.
			to		to		
			45	4	83	31	
171	„ „	Bunga ee ...	45	0	64	0	Several large icebergs were seen between 64° and 85° East.
					85	0	
172	Dec. 2, „	Charles Racine ..	...		...		When sixty miles north of the Crozets twelve icebergs were passed.
	„ 3, „	„ ..	...		...		Almost embayed in floe ice, which was almost awash. Later immense bergs, estimated at from 1200 to 1500 feet in height and one mile in diameter, were in sight.
173	„ 3, „	Gulf of Venice ...	44	30	61	24	The first berg seen. Next day there were four in sight, one very close to the ship. Suddenly, without warning, there was a tremendous report, followed by several others, as the berg broke up into pieces, which, falling into the sea, created great commotion for a time.
	„ 4, „	„ ..	45	0	68	0	
	„ 5, „	„ ...	...		79	47	
174	„ 5, „	Perthshire	45	30	57	50	Met the first ice; during the next few days there were counted in all one hundred and five bergs during daylight, consequently it may be assumed an equal number passed at night. Some were very large, varying from two hundred to five hundred feet high. The last ice noted.
		„	46	14	85	0	
175	„ 7, „	Dungaree	45	0	68	50	At 8 p.m. passed an iceberg four hundred feet high. Temperature of air 38°, water 43°.

ICEBERGS IN THE SOUTHERN OCEAN.

Ref. No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks.
175	Dec. 8, 1896	Bungaree	45	0	73	50	At 3 p.m. passed an iceberg two hundred feet high. Temperature of air 41°, water 48°.
	„ 10, „	„	45	0	83	48	At 4 a.m. passed an iceberg seventy feet high. Temperature of air 41°, water 50°.
176	„ 23, „	Gulf of Martaban ...	45	3	63	55	At 10·30 a.m., passed an iceberg fifty feet high and three hundred and fifty feet long.
177	„ 24, „	Damascus	46	20	49	40	On the morning of December 24 ice was met with; twenty-three large icebergs were passed, and numerous small pieces, between these positions.
	„ 25, „	„	47	30	49	0	
	„ 26, „	„	48	10	54	30	Ice again met with, and from that position to the 29th of December nine hundred and fifty four large bergs and innumerable small pieces were passed. So close were they in some places that some difficulty was experienced in keeping clear of them. The average height of the icebergs was estimated at one hundred and eighty feet; many of them proved to exceed four hundred feet high and half a mile long. From midnight on the 26th till midnight on the 27th, between latitude 48° 50′ South, longitude 58° 46′ East, and latitude 49° 20′ South, and longitude 66° 10′ East, the icebergs were most numerous, seven hundred and eight being passed in 24 hours—two hundred and thirty six from 4 till 8 a.m. The weather at this time was beautifully clear. Numerous large bergs stranded on Kerguelen Island on the 29th, and also on some of the outlying islands.
	„ 29, „	„	50	30	77	0	
178	„ 25, „	Culgoa	45	50	53	30	At 10 a.m. two large bergs were sighted. At 11 a.m., being then six miles distant from the nearer one, its dimensions were—height two hundred feet, length 1100

Ref. No	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
178	Dec. 25, 1896	Culgoa	45 50	53 30	feet. Water temperature had not varied more than 2° during previous 24 hours, from 41° to 43°. Several more bergs and drift ice, only a few feet above water, passed during the afternoon ; the bergs ranged in height from eighty feet to one hundred and fifty feet. At 2 a.m. another enormous berg passed to the northward about seven miles distant; the light being insufficient, no measurements were taken ; surface temperature still remained at 42° and 43°. No more bergs were seen after 4 a.m. on December 26 ; at noon the surface water temperature had risen to 51°, falling again at midnight to 46°. At 8 a.m. on 27th December passed within a mile of two bergs one hundred and thirty feet and one hundred and sixty-five feet in height ; were constantly passing bergs of all sizes up to three hundred feet in height ; last ice left behind shortly after 3 p.m. on 27th ; frequent temperatures of surface water were taken, ranging from 41° to 43° ; at 6·30 a.m. on December 30, one small berg seen about five miles distant, temperature of air at the time 50° and water 48°. The length of the district in which the ice was met was about seven hundred miles between longitude of the Crozet Islands and Kerguelen Island, and the width may be safely assumed at twenty-five miles.
	„ 27, „	„	45 38	67 0	
	„ 30, „	„	45 30	87 30	
179	„ „	Ellesmere	43 0	43 0	First ice met with ; the spectacle lasted for three days, during which time some enormous bergs were sighted measuring three hundred feet in height and 1000 feet long. Appeared to be trending from W.S,W. to E.N.E.

ICEBERGS IN THE SOUTHERN OCEAN.

Ref. No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks.
180	Jan. 10, 1897	Ellora	46	0	41	47	At midnight the vessel touched some drift ice; next day the vessel was completely beset, some of the bergs were from five to eight hundred feet high; up to the 19th
			42	45	41	10	bergs were seen in all directions. Last ice seen in 42° 45′ S. and 41° 10′ E.
181	,, ,,	Gulf of Lions ...	43	52	40	57	Fell into the icy region which lasted to 79° 20′ E., during which time one hundred and twenty-four large bergs from one hundred and fifty to six hundred feet high were counted, besides countless field ice, in fact for a distance of over 1600 miles the ice in bergs or floes remained, the
	,, 18, ,,	,, ..	47	7	79	20	weather being intensely cold.
182	,, 11, ,,	Gulf of Ancud ..	45	0	...		From 7th to 11th navigating through a field of ice floes, with light winds and and a dense fog.
183	,, 13, ,,	Port Chalmers ...	44	19	44	53	At 6 a.m. passed an iceberg to southward; passing icebergs all day, last one seen at 10·30 p.m.; passed in all twenty-nine bergs ranging from a quarter to two miles in length and many small pieces.
	,, 15, ,,	,, ...	45	24	57	2	At 3·15 passed an iceberg; temperature of water 45·8°.
	,, 16, ,,	,, ...	45	19	63	3	At 4·8 a.m. passed eight icebergs and many small pieces; at 8·12 a.m. passed five icebergs; at 7 p.m. passed two icebergs; at 10·10 p.m. passed an iceberg.
	,, 17, ,,	,, ...	45	22	69	44	At 3·30 p.m. sighted an iceberg; at 4·8 p.m. passed five icebergs and many small pieces; at 11·10 p.m. passed an iceberg; at 11·25 p.m. passed a very large iceberg.
		,, ...	...		72	0	Last ice seen.
184	,, 17, ,,	Hubbuck	45	6	39	26	Two bergs each half a mile long were passed. The next day a remarkable berg three miles long and six hundred feet high was in company; at 3·30 p.m. the same day

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
					two bergs eighty feet high were in sight, and at 8 p.m. a berg two and a half miles long and three hundred feet high, later on another was passed one mile long and four hundred feet high. A large berg aground close to Penguin Island. The vessel's course beset by bergs.
	Jan. 19, 1897	Hubbuck	..	...	
	„ 21, „	„	...	...	
	„ 22, „	„	47 0	73 0	A very large berg five miles long, and the last one seen.
185	„ 17, „	Fifeshire	43 0	52 0	Saw a very large iceberg, no others met with.
186	„ 19, „	Lindley	43 0	48 0	Passed three large icebergs about half a mile distant.
187	„ „	River Falloch ..	42 56	54 30	Sighted icebergs, distance between them fifty miles, the highest about three hundred feet.
188	„ 20, „	Nineveh	43 54	41 15	At 5 p.m. passed an iceberg, 7·30 p.m. passed an iceberg.
	„ 21, „	„	45 14	47 56	4·15 a.m. passed an iceberg, 4·45 a m. passed an iceberg.
	„ 22, „	„	45 59	54 44	6 a.m. passed an iceberg and a quantity of small ice.
	„ 23, „	„	46 39	61 0	2 p.m. passed an iceberg; 8 p.m. passed an iceberg.
	„ 24, „	„	46 54	65 0	Passed forty-two bergs and a lot of small ice to day, some of the bergs being eight hundred feet high and a quarter mile long. 6 a.m on the 25th passed an iceberg, the last one. The weather from the first day of sighting the ice was very foggy.
	„ 25, „	„	45 28	71 36	
189	„ 26, „	Essen	42 50	44 35	From the 26th to the 31st the vessel was completely beset on all sides as far as the eye could reach, the bergs in some cases were two to three hundred feet high, in many instances the bergs had so melted away at the base as to topple over, causing the most terrible noises as they broke into fragments, this being the only guide to their position ; for over 1,100 sea miles the course was shaped among bergs. The one seen in 69° E. was from 300 to 400 feet high, and spread over an area of 100 to 1,000 yards.
				69 0	

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
189	Jan. 27, 1897	Essen	...	...	A large iceberg observed stranded on the Crozets Islands.
	„ 30, „	„	...	...	Ice on each bow, ran into an iceberg, but evidently on a sloping declivity, for after it struck the steamer slid off again without the slightest damage.
190	„ „	Hebe	46 0	40 0	Ice first met with, and for the next eight days during which the vessel covered a distance of 2,000 miles, the ship was in sight of ice, and at times was surrounded by large and small bergs.
191	„ 22, „	Timaru	43 0	48 0 49 0	Several large icebergs passed, some of these were fully two hundred feet high. Next day passed several others, the weather being very foggy at the time.
192	„ „	Indian Empire ...	41 42	...	Fell in with ice during the run across the Southern Ocean, some of the bergs were very large and drifting directly across the track usually taken by the Australian traders, bergs and drift ice met with for three days.
193	„ 31, „	America	On voyage to Dunedin	N. Zealand	Among ice for forty-two days. At night on this date an immense iceberg grazed along side the ship followed by crackling and a noise like the report of a cannon.
194	„ 28, „	Lika	47 0	...	Saw two middling sized icebergs, none the day following,
			48 0	37 0	but the day after and the two subsequent days I saw several large and small icebergs.
	Feb. 2, „	„	...	...	From 11 p.m. to 1 a.m. there was a heavy fog, at 4 p.m. it became very thick with a whitish appearance ; suddenly we saw a large and high island of ice right ahead and in close vicinity.
	„ 5, „	„	47 0	62 0	Collided with the iceberg, after the collision every part of the ship was full of broken ice. Temperature was 44°
			45 0	66 0	Fah. The temperature went to 54° Fah., we were still in

Ref. No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks.
			44	0	...		close proximity to several large bergs. On the same date in the evening, the last of the ice was seen.
195	Jan. 7, 1897	Southern Cross ...	44	29	49	3	Passed three icebergs.
	,, 8, ,,	,, ...	45	15	55	26	Passed two icebergs.
	,, 10, ,,	,, ...	45	45	69	11	Passed fifty icebergs from fifty to three hundred feet high.
	,, 11, ,,	,, ...	45	51	76	0	Passed four small icebergs.
196	,, 18, ,,	Woolloomooloo ..	43	1	47	13	Passed an iceberg one hundred and thirty-seven feet high and six hundred feet long; Temperature sea water 50°; passed four icebergs, the largest four hundred and seventy feet high, nine hundred and eighty feet long; water 49°.
	,, 19, ,,	,, ...	43	43	54	18	Passed iceberg three hundred and fifty feet high and two miles long; passed two icebergs about fifty feet high; passed an iceberg one hundred and thirty feet high and three hundred and fifty feet long.
197	,, 20, ,,	,, ...	44	4	61	42	Passed a small berg.
	,, 22, ,,	Celtic King	42	0	49	0	Between 49° and 57° E. and mean parallel 42° we passed
	,, 23, ,,	,, ..	42	0	57	0	fifteen icebergs from one to five hundred and ten feet high, and a considerable quantity of drift ice; mean temperature of air was 55° and water 48° when most of the ice was passed. The last was seen at 4 p m. on the 23rd Feb., it was eight miles off, two hundred and eighty five feet high; temperature of air and water 61° during the time it was in sight.
198	,, 8, ,,	Nairnshire	43	30	45	0	A few days after passing the Cape two immense icebergs were sighted, one being estimated at over five hundred feet high. 10·40 p.m. ran stem on to a low iceberg, no serious damage. No less than sixty-two icebergs were passed, together with a quantity of small broken ice.
	,, 13, ,,	,, ...	...		...		

Ref No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks.
		Nairnshire	47	0	84	0	Emerged from the icefield.
199	Jan. 14, 1897	General Gordon ...	42	0	50	0	Between these positions twelve large icebergs were passed some fully two hundred feet high and half of a mile long, also a large quantity of drift ice was observed among the larger ones.
		,, ...	43	0	52	0	
200	,, 15, ,,	Gulf of Bothnia ...	44	14	44	37	Passed numerous bergs and large quantities of loose ice between these positions.
	,, 16, ,,	,, ...	44	46	50	6	
	,, 20, ,,	,, ...	44	56	73	49	Passed several icebergs and loose ice.
	,, 21, ,,	,, ...	45	8	79	50	Passed a large iceberg and quantity of loose ice.
		,,	44	58	82	53	More ice observed.
201	,, 15, ,,	Loch Doon	44	0	73	0	Passed a number of icebergs between these positions.
	,, 18, ,,	,, ...	45	0	83	0	
202	,, 20, ,,	Thermopylæ	45	29	44	46	First ice met with.
	,, 21, ,,	,, ...	46	12	51	27	Two icebergs near Apostles. Noon, numerous icebergs ashore on the islands. 6 p.m. passed East Island and numerous icebergs.
	,, 22, ,,	,, ...	46	29	58	47	Passed bergs at 8 a.m. and 8·15 a.m.
	,, 23, ,,	,, ...	46	36	65	58	At 8 a.m. large iceberg eight miles distant; passed bergs at noon. At 3 p.m. passed four icebergs, and from 4 to 8 p.m. passed ten icebergs; 8·12 p.m. passed twelve large bergs and numerous small ones.
	,, 24, ,,	,, ...	46	57	73	21	From midnight to 10 a.m. passed seven icebergs.
			47	30	80	0	Last ice seen. [NOTE.—See special account of ice in text.]
203	,, 24, ,,	Hawkes Bay ..	47	5	40	18	At 5 p.m. passed two icebergs and broken ice to the south.
	,, 25, ,,	,, ..	48	48	49	14	At 3 p.m. passed iceberg to southward.
	,, 26, ,,	,, ...	49	55	53	22	At 7 p.m. passed iceberg to southward, one mile distant.
	,, 27, ,,	,, ...	50	26	54	30	At 0h 30 passed two icebergs north and south respectively.
	,, 28, ,,	,, ...	50	51	64	54	At 2 p.m. iceberg to southward.

Ref. No.	Date.	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
	Jan. 28, 1897	Hawkes Bay ..	50 51	65 26	At 4·30 p.m. iceberg to northward.
	,, ,,	,, ..	50 52	64 24	At 7 p m. iceberg to southward.
	,, ,,	,, ...	50 53	64 24	At 8·15 p.m. two icebergs to southward.
	March 1, ,,	,, ...	50 55	64 26	At 3·30 a.m. iceberg to northward and some broken ice.
	,, ,,	,, ...	50 56	64 27	At 7 a.m. iceberg ten miles northward.
	,, ,,	,, ...	51 6	70 49	At 11·45 a.m. two icebergs, one 265 feet high.
	,, ,,	,, ..	51 6	71 33	At 2·45 p.m. passed iceberg 265 feet high.
	,, ,,	,, ...	51 5	71 45	At 3·30 p.m. a quantity of broken ice.
	,, 2, ,,	,, ...	51 4	74 17	At 1·30 a.m. large piece of ice to northward.
	,, 3, ,,	,, ...	51 0	82 22	Passed through quantity of broken ice, berg to southward.
	,, 4, ,,	,, ...	51 10	90 53	At 5·30 p.m. small berg to north, passed several pieces of kelp.
	,, 5, ,,	,, ...	51 5	98 39	Passed some kelp. In order to avoid ice, a course over the easting was made on the 51st parallel of latitude, but the Hawkes Bay even in this high latitude sighted numerous bergs and floes, the icy region proved to be between 39° 18′ E. and 83° 59′ E., some of the bergs were of large dimensions.
204	Feb. ,,	Gulf of Siam ...	42 0	50 0	First ice seen, two icebergs to northward, each about one hundred feet high ; on the following day several others were passed, and one of these was estimated to be from four to five hundred feet high ; another of similar size was passed to southward; during the next few days several others were seen, a few of which were remarkable for their size and quaint appearance. The vessel's course was kept between the parallels of 42° and 43° S. The icy region extended from 50° to 60° E., or over a distance of five hundred and seventy miles.
		,, ...	43 0	60 0	

Ref. No.	Date	Ship's Name.	South Lat. ° ′	East Long. ° ′	Remarks.
205	Mar. 14, „	Trafalgar	45 47	W. 119 35	Sighted an immense solitary berg.
206	„ 8, „	Buteshire	44 50	50 15	Ice fallen in with accompanied with dense fog, which lasted for a week.
	„ 14, „	„	46 22	70 39	The last ice seen.
207	„ „	Aberdeen	43 30	...	To avoid ice the easting was made on a higher parallel than usual, approximately on 43½° S., but ice was seen all the same.
		„	42 44	55 0	Two large bergs and a quantity of drift ice was met with, the bergs were about two hundred feet high, and were passed close to.
208	„ 14, „	Invercauld	45 0	47 30	Sighted a very large iceberg. March 22, another iceberg passed, on the morning of the same day in a thick mist, had a narrow escape from colliding with one.
	„ 22, „	„	...	...	
209	„ 13, „	Pericles	43 40	50 0	Met a lot of icebergs, and next day got clear of them.
210	„ 15, „	Mamari	On voyage Auckland,	London to N.Z.	Remarkable experience amongst ice; on March 15, passed through a channel of ice extending for eighty miles.
211	„ 15, „	Indramayo	44 25	49 30	At 5·30 p.m. passed two icebergs, one 10′ south of the other.
	„ 16, „	„	44 35	54 10	At 1·30 p.m. passed an iceberg.
	„ 19, „	„	45 30	72 25	At 11·10 a.m. passed a large iceberg.

The following Nos. 212 to 228, were obtained from the *Nautical Magazine* of April 1896, and February, March, April, May, and June, 1897.

212	Nov. 17, 1895	Kaikoura	45 0	52 0	Passed a very large iceberg.
213	Dec. 23, „	Gulf of Lions ...	47 0	50 0	Sighted a berg one hundred and thirty feet high and four hundred feet long.
214	„ 9, „	Auldgarth	56 0	72 0 W.	Passed two bergs about five hundred feet high and five miles in length.

Ref. No.	Date.	Ship's Name.	South Lat. °	′	East Long. °	′	Remarks.
	Dec. 10, 1895	Auldgarth	56	0	68	0 „	Sighted eight more varying in height from one to seevn hundred feet, and in length from one to five miles.
215	Jan. 9, 1896	Loch Garry	55	27	61	48 „	Sighted a large berg and several detached pieces.
216	Oct. 13, „	Loch Fergus ...	45	0	50	0	In sight of numerous bergs and much broken ice.
	„ 20, „	„ ...	46	0	78	0	
217	Nov. 14, „	Rimutaka	45	16	52	4	Passed two hundred and four bergs and very much small ice.
	„ 18, „	„	47	57	82	25	
218	„ 3, „	Morna	55	0	52	0 W.	Sighted several bergs, one of which was very large.
219	Dec. 16, „	Banklands	46	0	11	0	Passed about one hundred bergs and much small ice.
	„ 27, „	„	45	0	69	0	
220	„ „	Sailing vessel ..	46	0	11 to 80		Sighted many bergs.
221	„ 28, „	Waimate	44	0	42	0	Passed sixty bergs and much kelp, on the 1st January ship was surrounded by small ice.
	Jan. 4, 1897	„	48	0	88	0	
222	„ 10, „	Concordia	42	0	47	0	Several bergs were sighted.
223	„ 10, „	Kaikoura	45	0	42	0	Passed many bergs.
	„ 17, „	„	48	0	80	0	
224	„ 17, „	Khyber	44	0	42	0	Sea thickly strewn with enormous bergs.
	„ 18, „	„	42	0	52	0	
225	„ 28, „	Cornwall	41	0	52	0	Passed two bergs one hundred and fifty feet high and 1000 feet long.
226	„ 24, „	Serena	41	0	50	0	Sighted ten bergs.
227	Feb. 7, „	Tekoa	45	0	45	0	Passed fifty bergs, an ice island and much loose ice.
	„ 13, „	„	45	0	78	0	
228	„ „	Australia	42	0	47 to 60		Passed several bergs.
229	„ 22, „	Loch Sloy	45	0	45	0	Innumerable bergs on every hand and much small ice.
	Mar. 1, „	„	45	0	74	0	Last ice.
			LIFE		BUOYS		PASSED.
1	Jan. 25, 1897	Celtic King	39	40 N.	12	50 W	At 7 a.m. passed within fifty yards of a large black painted buoy, with 5 painted on it in white. There had been letters also painted on it, but they were worn or chafed off.
2	Aug. 3, 1896	Valetta	36	49 N.	8	24 W.	At 7 a.m. passed a large cask buoy, ends white, red bands and rope round centre.
	July 29, „	Woolloomooloo ...	43	5 S.	79	17 E.	Passing through small quantities of sea-weed.

AURORA AUSTRALIS.

By H. C. Russell, B.A., C.M.G., F.R.S.

[*Read before the Royal Society of N.S. Wales, Novembrr 3, 1897.*]

Within the last few years associations of persons interested in the study of auroral displays have been formed, in the countries which surround the North Pole, with the common object of investigating the phenomena presented. Many new and important facts have already been brought to light, and something has been done towards connecting the phenomena about the North and South Poles. I have done a little by collecting and publishing the reported Aurora Australis, but I feel that what has been done is not enough, and that if these records are published in our Society's volume they will reach a much wider circle, and further will, I hope, lead all those who see the Aurora Australis to report it.

Sailors generally believe that the Aurora is a sign of coming bad weather, and they are keen observers. Nearly all the information about displays come to me in ships' logs, but we want also the help of those on shore who are in good positions for observing. Two of the auroral displays in April this year were unusually magnificent, and one of them which I want to bring before you this evening was the finest ever seen in the southern hemisphere, so far as I have been able to ascertain.

This was observed by Capt. Campbell Hepworth, R.N.R., of the R.M.S. *Aorangi*, who sent me the following description of what he saw, which reads much more like the description of an aurora seen in the far north by arctic observers, than what we should expect to be seen between the Cape of Good Hope and Australia, where the *Aorangi* was in 96° East and 47½° South, when the aurora was seen :—

"BRIEF NOTES OF A FINE AURORA SEEN ON APRIL 20, 1897.

It was first seen as a diffused light over the southern horizon, like the light over a distant city which is illuminated by electric

light, from this light flashes or rays soon shot upwards, and in every direction increasing in length and brilliancy, until at 7·30 p.m., they were shooting across the sky to within 30° of the northern horizon. Cones and circles of light travelled rapidly over the whole sky, and flashing beams of intense light darted from one to the other. This continued until 8·30 p.m.

A remarkable change then occurred, the sky being cloudless, moon and stars shining brilliantly; an arch of bright green light, fading off into yellow, formed over the southern horizon rose rapidly to a higher and higher altitude, and was followed by similar arches in regular succession, until there were six arches quite distinct, their apices being from 10° above the southern horizon to 60° above the northern horizon; these arches appeared to be formed of vertical bars of light side by side, thus building the arches of light, which varied in width from 5° to 20° each, and all of them were bright green and yellow at the tops of the arches, and of a rosy hue where they touched the horizon. Subsequently these arches changed their shapes in all parts of the sky, forming remarkable bands of light, and in some cases patches of light, which in all cases seemed to be fragments of the original arches, from the curves they presented, with the exception of two places, where the bands seemed to meet at right angles.

Up to 8·30 p.m. the flashes of light which came from the southern centre of action seemed to shoot along the eastern horizon, and then rise up like bands of light on hinges at the north and south points of the horizon, sweeping across the sky to the west; after 8·30 the flashes of light seemed to shoot vertically upwards. A *circle of light* about 30° in diameter now formed about the zenith, and the rays of light before referred to seemed to rise up to the circle, but did not touch it exactly at right angles, but slightly tangential, so much so that they suggested the picture of a cyclonic centre with winds blowing tangentially round it.[1]

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[1] This is more like the Aurora observed in Melbourne 2/9/1858, than any other I know.

Pendent overhead one could see the cloudless blue in the centre of the ring-shaped tassel of coloured light. Later a spiral cord of light, shewing three perfect coils formed at the zenith, and like the ring of light, travelled to westward, while two patches of brilliant light, spiral in form like a waterspout, were flaring in the west.

The barometer had been for forty-eight hours prior to the display abnormally low, between 28″·90 and 28″80 (Board of Trade Barometer) and the wind from W.N.W. strong. A fresh to moderate gale had been blowing previously.

In the midst of the grand display just recorded, a remarkably bright meteor, starting from Canis Major in the north-west, travelled slowly across the sky to the south-west, discharging at intervals fragments of colour, and thus adding to the splendour of the scene. A special feature of the display must be mentioned. It was that all parts of the display had a motion to the west like a changing panorama. After 9·15 p.m. the aurora was less brilliant, but burst into greater activity a few minutes afterwards, more especially in the northern semicircle. The display lasted until 9·45, gradually fading after 9·30 p.m."

This short account was prepared by Commander Hepworth hurriedly, while he was getting ready for the first voyage in the new service with the *Aorangi*. He expressed his intention of sending a fuller account of the aurora to the Royal Meteorological Society, London, as soon as he could find leisure to write it.

In the mean time the third officer of the *Aorangi*, with the permission of the commander furnished me with the following account based on his own observations while on deck, and those of the chief, third, and sixth engineers who were very much interested in the aurora.

Mr. Bayldon, third officer, says, "Herewith I send you our account of the aurora. It is compiled from the notes I made at the time whilst actually watching the scene, and from an account written next day, and it has been overhauled by our chief, third, and

sixth engineers, who were all interested spectators, and nothing in the account was allowed to pass unchallenged."

In conference with Mr. Bayldon before he wrote the account for me, I asked him if possible, to compare what he saw with the pictures given in "The Aurora Borealis," by Alfred Angot (1896 London), and the references are to the plates in that work.

He says, "If the arches in the frontispiece were more regular they would fairly well represent the rising of our arches, but ours were much farther apart, and were most perfect when near the horizon. Figures 2 and 3 resemble the bands of light which we noted before 8·30 p.m., but ours were much fainter, and moved from east to west as if they were arches pivotted at north and south points. Figure 6 resembles many conditions we saw after 8·30 p.m., while figure 7 fairly represents the rays we saw radiating in all directions from the southern horizon, though with us they did not radiate with anything like the regularity and profusion shewn in the diagram. Figure 8 resembles very many patches of auroral light which we saw after 8·30 p.m., excepting the dark lines, which we did not see. The lower point of No. 8 might answer to what we have called a water spout. Figures 12, 13 and 14 (without the hook) were many times illustrated, especially in the circle and spiral chord, which we have described, though we saw nothing approaching figure 13 in grandeur.

"There is one feature of the illustrations which strikes us all as very different from what we saw, and that is they all shew the lower edge of the arches as defined and the upper one as shading off into drapery. In all that we saw, this was reversed; with us the upper edge was defined and the lower edge shaded away into drapery.

"The aurora first became visible at 6·30 p.m., on April 20th, 1897 (apparent time at ship), as a bright diffused light in the southern horizon, above a heavy bank of cumulus, the sky being perfectly clear elsewhere and stars shining brightly. Soon separate and distinct beams of light flashed from this diffused light in every

direction—horizontally, vertically, and obliquely—like electric search lights increasing in length, breadth and vividness until, at 7·30 p.m., the vertical beams reached to within 10° of the northern horizon. Faint beams of light during the same time also formed in the east, and swept rapidly across the entire sky from east to west, passing through the zenith and reaching from the southern to the northern horizons. Cones and patches of intense bright light also appeared in all directions, discharging beams and flashes of light incessantly from one to the other, like electrical discharges or lightning. This continued until 8·30 p.m. The moon rose at 7·18 p.m., and every particle of cloud disappeared, the night being very bright and clear with moderate north-west breeze. Barometer 29·00; thermometer 44°.

"At 8·30 a most remarkable change occurred; until then the aurora had been simply composed of white light of homogeneous structure, now colours and hues of every description appeared suspended vertically in the sky. A narrow arch—the upper edge perfect in outline as a rainbow, the lower edge serrated and fringed, owing to the difference in length of the beams or bars of which it was composed—suddenly appeared 15° above the southern horizon of rich green and yellow hues, and rapidly rose to a higher altitude. Another of the same description formed and followed it, others followed in similar order until there were six distinct arches of drapery, the first tier then being about 60° above the northern horizon. They were long narrow arches from 5° to 20° wide and made up of vertical stripes and streams of light, like Mr. Angot's frontispiece, which were suspended in a pendulous position in the sky, the upper half of the drapery being bright green and yellow, while the lower half was of pink and roseate hues. Rapidly the arches changed and contorted into fragmentary scrolls of many shapes; in all parts of the heavens other such formations appeared cloud-like and evanescent to north, south, east and west, in some cases lasting only a few seconds, in others for a minute or two; all of the brightest green, yellow, and roseate

hues, changing their shape and position with almost inconceivable rapidity. Dark arches also were visible.

"When any such drapery appeared directly overhead, only a gorgeously bright, very narrow, sinuous line was presented, but when viewed obliquely, the fringe-like depth of the scroll, with its different shades of colour was most beautifully apparent. Every formation was arranged in some sort of curve or spiral (excepting two which formed two distinct right angles); every one directly it appeared darted away to the westward, and in every one there appeared to some observers to be a rotatory movement amongst the coloured particles of which the drapery was composed, whilst to others this movement appeared to be wave-like; horizontal flashes continually darted from one nebulous mass to another. To add to the splendour of the scene, at 9·10 p.m. a remarkably bright meteor slowly passed across the western horizon from Canis Major, bursting into many coloured fragments and passing underneath several of the fragmentary parts of the aurora.

"In such an extensive and ever changing panorama it is impossible for one observer to accurately describe the many interesting aspects which so continually presented themselves, and so rapidly vanished. Each one would catch a glimpse of something different, and could only form a very general idea of what actually took place. However three formations were so brilliant as to be noted by all—First, at 9 p.m., when a magnificent circle of light appeared directly around the zenith, with a diameter of about 20° formed as before of draped rays of beautifully tinted light. Looking upwards through this circle it was plainly seen that these rays were not strictly perpendicular, but slightly slanting downwards from left to right, and the rotatory or wavelike movement of every particle was most apparent. Secondly at 9·5 p.m. when a spiral scroll of three chords arranged itself round a nucleus a few degrees to the northward of the zenith. Thirdly, at 9·15 p.m., when two forms of exceptionally bright light appeared like waterspouts 10° high in the western horizon, which was probably a perspective view of a sinuous line of drapery reaching below the horizon.

"After 9·17 p.m. the scene lost much of its brilliancy only to burst again into magnificent activity at 9·20 p.m., being brightest and most intense in the northern semicircle, and lasting until 9·30 p.m. After this the splendour gradually faded away, though occasional discharges of bright flashes or the appearance of clouds of diffused light continued until 9·45 p.m., again being of homogeneous nature.

"Generally throughout the display, first magnitude stars were visible, shining through the aurora, though at times its brilliancy was so radiant as to totally absorb their light. The moon was bright with no halo around. After 10 p.m. the sky rapidly clouded over with cirro-cumulus and cumulus, and slight rain fell, the breeze falling very light. Throughout the previous day (April 19), the weather had been cloudy and unsettled, with a fresh north-west gale, which gradually moderated on the 20th. During the night of the 20th, moderate to light north-west breezes until midnight, and then variable southerly breezes prevailed. At 8 p.m. on the 21st the wind rapidly freshened to a moderate south-west gale, which continued until the evening of the 22nd."

A second display of the Aurora Australis was witnessed from R.M.S. *Aorangi* throughout the whole of the night of April 23rd, 1897, from 7·15 p.m. until 4 a.m. April 24th, the ship being in Lat. 45° South, Long. 119° to 121° East; barometer 30·25; thermometer 45° F. Owing to the sky being very cloudy, with cumulus and showers occurring at intervals, but little could be noted of this aurora. A diffused light prevailed over the southern horizon throughout the night. At 9 p.m. two arches of more intense light appeared above the former southern horizon at the altitudes of about 20° and 45°, they were of a pale greenish hue. At 11 p.m. bright flashes in a vertical direction were apparent for a few minutes, all of a homogeneous structure. Throughout April 23rd, the wind was gradually moderating from a fresh south-south-west to light southerly breeze at midnight. At 8 a.m. on the 24th it again freshened to a moderate south-south-west gale which continued until noon of the 25th.

LIST OF AURORAS 1896-7.

No.	Date.	Name of Ship,	S. Lat. ° ′	E. Long. ° ′	Notes.
1	Aug. 21, 1896	Hawkesbury...	48 2	100 21	Aurora australis at midnight.
	,, 22, ,,	,, ..	48 1	101 20	Aurora at 4 a.m.
	,, 23, ,,	,, ...	47 49	106 31	Aurora at midnight no other particulars given.
2	Oct. ,,	Thermopylæ...	46 44	114 6	At midnight the aurora was very vivid.
3	Jan. 2, 1897	Damascus ...	48 9	107 10	Aurora australis visible.
4	Mar. 1, ,,	Hawkesbury...	51 4	73 49	Ditto ditto.
	,, 5, ,,	,, ...	51 34	93 53	Ditto ditto.
	,, ,,	,, ...	51 42	95 23	Ditto ditto.
5	April 20, ,,	Aorangi ...	47 25	96 40	Special notes in text
6	,, 23, ,,	,, ...	45 0	119 – 121	Ditto ditto.
7	Aug. 1, ,,	Damascus ..	46 0	108 40	At 8 p.m. cloudy, Aurora australis visible.

On "GREY GUM," (*EUCALYPTUS PUNCTATA*, DC.,) PARTICULARLY IN REGARD TO ITS ESSENTIAL OIL.

By R. T. Baker, F.L.S., Assistant Curator, and H. G. Smith, F.C.S., Mineralogist, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, September 1, 1897.*]

I.—Introduction.

Schimmel & Co. in their pamphlet under date April 1896, make the following statement:—"No reliable information of any kind can be given concerning the *botanical origin* of the Australian oil which we supply, as it is notorious that the leaves of the different varieties of Eucalyptus are no longer kept separate during the distilling process in Australia." It is the desire to remedy the state of things implied in the above paragraph, that has actuated us in entering upon our Eucalyptus oil research, (the first of which was read before this Society at its July meeting 1897), and as far

as New South Wales is concerned, we hope to bring under the notice of its commercial community, the means of removing this reproach, at present surrounding the Eucalyptus oils produced and exported from Australia. There can be no doubt from the above quotation, that the desideratum of future productions of the oil is that the botanical origin be authenticated.

Each species investigated is vouched for, and botanical material (leaves, buds, fruits, bark and timber) of the trees, from which the leaves were collected under our supervision, are placed in the Museum herbarium, for future reference, and to determine any botanical queries that may occur. This plan will be adopted throughout the series, and with the botanical material each oil will be shown in juxtaposition, in the Museum essential oil court.

In Victoria, Tasmania, South Australia, and Queensland, distillations of *E. globulus*, Labill., *E. oleosa*, F.v.M., *E. Risdoni*, Hook. f., *E. rostrata*, Schl., *E. cneorifolia*, DC., and *E. maculata*, Hook. var. *citriodora* have been carried on with more or less success. In regard to New South Wales very little has been done to develope the eucalyptus oil wealth. We hope to show that there is one widely distributed species at least in the coastal area of this colony, yielding on oil equal in quality to any yet known in Australia. Our reasons for dealing with *E. punctata*, DC., so early in the series is, that of the twelve or more species distilled, this one proves so far to be the best.

To the suggested divisions of the genus Eucalyptus, depending upon structural differences, we feel disposed to add another based on the chemical constituents of the several trees.

II.—Histological Notes.

As our chemical determinations on the oil of this particular species resemble those of *E. globulus*, Labill., we have histologically compared the leaves of this species with those of *E. punctata*.

Had we at first thought to examine the leaves microscopically before the distillation we should not have been surprised at the large yield of oil, for of the dozen species so investigated not one

has its leaves so "thoroughly honeycombed" (if one may use the expression) with oil cavities or glands as this one—a feature that can be better noted in dried specimens than fresh ones.

The cavities are plainly visible by holding up a leaf to a medium light, but of course are more plainly seen under an one-inch or half-inch objective.

We have almost invariably found that the oil glands are always attached to the under side of the upper cuticle of the leaf, so that when the two surfaces of a leaf are drawn apart the lower one is quite destitute of these organs. To this fact we are inclined to account for the singular character that eucalyptus leaves have of twisting on their petiole—a fact of which we have long been cognisant, but of which we could not hitherto advance any explanation. It seems to us very probable that in order to prevent the upper surface of the leaves being always exposed to the sun's rays it is turned from them by a mechanical contrivance, the lower surface thus being brought round to bear the brunt of the heat, and so protect the oil glands.

There is, perhaps, little to add to the explanation of Figs. 1 – 5 The cuticle shown so distinctly over the oil glands, with Fig. 2 and 3, is very possibly stretched or extended over that body, and thus the cellular walls are more emphasised than in the more opaque parts of the leaf, although of course the same structure pertains over the whole leaf, but not so easily detected owing to the presence of the chlorophyll. In a dried leaf (the drawings are from a fresh one) the walls of the chlorophyll bodies are very distinct.

In *E. globulus* the texture of the leaf is much thicker, the palisade layers being much more numerous, and consequently the oil glands are not too prominent, nor are they so numerous. The cuticle is *apparently* structureless as compared with that of *E. punctata*, the cell walls of which, as delineated, form irregular polygons (mostly hexagons and pentagons).

Sections of the leaf of *E. globulus* are given by Baron von Mueller in his Eucalyptographia, so that we have not figured our

own preparations of that species, as our work corresponds in almost every particular with his observations.

The stomata of *E. punctata* are much smaller than those of *E. globulus*, and require a higher power objective to discern them. The transverse section of the leaf requires no further remarks than are given in the explanation of the plate.

Habitat.—The species has a much more extensive range than is generally supposed. It extends along the whole coast district from Queensland to near the Victorian border, or at least to Cambewarra and over the Dividing Range, very possibly well into the level country, having been collected by one of us beyond Rylstone. Of course for a species to occur over such an area as this, one expects to find it designated by several local names, but on the whole "grey gum" seems to be its general vernacular.

III.—The Chemistry of the Essential Oil.

(a) *General remarks.*—We submit this research on the oil of *E. punctata* as the first of several good oils obtainable from common species of Eucalypts, growing plentifully in this colony, and which give an oil comparable with that obtained from *E. globulus*. We wish it to be understood at once, that we have no intention to disparage in any way the oil from *E. globulus*, and we admit its excellence; but this species does not occur to any extent in this colony, so that as far as we are concerned, it is not for our consideration, except for comparison. But the impression that *E. globulus*, is the only Eucalypt from which a first class oil can be obtained is not correct.

This investigation deals more fully with the products of several distillations than will perhaps be necessary in future papers, but it enables us to say at once, that the "grey gum" of the Sydney district, *E. punctata*, gives an oil every way equal to that obtained from the leaves of any Eucalypt, the composition of whose oil has been determined, and we think we shall be able to show that it is quite as rich in eucalyptol as that obtained from *E. globulus*.

The time has arrived when it is imperative that the percentage of eucalyptol in an oil must be of the highest. It is usually considered that the therapeutically active agent of eucalyptus oil is eucalyptol, and commercially eucalyptol is the constituent required, and the value of eucalyptus oil is determined on the amount of that body present. Besides, the demand for pure eucalyptol is increasing considerably, and everything points to the fact that the inferior eucalyptus oils, or those consisting principally of terpenes, will become less and less in demand where the oils are judged on scientific principles and in an open market. We hope that the distillation of these inferior oils for medicinal purposes will cease. By these researches we hope to be able to direct attention to those trees from which good oils can be obtained, and to point out those species that are to be avoided.

We think that this is the first attempt to obtain an oil from the leaves of the "grey gum," *E. punctata*. It is perhaps remarkable that this species should have escaped so long, but although much has been done in regard to the oil obtained from some of the eucalypts, *E. globulus*, *E. amygdalina*, etc., yet, but comparatively few species have been touched. Our researches justify us in stating that other trees besides *E. punctata* will prove of value as oil yielders. The yield of oil is good, but we have made no attempt to treat leaves only, but have taken the leaves with terminal branchlets, as described in our previous paper on *E. piperita*.

The amount of work that has been undertaken in the investigation of the essential oils obtained from the eucalypts is very great, and the literature on the subject is enormous. Mr. J. H. Maiden, F.L.S., has brought together references to most of this in his Bibliography of Economic Botany,[1] so that it will be unnecessary for us to reproduce it here. The severe remarks often made respecting eucalyptus oils should be seriously considered. Schimmel and Co., in their semi-annual reports, write strongly on this

[1] Government Printer, Sydney, 1892.

matter, and their statements are important, because of their reputation. It is not, perhaps, necessary to refer to their earlier remarks on eucalyptus oil, so we only quote a few of the statements made during the last five years. In the 1892 April report appears the following :—"We, therefore, for several months, have only sold and quoted rectified eucalyptus oils, and guaranteed to contain 60–70 per cent. pure eucalyptol, crystallising at – 1°C. On buying eucalyptus oil in the future not only the name but also the percentage of eucalyptol should be taken into consideration. Eucalyptol is to be considered as the constituent of eucalyptus oil, to which its medicinal action must be ascribed." The October report of the same year contains the following :—"The opinion always maintained by us that the value of commercial eucalyptus oils must be determined according to their percentage of eucalyptol (cineol), and not by their origin and source, has recently been supported also by English experts. A specimen was sent to us from another house in Australia under the name 'Oil of Eucalyptus crude,' which proved completely worthless. It possesses a sp. gr. of 0.8616, boils between 160 and 195°C., contains a large quantity of phellandrene, but only small quantities of cineol in the highest fractions. The optical rotation is – 52°." In October, 1893, they report as follows :—"Under the circumstances the variation in quality of the Australian distillates which has once more shown itself lately is more and more fatal to those varieties. After a careful sounding of the London market we come to the conclusion that about one-half of the oils there offered were quite destitute of cineol (eucalyptol), or only contained the substance in feeble proportions." In April, 1897, the following appears :—"In the prevailing brisk competition in the supply of this oil between Algiers and Australia the latter seems to meet with increasing success. The choice in the purchase of this commodity requires some skill and experience, inasmuch as the various brands show considerable variations in the percentage of eucalyptol. This alone is the sure criterion for the quality and value of the various brands, no matter of what botanical origin they may be."

We have quoted the above remarks to give an idea of the exact position of the industry, and to show that it is futile to continue distilling oils, that by their want of eucalyptol, are of little value.

(b) *Chemical investigations.*—We submit herewith the results of the investigations of the oil of ten distillations from the leaves of the various trees of *E. punctata*, and under varying conditions. We have taken the leaves of the largest trees in the district obtainable, and we have divided the leaves taken from one tree into two equal parts, and thus obtained two distillations from the leaves of one tree. We have taken the leaves from young trees from twenty to thirty feet in height, and in fact under almost all imaginable conditions. We have also distilled the oil from the leaves taken from "suckers,"[1] called by us "young leaves."

1. Oil from leaves collected near Canterbury, Sydney, 6th May, 1897. Distilled 7th May.

Oil light in colour; odour pleasant; yield 1·19 per cent., or 100 lbs. of leaves with branchlets gave 19 ounces of oil; specific gravity as obtained ·9192 @ 17°C.; specific rotation $[a]_D$ + 2·19.

On redistillation of 100 cc. a few drops only were obtained below 164·2°C. This portion contained aldehydes, the thermometer then slowly rose to 170·4°C., when the distillation proceeded steadily. The temperatures were read to whole degrees, and have been corrected to the nearest decimal. [See table.]

First fraction, specific gravity = .9127; specific rotation + 3·61.
Second „ „ „ = ·9187 „ „ + 1·9.
Eucalyptol in the crude oil = 60.8 per cent.
„ „ second fraction = 78·5 „

This is an excellent oil, and was from a fair sized tree, all leaves being also from one tree.

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[1] We were anxious to distil young leaves from this tree, and every care was taken to obtain them from the remains of undoubted "grey gums," judging from the bark, etc.

2. Oil from leaves collected near Canterbury, 5th May, 1897. Distilled 7th May, 1897.

Oil rather dark in colour; odour fairly pleasant; yield ·75 per cent., or 100 lbs. of leaves and branchlets gave 12 ounces of oil; specific gravity as obtained ·9142 @ 17°C.; specific rotation $[a]_D$ + 2·18.

On redistillation of 100 cc. the oil commenced to distil below 168·4°C., at which temperature five per cent. had been removed. This contained aldehydes. [See table.]

Second fraction, specific gravity ·9172; specific rotation + 1·9.

Eucalyptol in the crude oil = 50·65 per cent.

" " second fraction = 67 per cent.

These leaves were taken from a large tree.

3. Oil from leaves collected from "suckers," Canterbury. Collected 10th May, 1897. Distilled 12th May. Mentioned in this paper as "young leaves."

Oil light in colour; odour pleasant; yield ·63 per cent., or 100 lbs. of leaves and branchlets gave $10\frac{1}{5}$ ounces of oil; specific gravity as obtained ·9169 @ 17°C.; specific rotation $[a]_D$ + 4·44.

On redistillation of 100 cc., a few drops only below 161°C., when the thermometer slowly rose to 170·4, by which time twelve per cent. has distilled. [See table.]

The residue in still was more fluid, and less dark than was generally the case.

Second fraction, specific gravity ·9181; specific rotation + 4.35·

Eucalyptol in the crude oil = 54·4 per cent.

" " second fraction = 74.7 per cent.

From the above it is seen that the young leaves give an excellent oil.

4. Oil from leaves collected near Canterbury, 11th May, 1897. Distilled 13th May.

Oil darker in colour than usual, tint brownish-yellow inclining to orange; odour pleasant, but not so much so as the lighter oils;

yield ·885 per cent., or 100 lbs. of leaves and branchlets gave $14\frac{1}{6}$ ounces of oil; specific gravity as obtained ·9205 @ 17° C.; specific rotation $[a]_D - 0{\cdot}92$.

On redistillation of 100 cc. a few drops only below 167·3° C. [See table.]

Second fraction, specific gravity ·9185; specific rotation - ·92.

Eucalyptol in the crude oil = 51·6 per cent.

„ „ second fraction = 67·2 per cent.

Leaves were from a large tree. Although the specific gravity is high, the oil is not so good as those that are less dark, and dextro-rotatory.

5. Oil from leaves collected near Canterbury, 12th May, 1897.

Distilled 13th May.

Oil rather dark in colour, odour pleasant; yield ·75 per cent., or 100 lbs. of leaves and branchlets gave 12 ounces of oil; specific gravity as obtained ·9129 @ 17° C.; specific rotation $[a]_D + 1{\cdot}37$.

On redistillation of 100 cc. more drops came over below 167·3° C. than usual. [See table.]

Second fraction, specific gravity ·913; specific rotation + 1·26.

Eucalyptol in the crude oil = 48·9 per cent.

„ „ second fraction = 52·9 per cent.

These were mixed leaves from old trees. Most of the terpenes remain in the large fraction, thus reducing the value of that portion.

6. Oil from leaves collected near Canterbury, 13th May, 1897.

Distilled 14th May.

Oil but slightly coloured; odour very pleasant; yield ·844 per cent. or 100 lbs. of leaves and branchlets gave $13\frac{1}{2}$ ounces of oil; specific gravity as obtained ·9164; specific rotation $[a]_D + 0{\cdot}54$.

On redistillation of 100 cc. only two or three drops came over below 164·2°C., at 166·3 commences to come over somewhat rapidly. [See table.]

Second fraction, specific gravity ·9183; specific rotation + 1·09.

Eucalyptol in the crude oil = 64·5 per cent.
" " second fraction = 78·4 per cent.

This is an excellent oil, and was from young trees from twenty to thirty feet in height.

7. Oil from leaves collected near Canterbury, 13th May, 1897.
Distilled 17th May.

Oil rather dark coloured, odour pleasant; yield ·734 per cent., or 100 lbs. leaves with branchlets gave $11\frac{3}{4}$ ounces of oil; specific gravity as obtained = ·9166 @ 17° C.; specific rotation $[a]_D + 0·54$.

On redistillation of 100 cc. below 168·4° C. three per cent. had been obtained, this was removed. It contained aldehydes. [See table.]

Second fraction, specific gravity ·9185; specific rotation + ·87.
Eucalyptol in the crude oil = 58·4 per cent.
" " second fraction = 75·5 per cent.

Mixed leaves from fair sized trees.

8. Oil from leaves collected near Canterbury, 8th June, 1897.
Distilled 9th June.

Oil almost colourless; odour quite pleasant; yield ·66 per cent., or 100 lbs. of leaves and branchlets gave $10\frac{1}{2}$ ounces of oil.; specific gravity as obtained ·9164 @ 15° C.; specific rotation $[a]_D + 0·66$.

On redistillation of 100 cc. only two or three drops came over below 165·2° C., the mercury then rose rapidly to 167° C. [See table.]

First fraction, specific gravity = ·9072; specific rotation + 1·71.
Second " " " = ·916 " " + 0·982.
Eucalyptol in the crude oil = 56·6 per cent.
" " second fraction = 67·2 per cent.

These leaves were taken from a fair sized tree. The rotation of the terpenes in the first fraction is small.

9. Oil from leaves collected near Canterbury, 8th June, 1897.
Distilled 10th June.

Oil rather dark in colour, in fact the darkest of the whole of the specimens; yield ·72 per cent., or 100 lbs. of leaves and

branchlets gave 11½ ounces of oil; specific gravity as obtained ·9122 @ 15° C.; specific rotation $[a]_D$ – 2·52.

On redistillation of 100 cc., a few drops only to 165·2° C., but more than usual to 170·4° C. [See table.]

First fraction, specific gravity ·9034; specific rotation – 3·04.
Second „ „ „ ·9112; „ „ – 1·92.
Eucalyptol in the crude oil = 46·4 per cent.
„ „ second fraction = 53·8 per cent.

These leaves were from a very fine tree, they were divided into two parts. The oil from the other part had the same specific gravity, specific rotation, and contained the same amount of eucalyptol in the crude oil.

10. Oil obtained by mixing equal volumes of each of the nine oils investigated of *Eucalyptus punctata*, DC. This was done, the better to compare the oil from this tree with that of a commercial sample of the "blue gum," *Eucalyptus globulus*, received from the Tasmanian Eucalyptus Oil Co. Specific gravity at 16° C. = ·9153. Specific rotation $[a]_D$ + ·927.

On redistillation of 100 cc. a few drops came over below 167·3° C. It commenced to distil at that temperature, and slowly rose to 170·4° C. [See table.]

This oil is but little coloured, brownish yellow in tint.

First fraction, specific gravity ·910; specific rotation + 2·36.
Second „ „ „ ·9156; „ „ + 1·2.
Eucalyptol in the crude oil = 55·11 per cent.
„ „ second fraction = 62·6 per cent.

This oil does not contain phellandrene, but with the nitrite test the oil becomes an emerald green colour. It differs in this respect from the oil of *E. globulus*.

11. Oil obtained from the "blue gum," *Eucalyptus globulus*, Platypus brand.

Oil light in colour, yellowish in tint; specific gravity, as received, ·9185 @ 16° C.; specific rotation $[a]_D$ + 3·48.

On redistillation of 100 cc. a few drops only came over below 167·3° C. These contained some aldehydes; this portion was removed, and the oil then commenced to distil rapidly, fifteen per cent. being obtained below 170·4° C. [See table.]

This oil evidently contained more terpenes boiling below 171·4° C. than does the mixed oil of *E. punctata*, and these are also considerably more dextro-rotatory.

First fraction, sp g. ·9077 ; specific rotation + 8·9. Second fraction, sp. g. ·9173 ; specific rotation + 3·38. Eucalyptol in the original oil = 49·8 per cent. ; second fraction = 59·9 per cent.

This oil does not contain phellandrene.

This table gives the results of the several redistillations of the oils determined on 100 cc. of oil. The numbers are those given to the oils in the paper. The temperatures are corrected. The results are percentages obtained from one temperature to another, the first being the percentage obtained below 170·4° C., except No. 6. The (*a*) denotes where the second fraction commences, and in all instances this is completed at 182·8° C. except in No. 1, which was stopped at 179·7° C.

No.	Species.	170·4	171·4	172·4	173·5	174·5	175·5	176·5	177·6	178·6	179·7	180·7	182·8	193·2	Residue left in still.
1	*Eucalyptus punctata*	8	14	24	34*a*	49	59	68	74	78	84	—	—	—	
2	,, ,,	12	...	26*a*	32	39	47	58	65	71	77	...	84	89	
3	,, ,,	11	...	26*a*	35	46	56	63	72	81	...	...	88	94	
4	,, ,,	5	...	10	22*a*	31	41	51	64	70	...	75	79	85	
5	,, ,,	11	...	21*a*	31	40	51	59	70	...	...	...	81	88	
6	,, ,,	...	13	28*a*	38	58	71	81	85	...	89	...	91	93	
7	,, ,,	7	12	26*a*	30	36	43	56	67	72	...	...	81	87	
8	,, ,,	9	20	30	45*a*	61	70	78	83	86	...	...	90	94	
9	,, ,,	13	27	41*a*	47	57	63	68	74	77	...	81	86	91	
10	Mixed oils	10	22	30*a*	43	49	58	65	70	77	...	82	86	91	
11	*Eucalyptus globulus*	15	26	36*a*	51	56	63	70	74	78	...	81	86	91	

Table of Results on the Oil of the "Grey Gum" *Eucalyptus punctata*, DC.

No.	Colour of Crude Oil.	Percentage Yield.	$[a]_D$ Crude Oil.	Specific Gravity Crude Oil.	$[a]_D$ First Fraction.	Specific Gravity First Fraction.	$[a]_D$ Second Fraction.	Specific Gravity Second Fraction.	Eucalyptol Crude Oil Percentage	Eucalyptol Second Fraction Percentage
1	Very light	1·19	+2·19	·9192 @ 17° C.	+3·61	·9127	+1·9	·9187	60·8	78·5
2	Rather dark	·75	+2·18	·9142 @ 17° C.	...	...	+1·9	·9172	50·65	67·0
3	Light	·63	+4·44	·9169 @ 17° C.	...	...	+4·35	·9181	54·4	74·7
4	Rather dark	·885	−0·92	·9205 @ 17° C.	...	...	−0·92	·9185	51·6	67·2
5	Rather dark	·75	+1·37	·9129 @ 17° C.	...	...	+1·26	·913	48·9	52·9
6	Almost colourless ...	·844	+0·54	·9164 @ 17° C.	...	...	+1·09	·9183	64·5	78·4
7	Rather dark	·734	+0·54	·9166 @ 17° C.	...	...	+0·87	·9185	58·4	75·5
8	Almost colourless ...	·66	+0·66	·9164 @ 15° C.	+1·71	·9072	+0·982	·916	56·6	67·2
9	Dark coloured	·72	−2·52	·9122 @ 16° C.	−3·04	·9034	−1·92	·9112	46·4	53·8
10	Slightly coloured ..	Mean of the above ·796	+0·927	·9153 @ 16° C.	+2·36	·910	+1·20	·9156	55·112	62·6
		Oil of	*Eucalyptus globulus*		for	Comparison.				
	Yellowish in tint as received	...	+3·48	·9185 @ 16° C.	+8·9	·9077	+3·38	·9173	49·812	59·9

From these results we are enabled to make the following announcements, and what is true of the oil of this tree we consider to be true of any species of this class of Eucalypt, because we are slowly obtaining evidence that the Eucalypts are divisible into classes as regards their oil and its quality, as well as into classes based on the composition of their kinos, or by their anthers.

1. *Optical rotation of the oils.*—The action these oils have on a ray of light is not constant, except the leaves be taken from one tree. We find that both dextro-rotatory and levo-rotatory oils are obtained from trees growing near each other and in the same soil. The specific rotation varies from $[a]_D + 0{\cdot}54^\circ$ to $+4{\cdot}44^\circ$ and from $-0{\cdot}92^\circ$ to $-2{\cdot}52^\circ$. The rotation was dextro-rotatory in most cases, but the activity was not great in any case. It was also found that when the original oil was dextro-rotatory, that the first two fractions were also dextro-rotatory, and that when the original oil was levo-rotatory that the first two fractions were also levo-rotatory, and that the increased rotation of the first fraction was that of the original oil, whether levo- or dextro-rotatory. The readings were taken in a 200 mm. tube and the temperature was near 17° C. The determinations were usually made two days after the oil had been obtained. Although the oil from the leaves of each individual tree has the same rotation, yet, owing to the want of constancy in the rotation of oil from several trees as experienced by us in these determinations, we are forced to admit that the specific rotation is not of much value except for scientific investigation.

2. *Specific gravity of the oils.*—The specific gravity of the several oils is not constant, except when obtained from leaves growing on the same tree. We distilled oil from a fine tree in two separate parcels, and we found the specific gravity of the oil to be ·9122 in both cases. The oil from another fine tree had a specific gravity ·9192, while that of another was ·9205. The specific gravity of the oils from various trees not kept separate was about ·9165, while that obtained by mixing together equal volumes of the oils investigated, was found to be ·9153. The oil

from the young leaves had a specific gravity ·9169. The specific gravity was taken in a delicate Sprengel pyknometer holding about ten grams. From the results of the specific gravity determinations, as well as the rotations, we find that the oils obtained from various trees of one species are not constant.

3. *Yield of oil.*—The yield of oil from the several trees is not constant, ranging from 1·19 per cent. from the leaves of one tree to ·63 per cent. from the young leaves. Leaves and terminal branchlets were used in all cases, and therefore the results are not strictly comparable, because some might have contained less branchlets than others, but not sufficient to account for the differences obtained. The yield from the 'young leaves' was the least obtained, this being contrary to the generally accepted theory. The average yield of oil of nine distillations was ·796 per cent., and the whole weight of leaves taken was 1377 pounds avoirdupois.

4. *Removal of the terpenes.*—The terpenes in these oils, both dextro- and levo-rotatory, are largely removed below 172·4° C. An oil which had a specific rotation $[a]_D + 2{\cdot}19$ when redistilled gave the following results:—The fraction (24%) boiling between 170·4 and 172·4° C. was found to have a specific rotation +3·61° while the fraction (60%) boiling between 172·4 and 179·7° C. had a specific rotation +1·9° in the same tube. As the distillation was stopped at 179·7° C. a portion of the eucalyptol, as well as another body whose rotation was also nil, remained in the still, and which would have reduced the rotation in the large fraction. We thus see that although the dextro-rotatory terpene is largely removed below 172·4° C., yet, it is not possible to remove it by the one fractional distillation, and the same remark applies with almost equal force to the levo-rotatory terpene.

To account for these different terpenes we advance the following:—The dextro-rotatory terpene is first formed, as the oil from the young leaves had a specific rotation +4·44°, but as the age of the tree advances this terpene gives place to the levo-rotatory form, as the oil obtained from a very fine tree, of a good age, had

a specific rotation $-2{\cdot}52°$. This probably accounts for the want of constancy in the rotation of the several oils from *E. punctata*.

The fractions boiling between 182·8 and 193·2° C. when mixed together were found to have no rotation. The redistillations of these oils were all made in a small metal still holding about 130 cc. the outlet being 140 mm. above the surface of the oil, the bulb of the thermometer being just below this outlet. The heat was obtained from a small bunsen impinging on the bottom of the still and the whole enclosed in an outer casing of metal plate. It was possible to regulate the temperature with this arrangement accurately to one degree, between 170 and 180° C., by careful watching and regulation of the heat supply. The temperatures were corrected, 2·4° being added to the reading of 168° C., and 2·8° to that of 180° C., and 3·2° to 190° C.

5. *The eucalyptol in the oils.*—The eucalyptol content of the oil is not constant unless the leaves are taken from the same tree. It is perhaps remarkable that the oils from *E. punctata* that are the least coloured are the richest in eucalyptol, and as a rule they contain the greatest percentage of dextro-rotatory terpenes, and the amount obtained when redistilled coming over below 182·8° C. is greater than is the case with the darker oils. One oil, a very light one, gave 77 per cent. between 170·4 and 182·8° C. while another light oil gave 76 per cent. between 170·4 and 179·7° C.

The percentage of eucalyptol is greater in the fraction boiling between 172·4 and 182·8° C. than in that distilling between 171·4 and 182·8° C., as much as 15 per cent., distilling in some cases between 171·4 and 172·4° C. The percentage of eucalyptol ranges from 46·4 to 64·5 in the crude oils; one that gave 60·8 per cent. of eucalyptol gave a fraction boiling between 172·4 and 179·7° C. (60 per cent. of the whole) from which 78·5 per cent. of eucalyptol was obtained, while a crude oil giving 64·5 per cent. of eucalyptol gave a fraction between 171·4 and 182·8° C., from which 78·4 per cent. of eucalyptol was obtained, the difference being accounted for by the presence of 15 per cent. boiling between 171·4 and 172·4° C. in the latter oil.

We find that the specific gravity of the oil is no indication of the amount of eucalyptol present, as the oil giving the highest specific gravity ·9205 gave only 51·6 per cent. of eucalyptol, while an oil whose specific gravity was ·9164 gave 64·5 per cent. eucalyptol. We regret that our researches on this oil prevent our endorsing the applicability of the ingenious method for the determination of eucalyptol in an oil by taking advantage of its physical determinations as worked out by Mr. W. Percy Wilkinson.[1]

It is most probable that the Eucalyptus oils are divisible into groups, the members of which contain certain specific constituents, other than eucalyptol in varying quantities, the physical constants of which are not yet worked out. If eucalyptol and one terpene were the only consituents present in these oils, their investigation would be much simplified. The fraction boiling between 182·8 and 193° C., and which varies from two to seven per cent. of the original oil, contains only a small quantity of eucalyptol,[2] 28 per cent.; it has no action on light, and probably consists largely of an ester partly decomposed by distillation, as an odour of acetic acid is readily detected. It will be further investigated.

It appears to us at present not to be advantageous to rectify this oil beyond 183° C. as the fraction between this and 193° C. would tend to lower the eucalyptol content of the large fraction. The determinations of the eucalyptol were made by the phosphoric acid method, a powerful letter press being used to remove the adhering terpenes etc. Most of the determinations were made in duplicate, and the more important ones in triplicate, the mean of these results being given.

Determinations under exactly the same conditions were made on a sample of the oil of *E. globulus*, kindly sent to the Museum by the Tasmanian Eucalyptus Oil Co., the manufacturers of the "Platypus Brand." Three determinations of eucalyptol on this oil gave 49·6, 49·8, and 49·9 per cent., while the lowest determin-

[1] Proc. Roy. Soc. Vic., Vol. VI., New Series, page 195.

[2] This same fraction of *E. globulus* is principally eucalyptol.

ation with the oil of *E. punctata* was 46·4 per cent. As the sample of *E. globulus* was a commercial one, it was of course obtained from several trees. The eucalyptol present in the crude oil of the nine samples in the table, obtained by adding together equal volumes of each, was 55·112 per cent., or five per cent. better than the sample of *E. globulus*. The calculations were made according to the formula $C_{10}H_{18}O$, H_3PO_4.

6. *The colour of the oils.*—The oil which was found to be only slightly dextro-rotatory, came over at the original distillation darker in colour than that which was more dextro-rotatory, this being but slightly coloured; but the oil which was the most levo-rotatory was the darkest of any of those obtained. None of the oils however were very dark, the darkest being about the colour of pale ale, and it was possible to easily take their readings in a polarimeter with a 200 mm. tube. We were very much concerned at first at obtaining these different coloured oils, as it appeared to us unaccountable, as no matter what the pressure of steam, the results were the same with the same oil. It is hardly possible, therefore, to obtain a colourless oil from mixed leaves of *E. punctata* when distilled commercially by steam, although it may be obtained but slightly coloured from some trees, but this is no defect, as all oils should be rectified before being used medicinally, and the colour remains with the residue, the first two fractions being almost "water white."

We think the colour in some of these oils may be accounted for by the presence of two substances boiling between the temperatures 219 and 261° C., and it appears probable that one of these, most likely the larger portion, other than the aldehyde, is derived from the alteration of the dextro-rotatory terpene, as this appears hardly to exist in the darker oils.

The residues of the several distillations boiling above 193° C. were collected, and 50 cc. taken for further distillation; only a few drops were obtained below 219° C., (these were removed). Between this and 240° C. ½ cc. was obtained.

From	240	to	245° C.	4 cc. had been	obtained
„	245	„	251	7	„
„	251	„	256	8	„
„	256	„	261	10	„

The mercury then continued to fall although the heat was increased. We have thus obtained nearly 10 cc. boiling between 240 and 261° C. from 50 cc. of original residues which represent from 800 to 1000 cc. of the original oil, so that these bodies are present to the extent of about one per cent. in the original oil taken collectively, and as we consider that the colour of the oil is partly due to these bodies, and as the colour is almost absent in some oils, we think that they are present in greater quantity in the older trees.

The specific gravity of this distillate was found to be ·9361. It was treated with acid sulphite of soda, when a small quantity of a crystalline compound was obtained, showing the presence of an aldehyde. The mixed bodies have somewhat the odour of cumin oil, which is much more pronounced in the regenerated substance. As cuminic aldehyde boils at 237° C., we think we are justified in stating that this substance is present in a very small quantity in this oil.

The remaining body removed from the aldehyde has a very pungent odour, and when diffused sufficiently not at all unpleasant. This odour becomes less marked after some time, further alteration evidently taking place. It is of a deep orange brown colour, is an oil, and no signs of crystallisation are apparent. We hope eventually to obtain sufficient material to further investigate it. As there is a connection between the constituents of the species of the genus Eucalyptus, we may perhaps obtain it in larger quantities from the oil of other species. We hardly think it can be closely connected with the other constituents of the oil, as the differences in boiling points are too distinct, very little oil being obtained between 193 and 240° C.

As the levo-rotation of the oil increases the eucalyptol appears to exist in less quantity.

The best fraction for eucalyptol content appears to be that obtained from the lighter coloured oils, consisting of about 60 per cent. of the crude oil, distilling between 172·4 and 182·8° C., but as from 10 to 15 per cent. distils between 171·4 and 172·4° C., much of which is eucalyptol, it is questionable whether this could be dispensed with commercially. If added to the large fraction the eucalyptol content would certainly be diminished, and this also applies to that portion boiling between 182·8 and 193·2° C., although this would increase the specific gravity, it having a sp. gr. ·9253 at 16° C. The greatest quantity of this latter, however, was 7 per cent., but in some cases only half this amount was obtained, so that the loss would not be great if this portion was discarded. That portion boiling below 171° C. should not be added to the rectified oil because of the predominance of terpenes boiling at a low temperature, and because of the presence of aldehydes.

The product of crude distillation of all eucalyptus oils should not be used medicinally as such, but the oil should be rectified, principally for the following reasons :—

1. Aldehydes appear always to be present in a greater or lesser amount in the oil as first distilled, and these bodies are considered very objectionable, are cough producing, and in affections of the respiratory organs should not be used. They are not difficult to remove, as they generally boil at a lower temperature than that of the principal constituents of the oil, and can thus be readily got rid of.

2. A portion of the terpenes boiling below the temperature required to distil eucalyptol can also be removed, thus considerably increasing the eucalyptol content in the portions boiling at a higher temperature.

3. The higher oxidised portions boiling above 193° C. are removed ; the colouring matter of the original oil is also retained in the residue, so that we obtain by rectification a clear, almost colourless product. The residue also retains those portions of a

sticky nature that are not volatile. The distillate boiling below 193° C. is entirely volatile, while the crude oil is not so.

4. The large fraction, consisting of about 60 per cent. of the original oil of *E. punctata*, is, by such rectification, improved to such an extent as to consist very largely of eucalyptol. This oil does not contain phellandrene, and is practically as good as it is possible to obtain eucalyptus oil commercially, and removes the necessity, to a large extent, for the use of pure eucalyptol, particularly when the expense of the latter has to be taken into consideration.

IV.—Explanation of Figures.

E. punctata, DC.

Fig. 1—Part of a leaf with the lower surface removed, showing the oil glands—some with the oil globule and some without it.

„ 2—An oil gland under a higher magnifying power than No. 1, the cell being empty.

„ 3—A portion of No. 2 still further magnified; the sphere represents the oil globule enclosed in the cell.

„ 4—Stomata.

„ 5—Transverse section of a leaf. *a*. epidermis, upper surface. *b*. epidermis lower surface. *c*. lysigenous oil cell (empty). *d*. lysigenous oil cell containing globule of oil. *e*. stomata. *f*. palisade layers. *g*. spongy tissue. *h*. small vascular bundles.

Acknowledgments.—We beg to tender our sincerest thanks to the following gentlemen who have assisted us in various ways in the preparation of this paper:—Dr. R. N. Morris, Superintendent of Technical Education, for every assistance by placing the resources of the Technical College at our disposal; Rev. J. Milne Curran, F.G.S., for the micro-photographs of timbers; Mr. C. E. Finckh, for section cutting of the leaves; Mr. M. Connelly, for photographical work; Mr. O. Blacket, for timber tests; Mr. F. Camroux and Mr. H. T. Gould, Manager Tas. Euc. Oil Co., for sample of *E. globulus* oil.

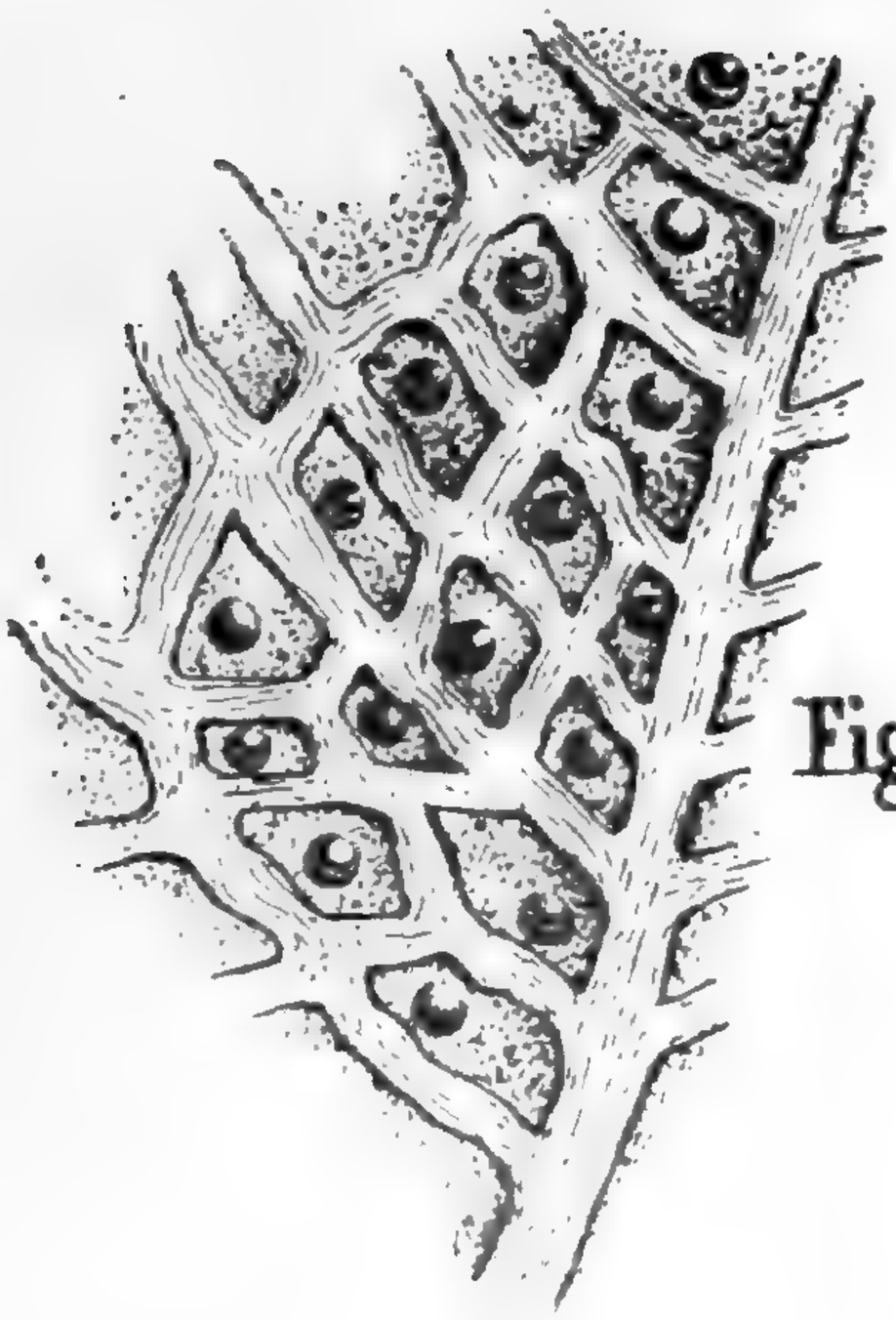


Fig 1

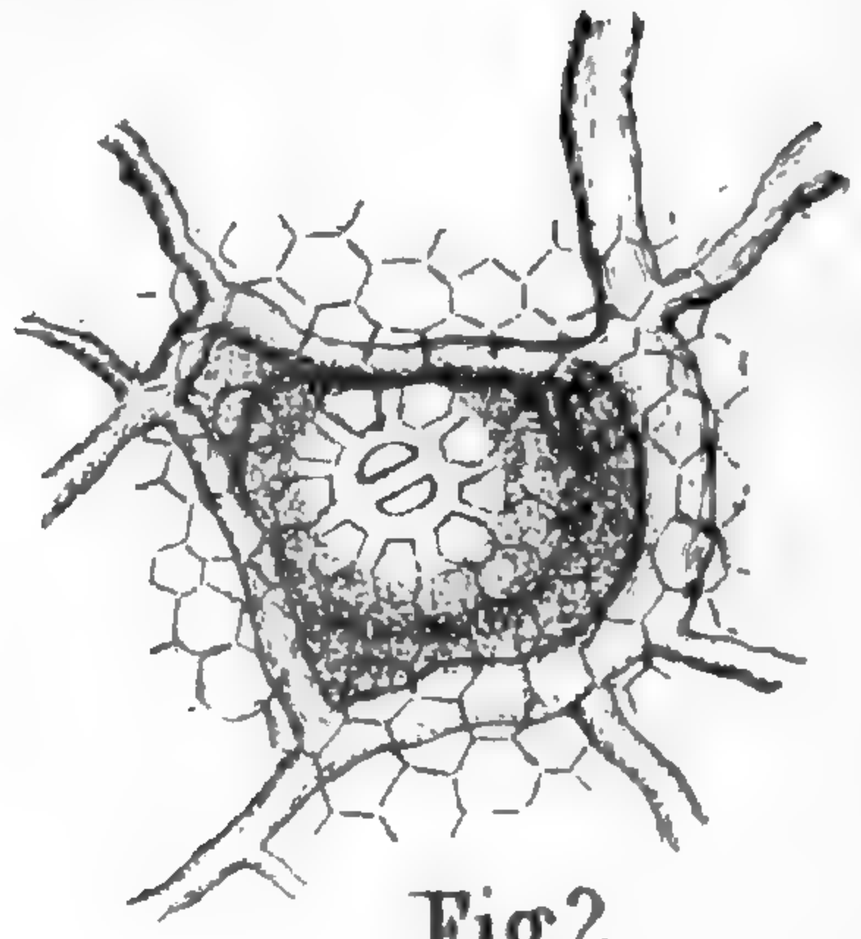
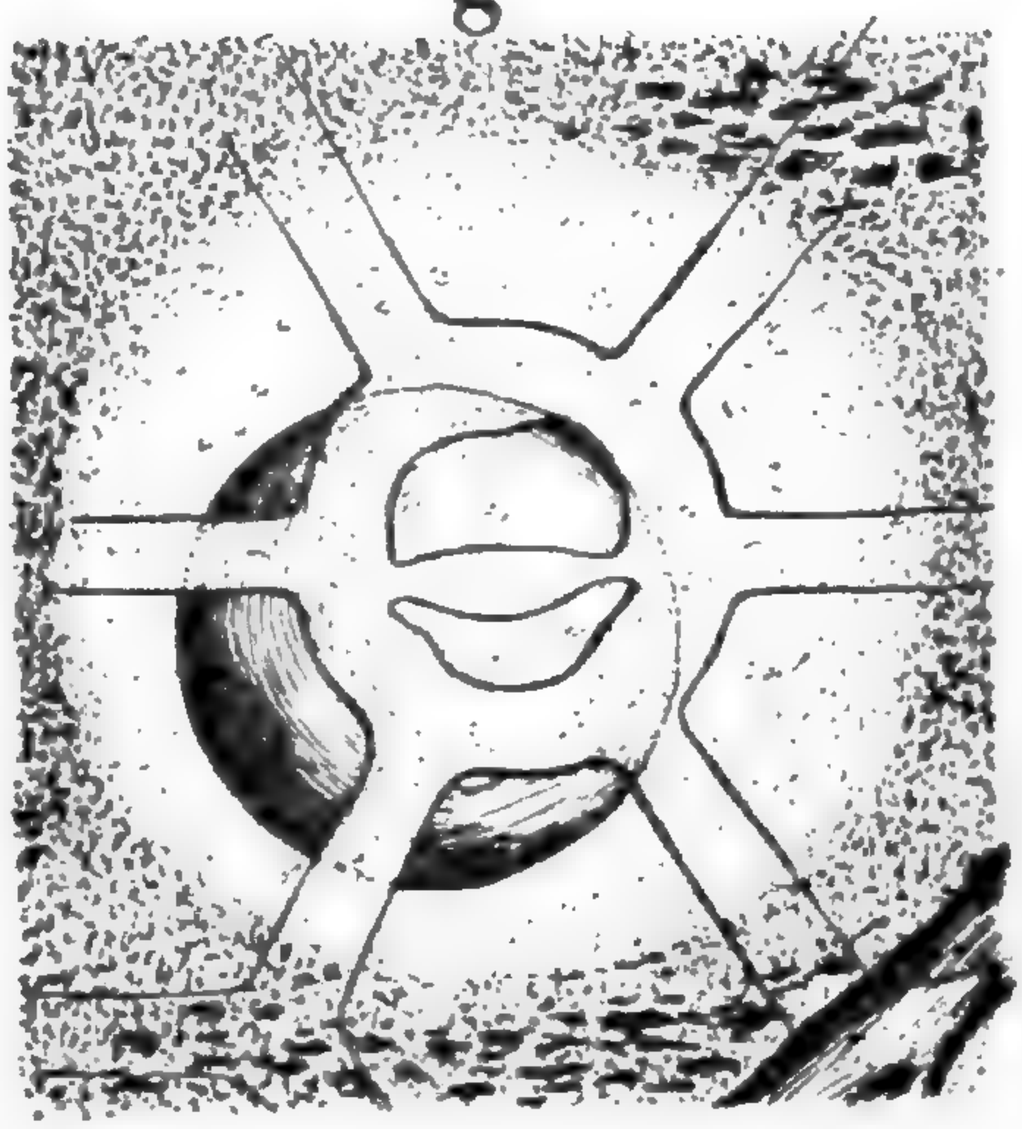


Fig 2

Fig 3



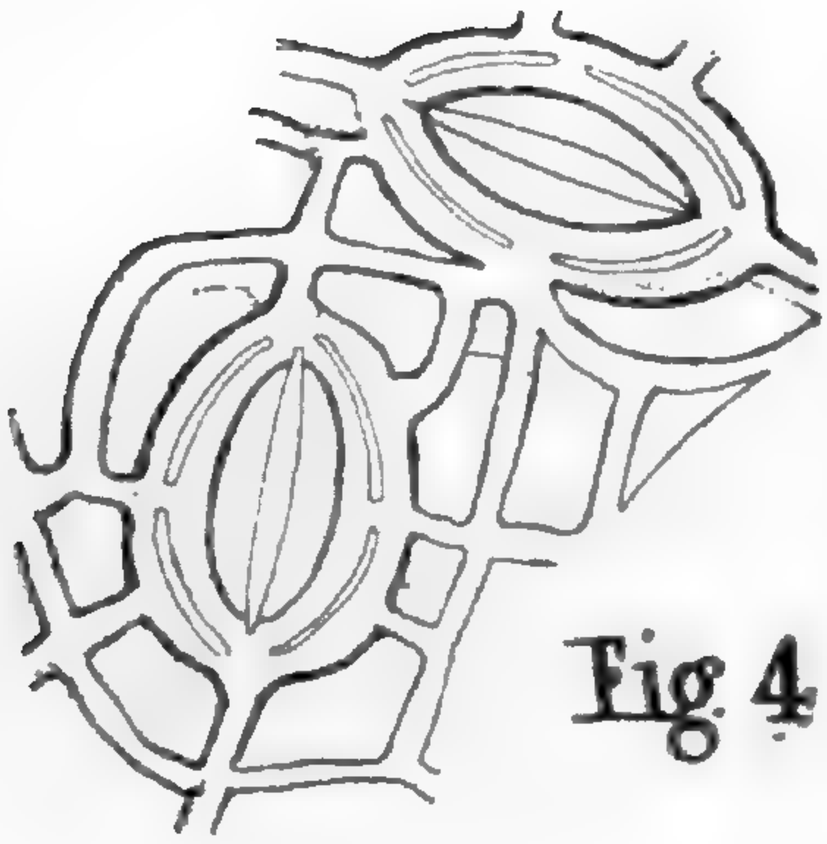
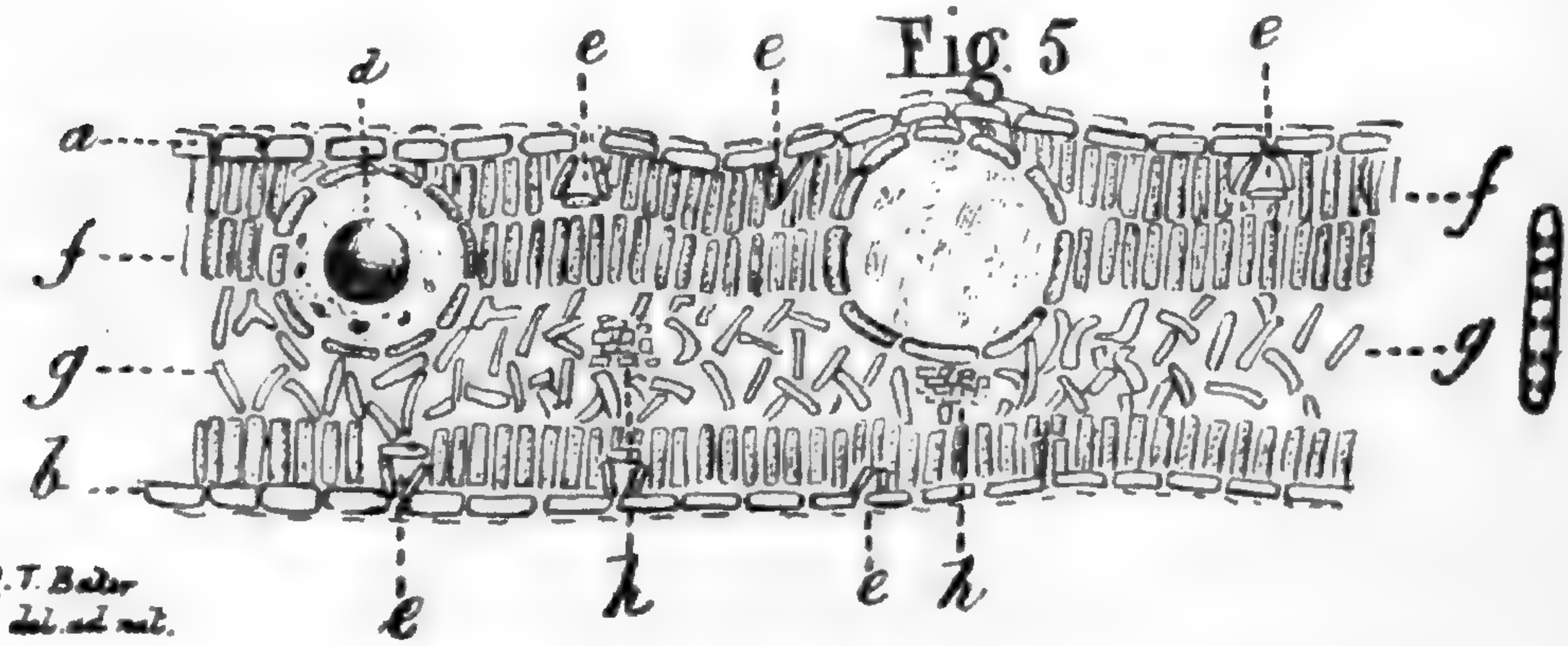


Fig 4

Fig. 5



Parts of the leaves of E. punctata, DC. (mag.)

THE EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE PROPERTIES OF COPPER.

By Professor WARREN, M. Inst. C.E., M. Am. Soc. C.E., Wh. Sc., and S. H. BARRACLOUGH, M.M.E.

[*Read before the Royal Society of N. S. Wales, November 3, 1897.*]

1. *Object of the present tests.*—The series of tests described in the following paper were undertaken with the view of determining the effect which temperature has on the tensile and compressive properties of copper. The tests were made on specimens of hot-rolled copper[1] kindly supplied by Mr. W. Thow, M. Inst. C.E., Chief Locomotive Engineer to the N. S. Wales Government Railways, under whose directions the test pieces were prepared in the Eveleigh Workshops. The dimensions and relative proportions of the test pieces are shown in Fig. 1.

2. *Apparatus and methods adopted.*—In arranging for the tests the two conditions to be complied with were—(*a*) It should be possible to conveniently vary the temperature over a large range, and to keep it constant at any part of the range for a considerable time. (*b*) The apparatus used should not interfere with the truly axial application of the stress, especially in the compressive tests. These conditions seemed to be best met by the adoption of a cast iron bath of considerable capacity, having at each end a loosely fitting stuffing-box, through which the necessary connection could be made with the test piece in the bath. The general appearance of the bath for the tensile and compressive tests is shown in Fig. 1 and Fig. 2 respectively. The tests were made on one of Greenwood and Batley's machines of 100,000 lbs. capacity. To secure the axial application of the stress in the tensile tests special spherical bearings, as illustrated in fig. 3 were designed for this machine by Prof. Warren, for the purposes of these tests, and the

[1] See Appendix.

APPARATUS FOR TESTINC MATERIALS AT VARIOUS TEMPERATURES

SCALE INCHES

DIMENSIONS OF TEST PIECE

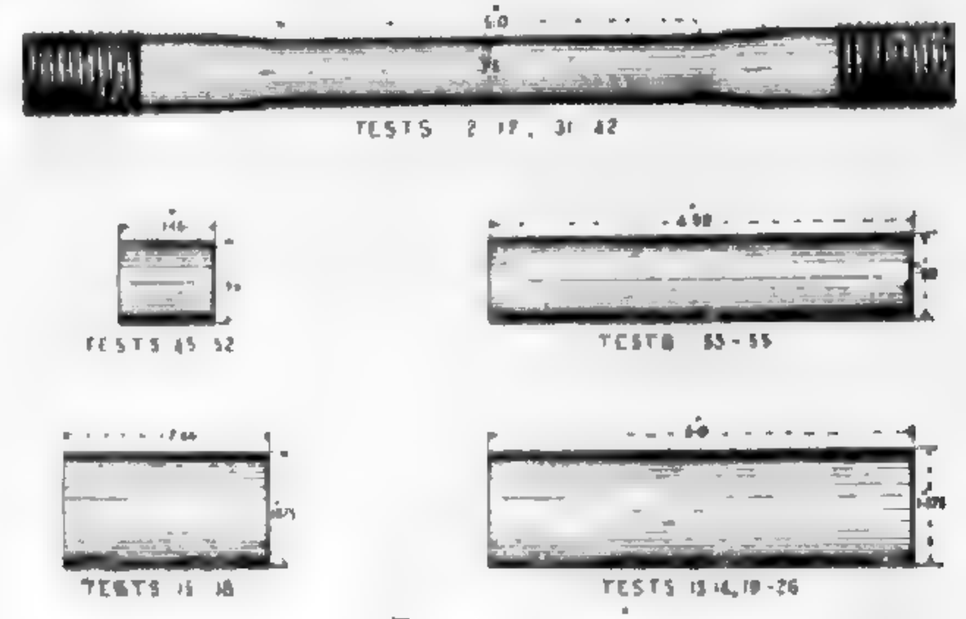
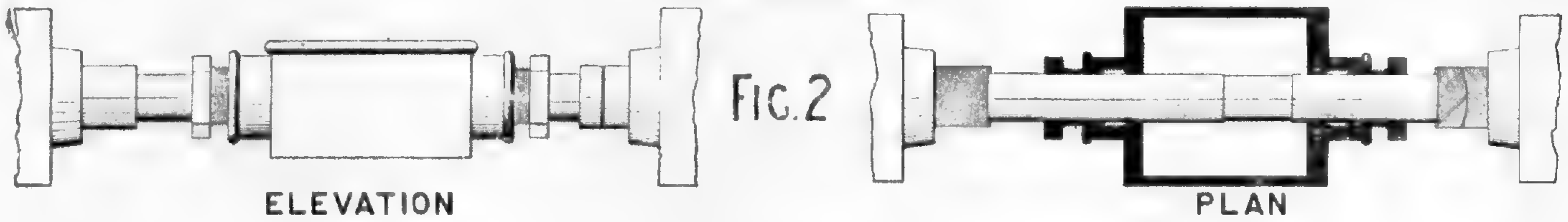


Fig 1

COMPRESSION

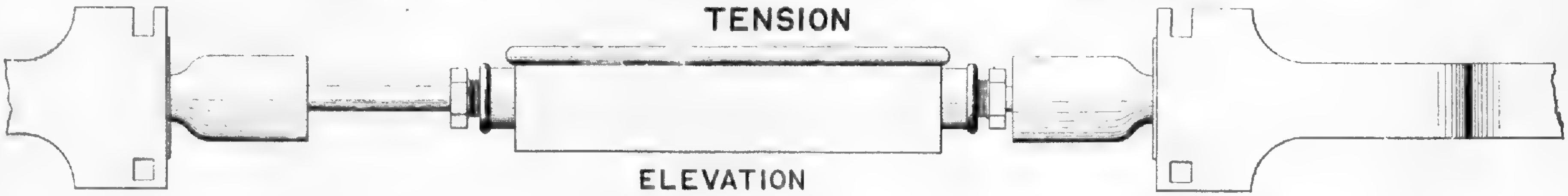


ELEVATION

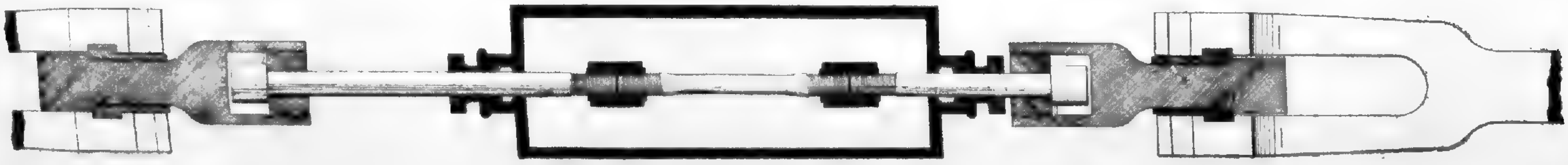
Fig. 2

PLAN

TENSION



ELEVATION



PLAN

same end was attained in the compression tests by the use of an ordinary cup bearing.

The oil used in the majority of the tests was a very heavy cylinder oil guaranteed not to "flash" at 700° F., and which proved in every way satisfactory. For a few of the tests at the lower temperatures the oil was replaced by a mixture of ice and water, or ice and salt. The actual range of temperature attained was from 25° F. to 535° F. The temperatures with the exception of those in the neighbourhood of the freezing point were measured by means of a mercurial thermometer, graduated to two degrees and reading to 600° F. The readings of this thermometer up to 410° were compared with those of two mercurial thermometers provided with Kew certificates, and it was found to have a small negative error in the neighbourhood of 100° diminishing to zero at about 300°, and increasing to a small positive error in the neighbourhood of 400°—the maximum error being two degrees. From 420° to 500° it was compared with a nitrogen thermometer reading to 900° F., but not certified. As however the relative readings of the two were uniform over this range, there is no reason to suspect the presence of any errors, but such as are negligible for the purposes of these tests.

The extensions and compressions in the majority of the tests were measured by a special modification of Kennedy's well known lever-extensometer. This instrument is provided with a scale reading nominally to ·0001 inch, but it was calibrated by comparison with a Brown and Sharpe micrometer calliper, and the scale values so obtained were used in plotting the stress-strain curves. In three tests, one in tension and two in compression, the strains were measured by means of Marten's mirror extensometer reading to ·0001 mm. This instrument and its proper method of use have already been brought before the Society.[1] The autographic diagrams were obtained by means of the apparatus attached to the Greenwood and Batley testing machine.

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[1] See papers read by Prof. Warren, and by Mr. G. H. Knibbs.—Proc. Roy. Soc., N. S. Wales, Vol. xxxi., pp. 89 - 111.

The general method of making a test was as follows :—the specimen having been placed in position in the bath, a slight load (approximately 200 lbs.) was applied in order to keep everything "taut" and in line. Then the extensometer or autographic apparatus was attached, as the case might require, and the bath was filled with oil to within a short distance of the top. By means of two gas kettle boilers the oil was heated to the required temperature—a process occupying from some twenty minutes for the lower temperatures, to three hours for the highest. It was found possible in the majority of the tests, by regulating the gas flames to maintain the temperature of the oil practically constant at any point, the variation not being more than one or two degrees on either side of the mean. The oil being thus maintained at the required temperature, the load was uniformly increased, and the readings of the stress-strain apparatus were taken at equal intervals of load. In those tests in which the specimens were actually broken, the gas was extinguished a little before the ultimate stress was reached to avoid the risk of some of the hot oil being thrown into the flame by the shock.

3. *Expansion of test piece by heat.*—It was easily observable by the gradual raising or lowering of the "floating" lever of the testing machine, that during the heating of the bath the initial stress, referred to above, was markedly increased or diminished (in the compressive and tensile tests respectively) by the expansion of the test piece, and this more especially of course at the higher temperatures. A rough measure of the coefficient of linear expansion of copper was obtainable by observing the variation in the reading of the extensometer-lever, as the temperature rose. This could of course be only of the nature of a rough approximation, since the extensometer frames could not be kept at a constant temperature. No alteration in the total stress applied to the test piece is caused by this action; it will only modify slightly the rate and method of application of the stress at the lower loads. A slight error is introduced by the expansion, inasmuch as the dimensions of the specimen when being tested at a high tempera-

ture differ from those actually measured at the ordinary temperature. Taking the extreme case, in which the increase of temperature is 500° F., and assuming the linear coefficient of expansion, per degree Fahrenheit, of copper to be ·0000095 or ·00475 per 500°, the following statement shows the error involved in the particular case of compression pieces 13 – 25, and will serve as an illustration for the whole series.

	Length ins.	Diam. ins.	Area sq. ins.
Original	5·000	1·375	1·485
Final	5·024	1·381	1·498

This error being negligible for the purpose in hand, and being the greatest that can occur, will not be further referred to in the following enquiry.

4. *Temperature and ultimate tensile strength.*—The variation of the ultimate tensile strength with temperature is shown in the following table, and the results are plotted in Fig. 3.

Table I.

No. of Test.	Temp. of bath F.°	Diameter Inches.	Area Sq. Inches.	Breaking Stress —total lbs.	Breaking Stress lbs. per sq. in.
41	25	·750	·4418	13,850	31,350
37	33	·750	·4418	14,375	32,540
38	35	·750	·4418	14,250	32,256
9	36	·750	·4418	13,875	31,410
32	166	·750	·4418	12,500	28,290
11	208	·750	·4418	12,100	27,390
33	244	·750	·4418	11,750	26,600
34	348	·750	·4418	10,900	24,670
10	402	·751	·4431	10,500	23,700
35	444	·750	·4418	10,150	22,970
42	500	·750	·4418	9,500	21,500
2	506	·745	·4458	9,550	21,910
36	518	·750	·4418	9,000	20,370
3	57	·748	·4396	13,300	30,260
31	57	·750	·4418	13,874	31,410
7	33	·750	·4418	14,075	31,860
6	102	·750	·4418	13,400	30,330
5	208	·750	·4418	12,300	27,840
4	351	·751	·4431	10,450	23,580

In the above table No. 1 is not included, as the dimensions of the test piece differed altogether from those of the other tests. Nos. 41 – 36 were tested without any re-heating or re-stressing. Nos. 3 and 31 were tested in air; the mean value of the two tests is indicated on the diagram. The remaining four, Nos. 7 – 4, were first stressed beyond the elastic limit, then their temperature was brought back to the normal, then they were re-heated (or cooled) and stressed to the breaking point. They are not shown in the diagram, but it will be found that they confirm fairly the position of the curve as shown.

It is evident that, at least within the temperature range covered by the tests, the tenacity may satisfactorily be represented by a straight line curve whose equation is approximately

$$f = 32000 - 21\ t$$

where f is the ultimate strength in lbs. per square inch, at a temperature $t°$ F. Prof. Unwin states[1] that he has found approximately that

$$f = 33{,}150 - \cdot 03136\ (t - 60)^2$$

but as the data upon which the equation is based are not supplied, no comparison is possible. The well known experiments made by a Committee of the Franklin Institute[2] between the years 1832 and 1837 embraced a range of temperature of from 100° to 1100° F., and the results obtained, although somewhat irregular, may be approximately represented by a straight line curve, a portion of which is shown in Fig. 3, for purposes of comparison. The rate of decrease of tenacity with increase of temperature does not differ greatly from that obtained in the present series of tests, although the absolute tenacity of the material was slightly greater.

Evidently the straight line curve if continued, will cut the axis of temperature at a point some 500° below the melting point of

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[1] *Elements of Machine Design*, Part I., p. 17. In the equation given above, the stress is altered from tons per square inch, as used by Prof. Unwin, to lbs. per square inch.

[2] The original communication not being available, use has been made of the results as quoted by Prof. Thurston in *Alloys, Brasses and Bronzes*, Pt. III.

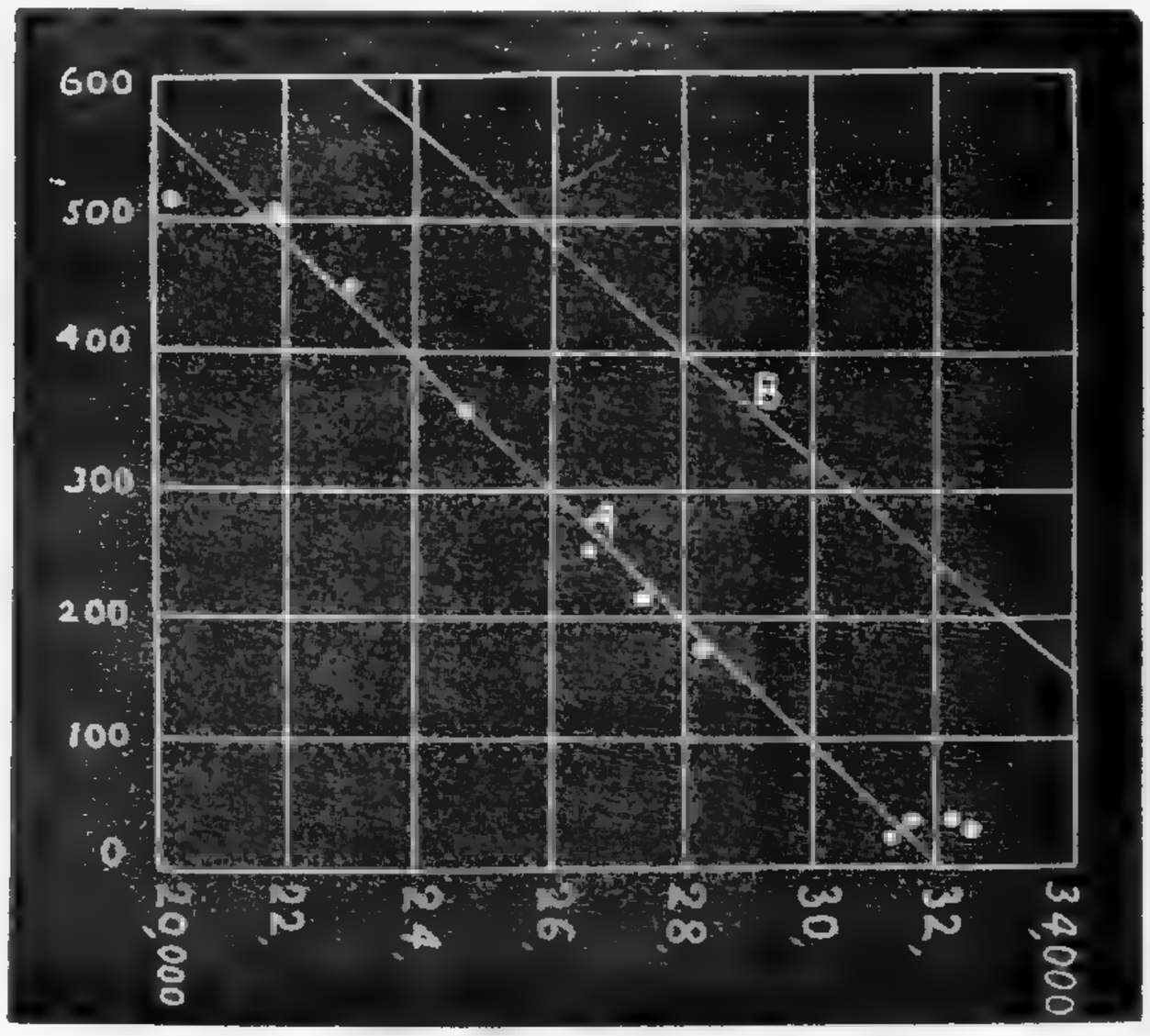


Fig 3.

Ordinates Temperatures Fahr.
Abscissæ—Ultimate strength lbs. per sq. inch.
Curve A.—Present Series.
Curve B.—Franklin Institute Series.

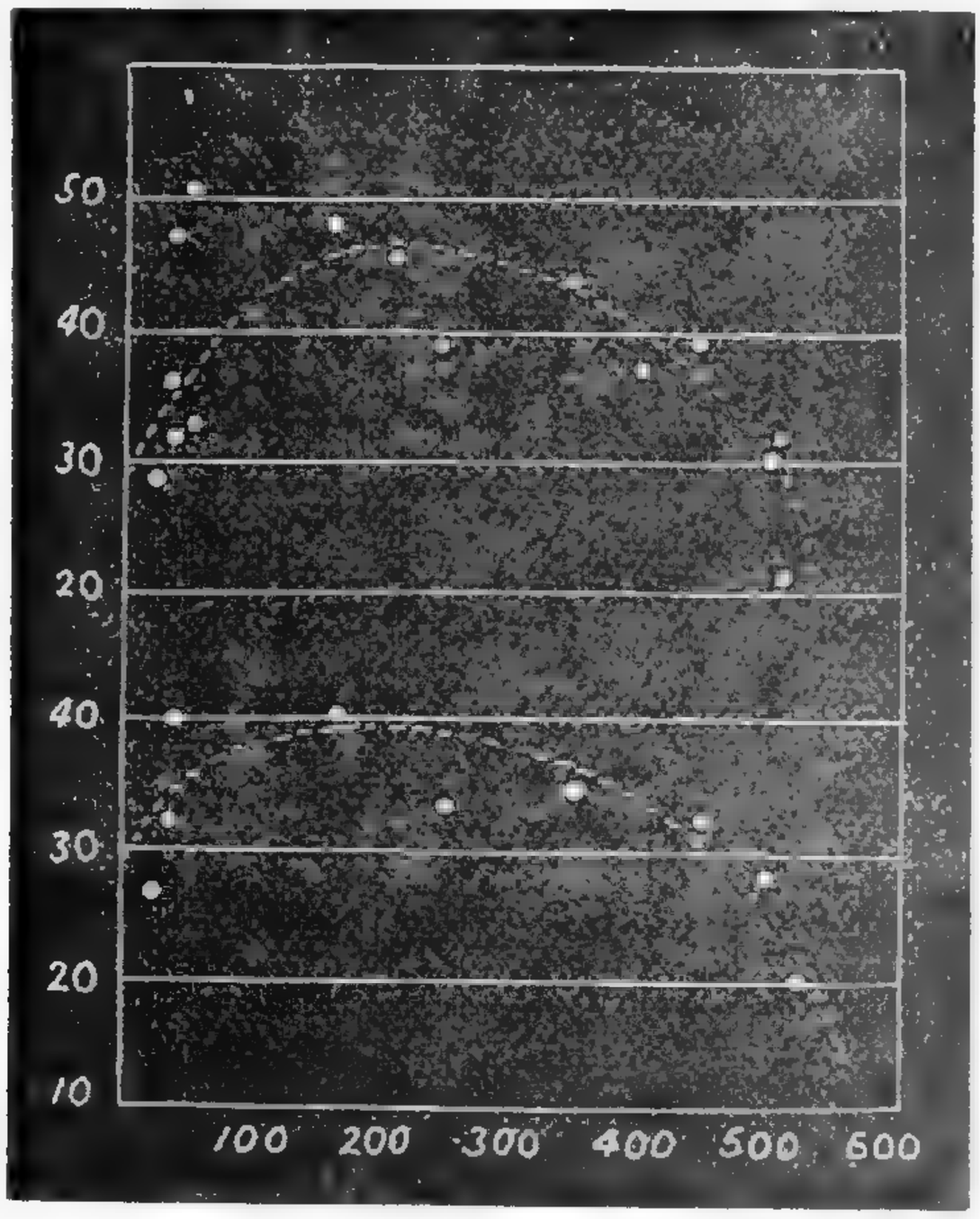
copper ; hence the above expression for the tenacity at any temperature can only be used for temperatures within the range covered by experiment—*i.e.* up to 500° F. certainly, and, relying upon the Franklin Institute results, up to 1000° F., probably.

5. *Temperature and percentage elongation.*—Before being tested, the working length of test pieces, Nos. 32–38, and 41, 42, was marked off into quarter inches, and the general elongation was thus distinguished from the total, according to Tetmaier's method. In the other tensile tests only the total elongations were obtained. The following table summarises the results :—

Table II.

Test No.	Temperature	Elongations— Total	Elongations— General	Test No.	Temperature	Total Elongation.
32	166	49·2	40 4	2	506	31·6
33	244	39·2	33·6	3	57	32·6
34	348	43·2	34·0	9	36	30·8
35	444	39·6	32·4	10	402	37·2
36	518	21·2	19·6	11	208	46·0
37	33	36·4	32·0	31	57	50·8
38	35	47·6	40·0			
41	25	28·4	26·4			
42	500	30·0	27·7			

It is evident from these figures that besides temperature, there are other, and probably uncontrollable, conditions which affect the elongation. Although the curves (Figs. 4 and 5) of total and



Figs. 4 and 5.

Abscissæ Temperatures Fahr.
Ordinates Fig. 4, Total Elongation %.
Ordinates Fig. 5, General Elongation %.

general elongation are consequently but ill-defined in position, they yet indicate the probable presence of a maximum elongation at a temperature of approximately 200° F. It would not seem possible however to specify any particular percentage of elongation which a test specimen of copper should comply with.

6. *Temperature and contraction of area.*—The contraction of area as measured on test pieces, Nos. 1 – 11, varied from 37 to 63 per cent., but the method of variation with temperature was exceedingly irregular, it being impossible to deduce any simple relationship between the two quantities. As in the case of the percentage elongation, the results when plotted appeared to indicate the presence of a maximum contraction of area at a temperature of 200° to 250°, but the conclusion could not be relied upon with any degree of certainty, and for that reason the curves are not reproduced.

7. *Temperature and rate of permanent elongation.*—Autographic diagrams were taken in tests 2, 3, 8, 9, 10, 11, 41 and 42, and these are reproduced in Fig. 6, with the exception of 2 and 3,

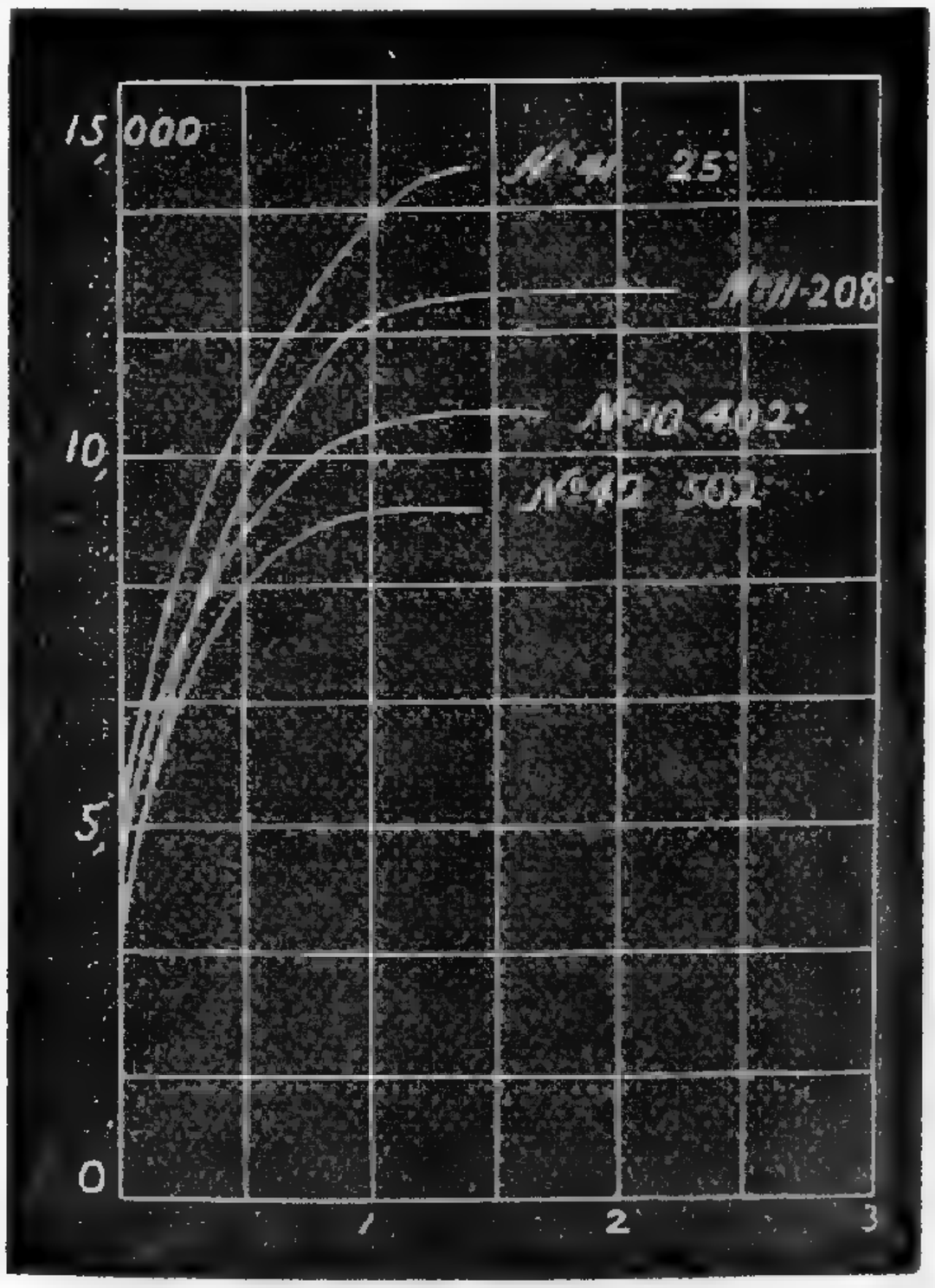
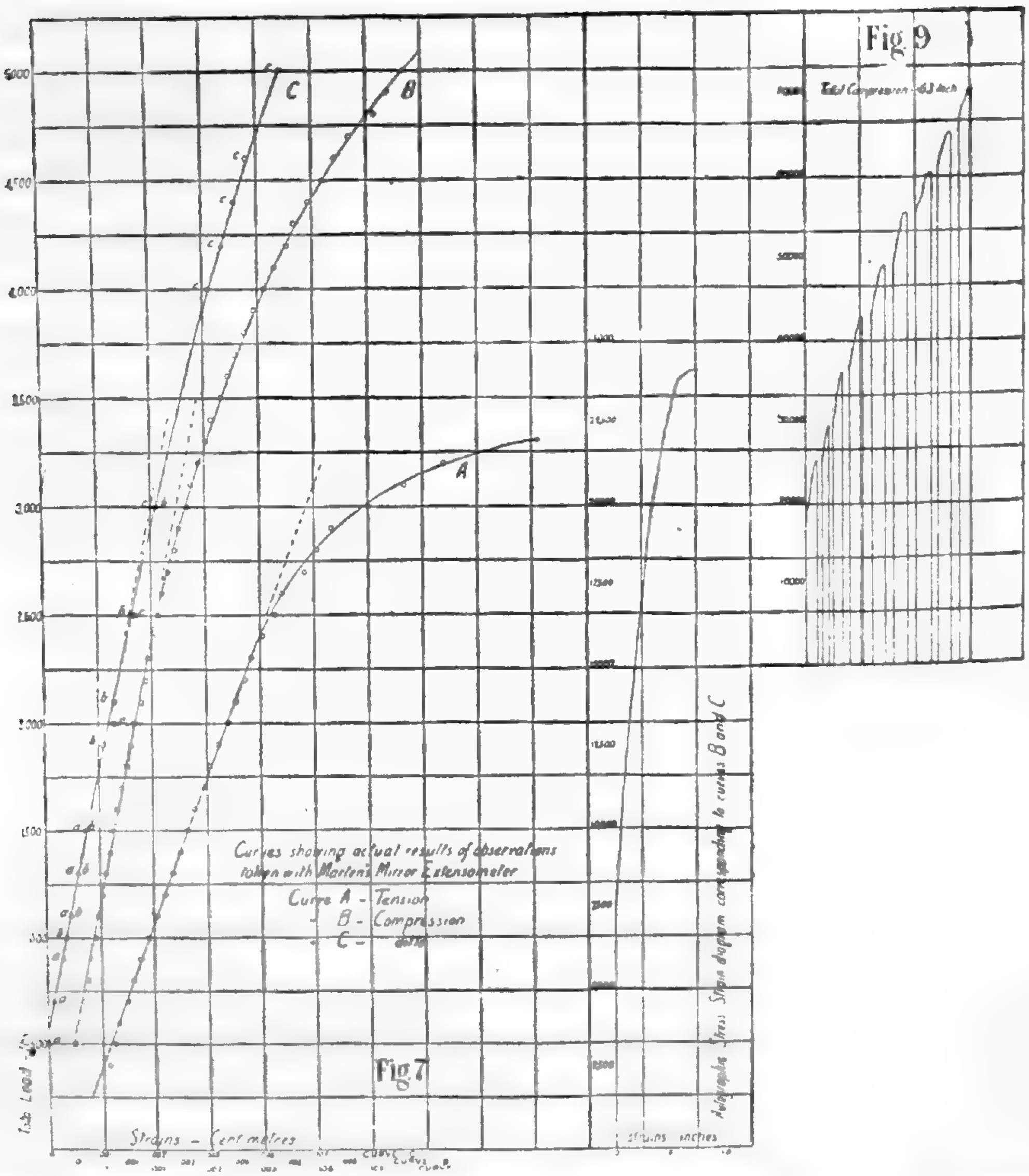


Fig. 6.

Ordinates actual load in lbs.
Abscissæ Extension in inches.

in which the autographic apparatus failed, and also of 8 in which the test was stopped before the piece broke, for the sake of obtaining a desired museum specimen. The rate of permanent elongation evidently increases rapidly as the temperature rises, and the 'yield point' shows a corresponding diminution. Since the abscissa of the final point of each curve gives the elongation for the corresponding test piece, a curve drawn through these points would correspond approximately to the curve of elongations referred to in § 5.

8. *The elastic limit in tension.*—The stress-strain curve for a tensile test, No. 31, obtained by means of Marten's mirror extensometer, shows clearly the elastic limit as marked by the point of departure of the curve from proportionality of stress and strain (Fig. 7, curve C.). This limit occurs at about 5,400 lbs. per



square inch. It being impossible to use the Marten's apparatus for tests in the oil bath, tests 32 – 38 were carried out with Kennedy's apparatus at temperatures ranging from 33° to 518°, (see Table I.), in order to determine the relation between temperature and elastic limit. These tests gave negative results, inasmuch as they failed to show, with certainty, any simple relation between the two quantities, and for this reason the tables and curves are not reproduced. From four of the above tests the inference would be drawn that the elastic limit decreased regularly with increase of temperature (as would probably be expected), but since all the tests were made with equal care, and since the remainder of the tests do not confirm the inference, the only conclusion to be drawn is that the elastic properties of copper differ

considerably in different specimens or at least in the particular set of specimens under discussion.

9. *Temperature and permanent compressions.*—Six tests were made, and the corresponding autographic diagrams obtained, on cylinders of the dimensions stated below, in order to determine the effect which a change in the temperature has upon the permanent compression produced by any particular stress. The autographic diagrams are reproduced in Fig. 8.

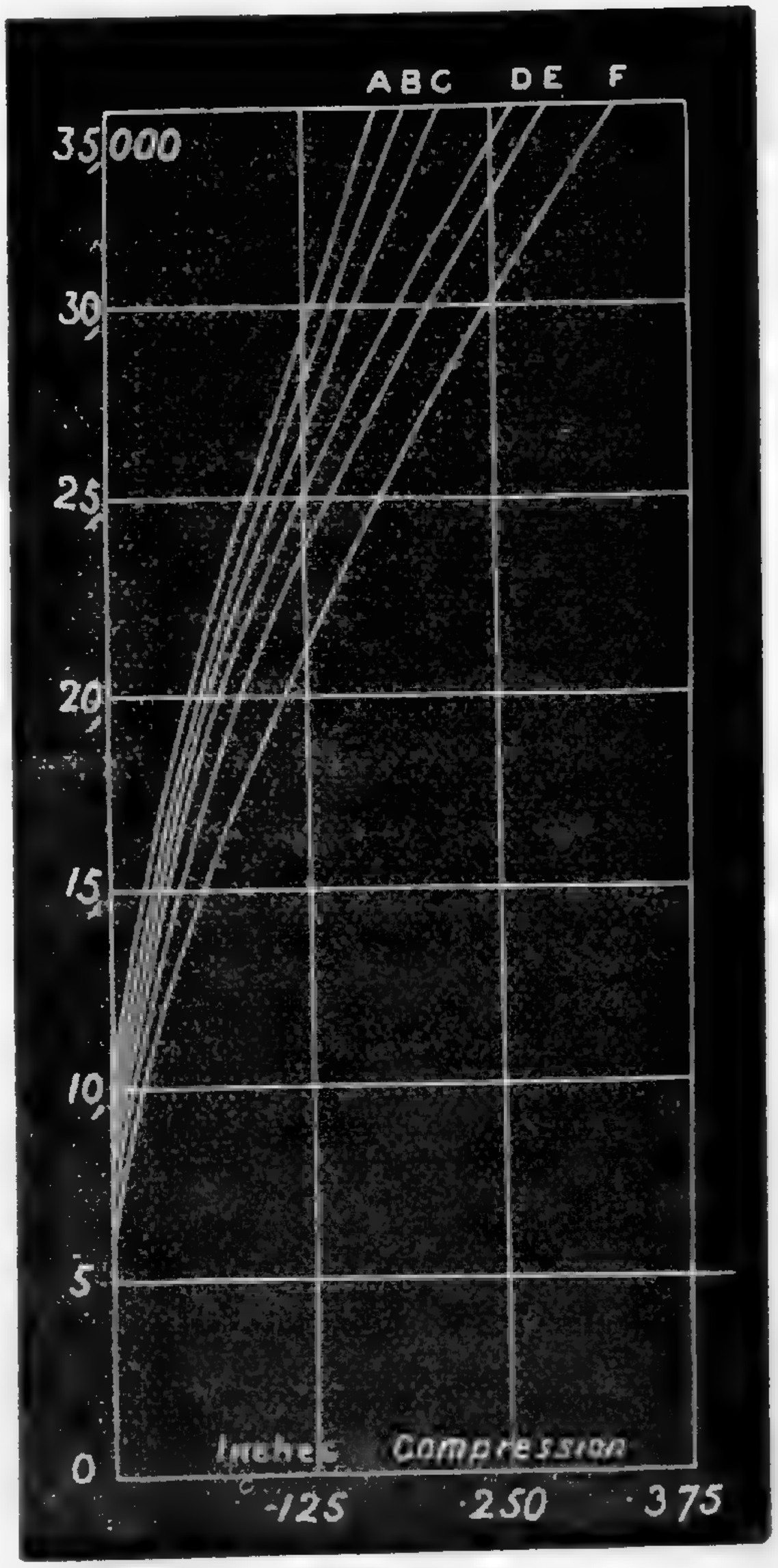


Fig. 8.

Table III.

No. of Test.	Length.	Original Diam.	Area.	Maximum Load. Total.	Maximum Load. Per sq. in.	Final Length.	Total Compression.	Temperature of Test.
45	1·555	·997	·7807	35000	44830	·957	·198	62
46	1·160	·997	·7807	35000	44830	·946	·214	123
47	1·185	·997	·7807	35000	44830	·943	·242	199
48	1·166	·997	·7807	35000	44830	·894	·272	300
49	1·162	·997	·7807	35000	44830	·849	·313	396
50	1·160	·997	·7807	35000	44830	·823	·337	464

Test No. 45 was made in air.

It is evident that the copper is rendered much more plastic by the increase of temperature. The 'yield point,' or point of marked departure of the autographic diagram from the vertical is lowered

by increase of temperature, but it is not possible to deduce from the curves the exact relationship between the two. The behaviour of a metal such as copper, under gradually increasing stress, is well illustrated by Fig. 9, which is the autographic stress-strain record of test 18. In this test the load was first increased up to a point, a little past the elastic limit, at which marked plastic deformation, corresponding to permanent shortening of length and increase of area, was evident. The load was then removed and re-applied, but no further change in the test piece took place till the maximum load previously applied was reached, the previous increase of area being sufficient to reduce the stress per unit area to a value lower than was necessary to produce plastic flow.

10. *The elastic limit in compression.*—Two compressive tests, Nos. 53 and 54, were made on cylindrical test pieces approximately five inches long and an inch in diameter, with Marten's mirror apparatus, to determine the position of the true elastic limit and the shape of the stress-strain curve at low loads. The observations as taken are given in Table IV., and the corresponding curves are plotted on Fig. 7, B and C.

On examining curve B, the position of the points at the lower loads would indicate that the stress-strain line was curved continuously, and that there was therefore no definitely marked elastic limit. To check this, test 54 was made, in which the load was reduced at different points of the test, and observations were taken as to whether the test piece perfectly recovered itself. As will be seen in the table, the recovery up to a load of 1500 lbs. was perfect; beyond that load the matter is doubtful, as the point "*c*" at a load of 2000 lbs. appears to show a slight permanent set (which may however, be due to an error of observation), whereas the point "*c*" at 3000 lbs. shows an apparent perfect recovery (which again may be due to an error of observation). The uncertainty is however confined within fairly narrow limits, so that the elastic limits as shown on curves B and C are probably not subject to a large error.

Table IV.

No. **53**—Length of Test-piece = 5·″00 Diameter = ·997. Temperature of air = 68° F.

Total Loads lbs.	Scale Readings. Left. cm.	Right. cm.	Total = Compression $\frac{1}{1000}$ cm.
500	6·00	0·00	·00
600	6·07	0·03	·10
700	6·11	0·07	·18
800	6·17	0·10	·27
900	6·20	0·12	·32
1000	6·24	0·17	·41
1100	6·28	0·19	·47
1200	6·32	0·21	·53
1300	6·36	0·23	·59
1400	6·40	0·28	·68
1500	6·42	0·30	·72
1600	6·47	0·35	·82
1700	6·51	0·40	·91
1800	6·55	0·46	1·01
1900	6·58	0·50	1·08
2000	6·61	0·55	1·16
2100	6·63	0·67	1·30
2200	6·69	0·69	1·38
2300	6·72	0·72	1·44
2400	6·78	0·76	1·54
2500	6·82	0·80	1·62
2600	6·86	0·84	1·70
2700	6·90	0·91	1·81
2800	6·96	0·98	1·94
2900	7·01	1·02	2·03
3000	7·07	1·10	2·17
3100	7·12	1·13	2·25
3200	7·20	1·19	2·39
3300	7·26	1·27	2·53
3400	7·32	1·30	2·62
3500	7·44	1·38	2·82
3600	7·51	1·43	2·94
3700	7·58	1·50	3·08
3800	7·68	1·58	3·26
3900	7·78	1·65	3·43
4000	7·88	1·74	3·62
4100	7·99	1·83	3·82
4200	8·10	1·94	4·04
4300	8·17	2·00	4·17
4400	8·30	2·14	4·44
4500	8·42	2·28	4·70
4600	8·52	2·40	4·92
4700	8 65	2·51	5·19
4800	8·90	2·74	5·64
4900	9 01	2·87	5·88
5000	9·18	3·02	6·20

No. **54**—Length of Test-piece = 4·″99 Diameter = ·997. Temperature of air = 68° F.

Total Loads lbs.	Scale Readings. Left. cm.	Right. cm.	Total = Compression $\frac{1}{1000}$ cm.
500	6·00	0·00	·00
700	6·10	0·02	·12
900	6·18	0·11	·29
1100	6·27	0·19	·46
1300	6·33	0·25	·58
1500	6·41	0·32	·73
1000	6·23	0·13	·36
1100	6·29	0·17	·46
1300	6·32	0·26	·58
1500	6·40	0·33	·73
1900	6·54	0·53	1·07
2100	6·66	0·62	1·28
2500	6·79	0·81	1·60
3000	6·99	0·09	2·08
2000	6·64	0·64	1·28
2500	6·80	0·88	1·68
3000	6·98	1·09	2·07
4000	7·45	1·64	3·09
4200	7·57	1·78	3·35
4400	7·69	1·89	3·58
4600	7·81	2·00	3·81
5000	8·12	2·32	4·44

The autographic diagram shown was taken from test piece 55, the dimensions of which were length 5·″00, diameter ·997″. The conditions of the three tests, 53, 54 and 55, are thus practically identical. It is evident that very little can be learnt from the autographic diagram as to the elastic properties of the copper. The compression of test piece 55 is largely due to its yielding laterally over the middle half of its length, in the fashion of a long column fixed at both ends.

11. *Temperature and the compressive elastic limit.*—For the purpose of determining the effect of change of temperature upon the elastic limit, tests 20 – 25 were made on specimens of the dimensions and at the temperatures stated in the following table:—

Test No.	Original			Temp. F.°	Compression in $\frac{1}{1000}$th inch at load (total per square inch) of												
	Length	Diam.	Area.		8000	9000	10000	11900	12000	13000	14000	15000	16000	17000	18000	19000	20000
					5390	6063	6735	7414	8085	8760	9430	10120	10780	11450	12130	12800	13475
25	5	1·375	1·485	33				1·9	2·7	4·4	7·2	25·0	43·2	64·2	79·0	93·5	106·0
20	5	1·375	1·485	103			·6	1·6	3·1	4·6	7·0	14·9	26·2	36·5	50·2	64·0	76·5
21	5	1·375	1·485	198	·3	·9	2·2	5·7	12·3	22·5	34·8	46·9	60·4	75·5	90·0	105·5	—
23	5	1·375	1·485	435	·2	·6	·8	1·0	1·0	1·3	2·0	8·9	18·8	35·4	52·5	72·0	91·0
24	5	1·375	1·485	537	1·5	3·2	6·4	11·4	22·1	38·2	52·5	71·0	89·1	108·4	—	—	—

Test 22, intended to be at a temperature of 300° F., was rejected on account of the temperature having varied greatly. In the other tests the temperature was practically constant.

The compressions at the various loads are given in the table, and are co-ordinated in Fig. 10. Nos. 25, 21 and 24 indicate that the elastic limit in compression is lowered by increase of temperature, but No. 23 is erratic, a result due probably to some peculiarity of the individual test piece.

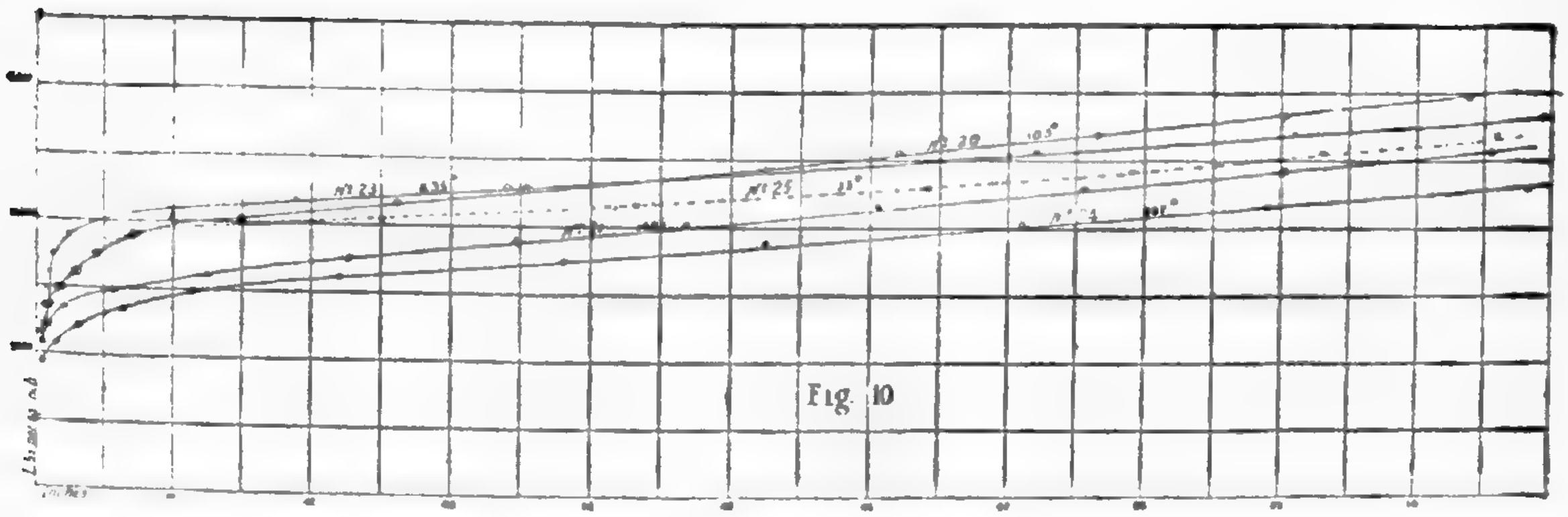


Fig. 10

12. *Summary of Results.*—The results of the investigation may be summarized thus:—(*a*) The relation between the ultimate tensile strength and the temperature may be very closely represented by the equation $f = 32000 - 21\ t$, where f is the tensile strength expressed in pounds per square inch, and t is the temperature expressed in degrees F. (*b*) Temperature does not affect the elongation or contraction of area in any regular manner: and at any one temperature the variation in these two quantities is so great for different specimens that no particular percentage could be included in a specification for the supply of copper. (*c*) The elastic limit in tension occurs at about 5,400 lbs. per square inch at a temperature of 57° F.: this limit probably decreases rapidly with increase of temperature, but the differences in the behaviour of individual specimens are so great as to prevent the determination of the relationship between the two quantities. (*d*) The elastic limit in compression occurs at about 3,200 lbs. per square inch at a temperature of 57° F.: it decreases with increase of temperature, the relationship between the two being more regular than in the tensile tests. (*e*) The rate of permanent extension and compression increases rapidly with increase of temperature, as shown by the autographic stress-strain curves.

NOTES ON THE BASALTS OF BATHURST AND THE NEIGHBOURING DISTRICTS.

By W. J. CLUNIES ROSS, B.Sc., *Lond.*, F.G.S.

[Communicated by J. H. Maiden, F.L.S.]

[*Read before the Royal Society of N. S. Wales, November 3, 1897.*]

INTRODUCTORY.

ALL residents in Bathurst are familiar with the Bald Hills, which form a prominent feature to the south-west of the city. They are the sources of the blue metal used for making the streets, and the columns of basalt are used for kerbs for gutters and for corner-posts. Being so well-known as basalt-capped hills, they have not escaped the notice of geologists. The late Government Geologist, Mr. C. S. Wilkinson, alluded to them, and said that the basalt came from Swatchfield. The Rev. J. M. Curran has described the petrological characters of the rock in his paper dealing with the geology of Bathurst,[1] and also in his prize essay "On the Microscopical Characters of New South Wales Rocks."[2] Lastly, the writer dealt with their character in his paper "On the Geology of Bathurst."[3]

Although, however, a good deal of work has been done in connection with the petrological characters of the basalt, very little attention seems to have been paid to the chemical composition of that or of the other Bathurst rocks, especially in the way of comparison with those of other centres.

Now the microscopic characters of a rock are very important for giving one a knowledge of its structure and mineral constitu-

1 "A Contribution to the Geology and Petrography of Bathurst, N. S. Wales."—Proc. Linn. Soc. N. S. Wales, ser. 2, Vol. XI., pp. 173 – 234; sep. copies pub. Angus and Robertson, Sydney, 1891.

2 "A Contribution to the Microscopic Structure of some Australian Rocks."—Sep. copies, Angus and Robertson, Sydney, 1892.

3 Q.J.G.S., Vol. L., 1894, pp. 105 – 119.

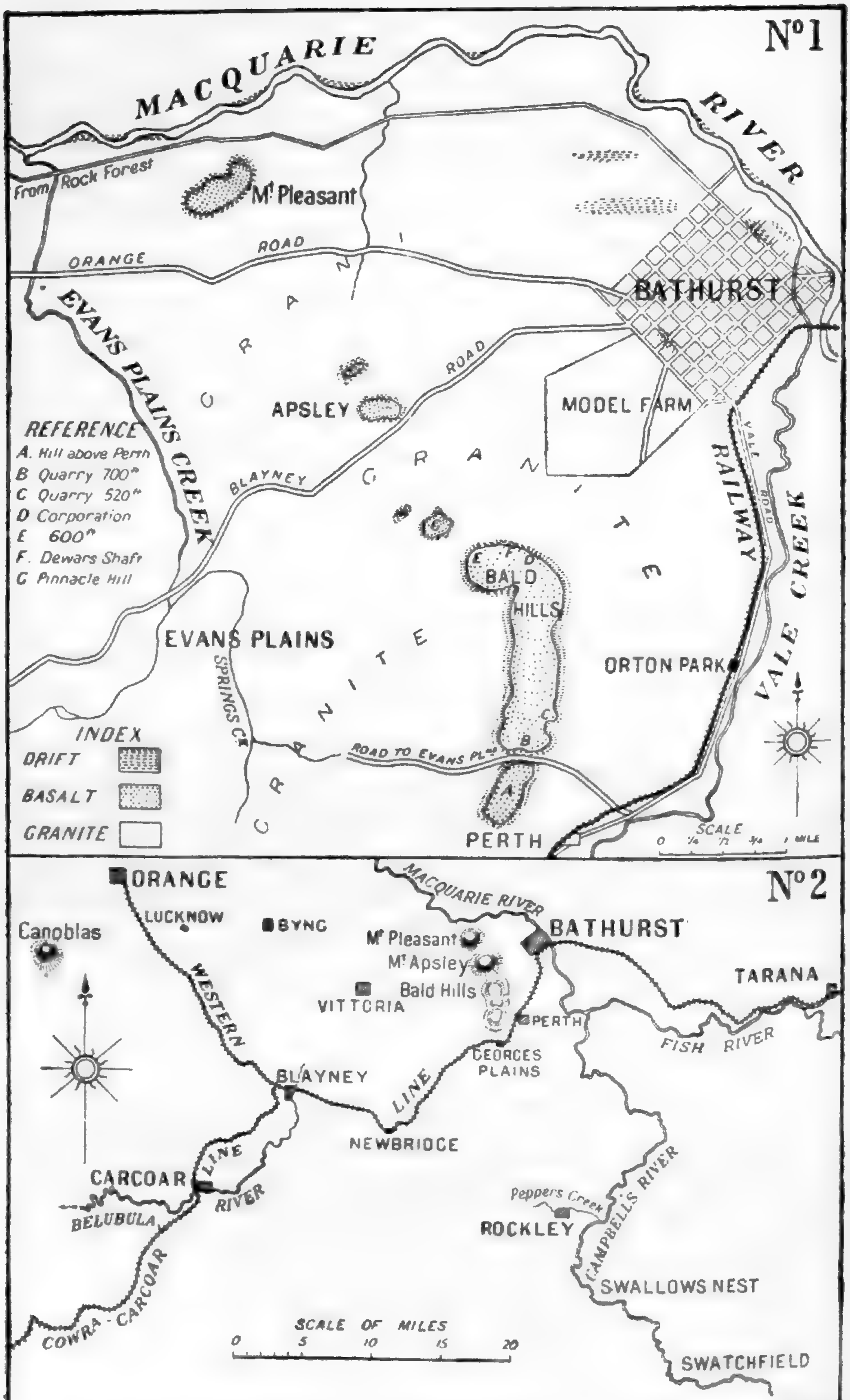
tion, but it is highly desirable that the knowledge thus gained should be supplemented by a chemical examination. I therefore determined, about two years ago, to commence a series of analyses of the various rocks of the district and also to have microscopic slides prepared from the same specimens, so that there might be no mistake as to the rock to which a particular analysis referred. A collection of rocks was sent to England to be cut by a very skilful workman, and I commenced my analyses of the pieces which I retained. Owing to the pressure of official work, however, I could only give a limited amount of time to analytical work, and as rock analysis is rather tedious, I found it would be a long while before I should be able to obtain anything like a complete series of analyses. I therefore decided to drop the granites and similar rocks for the time, and to confine myself to the basalts.

The results obtained so far appear to be of considerable interest and worth placing on record. Basalts have been examined from various parts of the Bald Hills, from Mount Apsley and Mount Pleasant, two outliers in the neighbourhood, and from Rock Forest, a locality on the Macquarie River, about twelve miles below Bathurst. For comparison with these, sections of basalt from Oberon, thirty miles south-east; Orange, thirty-six miles west; Blayney, twenty miles south-west; and Kiama, have been obtained and at any rate partial analyses made. For the most part, I have confined my attention to determining the silica, alumina, oxide of iron, lime, and magnesia, these being the constituents of most interest in a basalt.

In order to give a clear idea of what has been done, it will perhaps be well to describe briefly the various rocks examined, and then consider some of the questions which arise in connection with them. In order to render one's remarks intelligible it will be necessary to give some particulars which have already appeared in print in the various papers to which allusion has been made.

Mode of Occurrence of Bathurst Rocks.

To commence with the rocks in the immediate neighbourhood of Bathurst. It will be seen from the sketch map that the main


Nº1
MACQUARIE
RIVER
From Rock Forest
Mt Pleasant
ORANGE ROAD
BATHURST
EVANS PLAINS CREEK
GRANITE
APSLEY
MODEL FARM
BLAYNEY ROAD
REFERENCE
A. Hill above Perth
B Quarry 700ft
C Quarry 520ft
D Corporation
E 600ft
F. Dewars Shaft
G Pinnacle Hill
BALD HILLS
EVANS PLAINS
SPRINGS CK
ROAD TO EVANS PLAINS
ORTON PARK
VALE RAILWAY
VALE CREEK
INDEX
DRIFT
BASALT
GRANITE
PERTH
SCALE
0 ¼ ½ ¾ 1 MILE
Nº2
ORANGE
MACQUARIE RIVER
LUCKNOW
BYNG
Canoblas
Mt Pleasant
Mt Apsley
BATHURST
TARANA
WESTERN
Bald Hills
VITTORIA
PERTH
FISH RIVER
GEORGES PLAINS
BLAYNEY
LINE
NEWBRIDGE
CARCOAR
BELUBULA
RIVER
Peppers Creek
ROCKLEY
CAMPBELLS RIVER
SWALLOWS NEST
COWRA - CARCOAR
SCALE OF MILES
0 5 10 15 20
SWATCHFIELD
H E C Robinson. Delt Sydney

mass of basalt is of considerable extent, about three miles in length by about a quarter to a third of a mile in breadth, having a general north and south trend, with a bend to the west at the northern extremity and a smaller one in the same direction at the southern end. It forms a connected whole, except for a small interruption where the road from Perth to Evan's Plains crosses the hills, and there are two small pinnacle hills with a thin cap of loose boulders of basalt, in the direction of Mount Apsley. The base of the basalt undulates gently round the hills, but is on the whole tolerably level, although it is difficult to determine the exact junction with the drift which underlies it, owing to loose earth and boulders having rolled or been washed down the sides. At the nearest point to the city, the base of the basalt is about four hundred and fifty feet above the Bathurst Court House, which has been taken as a datum level. The Court House is just about fifty feet above the Bathurst Railway Station, which is two thousand one hundred and fifty-two feet above sea level, so that the datum is, roughly, two thousand two hundred feet above the sea.

The highest part of the Bald Hills is from six hundred and fifty to seven hundred feet above the datum, making the thickness of the basalt at least two hundred feet over much of the hills. The upper part is more or less weathered into large blocks and irregular columns, with earthy matter between, and the basalt was once probably considerably thicker than it is now. The lower part is columnar wherever it can be seen, but is only visible in quarries as a rule. There are fortunately, however, quite a number of small quarries around the side of the hills between Perth and Bathurst. By far the most extensive exposure is that at the quarry opened by the Corporation of Bathurst in order to obtain "blue metal" for the streets. This has only been opened a few years, but already there is a fine face about fifty feet in height. The upper part of the face is columnar, but the columns are much weathered and broken, only about sixteen feet at the bottom shewing tolerably perfect specimens. The floor of the quarry is

four hundred and seventy feet above datum and does not reach the base of the basalt. A photograph of this quarry is exhibited.

Another very interesting section of the basalt is that exposed in the shaft sunk by Mr. James Dewar, with aid from the prospecting vote, to test the underlying drift. The shaft is not far from the Corporation quarry, but at a higher level, about five hundred and sixty feet above datum. The following is a list of the rocks passed through in sinking:—

Decomposed basalt	25 ft.	
Solid basalt	66 ,,	6 in.
Columnar basalt	15 ,,	
Total basalt	106 ft.	6 in.
Beneath basalt—White sandy clay	5 ,,	
Very fine white sand ...	5 ,,	
Tough yellow clay	2 ,,	
Conglomerate	1 ,,	
Wash, carrying fine gold ...	2 ,,	
Total depth of shaft to granite	121 ft.	6 in.

A tunnel has been driven from the bottom of the shaft to th south-east. This commenced in granite, but the drift was afterwards met with and, after driving seventy feet on the level, it was carried in a sloping direction, following the wash down. The gravel is coarser than at first and still carries fine gold but is not payable as yet. The drive has since been continued and is now (October, 1897) one hundred and thirty feet from the shaft. The drift has been followed to a depth of one hundred and fifty feet from surface and is a coarse red gravel.

Beneath the basalt there is drift all round the hills. It is of variable thickness, and composed almost wholly of well rolled quartz pebbles. At Mr. Dewar's shaft it is fifteen feet thick and becomes deeper in the tunnel. Good exposures are uncommon, but about a mile to the south of the Corporation quarry a tunnel was driven

about twelve years ago. This cut the drift at some distance from the opening, but the roof fell in, and although attempts have since been made to reach the lowest layers of drift they have not been successful.

Near the top of the saddle-shaped hill above Perth (A), on the Evan's Plains side, there is a very compact conglomerate, with siliceous cement. It occurs in large massess on the hillside, but cannot be followed far, as both basalt and drift have been denuded away from the depression where the road from Perth to Evan's Plains crosses. On this same hill the granite occurs at a height of over five hundred feet, but a short distance away the basalt appears to be *in situ* at a much lower level. On following the five hundred feet level round towards Bathurst one again meets with the compact conglomerate, but again only for a short distance, and, as blocks of it may be found on the other side of the hills, it probably passes across as a band under the basalt.

Although the basalt in some quarries appears to be lower than the drift close to it, I have never found basalt underlying drift, or any evidence of successive flows of lava at considerable intervals of time.

Mr. Curran mentions[1] the varying number of sides shewn by the basalt columns, and measured the angles. So far as my experience goes, regular hexagons are rare. He did not find any instance of the ball and socket arangement of jointing, so well-known in some basalts. It is certainly uncommon, but a column in the Bathurst Technological Museum shews a very fair ball joint, and the corners seem to indicate the tenons also well known to occur. After twelve years searching, I have been unable to find a fossil of any kind, except specimens of silicified wood, in any of the Bathurst drifts. The silicified wood is dull and opaque. I have not seen any examples of opalised wood, although good specimens are obtainable from Orange.

On following the basalt in its westerly trend, at the northern end, one passes off the basalt for a short distance, and then

1 Geology of Bathurst, p. 49.

reaches the conical hill (G) with a thin capping of basalt. Beyond this there is another similar hill which has lost its cap. There is then a gap of about a mile, and, after crossing the Blayney road, one comes to another outlier of basalt at Mount Apsley, or "Cherry Tree," as it is often called. This is rather an interesting hill. The top is about five hundred and twenty feet above datum, and the basalt is from fifty to one hundred feet thick. The drift underlying it may be well seen in two tunnels which have been driven in the hope of finding gold. As usual the pebbles are of quartz, well rounded, and there are also some large floating boulders of granite, several feet in length, but much decomposed. Only fine gold was found in the tunnels, but from some of the neighbouring gullies very fair gold has been obtained.

Beyond Apsley, to the south-west, there is a conical hill with a capping of drift, but only a few boulders of basalt. Following the same line we pass over an undulating country, and after about two miles reach the last outlier of basalt in the neighbourhood of Bathurst. This is generally known as "The Mount," from the well known residence of Mr. James Stewart at its foot. It is also called Mount Pleasant, although the village of that name is shewn on the parish map as some little distance away. There is a considerable descent from Apsley to the mount, the top of the latter being only about two hundred and fifty feet above Bathurst. The basalt is very compact, but, as no quarries have been opened, it is difficult to obtain fresh specimens, or to be confident about its thickness, especially as the drift appears to be very thin. It may be estimated as about one hundred feet thick.

Petrological Characters.

Macroscopically the basalt is a blue-black, fine grained rock, but varies somewhat in texture, the basalt from some of the lower quarries and from Mount Apsley being the coarsest. There are nests of crystals of a green colour in some specimens, which I should have taken for olivine, but Mr. Curran appears to consider them as augite. A good number of small zeolitic spots are seen in some of the quarries, but they effervesce freely with acid and

are probably calcite. Under the microscope the rock is uniformly micro-porphyritic. The porphyritic constituents are augite and olivine, with a few moderate sized felspars. Most of the felspar, however, exists as very small lath shaped crystals scattered through the ground mass. They are gathered round the larger crystals and shew flow structure beautifully. Mr. Curran has so well described the crystals in detail that it is unnecessary to repeat. He considers the magnetite, which is abundant, to be a primary constituent of the basalt, it having been one of the first minerals to crystallise out from the magma. It occurs enclosed within the augite and olivine crystals, and occasionally, in the larger felspars. Much of it, however, is scattered through the ground mass. I am inclined to think that it may have a patho-logical significance, and be a result of alteration in the rock. It certainly appears to me that the crystals in which magnetite is present are clearer and lighter than those in which none appears.

There appear to be no cases in which felspar is actually included in the augite or olivine, although in some cases felspar and one of the other minerals have mutually interfered with one another's development. The basalt cannot be considered of the ophitic type, but rather of a granulitic character. Professor Judd[1] considers that the ophitic type of structure is characteristic of basalts which have solidified with perfect internal equilibrium, while the granulitic type indicates internal movement during consolidation. The flow structure being so well shewn in our rock, this view of the granulitic structure is confirmed.

Mr. Curran has had thirty slices cut from the Bald Hills and Mount Pleasant basalt, and mentions the localities from which his specimens were obtained. My own specimens have been obtained from different localities and mainly from those marked B, C, D, and E on the map. Locality B, is at the highest part of the Bald Hill, near Perth, about seven hundred feet above Bathurst. A shallow quarry exists there and the freshest

[1] The gabbros, etc., of Tertiary Age in Scotland and Ireland.—Q.J.G.S., Vol. XLII. (1886), p. 87.

specimens were chosen for examination. The rock is a good deal weathered, but presents the usual appearance of a porphyritic basalt under the microscope.

C. This is one of the quarries in the columnar basalt, at a height of five hundred and twenty feet. It is much fresher and rather coarser grained, otherwise it resembles the rock from B.

D. This is the site of the Corporation quarry. The specimens were taken from near the floor of the quarry, height about five hundred feet. Most of the rock is much weathered and it is difficult to obtain good pieces for section cutting. General character as before.

E. At the north-west end of the hills, at the part nearest to Mount Apsley. Specimens were obtained at a height of about 600 feet. While generally resembling the other sections, the felspar crystals in the ground mass are larger and the rock bears more resemblance to that found at Apsley. All these specimens are remarkably similar and approximate very closely in appearance to those figured by Mr. Curran.[1]

Passing now to Mount Apsley, we find a distinct change in the microscopic characters of the rock. Mr. Curran does not seem to have examined sections from this locality. He mentions obtaining them from the Bald Hills, near Perth, from the Pinnacle Hill (G), and from Mount Pleasant. As one notices the various outliers it appears so obvious that the basalt must have flowed from the Bald Hills, viâ Pinnacle to Apsley, and thence to Mount Pleasant, that it would hardly appear necessary to specially examine the Apsley rock. I was therefore astonished when, having had a section cut, I found it to be very different from those from the Bald Hills. Instead of a porphyritic rock, with a ground mass of small felspars and granules of other minerals, one finds a comparatively coarse-grained basalt of tolerably uniform texture, the felspars in particular forming an

1 "Geology of Bathurst," pl. 14. "Microscopic Structure of Australian Rocks," Journal of Royal Society of N.S.W., Vol. xxv., pl. 21.

interlacing mass of fair sized crystals. Mr. Curran mentions how readily a slice of Bathurst basalt may be distinguished from that from Orange, even when the slice is still comparatively thick. This is certainly the case when we are making a section of Bald Hills basalt, but it is by no means so when the Apsley rock is compared with the Orange basalt. On the contrary, they are so much alike that one would think they came from the same place, and when I received the slides I at first thought a mistake had been made in labelling them. Subsequently obtaining sections from fresh pieces of Apsley basalt, it was found that they were all alike, and all differed from the Bald Hills rocks. In each case, as soon as a slice was thin enough to transmit light, one could at once say whence it had been obtained. Slides 1, 2, and 5, and the microphotographs similarly numbered, accompanying this paper, will shew what is meant.

So marked a distinction between rocks obtained close together, naturally led one to try and account for the difference. The first idea that suggested itself was that the Apsley basalt might belong to a different flow of lava from that which covered most of the Bald Hills. Specimens collected from the most widely separated parts of the latter, have so far, however, failed to supply anything really like the rock from Apsley. Moreover, in chemical composition and specific gravity the two series of specimens agree very closely. The most probable explanation of the difference appears to be that it is due to different conditions of cooling. The felspars in the Apsley rock, besides being much larger, can be seen to intersect the olivine and augite crystals. There is a good deal of rather coarse magnetite between the other crystals, but not so much as in the Bald Hills rock, and scarcely any within the minerals themselves. There is little or no evidence of flow structure. The rock on the whole appears to resemble the ophitic type of basalt, as figured by Professor Judd,[1] rather than the granulitic, and the difference may be due to the Apsley rock having solidified with little or no internal movement.

[1] Q.J.G.S., Vol. XLII. (1886), pls. v. and vi.

Passing on to the Mount Pleasant rock, there is not much to say. It is finer grained than the Apsley and than most of the Bald Hills basalt. Mr. Curran describes and figures it as a micro-porphyritic rock similar to that of the Bald Hills. He says he has about ten sections. I have only one good section and that is somewhat weathered. It is not decidedly porphyritic and shews only slight indications of flow structure. It rather suggests a fine grained edition of the Apsley rock. In view of Mr. Curran's greater experience of the rock, however, it is possible that my section is not typical.

Chemical Composition.

The only analysis of the Bathurst basalt with which I am acquainted is a very complete one by Mr. Mingaye, of the Mines Department, quoted by Mr. Curran.[2] My own determinations agree fairly well with his, except that I make the percentage of silica rather more, and that of the alumina rather less. My results are as follows :—

From the Bald Hills, Corporation Quarry, I obtained silica 47·75 per cent. From the small quarry near Perth, at about seven hundred feet, 47·55 per cent. Mount Apsley, mean of three determinations, gave 48·2 per cent. Mount Pleasant gave a higher result, 49·8 to 50 per cent.

Alumina, Bald Hills, 18·5 to 19 per cent. Apsley 17·5 to 18 per cent. Mount Pleasant 15·5 per cent.

Ferric oxide, Bald Hills, 12·5 to 15 per cent.; Apsley 14·5 per cent.; Mount Pleasant 14·5 per cent

Lime, Bald Hills, 8·4 to 10·6 per cent.; Apsley 10·08 per cent.; Mount Pleasant 7·5 per cent.

Magnesia, Bald Hills, 7·5 to 9·2 per cent.; Apsley 6·86 to 7·56 per cent.; Mount Pleasant, I did not obtain a satisfactory result.

Considerable variation was noted in the percentage of bases, and this is only what one might expect in a porphyritic rock, as

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[2] Geology of Bathurst, p. 57.

it is unlikely that various specimens selected for analysis would all contain the same proportion of constituent minerals. A specimen rich in olivine would be likely to show a high percentage of magnesia and iron ; one with an excess of augite would probably be rich in lime, while a large amount of felspar would bring up the alumina percentage.

Specific Gravity.

The Bald Hills rock gave results ranging from 2·9 to 3·05. That from Apsley was nearly the same, about 2·9. The Mount Pleasant rock is lighter, three specimens all giving about 2·68.

Comparison with other Centres.

One naturally desires to find out the source of our Bathurst basalts. Around Bathurst itself there are no indications whatever of old craters or volcanic necks from which the basalt might have been erupted, but within a radius of forty miles there are three districts where basalts and allied rocks occur under conditions which render it likely that they were once centres of volcanic activity. These are, 1. The Blayney-Carcoar area, 2. The Orange district and, 3. That of Swatchfield. Map 2 shews the relative position of these centres, and it will be seen that all are at considerable, and not very unequal distances from Bathurst. If we take Carcoar as a possible centre, that is about thirty miles away. The Canoblas, near Orange, are about thirty-six miles, and the Swatchfield area is about thirty-five miles distant.

Blayney—This town is rather over twenty miles from Bathurst in a south-easterly direction. It is the centre of a very interesting district, where a great variety of rocks occur, and would well repay detailed geological study, which would, however, entail long and careful work on the spot. One finds, within a short distance of the town, granites sending veins into the altered contact rocks, such as are so common around Bathurst ; schists, phyliites, of various types, with beds of limestone carrying fossil corals. There are also veins of copper ore which have been worked to a considerable extent and, what is of more immediate importance, intrusive dykes of basic igneous rocks, together with basaltic

cappings to some of the hills. If we travel south, about ten miles, we reach Carcoar, another interesting locality, where there are dense holocrystalline, coarse-grained, basic rocks, which may be classed as gabbro. A section of one of these, obtained from a cutting near Carcoar station, shows it to consist mainly of plagioclase felspar, together with a green mineral in large crystals but without a definite outline. The rock appears to be a good deal weathered and one feels rather doubtful about naming the latter mineral. It is probably an altered pyroxene, and appears schillerized but does not shew the strong cleavage of diallage very clearly. It is strongly dichroic and may be passing into hornblende. Mr. Curran mentions obtaining sections of an apparently similar rock from Carcoar.[1]

Near Blayney, in a cutting on the Carcoar line, a dyke of a fine porphyritic rock occurs, having white prismatic crystals of felspar scattered through it. A similar rock, in microscopic character, is well known at Dripstone, near Wellington. I have not a section of either of these, and one from a similar rock obtained near Carcoar is very much weathered. Mr. Curran mentions similar rocks as occurring near Cowra and calls them, and also the Wellington rocks, diabase porphyrites. This is the name which I applied provisionally to the Blayney rock before seeing his paper. The specific gravity of a specimen was 2·36.

The nearest approach to a true basalt was obtained from the top of a hill near the Blayney cemetery. It is a close-grained, black rock, which under the microscope is seen to be an aggregate of rather coarse crystals, much weathered, and of quite a different type from the Bathurst basalts. From two or three determinations, the silica was found to be forty-nine or fifty per cent. The alumina was not as satisfactorily determined but appeared to be fully 20 per cent., ferric oxide 13·5, lime 6·72, magnesia 4·86. The specific gravity varied in different specimens from 2·8 to 3. Blayney is on the Belubula River, which belongs to the Lachlan

1 "The Microscopic Structure of Australian Rocks," p. 46.

system. The water parting between the Belubula and the Macquarie appears to be near King's Plains, north-east of Blayney. The country is considerably higher than Bathurst, Blayney being 2,840 feet above sea, but there does not seem to be any evidence that the Bathurst basalts are related to the Blayney-Carcoar series.

Near Orange igneous rocks are extensively developed. The Canoblas hills appear to be almost wholly volcanic and the summit of the Pinnacle is a coarse grained, apparently plutonic rock but so much altered by weathering that it was useless to have a section cut from specimens which I collected. Near the foot of the hills there is plenty of tolerably fresh columnar basalt. The Rev. J. M. Curran has numerous slices of Orange basalt, which are so much like mine, that there can be no doubt that they are practically the same rock. I find it microscopically to be a coarse-grained rock largely made up of felspar, with augite and a little olivine. There is not much magnetite, but the section (5) and microphotograph shew a very perfect octahedron of that mineral in the very centre of a crystal of augite. The rock appears to be rather of the ophitic type, and, as already mentioned, it resembles the Mount Apsley rock in microscopic characters. Examined chemically, however, there is a marked difference. The silica obtained ranged from 55·75 to 56 per cent., alumina about 15 per cent., ferric oxide 10·1 per cent., magnesia 7·5 per cent., lime 7·3 per cent. Specific gravity 2·74.

It is evident that this differs considerably from any of the Bathurst basalts, and macroscopically, in hand specimens, it has also a distinct character. The country around Orange is much higher than Bathurst, Orange itself being 2,844 feet above sea-level. Pinnacle, Canoblas, by aneroid, is 1,150 feet above Orange. The hydrography of the district would have to be very different from what it is now, however, to allow of lava flowing down a river channel from Orange to Bathurst. On all grounds, therefore, it is unlikely that our basalt was derived from Orange.

Lastly, we come to the Swatchfield area. I have not examined this district personally, but the late Mr. C. S. Wilkinson compiled

a geological map and partly described it.[1] He shows several outcrops of basalt, and mentions that a creek at Swallow's Nest has excavated a channel two hundred feet deep in solid basalt. He was of opinion that the Bathurst basalt was poured out as lava stream in that district. Swatchfield itself is the name of a large parish, about thirty to thirty-five miles from Bathurst. It is some miles south of the township of Oberon and not far from the sources of the Fish and Campbell Rivers, which rise near together but afterwards separate widely, finally uniting to form the Macquarie. Swatchfield is thus on the river system that drains the Bathurst area, and, assuming that the drifts below the basalt were brought down by a river which followed approximately the course of the present Macquarie, there can be little doubt that we have in this district the source of our Bathurst basalts. It is highly desirable, however, to obtain confirmation of the assumption, if possible. A specimen of basalt from the neighbourhood of Oberon was therefore very welcome, and it has been cut and analysed. (Slide and micro-photograph, No. 6). The rock is much weathered but its structure may be made out. It is a distinctly porphyritic rock and carries large crystals of olivine, much corroded at the edges and crossed by cracks filled with serpentinous matter. Apart from these, the crystals are clear and shew little or no included magnetite. It appears probable that they were brought up by the lava in a solid form and were not formed in the rock itself. The ground mass is much decomposed, but small crystals of felspar similar to those in the ground mass of the Bald Hills basalt may be seen, and there are indications of flow structure. When analysed, the silica was found to be from 46·75 to 47·75 per cent. The alumina 19·2 per cent.; ferric oxide 14·5 per cent.; lime 7·84 per cent.; magnesia 8·2 per cent. The specific gravity 2·83.

This similarity of character is a strong point in favour of the view held by Mr. Wilkinson. The township of Oberon is about 3,500 feet above sea level, so that there is a fall of about eight

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[1] Report of Department of Mines, 1877 (Sydney 1878) pp. 200 to 205, and map.

hundred feet from there to the base of the basalt near Bathurst. If the basalt flowed from Swatchfield, it must have been a very extensive lava flow to travel so far and arrive at the site of the Bald Hills with a thickness of over two hundred and fifty feet. Equally extensive flows of lava are known, however, in modern times, as, for example, that of Skaptor Jokul, in 1783.[1] It is rather remarkable, however, that there appear to be no outliers of basalt along the valley of the Campbell or Fish Rivers. The whole of it appears to have been denuded away, except in the immediate neighbourhood of Swatchfield.

It is true that boulders of basalt have been several times reported as existing near the lagoon, about ten miles from Bathurst, As this would be on the line of flow of the basalt, the lagoon being close to the Campbell's River, I was anxious to obtain a specimen. At first I failed to find them, but afterwards Mr. Woolley, who has charge of the Public School at Lagoon, and knew the country well, kindly drove me to some boulders of dark rock, which were the only ones he knew in that neighbourhood. They proved to be near the summit of a hill, at a height of about four hundred feet above Bathurst, and were of several types. Some were moderately coarse grained rocks, probably diorite or dolerite. Others were more like basalt, and a slice was cut from one of these. Although not a satisfactory section, it is sufficiently clear to shew that it differs essentially from any of our rocks hitherto examined, and is hardly a typical basalt. A determination of the silica gave 55 per cent. Specific gravity of two specimens 2·7 and 2·8. These results indicate a basic rock, but not a Bathurst basalt. It is hoped that the origin of these boulders may be traced, and indeed, the country between twenty and thirty miles from Bathurst offers a fine field for investigation.

After endeavouring to trace the source from whence our basalts were derived, one would naturally like to find out where they

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[1] Well described by Lyell—"Principles of Geology," 12th Edition, Vol. II., p. 49.

went to after passing Mount Pleasant. For some distance down the Macquarie there are no indications of basalt, but at Rock Forest, about six or eight miles below the Mount, there are some basalt-capped hills, where attempts are now being made to test the underlying drifts for gold. Not being able to visit the locality personally, I am indebted to Mr. J. J. Sullivan, of Rock Forest, for specimens. The rock is very compact and fine grained; under the microscope it somewhat resembles the Mount Pleasant rock. I obtained 52·5 per cent. of silica, and found the specific gravity to be 2·65.

For comparison with our western rocks, a section of Kiama basalt may be interesting, and one is exhibited. An analysis gave, silica 56·2; alumina 16·5; ferric oxide 12·5; lime 7·28; magnesia 4·68. It is evidently a much weathered rock, but microliths and larger crystals of felspar are visible.

Summary.

It has been shewn that the basalts of the Bald Hills are similar in microscopic and chemical character wherever obtained; specimens having been tested from places three miles apart, and at heights ranging from five to seven hundred feet above Bathurst. The detached outlier of Mount Apsley is found to differ considerably in microscopic characters, but to be similar in chemical composition. The difference may be due to different rates, or varying conditions, of cooling. At Apsley it may have filled a deep pool in the river, any lava which followed having passed over it. The Mount Pleasant basalt is rather richer in silica and of lower specific gravity. Lower down the Macquarie there is another exposure of basalt at Rock Forest. It is of similar character and probably belongs to the same flow as the Mount Pleasant rock. The attempt to prove the existence of several distinct flows of lava has, so far, not been successful.

As a result of testing basalts from neighbouring districts, it has been proved that the Orange basalt has a higher percentage of silica than the Bathurst rocks, although it shews a curious similarity in microscopic structure to the Apsley basalt. The

Blayney basalt appears to be quite different in structure from either of the others. It is not likely that our basalts have been derived from either of these districts.

At Oberon, there are basalts closely resembling the Bathurst rocks in chemical composition, and also not unlike them microscopically. Swatchfield, in the same district is on the Macquarie River system, and, as conjectured by the late Mr. C. S. Wilkinson, is probably the locality from which our rocks were derived. The old lavas probably flowed down the valley of what is now the Campbell's River. The exact centres of eruption have not yet been determined. It appears likely that the Blayney-Carcoar, the Orange, and the Swatchfield areas formed distinct centres of eruption, and the lavas may be of different age. Of the exact age there is very little evidence available as yet. They are probably late Tertiary, and newer than the present drainage system of the country, but beyond that one can hardly speak with confidence.

In conclusion, I desire to express my indebtedness to Mr. A. Page, for preparing microphotographs, and to Mr. W. Pascoe, for grinding rock sections.

ON THE STEADY FLOW OF WATER IN UNIFORM PIPES AND CHANNELS.

By G. H. KNIBBS, F.R.A.S.,
Lecturer in Surveying, University of Sydney.

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26. Indications for further experimental investigation with pipes and channels. Conclusion.

1. *Introduction.*—Though the problem of the motion of water in pipes and channels, said by St. Venant to constitute a hopeless enigma,[1] has received some attention from mathematical physicists, even its empirical solution cannot yet be said to have been satisfactorily reached. The formulæ used by engineers are in general either those furnished by MM. Darcy and Bazin, or the very ingenious modification by which MM. Ganguillet and Kutter endeavoured to embrace every possible case of flow in uniform channels. The degree of precision to which results, founded upon such formulæ, are usually expressed, indicate how imperfectly their limitations are appreciated: it will be shewn in the course of this paper, that even in respect of their mathematical form they are systematically defective.

2. *The motion of water in a pipe or channel.*—In a pipe or channel of uniform section the steady motion of water—defined by the condition $du/dt = 0$—[2]under the action of an accelerating force such as gravity, involves the recognition of an equal and equally constant retardation; which must be conceived as arising from the internal friction of the fluid, in some cases largely influenced, however, as to the mode of its action, by boundary conditions. In a uniform and horizontal pipe there is always a fall in pressure from point to point, in the direction of the motion of the fluid within, due to the internal friction.

The part played by friction was perhaps first clearly recognized by Mariotte in 1686,[3] and following him, by Guglielmini, Couplet, D'Alembert, Bossut, and DuBuat. Nevertheless it was not till 1799 that a satisfactory attempt was made to obtain a numerical expression for it. The course of the investigation of this quantity —the viscosity constant for water—together with a reëxamination

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[1] Déspérante énigme.—C. R. t. 74, p. 774.

[2] In which as usual, t denotes time and u denotes the velocity parallel to the axis of any point in a right section; the actual velocity of each particle, when the motion is rectilinear, or the mean of the velocities when non-linear. The latter condition is in some sense periodic.

[3] Traité du mouvement des eaux. Paris 1686.

and a fresh reduction of the whole of the experimental data, has been given at length in two earlier papers, viz., that of July 1895, and of September 1896, read before this Society.[1] In obtaining the value of the constant, a rational solution of the problem of flow in circular, and elliptical cylinders, and slightly tapering cones, was reached, for the case of non-sinuous motion, *i.e.*, motion such that each particle moves parallel to the axis of the pipe.

The viscosity was defined in the paper above referred to,[2] as the ratio of the tangential resistance between parallel strata of fluid moving with different velocities, to the rate of variation of the velocity measured perpendicularly to the direction of motion. Thus it may be regarded as a measure of the resistance of the fluid to the distortions or shear, involved by the circumstances of flow. It was likewise shewn that the velocity of water in contact with a pipe is zero; and that the fall in pressure from point to point of a horizontal pipe is wholly the consequence of the resistances between the surfaces of the elementary coäxial cylinders into which the whole volume of the liquid may be conceived to be divided, each one of which is moving more and more rapidly, as the axis of the pipe is approached. This type of motion may be described as *steady* and *rectilinear*. When the motion is non-linear, but otherwise steady, that is to say, when equal volumes pass each section in a unit of time, the velocities of translation must be in some sense periodic, although the periodicity may, and really appears to be, somewhat irregular. When the mean velocity of translation past any section is constant, the flow may be called steady non-linear or uniform turbulent flow.

3. *Velocity in elliptical pipe with steady rectilinear flow.*—When the viscosity coëfficient for a fluid is known, the mean velocity U

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[1] The History, Theory, and Determination of the Viscosity of Water by the Efflux Method.—G. H. Knibbs, Journ. Royal Society, N.S.W., Vol. xxix., pp. 77–146. Also, Note on Recent determinations of the Viscosity of Water by the Efflux Method.—Journ. Roy. Soc. N.S.W., Vol. xxx., pp. 186–193.

[2] *Loc. cit.*, p. 88.

in a pipe of elliptical section may be readily found, if the flow be as just described, *i.e.*, if the motion of all particles be parallel to the axis of the pipe. The following expression for mean velocity, or rather its equivalent, was deduced from Navier's equations[1] and justified in my paper before referred to.[2]

$$U = \frac{g}{8}\frac{\rho}{\eta}\frac{H}{L}\frac{B^2C^2}{\frac{1}{2}(B^2+C^2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

in which g is the acceleration of gravity, ρ the density of the fluid, by means of a column of which, of the height H, the difference of the pressures, at two sections of a horizontal tube, the distance L apart, is measured, B and C are the semiaxes of the ellipse, and η is the viscosity of the fluid.

If the units are C.G.S. throughout, the viscosity factor—a function of the temperature—is fairly well represented for water, by the formula

$$\frac{1}{\eta} = 55{\cdot}89\,(1 + 0{\cdot}0325\,\tau + 0{\cdot}0005\,\tau^2) \quad \ldots\ldots\ldots\ldots(2)^3$$

from 0 to 8° C.; and by

$$\frac{1}{\eta} = 55{\cdot}89\,(1 + 0{\cdot}03395\,\tau + 0{\cdot}000235\,\tau^2) \quad \ldots\ldots\ldots(3)$$

from 0° to 40° C.: τ being the temperature in Celsius degrees. Instead of $\rho g H$, its equivalent P may be written, P being the difference of pressure in dynes per square centimetre, at the two sections. For more accurate results the value of $1/\eta$ may be taken from the table hereinafter. (Table I.)

For pipes of circular section the final factor $B^2C^2/\frac{1}{2}(B^2+C^2)$ becomes of course R^2. The ratio per unit of length of the fall in pressure, measured by a column of the same temperature as the fluid in motion, *i.e.*, H/L, will be denoted hereinafter by I. This quantity is often called the slope or hydraulic gradient.

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[1] Mem. de l'Académie, t. 6, pp. 389 – 440, 1823.

[2] *Loc. cit.*, pp. 110 – 113.

[3] The factor 0·0325 is wrongly written 0·0225 in the "Note on recent determinations &c." previously quoted, see p. 191. The proper quantity was however used throughout in the calculations.

For engineering requirements, $\rho g/8\eta_o$ may be put as a single factor, g being taken as 980·6, and ρ as ·999. Hence for centimetre units for velocity and radius, and for metre units, we have respectively

$$U_{cm} = 6844\, f\, I\, R^2_{cm} \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$U_{m} = 684400\, f\, I\, R^2_{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

f denoting the relative fluidity, viz., the quantity expressed in brackets in formulæ (2) and (3). The results by these formulæ would be excessively great if they were generally employed, that is if they were used where the flow is non-linear or turbulent; for it is this latter condition that usually exists in cases with which engineers are concerned.

4. *Values of the fluidity and viscosity.*—In all computations the results of which are subsequently given, the following values of the fluidity, and of the reciprocals of the viscosity are used. Both the natural numbers and their logarithms are entered so as to

TABLE I.

Relative fluidity (f), and reciprocals of the viscosity $\left(\frac{1}{\eta}\right)$ of water from 0° to 39° C. C.G.S. units.

Temp. C.	f.	log. f.	$\frac{1}{\eta}$	log. $\frac{1}{\eta}$	Temp. C.	f.	log. f.	$\frac{1}{\eta}$	log. $\frac{1}{\eta}$
0°	1·000	·0000	55·89	1·7474	20°	1·770	·2480	98·93	1·9953
1	1·033	·0141	57·74	1·7615	21	1·814	·2586	101·39	2·0060
2	1·067	·0282	59·64	1·7756	22	1·858	·2690	103·85	2·0164
3	1·102	·0422	61·60	1·7896	23	1·903	·2794	106·37	2·0268
4	1·138	·0561	63·61	1·8035	24	1·948	·2896	108·88	2·0369
5	1·175	·0700	65·68	1·8174	25	1·993	·2995	111·40	2·0469
6	1·213	·0839	67·80	1·8312	26	2·039	·3094	113·97	2·0568
7	1·251	·0973	69·92	1·8446	27	2·085	·3191	116·54	2·0665
8	1·289	·1103	72·05	1·8576	28	2·131	·3286	119·11	2·0759
9	1·327	·1229	74·17	1·8702	29	2·178	·3381	121·74	2·0854
10	1·365	·1351	76·30	1·8825	30	2·225	·3473	124·36	2·0947
11	1·403	·1471	78·42	1·8944	31	2·273	·3566	127·05	2·1040
12	1·441	·1587	80·54	1·9060	32	2·321	·3657	129·73	2·1130
13	1·480	·1703	82·72	1·9176	33	2·370	·3747	132·47	2·1221
14	1·519	·1816	84·90	1·9289	34	2·419	·3836	135·21	2·1310
15	1·559	·1928	87·14	1·9402	35	2·469	·3925	138·00	2·1399
16	1·600	·2041	89·43	1·9515	36	2·519	·4012	140·80	2·1486
17	1·641	·2151	91·72	1·9625	37	2·570	·4099	143·65	2·1573
18	1·683	·2261	94·07	1·9735	38	2·622	·4186	146·55	2·1660
19	1·726	·2370	96·47	1·9844	39	2·675	·4273	149·52	2·1747

facilitate either natural or logarithmic computation. The table is based upon the assumption that the viscosity at 10° C. is 0·013107, and that the relative fluidity at that temperature is 1·365, that at 0° being unity, η_o is consequently 0·017891.

The following supplementary table of values of the fluidity from 40° to 100° C. is based on the mean of Slotte's (1883) and Thorpe and Rodger's (1894) values. These have been so adjusted that the differences progress regularly, but since Slotte gives for the higher temperature 5·983 and Thorpe and Rodger 6·282, the fluidity must be considered as very uncertain for the higher temperatures.[1]

TABLE II.

Temp. τ.	40°C.	45	50	55	60	65	70
Fluidity f.	2·72	2·97	3·23	3·50	3·77	4·05	4·34
Log. f.	·435	·473	·509	·544	·576	·607	·637
Temp. τ.	75°C.	80	85	90	95	100	
Fluidity f.	4·63	4·92	5·22	5·52	5·82	6·13	
Log. f.	·666	·692	·718	·742	·765	·787	

5. *Instability of rectilinear flow in pipes.*—It has long been known that the circumstances of the motion of water in pipes and channels are subject to characteristic differences, the general cause of which was indicated by Stokes in 1842.[2] Hagen in 1853, while investigating the influence of temperature,[3] distinctly

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[1] See Journ. Roy. Soc. N.S.W., Vol. xxx., p. 193, 1896.

[2] On the steady motion of incompressible fluids.—Trans. Camb. Phil. Soc., Vol. vii., pp. 434 – 454 and 465, 1842. On the analytical condition of the rectilinear motion of fluids etc.—Phil. Mag. Vol. xxi., pp. 297 – 300, 1842, and Vol. xxii., pp. 55, 56, 1843.

[3] Ueber den Einfluss der Temperatur auf die Bewegung des Wassers in Röhren.—Abhandl. Akad. Wiss. Berlin, 1854, Math. Abt. pp. 17. The paper was read 10th Nov., 1853. The following passage illustrates the point:—"Hieraus ergiebt sich, dass die innern Bewegungen sich bilden, oder wenigstens sehr stark zunehmen, sobald die Geschwindigkeit das maximum erreicht, und die Vermuthung liegt sich nahe, dass diese innern Bewegungen die Ursache sind, weshalb die mittlere Geschwindigkeit in weiterer Erwärmung des Wassers sich nicht vergrössern kann, indem sich sogar verkleinert. Die bisher mit c bezeichnete Geschwindigkeit ist

recognised the critical change, which takes place, as the velocity of flow increases, and he further observed that the régime following the break-down of the rectilinear condition, was turbulent or eddying.[3] The change was witnessed in glass tubes specially employed for the purpose, and its significance justly appreciated and interpreted. As recently however as 1883, Reynolds, who gives no indication that he was aware of Hagen's work, but on the contrary claims to have been the first to realize experimentally the two régimes, repeated the observation of Hagen, and apparently found that the velocity beyond which it is impossible to maintain the rectilinear régime, varies with the dimensions of the tube in which the flow occurs.[1] This velocity according to Reynolds, may with great care reach a certain maximum amount, depending upon the radius of the tube; and this maximum he calls the *critical velocity*. Ordinarily the rectilinear régime breaks down, in his view, before the critical velocity is reached. Both Hagen

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nämlich aus der ausfliessenden Wassermenge hergeleitet; sie ist daher nur in Richtung der Röhrenaxe gemessen und bezieht sich nicht auf die innern Bewegungen und Wirbel. Sie stellt daher keineswegs die ganze Bewegung des Wassers dar vielmehr nur denjenigen Theil derselben, der das Fortschreiten der ganze Masse bezeichnet. Besondere Beobachtungen, die ich mit Glasröhren anstellte, zeigten beiden Arten der Bewegungen sehr deutlich. Indem ich durch dieselbe Röhre zugleich mit dem Wasser auch Sägespähne hindurch treiben liess, so bemerkte ich, dass dieselben bei geringen Drucke nur in dem Richtung der Röhre fortschritten, bei starkem Drucke dagegen, von der einen Seite zur andern geschleudert wurden, und oft in wirbelnde Bewegung geriethen. . . . Diese Vergrösserung giebt sich sehr deutlich in der Ergiebigkeit der Röhrenleitung zu erkennen, so lange die Bewegung nur der Röhre parallel ist. Sobald aber die Widerstände sich soweit vermindert haben, dass die Spannung aufhört und das Wasser, indem es dem Impulse frei folgt, dem Drucke ganz entzogen wird, so hindert nichts das Entstehen der innern Bewegungen, welche durch jede kleinste Unregelmässigkeit der Röhrenwand, oder vielleicht auch schon durch das Eintreten in die Röhre veranlasst werden. Diese Bewegungen nehmen einen Theil der einwirkenden lebendigen Kraft auf, und schwächen dadurch die fortschreitende Bewegung, die allein gemessen werden kann." See pp. 80, 81.

[1] An experimental investigation of the circumstances which determine whether the motion of water shall be direct or sinuous, and of the law of resistance in parallel channels.—Phil. Trans., Vol. CLXXIV., pp. 935 – 982 1883.

and Reynolds clearly recognise that as the so-called critical velocity is approached the condition of flow becomes unstable. Hagen is not committed to any definitive doctrine as to the limits of stability of the rectilinear régime, but Reynolds has given an expression for the velocity, beyond which that régime cannot, he supposes, be maintained. His expression has however, certainly not been tested between sufficiently wide limits to justify the conclusion he makes from his experiments. For centimetre units, Reynold's formula may be written

$$U_c = \frac{114{\cdot}18}{Rf} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

U_c being the alleged critical velocity, f the relative fluidity, ($1/P$ in Reynold's formula) and R the radius of the pipe. The numerical coëfficient is for glass pipes, and great steadiness. In Darcy's experiments the highest velocity of the rectilinear régime is only about one-sixth of the above amount, when it passes into the so-called second régime, so that the coëfficient in (6) would require to be reduced to about 18 to apply to Darcy's pipes.

Reynold's conclusion as to the existence of a definite critical velocity, discoverable in his formula, is questionable. Lord Kelvin in papers on "The steady motion of fluids,"[1] says:—"It seems "probable, indeed almost certain, that analysis similar to § 38 and "§ 39," of his papers, "will demonstrate that steady motion is stable for any viscosity however small," and that practical unsteadiness is to be "explained *by the limits of stability becoming narrower and narrower*[2] *the smaller the viscosity.*" Although the force of these observations was hardly admitted by Lord Rayleigh,[3] they are strongly endorsed by Rudski.[4] Perhaps the best way of

[1] Phil. Mag. 1887 (1) pp. 459 – 464; 529 – 539; 1887 (2) pp. 188 – 196; 272 – 278; 342 – 355.

[2] The italics are mine.

[3] Lord Rayleigh's papers on the subject are:—(*a*) "On the Instability of certain fluid motions."—Proc. Lond. Math. Soc., Feb. 12, 1880. (*b*) "On the Question of the stability of the Flow of Liquids."—Phil. Mag. 1892, Vol xxxiv., pp. 59 – 70; 145 – 154; 177 – 180.

[4] "Note on the flow of water in a straight pipe."—Phil. Mag. 1893 (1) 439 – 440.

satisfying oneself as to this point, is to observe the circumstances of flow when they are such that one may establish either régime at will. The ease with which the rectilinear régime may be disestablished increases with increase of velocity and with increase of fluidity. The variableness of the relations between velocity and 'hydraulic gradient' (I) in the region lying between what may be called—speaking relatively—the stable linear and stable turbulent régimes—admirably illustrated in Hagen's curves of velocity, and by Reynold's experiments also—is a further indication that the view of Sir Wm. Thomson is correct.

6. *The rationalization of Reynold's formula for rectilinear flow in pipes.*—Reynolds has given in his paper, before referred to, an alleged general formula for flow in pipes, which may be written

$$M f^2 R^3 I = (N f R U)^n \ldots\ldots\ldots\ldots (7)$$

M and N being constants for all classes of pipe, f the relative fluidity, and R and U having the same meanings as before.[1] This he says, holds for every pipe and every condition of water: a statement which demands further examination. Considering for the present only the case for rectilinear flow, the exponent n is then unity; hence, since $H/L = I$, the above expression may be written

$$U = \frac{M}{N} f I R^2 \ldots\ldots\ldots\ldots (8)$$

Comparing this with (1) and remembering that $1/\eta = f/\eta_o$, we see that the ratio of Reynold's factors is simply

$$\frac{M}{N} = \frac{g \rho}{8 \eta_o} \ldots\ldots\ldots\ldots (9)$$

If these expressions were identically equal, the rationalization would be complete; but they are not so: the factors M and N are merely empirical. Thus while (1) is a rational, (7) and (8) are only empirical formulæ.

Proceeding to the testing of Reynold's ratio, it may be remarked that for engineering purposes the variations of density (ρ) and of gravity (g) may be generally neglected, and consequently M/N

[1] $M = 8A$, and $N = 2B$, and $f = 1/P$ in Reynolds's formula.

treated as a constant, which strictly of course it is not, being a function of gravity and of the density of the column of fluid by means of which the difference of pressure at two points in the supposed-horizontal pipe is measured. Accepting the results given in Table I., taking the value of g for latitude 45° and sea-level, as 980·61, we have, for water,

$$\frac{M}{N} = 6851{\cdot}26 \text{ or } 6145{\cdot}6 \text{ at } 15^\circ \text{ C}.....(10)$$

the density being regarded as ·999173 at the latter temperature. Reynolds gives for $\frac{1}{8}M$ the value 67·70 and for $\frac{1}{2}N$ 0·03963, both reduced for the centimetre unit. Hence according to him, the above ratio is 6833·2 a value which, though sensibly the same as that above (10), is very probably slightly under the truth. The difference, 0·18%, is quite negligible from an engineering point of view. The logarithm of 6145·6 is 3·8354 : obviously the computation of (1) or (8) logarithmically, leaves nothing to be desired on the score of simplicity.

In the rationalized form, the formula for rectilinear flow in circular pipes is not Reynold's, but Neumann's: it was given some time prior to 1860. Had Reynold's expression really held for both régimes, then although empirical, its generality would have commended it. The question of its general correctness will be hereinafter examined.

7. *Hagens's discussion of linear and non-linear flow in pipes, in 1853.*—As already remarked, Hagen, as far back as 1853, observed that fluids were subject not only to a rectilinear, but also to a turbulent or eddying condition of flow ; and that in the latter case some of the energy was ineffective in the production of motion parallel to the axis of the pipe, since it was expended in the eddying agitation. The tabulated results and diagrams by means of which his treatise was illustrated, shewed very clearly the significance of the change from the rectilinear to the non-rectilinear régime. Hagen's experiments were made mainly with three tubes of sheet brass soldered into the form of pipes, their radii in centimetres being A ·14083, B ·20242 and C ·2974 at 15° R,

assuming the zoll to be 2·61544 cm. Unfortunately the pressures were small and were determined by measuring the height in the reservoir of supply, instead of manometrically at two sections in the pipe itself ; so that although the experiments are numerous, their value for the purpose of very accurately ascertaining the form of the temperature function, and the laws of flow generally, is not high. The reduction of the head for the circumstances at the influx end of the tube is subject to some uncertainty as I have previously shewn from Poiseuille's and Jacobson's experiments,[1] and as is generally known. Consequently the fall in pressure per unit length of tube—I or dP/dL—is doubtful, and variable in amount, and the velocities opposite each temperature therefore require corrections in order to make them comparable.

Hagen in discussing his results, treats independently the velocity law for the two main branches of his curves shewing the relation of hydraulic gradient to velocity. The first branch he recognises as belonging to the rectilinear régime and analyses it by the formula

$$H = sU + tU^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

s and t depending on the temperatures of the water, and on the dimensions of the tubes. The term in U—the large term—is the Poiseuille's law term : that in U^2 is the loss of head at the influx end of the pipe.[2] Passing over the intermediate régime, Hagen obtains by logarithmic methods, exactly as St. Venant did before him, the relation of the resistance head to the velocity in, and to the radius of, the pipes. Employing the formulæ

$$h = kU^n, \text{ whence } \log h = \log k + n \log U \quad \ldots\ldots\ldots (12), (12a)$$

he finds for the three tubes the following values of n, viz., for $A = 1{\cdot}7949 \pm {\cdot}0690$; for B $1{\cdot}7393 \pm {\cdot}0181$; and for C $1{\cdot}7987 \pm {\cdot}0168$, taking the mean as $1{\cdot}75$. He further discusses the relation between n and the exponent of R and finally proposes for the turbulent régime the formula

$$h = k\,L\,R^{-1{\cdot}25}\,U^{1{\cdot}75} \quad \ldots\ldots\ldots\ldots (13)$$

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[1] Journ. Roy. Soc. of N.S.W., Vol. XXIX., pp. 93 – 103, 1895.

[2] See in place last cited, formulæ (3), (3a), (9), also pp. 102, 103.

in which h is the resistance head, and k is a coëfficient varying, for the one class of pipe, only with the temperature: he gives values of the coëfficient k.[1]

This in 1853. It is remarkable therefore to find Reynolds in 1883, asserting without qualification, that no previous experimenter had discovered the law $I \propto U^n$, and that without exception they had employed either the relations $I \propto U^2$, or $I \propto (U + BU^2)$. St. Venant in 1850 mentioned[2] that DuBuat had long ago observed that the exponent n was too great (probably in the latter's Principes d'hydraulique, Paris 1786). In 1869 Hagen referred to the fact[3] that Woltmann had first employed the expression $n = \frac{7}{4}$ —doubtless toward the end of last century—and also that Eytelwein[1] had used $\frac{3}{1}\frac{5}{8}$ or 2, which latter, he says, Darcy accepted while St. Venant selected $\frac{1}{7}^{2}$. Even as far back as 1850, St. Venant[4] employed the graphic method of plotting the logarithms of the related quantities, by which means he said, the conviction that the variation is as U^n, (n being less than 2) was easily reached, and he assigned the values $\frac{2}{1}\frac{1}{1}$ for canals and $\frac{1}{7}^{2}$ for pipes. He moreover clearly perceived the state of turbulent agitation ("l'état torrentueux" p. 583), and its signal influence upon the coëfficient of internal friction.[5] In 1872 he described the state of

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[1] *Loc. cit.*, p. 86.

[2] His words are :—"bien que cette expression" (viz U^2) "soit contraire "à ce que l'expérience a appris et fait dire depuis longtemps à Du Buat, "que les résistances croissent en moindre raison que les carrés des vitesses."

[3] Ueber die Bewegung des Wassers, etc.—Abhand. Akad. Berlin 1869, (2) Math. Teil. pp. 1 – 29. See in particular p. 6.

[4] Mémoire sur des formules nouvelles pour la solution des problèmes relatifs aux eaux courantes.—Comptes rendus t. 31, pp. 283 – 286, 581 – 583, 1850. St. Venant says :—On en acquiert facilement la conviction en prenant les logarithmes, ce qui donne $\log (RI) = \log c + m \log U$ et en construisant deux suites des points ayant pour abscisses les valeurs de $\log R$ et pour ordonnées celles correspondantes de $\log (RI)$ fournies par les expériences sur les canaux et par les expériences sur les tuyaux; car on voit que chacun de ces deux ensemble affecte une direction rectiligne, sauf les anomalies attribuables aux erreurs d'observation.

[5] Sur l'hydrodynamique des cours d'eau.—Comptes Rendus, t. 74, pp. 570 – 577, 649 – 657, 770 – 774, 1872.

turbulent agitation, and discussed the manner in which the problem of flow might be attacked.[2] Gauckler also, in 1867, used a monomial expression, and recognised that the law of flow for very small slopes required a separate formula.[1] Reynolds has therefore been anticipated five or six times.

8. *General conception of the turbulent régime.*—If, the rectilinear régime being established, say in a glass pipe, its stability be overcome by increase of pressure, or temperature, or by unsteadiness, a condition supervenes of which the first indication is a waviness of the stream lines, as shewn by the motion of coloured threads of liquid in Reynolds' experiments. This is followed by the development of vortices in great numbers, so that when the turbulent or vortex condition is well established, the liquid may be said to constitute a tangle of vortices, the tangle having a motion of translation along the pipe. In the rectilinear régime, the evidence shews very conclusively that there can be no velocity at the boundary,[2] the rugosity of which does not in such a case affect the flow, since there is no slipping of the water past it, such as might be supposed to call into action some species of friction—nor is there any disturbance therefrom across the pipe to interfere with the continuity of the motion of translation parallel to its axis. In rectilinear flow, if we consider the particles of water distributed at any instant of time, across a right section of the pipe, then at any later instant the same particles will lie on the surface of a paraboloid, the axis of which is that of the pipe, and whose base is the right section considered.

In the turbulent régime it is extremely probable if not certain, that the water actually in contact with the boundary also has no velocity. Again considering the particles at any moment in a right section, these will move in all directions owing to the agitations, but they will on the whole be subjected to a motion of translation parallel to the axis of the pipe. If then we imagine

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[1] Etudes théoriques et pratiques sur l'écoulement et les mouvement des eaux.—Comptes rendus, t. 64, pp. 818 – 822, 1867.

[2] See Journ. Roy. Soc. N.S.W., Vol. xxix., § 6, pp. 89 – 93.

a series of fictitious particles the movements of which, parallel to that axis are the means of the similar movements of particles in the same relative position, these fictitious particles will lie also on a conoidal surface but not that of a paraboloid, the conoid being much flatter at the apex, see Fig. 1, in which the points at one-third and two-thirds of the diameter are plotted from the mean of Darcy's experiments.

The problem of turbulent flow was attacked by Boussinesq in 1872, in his incomparable "Essai sur la théorie des eaux courantes."[1] His method of analysis is as follows :—The real velocities are considered to rapidly and abruptly change from point to point in any section, and thus to produce a degree of friction of quite another and greater order of magnitude than can occur in the rectilinear régime. The mean action across any fixed plane element is measured, not merely by the mean local velocities or by their first derivatives defining the rate of shear of the fluid, but also by the intensity of agitation at the point considered. The causes of the agitations having been ascertained, the coëfficient of internal friction is made to vary with them. As equations of motion are selected, not those which express, at a given instant, the dynamic equilibrium of different elementary volumes of the fluid, but the mean of these during a short but sufficient time : so that one is able to call them, the equations of the mean dynamic equilibrium of the fluid particles which successively pass any particular point.[2] This statement of part of the great problem, to the solution of which Boussinesq applied himself, presents a definite conception of the nature of the movement. The analysis of the problem now attempted has for its object, the discovery, without reference to Boussinesq's deductions, of the mathematical form in which the results of observation can be consistently expressed, so that they will really represent the observed phænomena.

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[1] Mém. des Savants étrangers, t. 23, pp. 1 – 680, 1877.

[2] *Loc. cit.*, pp. 6, 7.

9. *Defects of the ordinary velocity formulæ.*—Brahm's and Chezy are said to be the authors of the usual formula for flow in pipes or channels, viz.,

$$U = k\sqrt{(R\,I)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(14)$$

an expression which seems to have served as a mould for the great majority of evaluations of velocity, and which is generally known as the "Chezy formula."

Darcy[1] and Bazin's[2] modification of this, in view of an obvious defect in a formula proposed by de Prony,[3] was

$$U = \sqrt{\left(\frac{1}{\alpha + \frac{\beta}{R}}\right)}\sqrt{(R\,I)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(15)$$

α and β being coëfficients which varied with the roughness of the surface of the pipe or channel, a factor wholly ignored by de Prony. Both Darcy and Bazin recognised that this expression did not represent the phenomena in all their generality, but regarded it as a sufficient approximation for practical purposes.

The limitations of this formula were studied by Ganguillet and Kutter,[4] who, in order to embrace all sizes of pipe or channel, developed, in a most ingenious manner, the empirical expression

$$U = \frac{a + \frac{b}{\gamma} + \frac{c}{I}}{1 + \left(a + \frac{c}{I}\right)\frac{\gamma}{\sqrt{\mathrm{R}}}}\sqrt{(\mathrm{R}\,I)} \quad \ldots\ldots\ldots\ldots(16)$$

in which a, b and c are constant for every case, and γ is a coëfficient, depending upon and increasing with the roughness of the boundary, and R is the hydraulic radius $= \frac{1}{2}R$ in the case of a pipe. For C.G.S. units $a = 230$, $b = 10$, $c = \cdot 0155$ and γ varies between $\cdot 006$

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[1] Recherches expérimentales relatives au movement de l'eau dans les tuyaux.—Mém. des Sav. étrang., t. 15, pp. 141 – 403, 1858.

[2] Recherches expérimentales sur l'écoulement de l'eau dans les canaux découverts.—Mém. des Sav. Etrang., t. 19, pp. 1 – 494, 1865.

[3] Recherches physico-mathématiques 1790. The formula was $a\,U + \beta\,U^2 = R\,I$.

[4] A general formula for the uniform flow of water in rivers and other channels. Trans. by Hering and Trautwine. Macmillan, 1889.

—for the smoothest possible channel—and ·055 for a channel with irregular banks, covered with aquatic plants. Not one of these formulæ recognises the influence of temperature.

For a pipe subject to flow at constant temperature but under different pressures, we have from (14) and (15), since the radius, and the roughness of the boundary, are constants,

$$U^2 = k\,I \quad \ldots\ldots\ldots\ldots\ldots\ldots(17)$$

k denoting $k'\,R^2$ in the Chezy formula, and $R^2/(\alpha\,R+\beta)$ in the Darcy and Bazin; that is to say k is a quantity which does not vary with either U or I. Hence this expression affirms that *the rate of fall of pressure*—that is the slope, or hydraulic gradient—*varies as the square of the velocity.*

In Kutter's formula, as it is generally called, let us put

$$a\,\gamma + b = \lambda\,;\ a\,\gamma + \sqrt{\mathrm{R}} = \mu\,;\ \text{and}\ c\,\gamma = \nu$$

so that λ, μ and ν are absolutely constants in the case of any pipe, then we shall have from (16)

$$U^2 = \mathrm{R}^2 \left(\frac{I\,\lambda+\nu}{I\,\mu+\nu}\right)^2 I \quad \ldots\ldots\ldots\ldots(18)$$

which implies that the hydraulic gradient varies as the square of the velocity only when $\lambda = \mu$, that is when $\sqrt{\mathrm{R}} = b$, or expressed in centimetres, is 10. It is obvious that any sensible deviation from the law expressed by either of these formulæ, viz., (17) or (18), is a sufficient reason for rejecting them as empirical expressions representing the relation of the mean velocity to the rate of fall in pressure. Further it will be quite unnecessary to discuss the latter somewhat complex relation, if it be shewn that $U^n \propto I$, n being a simple index. It may also be noticed that it would be easy to examine whether in the case of a pipe of 100 cm. 'hydraulic radius,' or 200 cm. actual radius, the velocity varied as the square of the hydraulic gradient. Ganguillet and Kutter lay great stress upon their discovery of this relation, *which implies that the index of U varies with the radius*, though this consequence was not specifically indicated by them, inasmuch as, accepting the expression $k'\,\sqrt{(\mathrm{R}\,I)}$, they concerned themselves only with the law of variation of k'.

Now as previously pointed out, when shewing that Reynolds was in error in stating that he was the first to recognise the law $U^n \propto I$, it has long been known that for pipes n is, at least generally, less than 2; if it differ sensibly from that number there appears to be no cogent reason for adopting it.

10. *Experimental proof of St. Venant's law, viz., that* $U^n \propto I$ *for pipes.*—We are here concerned only with the proof that this law holds for the second or turbulent régime, that it holds for rectilinear flow is beyond question, n being in that case unity. Reynolds has given the following values for the index, as the result of his investigation of his own and Darcy's experiments, viz.—

1·723 Perfectly jointless glass tube.
1·746 Lead and bituminous pipes.
1·79 Glass and lead pipes.
1·82 Varnished lead, new cast iron and glass pipes.
1·91 Cleaned iron pipes.
1·92 Cast iron pipes.
2·00 Incrusted iron pipes.

See however the values deduced later on, herein.

The best available material for the discussion of the question is Darcy's, because his experimental work was carefully conducted—it is incomparably more accurate than the general run of hydraulic experiments—and in a great many instances he gives temperatures.[1]

Reverting to St. Venant's and Hagen's equation, it may, for any particular pipe, be put in the form

$$U^n = k'' I \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

provided the temperature of the water, be kept constant. Hence taking the logarithm of both sides, and dividing by n

$$\log U = \frac{\log k''}{n} + \frac{1}{n} \log I \ldots\ldots\ldots\ldots (20)$$

the equation of a straight line, determined by plotting the values

[1] It is greatly to be regretted that he failed to do this always: at the time it was thought unessential. A very little relative increase of the expense these experiments might have been made to furnish all the requisite material for a thorough examination of the whole question.

of log I as abscissæ, and the corresponding values of log U as ordinates: and $\frac{1}{n}$ will be the tangent of the angle which the line makes with the axis of abscissæ. There are slight variations of temperature in Reynolds' and Darcy's experiments, hence the velocities must first be corrected to the one temperature, which I have taken generally to be about the mean for the series. For this purpose, Reynolds' formula—see (7) § 6—has, after some partial justification, been asumed to be true in so far as its theory of temperature correction is concerned; and the very small required correction[1] has been applied from approximate values of n, in the manner indicated in the discussion of this question hereinafter. It may be remarked that on the scale of the figures, the effect of the temperature correction is hardly noticeable.

On looking over Figs. 2 to 6, it will be observed that not only is the relation evidently linear; but the precision of that relation is very remarkable. Moreover, it is evident that it is not possible to make the index of U, 2, without involving appreciable error, except in three instances, viz., those of lines 14, 18 and 20 of Table A. hereinafter, in which all the results are entered for the sake of easy reference.

Again, the practical difficulty of computing the velocity of flow is rendered apparent, since for the same material and class of pipe there are sensible differences in the index n. It appears to be certain that n increases with the roughness of the pipe, but it varies between wide limits, as for example in lead pipes, from 1·695 to 1·784: in new cast iron—rejecting 1·861 as a doubtful case—from 1·917 to 1·957, and in incrusted cast iron from 1·908 to 1·985. In the light of this evidence it is beyond question that, in calculations of velocity from fall in pressure, precision depends upon a nice discrimination of the roughness of the boundary, so as to correctly estimate the value of n.

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[1] Reynolds' temperature correction, if in error, is too small. However the results are more nearly comparable after the correction has been applied.

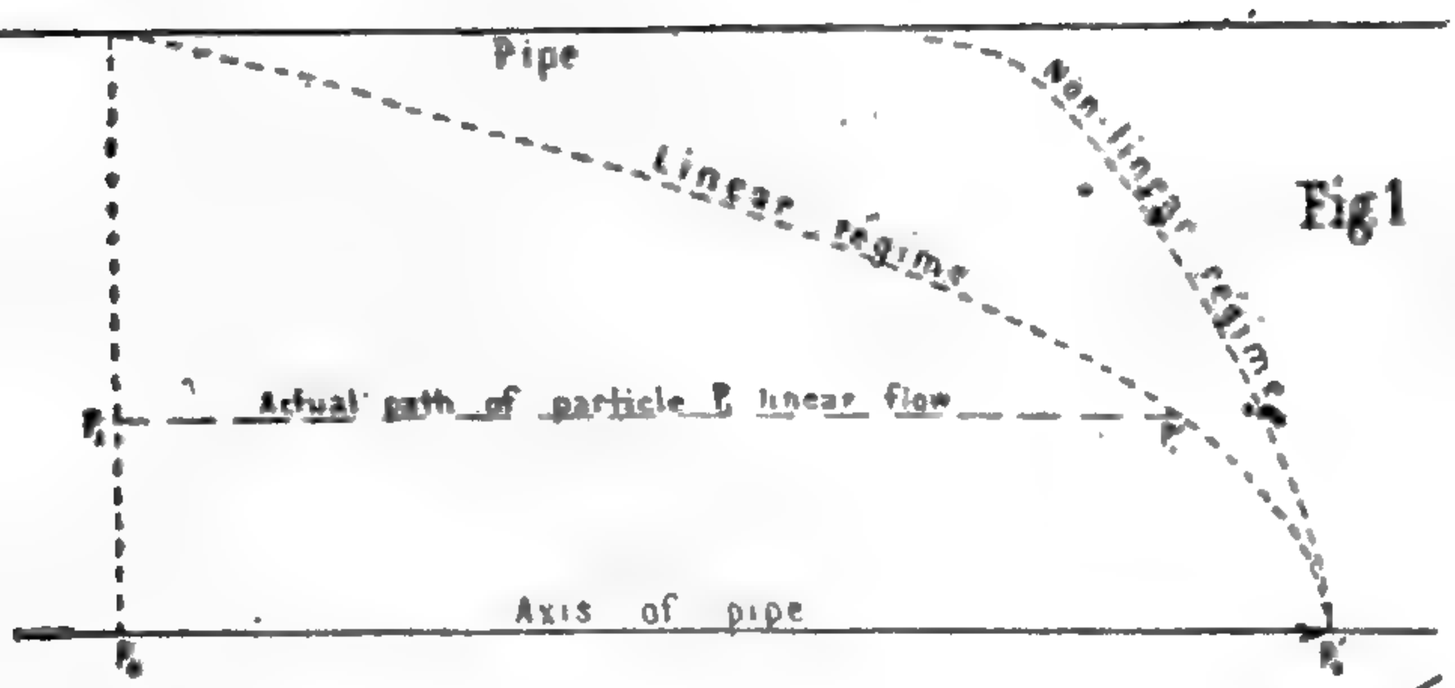

Fig 1

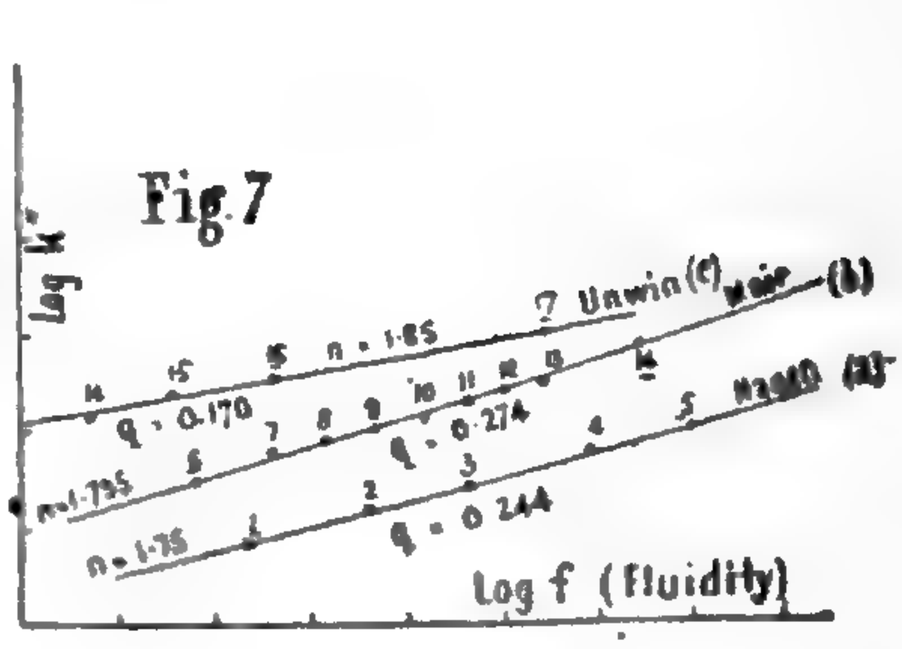

Fig 7

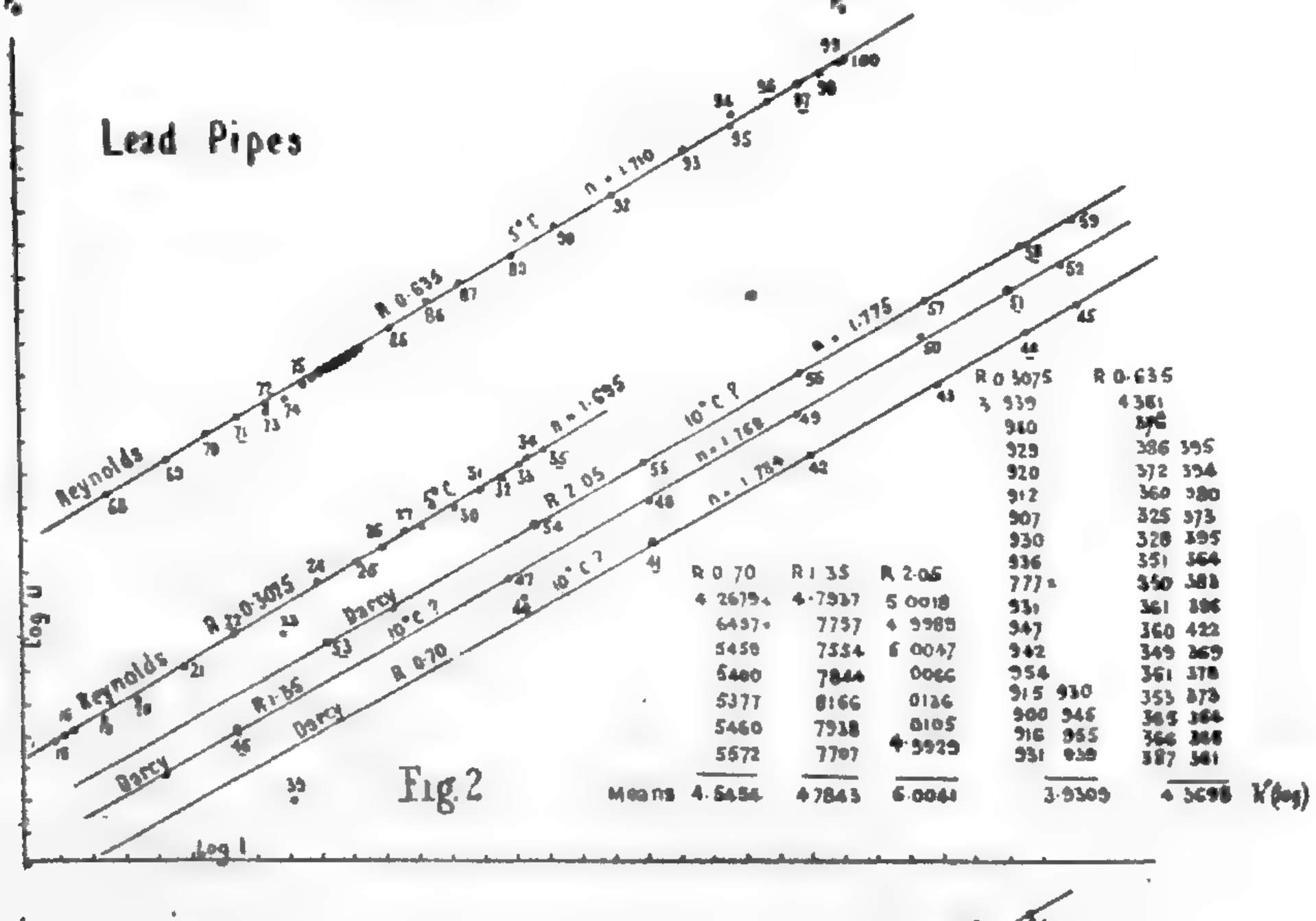

Fig 2

Fig 3

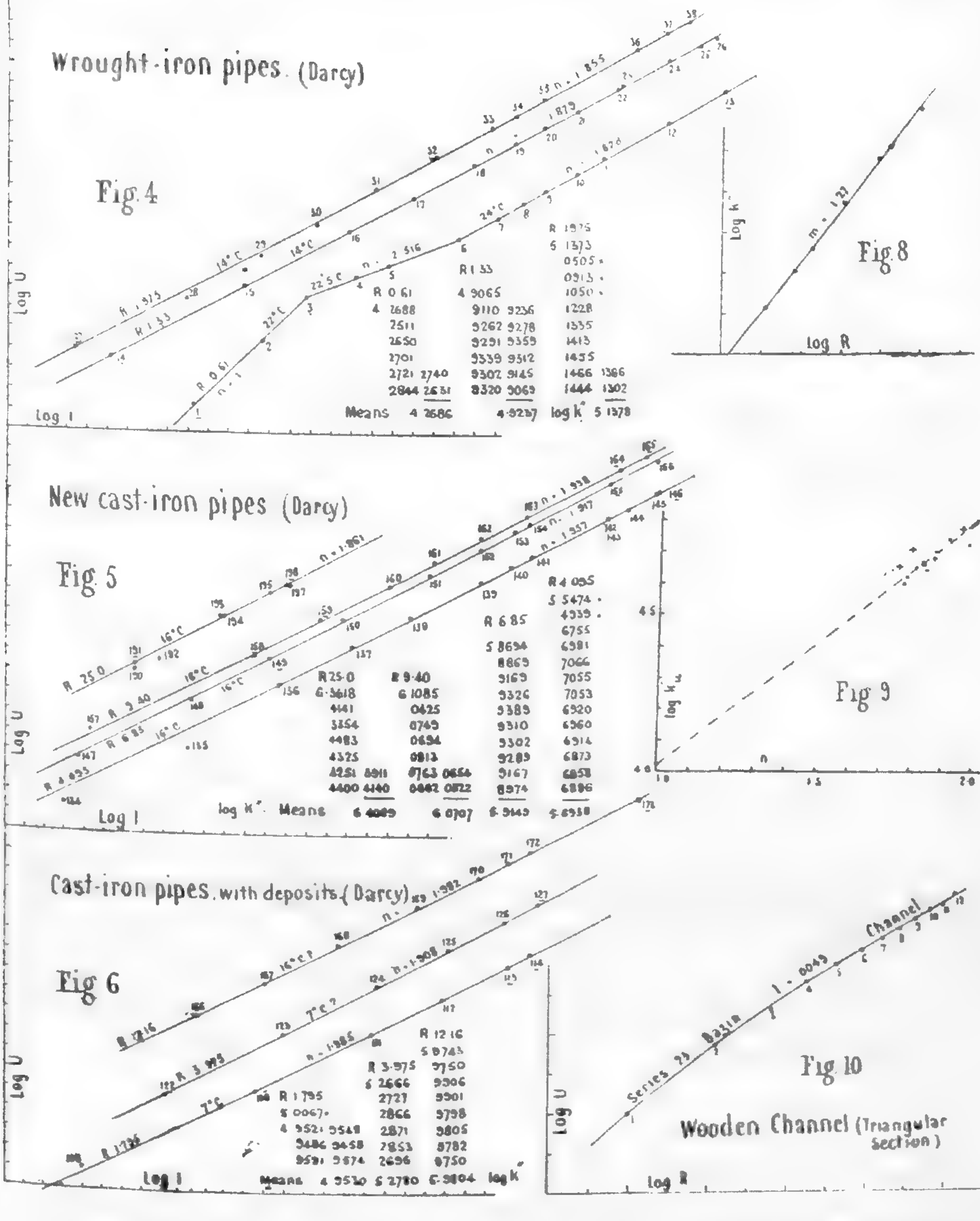

Fig. 4

Fig. 8

Fig. 5

Fig 9

Fig 6

Fig 10

Wooden Channel (Triangular Section)

11. *On the determination of k'' in the expression $U^n = k'' I$.*— Resuming equation (19) we have, on taking the logarithm of both sides, and transposing,

$$\log k'' = n \log U - \log I \quad \ldots\ldots\ldots\ldots (21)$$

hence $\log k''$ may be found for each observation made, by multiplying the logarithms of the velocities by the proper value of n, and subtracting the logarithm of the 'slope.' The mean for each series

TABLE A.

Ref. No.	Observer.	Experiment Number.	Pipe.	Radius.	Temp. °C.	n	$\frac{1}{n}$	$\log k''_t$	$\log k''_{14}$	$\log k'_{14}$
1	R	15 – 35	Lead	0·3075	5	1·695	·5901	3·9309	3·965	4·615
2	,,	68 – 100	,, ...	0·635	5	1·710	·5848	4·3698	4·402	4·650
3	D	41 – 45	,, ...	0·70	10?	1·784	·5605	4·5454	4·555	4·752
4	,,	46 – 52	,, ...	1·35	10?	1·768	·5656	4·7843	4·795	4·630
5	,,	53 – 59	,, ...	2·05	10?	1·775	·5634	5·0041	5·015	4·619
6	,,	102 – 107	Glass	2·484	17?	1·806	·5537	5·1566	5·150	4·648
7	,,	62 – 71	Tarred Sheet Iron ...	1·34	14	1·769	·5653	4·7572	4·757	4·596
8	,,	74 – 83	,, ,, ...	4·13	22	1·808	·5531	5·4982	5·481	4·699
9	,,	85 – 94	,, ,, ...	9·80	7	1·778	·5624	5·8622	5·881	4·622
10	,,	96 – 101	,, ,, ...	14·25	21	1·803	·5546	6·0805	6·065	4 599
11	,,	6 – 13	Drawn Iron	0·61	24	1·828	·5470	4·2686	4·250	4 523
12	,,	14 – 26	,, ,, ...	1·33	14	1·879	·5322	4·9237	4·924	4 767
13	,,	27 – 28	,, ,, ...	1·975	14	1·855	·5391	5·1378	5·138	4·762
14	,,	136 – 146	New Cast Iron ...	4·095	16	1·957	·5110	5·6938	5·693	4·916
15	,,	147 – 156	,, ,, ,, ...	6·85	16	1·917	·5216	5·9149	5·913	4·857
16	,,	157 – 165	,, ,, ,, ...	9·40	16	1·938	·5160	6·0707	6·069	4·833
17	,,	190 – 198	,, ,, ,, ...	25·0	16	1·861?	·5373	6·4069	6·404	4·629
18	,,	109 – 114	Cast Iron incrusted...	1·795	7	1·985	·5038	4·9530	4·954	4·631
19	,,	122 – 127	,, ,, ,, ...	3·975	7?	1·908	·5241	5·2780	5·286	4·525
20	,,	166 – 173	,, ,, ,, ...	12·16	16?	1·982	·5045	5·9804	5·980	4·602

NOTE.—R denotes Reynolds'; D Darcy's experiments. ? denotes that the temperature is uncertain.

is the quantity given in Table A., $\log k''$ is of course the value of $-\log I$ when $\log U = 0$, and therefore gives the 'slope'—supposing the régime, or rather law of flow, to be continuously maintained—

at which the velocity would be unity, 1 cm.—and it defines the point at which the n lines Fig. 2 – 6 intersect the axes of abscissæ.

An examination of the values of the coëfficient k'', shews that not only is it a function of the radius of the pipe, but also of its rugosity. It may also be assumed to be a function of the temperature, and therefore of the fluidity of the water. Hence, if the index n be treated as itself a function of the roughness of the pipe, or rather of the degree of vortex agitation which is set up in the fluid by the agency of the boundary conditions, then we may put as certainly true, $k'' = \phi(f R)$, and as probably true $k'' = \phi(f.n.R)$.

12. *Experimental proof that the temperature function is f^q, f being the 'fluidity.'*—In his 1853 experiments previously referred to, Hagen obtained a formula expressing the flow in his pipes, which may be written

$$U^n = c' R^m I \ldots\ldots\ldots\ldots (22)$$

in which n was on the average about 1·774, but was taken as 1·75, and m as 1·25. The values of the logarithms c'—the reciprocals of Hagen's (m) quantities—for the temperatures given by him, expressed in Celsius instead of Reaumur degrees, are as follows:—

Table B.

Temperature C.	$18\frac{3}{4}°$	$31\frac{1}{4}°$	$43\frac{3}{4}°$	$62\frac{1}{2}°$	$81\frac{1}{4}°$
Values of log f	·234	·359	·463	·591	·698
Value of log c'	4·4854	4·5185	4·5414	4·5756	4·5985

The values of log f are taken from Tables I. and II.; and for the higher temperatures are practically a mean of Slotte's (1893) and Thorpe and Rodger's (1894) corrected values.

From the above equation it is obvious that the $U^n \propto c'$ when $R^m I$ is constant: consequently c' is a function of the fluidity. Now since the increase of fluidity of any liquid flowing through a tube, facilitates the intensity of the internal agitation, very much in the same manner as increase of velocity would intensify it, when once the stability of the rectilinear régime has been overcome, it may be supposed likely that the relation

$$c' = c f^q \ldots\ldots\ldots\ldots (23)$$

will hold good, or will at least very approximately represent the facts; hence taking logarithms, in order to test the relation, we have

$$\log c' = \log c + q \log f \text{ .. ..(24)}$$

the equation of a straight line, determined by plotting $\log f$ as abscissæ and $\log c'$ as ordinates. Fig. 7 (a) shews the result: and q, the tangent of inclination with the axis of abscissæ, proves in this case to be 0·244. The experimental justification of the assumption is remarkably exact, as the figure shews, and as the following values for $\log c$ also indicate :—

No.	log c.	Diff.	
1	4·4283	+ 11	
2	309	− 15	
3	284	+ 10	Mean 4·4294 = log of 26880 = c.
4	314	− 20	
5	282	+ 12	

More recently Mair[1] has also investigated the influence of temperature—between 13·°9 and 71·1 C.—with a brass tube $\frac{3}{4}$ inch radius and 25 feet in length. His manometer was 1 foot from the tank of supply, and apparently he regards this as giving the total fall in pressure for the 24 feet between the manometer and efflux end.[2] Mair observes that the plots of the logarithms of the heads and velocities give $n = 1{\cdot}795$ for his pipe throughout, the lines being parallel for all temperatures. The measurements are however not sufficiently exact to allow much weight to this assertion, since for example, I find from plotting his results for 13·°9, 48·°9, and for 54·°4 C., the values respectively of 1·782, 1·790, and 1·772. Accepting however the coëfficients which he himself deduces for the several temperatures of his observations, we obtain

Table C.

Temp. C.	13·°9	21·1	26·7	32·2	37·8	43·3	48·9	54·4	71·1
Values of log f	0·180	·260	·316	·367	·417	·460	·501	·541	·643
Value of log c'	3·559	·580	·590	·602	·613	·629	·640	·648	·686

[1] As to the Effect of Temperature &c.—Proc. Inst. C.E., Lond., Vol. LXXXIV., pp. 424 – 435, 1886.

[2] In such experiments it is far preferable to employ two manometers, each sufficiently removed from the end to be unaffected by the terminal conditions.

from which q appears to be about 0·274. The consistency of the results is not quite equal to Hagen's. See Fig. 7 (*b*).

Again, Unwin,[1] in his experiments on the friction of discs rotating in water, obtained results which indicated that the moment of resistance μ of the disc, varied as the 1·85 power of the rate of revolution, V say: that is $c' \mu = V^n$. His experiments treated as above give

Table D.

Temp. Celsius		5·°1	11·7	21·3	54·7
Value of log f		·071	·155	·262	·542
Value of log c'	$x +$	·914	·939	·955	1·000

from which the value 0·170 is deduced for q. See Fig. 7 (*c*). In these three instances there is no indication of any systematic departure from the relation, which we set out to test, viz., $U^n \propto f^q$.

13. *Reynolds' supposed law, that $q = 2 - n$, not experimentally justified.*—Reynolds' formula (7) § 6 herein, asserts that $U^n \propto f^{2-n}$ which leads to this very remarkable result, viz., that when the roughness of the channel involves the velocity-and-'slope' relation $U^2 \propto I$, temperature has no influence on the flow, as remarked by Lord Rayleigh,[2] and as is immediately obvious from the formula itself. Moreover if n should exceed 2, increase of temperature and the consequent increase of fluidity would actually diminish the flow. If this be so, it is necessary to suppose that the general decrease of the resistance to tangential stresses and consequent acceleration of velocity is more than compensated by the quantity of internal agitation facilitated by this decrease itself. Since there is no reason to regard the condition as unstable, such a supposition seems in opposition to the law of least action, and to be wholly improbable. It is not very clear from Reynolds' paper, on what experimental, to say nothing of theoretical, grounds he justifies a formula leading to such remarkable consequences. Examining it in the light of the results reached in last section, we

[1] Flow of Water &c.—The Engineer, Vol. LXI., p. 1, Jan. 1886.

[2] See Phil. Mag. Vol. XXXIV., 1892, pp. 59 – 70, 145 – 154, 177 – 180.

find

Table E.

	n 1·750	$n = 1{\cdot}795$	$n = 1{\cdot}850$
By Reynolds' theory	Hagen ·250,	Mair ·205,	Unwin ·150
By observation	„ ·244,	„ ·274,	„ ·170
By calculation § 17 formula (35)	·242	·222	·199

These results can hardly be regarded as conclusive, for though Hagen's and Unwin's lend some colour to the view that the influence of temperature *diminished* as n increased, Mair's are in direct opposition to that assumption. The law of diminution if true, must be left to future experiments to decide. The mean of the three results is 0·23, which perhaps ought to be used until the question has been decided. We shall however, return to this question later, vide § 17.

14. *Correction of k'', or U^n, or of U for temperature.*—From § 12 it is evident that we may represent the actual observations by the expression

$$U^n = k' f^q I \ldots\ldots\ldots\ldots (25)$$

in which k' is function of the radius, and possibly of the roughness. Consequently

$$k'' = k' f^q \ldots\ldots\ldots\ldots (26)$$

The average of the temperatures in Table A. is about 14° C., and since the value of q is uncertain, we may calculate it by Reynolds' formula, the application of which will at any rate *partially* correct the results furnished by experiment, to that mean temperature. And since the greatest difference is 10°, the correction will be a small one. Logarithmically k''_1 may be determined from k''_2, and similarly with regard to U^n and U, thus :—

$$\log k''_1 = \log k''_2 + q(\log f_1 = \log f_2) \ldots\ldots\ldots\ldots (27)$$

$$\log U_1^n = \log U_2^n + q(\log f_1 - \log f_2) \ldots\ldots\ldots\ldots (28)$$

$$\log U_1 = \log U_2 + \frac{q}{n}(\log f_1 - \log f_2) \ldots\ldots\ldots\ldots (29)$$

formulæ which are very readily applied. k'' has to be increased if expressed for a higher, diminished if for a lower temperature, assuming of course q to be positive.

15. *Reynolds' theory that* $U^n \propto N^{-n} R^{3-n}$ *inconsistent with experiment.*—Reynolds' general formula (7) may, by putting M' for $M f^q$, be written

$$M' R^{3-n} N^{-n} = k'' = \frac{U^n}{I} \quad \ldots\ldots\ldots\ldots (30)$$

from which it is evident, by taking logarithms, that

$$\xi = \log k'' - (3-n) \log. R = \log M' - \log N(n) \quad \ldots\ldots\ldots\ldots (31)$$

a linear equation.

The values of ξ can be formed from Table A.; if then they be plotted as ordinates and the corresponding values of n as abscissæ the result will evidently be a straight line, *provided Reynolds' formula be correct.* The values of ξ arranged in the order of increase of n are as hereunder, the number above denoting the horizontal line in Table A.

Table F.

Calculated values of ξ by (31).

Line Table A.	1	2	4	7	5	9	3	10	6	8
$100\,\xi =$	463	466	464	460	463	467	474	468	468	475
Line	11	13	17	12	19	15	16	14	20	18
$100\,\xi =$	450	480	481	479	463	501	504	506	488	470

It may be supposed that the required linear relation would more conspicuously appear, if the means of a large number of observations be taken. In order to test this also, the mean results of the bottom of Table G. hereinafter, are used for the evaluations of ξ. The results arranged in order of n are

$100\,n =$	179	185	186	188	189	190	191
$100\,\xi =$	465	468	481	471	481	485	475

Neither of these series represent a straight line, nor do they indicate any law of progression whatsoever. Reynolds' theory of the variation of velocity with the radius of the pipe is consequently shewn to be inconsistent with the results of observation; and his assertion that his general formula holds for all pipes and all velocities, proved to be without sufficient justification, As his formula is purely empirical, inconsistency with experiment is a sufficient

reason for its rejection : other considerations indicated in the next section, will lend a still stronger sanction to its abandonment.

16. *Proof that the parabolic relation* $U^n \propto R^m$ *is experimentally justified for flow in pipes.*—In order to ascertain whether the variation of velocity with the radius of the pipe, depends also on the index n already found—though not in the way stated by Reynolds—and generally to see at a glance, if possible, the relations of k'' and R, the following table, shewing the values of k''_{14} for different pipes of the same radius,[1] was formed from the results given in Table A. The quantities marked * are taken directly; the others are logarithmically interpolated from the nearest quantity, after ascertaining that the logarithmic homologues, the coördinates of which are $\log k''$ and $\log R$, do not appreciably differ from straight lines. Since the interpolations are small, this process is not illegitimate.

Table G.

Line Table A.	n	Log R	Log k''_{14}	Pipe.	Line Table A.	n	Log R	Log k''_{14}	Pipe.
2	1·710	9·845	4·460	Lead	8	1·808	0·612	5·475	T. Iron
4 *	1·784	„	4·555	„	14 *	1·957	„	5·693	C. Iron
11	1·828	„	4·369	D. Iron	19	1·908	„	5·308	I. C. Iron
4	1·768	0·127	4·792	Lead	9	1·778	0·973	5·861	T. Iron
7 *	1·769	„	4·757	T. Iron	16 *	1·938	„	6·069	C. Iron
12	1·879	„	4·928	D. Iron	20	1·982	„	5·842	I. C. Iron
18	1·985	„	4·817	I. C. Iron	10	1·803	1·085	5·987	T. Iron
5	1·775	0·296	4·599	Lead	16	1·938	„	6·158	C. Iron
13 *	1·855	„	5·138	D. Iron	20 *	1·982	„	5·980	I. C. Iron
18′	1·985	„	5·005	I. C. Iron	17	1·861	1·398	6·404	C. Iron
Values of R	0·70 ;	1·34 ;	1·975 ;	4·095 ;	9·40 ;	12·16 ;	25·0		
Mean log k''	4·461 ;	4·823 ;	5·046 ;	5·492 ;	5·924 ;	6·042 ;	6·404		
Mean n	1·774 ;	1·850 ;	1·872 ;	1·891 ;	1·899 ;	1·908 ;	1·861		

The table shews many anomalies, but indicates clearly, of course, an increase of k'' with R. In order to find whether there is any evidence of a progression of the value of k'' with n, the sums of lines, with approximately the same value of n, are taken from each radius series. These summations are (*a*) $3 . \frac{1}{2} + \frac{1}{2} . 5 . 8 . 9$; (*b*) $11 . 12 . 13 . 19 . 16$; (*c*) $11 . 18 . 18' . 14 . 20$. The means of

[1] The suffix 14 denotes that the value of k' is for a temperature of 14°C.

the slope index and of log k'' so deduced are,—

Mean n	(a) 1·783	(b) 1·882	(c) 1·948
,, log k''	5·132	5·162	5·145

The differences from the mean—5·146—are too small to lend much force to the supposition of an increase of k'' with n, though undoubtedly such a supposition would minimise the inconsistency between theory and experiment so far as these three values themselves are concerned. It will also later appear that there is a sufficient reason for regarding k'' as increasing with n.

If with several series of pipes—each with surfaces identical in character, but different in the different series, and each series comprising pipes of identical radii but covering a wide range—one could obtain results shewing either no variation, or a systematic variation of n with the radius of the members of each series, the problem of finding the relation of k'' to the radius would be simple. But the anomalous nature of the results in regard to n, shewn in Table A., and in regard to k'', shewn in Table G., make it clear that a completely satisfactory solution is impossible with the existing experimental data, and one is inclined to dismiss the matter as hopelessly enigmatical.

There are, however, three ways in which these tabulated results may be tentatively examined. We may (i.) either take pipes of the same category with values of n as nearly as possible identical, and see whether the law of variation of k'' with R, changes systematically with the category itself: or (ii.) we may select pipes of any description with the same radius, and from the mean values of k'' (or of some other function thereof) endeavour to ascertain for each series with that radius, the variation of k'' with R, supposed in such a case to be quite independent of the category, and therefore also of the magnitude of n, the mean value of which varies with the category: or yet again (iii.) we may endeavour to ascertain whether the variation is one that involves R itself.

First as regards method (i.):—Since the loci of points, whose logarithmic coördinates are k'' and R, give indications of being at

least very nearly straight lines, it may with propriety be assumed that, very approximately,

$$k'' = k' R^m \text{ ....} (32)$$

whence $$\log k'' = \log k' + m \log R \text{.....} (33)$$

and consequently if k' be constant

$$m = \frac{\log k_2'' - \log k_1''}{\log R_2 - \log R_1} \text{ .....} (34)$$

Should there be a small variation of m with R, it will appear in the changing values of m, as the values of the radius are changed. The results of the application of this last formula, viz., (34) are shewn in Table H.

Table H.

Line in Table A.	n (mean)	Nature of Pipe.	$3-n$ Reynolds.	m Calc.	R Mean
1 – 2	1·700	Lead, Reynolds	1·30	1·39	0·47
4 – 5	1·771	„ Darcy	1·23	1·21	1·70
3 – 4	1·776	„ „	1·22	0·84	1·02
3 – 5	1·780	„ „	1·22	0·98	1·37
7 – 9	1·775	Tarred Iron, Darcy	1·21	1·30	5·57
8 – 10	1·805	„ „	1·19	1·09	9·19
11 – 13	1·841	Drawn Iron, „	1·16	1·74	1·29
12 – 13	1·867	„ „	1·13	1·24	1·65
15 – 16	1·927	New Cast Iron, „	1·07	1·14	8·12
14 – 16	1·947	„ „	1·05	1·04	6·75
18 – 20	1·983	Incrusted Iron, „	1·02	1·23	6·98
Means	1·834		1·166	1·20	4·01

The values of m in the table do not afford definite evidence of a regular variation either with the value of n—a conclusion previously reached—or with the class of pipe. Further, the absence of any systematic relation between m and $3 - n$ indicates the propriety, if not of wholly rejecting Reynolds' relation, at least of regarding it as not yet proven.

To test the next method, (ii.), we resort to graphics, using the mean values of $\log k''$ given in Table G.: the result is shewn in Fig. 8, and gives as a mean value for m, 1·27; while the mean value of n is 1·834, whence $2 - n = 1{\cdot}166$. The difference though

not large, is adverse to Reynolds' theory, which therefore may be rejected.

The means of the experimental results, in which alone the real relation may be supposed to be disclosed in the presence of apparently hopeless anomalies in individual cases, indicates an average relation, $k'' \propto R^{1\cdot27}$, as generally interpreting the experiments within their own limits; and this in the mean with a precision that could hardly have been anticipated. That this index is well determined cannot of course be alleged: experiments will have to be made with a far higher order of precision than in the past, before either the general constancy of the index can be really assured, or its exact value or law of variation accurately ascertained.

From some considerations it might seem probable that m would vary with R itself (case iii.,), and indeed also with n, the latter implying perhaps, that the roughness must be considered in relation to the dimensions of the pipe; a view from which there seems to be no escape, if extreme cases be contemplated. This view however is not supported directly by the order of the variations in the values of n—that is with the measure of roughness—shewn in Table A., excepting perhaps in line 17; but here the individual results are so inconsistent that no reliance can be placed upon the value of n derived therefrom. As however, there is some evidence that m is not constant, this question will be further considered, viz., in the section next following, § 17.

It is not unimportant to remember that a limited number of experiments may, through errors of observation, often suggest a relation, which a larger series will shew to be quite accidental. For example in considering the value of m, it might appear from Darcy's experiments with lead pipes, that m *increases* with R, see Table H. 3 – 4, 3 – 5, and 4 – 5; or from those with iron pipes, that it *diminishes* with R, see 7 – 9, 8 – 10; and 11 – 13, 12 – 13; and so on. This may possibly be accounted for by the fact that m is a function both of n and R, which at any rate must be admitted if a general formula is to be reached. No matter how

these observations are arranged, whether according to the categories, to the values of R, or of n, they fail to disclose any very striking indication of a regular variation. Hence there seems to be no alternative, but to base the law, as has been done, upon the mean results at the bottom of Table G.

It may be noticed that St. Venant puts $m = 1$, in his 1850 paper, while Hagen in his experiments in 1853 obtained 1·25, agreeing, it will be observed, with Reynolds' definition, $m = 3 - n$; *i.e.*, $3 - 1{\cdot}75$.

17. *An empirical generalization of the indices q and m considered as varying both with n and R.*—Returning to the question of possible variations in the indices q and m, it has already been noticed that q seems to diminish with the increase of internal agitation—in other words when n is large—and also, that there is a suspicion that m diminishes as R increases. First in regard to q. Any attempt to generalize the value of q, must take account of the fact that when $n = 1$, $q = 1$. If Hagen's, Mair's, and Unwin's experiments be relied upon, the values of q determined by them must be systematically included. And if, as I feel convinced is the case, q is *always* positive, it must not vanish for any value of n. This may be effected by putting it in some such form as

$$q = \frac{x}{a\,(n-1)^z + x} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (35)$$

in which if $x = 0{\cdot}18$, $a = 1$, and $z = 2$, the results will be as shewn in § 13. So that the temperature function is at least roughly

$$U^n \propto f^{\frac{\cdot 18}{(n-1)^2 + \cdot 18}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (36)$$

and this is true for either régime.

It is obvious that when $n = 1$, $q = 1$; when $n = 2$ q is ·15, and q does not become zero till $n = \infty$. When accurate values of q, determined for tubes with different values of n, are obtained, there will be no difficulty in adjusting (35) to them, by suitably choosing x, a and z. The results by the formula are shewn in Table E. § 13, for comparison with Hagen's, Mair's, and Unwin's observations.

A perfectly analogous method may be followed in regard to m, supposing it to vary with R: case iii., § 16. It may be noticed from Fig. 8, that there is a very slight indication of decrease in m with increase of R. This may be seen in Table H., and also in the following way:—Let the mean be taken of all the small radii, *i.e.*, under 2 cm., and of the correspondent values of m: and similarly also of all the larger, *i.e.*, between 5 and 10 cm. The results are:—for $R = 1{\cdot}25$, $m = 1{\cdot}23$ and for $R = 7{\cdot}32$, $m = 1{\cdot}16$. This decrease with increase of R is distinctly confirmed by the position of the point $R = 25$ cm. in Fig. 8, and though, as already remarked, there is intrinsic evidence that the precision of this series of observations is not high, it has to be remembered that there is confirmatory evidence in the case of open channels, as will be shewn in § 24 hereinafter. If then the formula is to be made to accord more exactly with the results, shewn in the figure, a second-degree curve must be made to pass through the points whose radii are 1·34, 4·095 and 25·0, and will then *well* represent the whole series. By a rough calculation the tangencies or values of m at the extremities and middle thereof are obtained, as shewn hereunder. Now in regard to these, the values seem respectively rather high and low at the extreme limits, though they are well within the range of the results shewn in Table H. If we are to have generality, then when R is zero or extremely small, its index must be 2, because the first régime must then exist. Then again at the radius, the logarithm of which is the mean of the two extreme radii just mentioned, the value of m must be 1·244 (viz., for $R = 5{\cdot}78$). And finally it seems likely that when R is very great its index is unity, the index assigned by St. Venant. These conditions will be satisfied by putting

$$m = 1 + \frac{x}{x + R^z} \quad \ldots\ldots\ldots\ldots\ldots\ldots(37)$$

If x be made 0·77, and z be made $\frac{1}{2}$, the result will be as follows:—

Table J.

$R =$	0	1·34	5·78	25·0	∞
m calculated	2	1·400	1·243	1·133	1.
m observed ?	2	1·446	1·244	1·042	?

Hence the observations are not only better represented by making m a function of R itself, but the formula attains to greater generality, and empirically expresses the observed results on giving that function the form

$$U^n \propto R^{\left(1+\frac{\cdot 77}{\cdot 77+\sqrt{R}}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(38)$$

It is easy to see that by suitably choosing x and z, the expression (37) may be made to represent a large range of observed values of m ascertained by future experiments. At the same time it should be noticed that for m to be entirely general, it must remain 2 as long as n remains 1. Hence the complete expression for m must have some such form as

$$m = 1 + \frac{x}{x + b\,(n-1)^y\,R^z} \quad \ldots\ldots\ldots\ldots\ldots\ldots(37a)$$

and the application of this latter or any similar formula might perhaps be considered when exact experiments are to hand.

It is, very probable I think, that careful experiments will shew that m is after all, as implied in this last equation, a function of the roughness. In further discussing the solution of the problem it is essential to keep in view the fact, that the *only* simple way in which the observed velocities can be *accurately* represented, with the fall in pressure as argument, is by the expression $U^n = k''I$, and that the only simple general relation by which all the observed velocities can be *approximately* defined, with the arguments, radius and fall in pressure, is by the formula $U^n = k'R^mI$, in which k'' and k' are the quantities in Table A., and $m = 1{\cdot}27$ or is determined by (37)—(38). But as already remarked in regard to the law of variation of the velocity with the radius, the table itself presents many anomalous features, and it seems to be impossible to *accurately* represent all the observations by formulæ of the preceding type, or indeed by any formula whatsoever. The real general problem may therefore perhaps be regarded as taking the form, not of determining an expression which will absolutely reproduce the experimental results—that seems to be impossible—but one which shall represent them *in their generality*, and which

therefore will not *systematically* deviate from the relations subsisting between them. The geometry of this analysis, by means of which the preceding formulæ have been deduced, will make obvious what is meant by this statement. The defects of the Chezy, of the Darcy and Bazin, of the Ganguillet and Kutter, and of the Reynolds' formula, is that each systematically departs from what may be called the general trend or indication of the experiments, upon which it is founded, as the course of the present investigation seems to shew.

Assuming that the radius function and its index m have been correctly ascertained, it may be eliminated from the values of $\log k''$ by means of equation (33), m being taken either as 1·27, or as determined say by (38). In forming the values of $\log k'_{14}$, Table A., the constant value for m has been assumed. As already remarked in § 11, the quantities $\log k'$ must be regarded as possibly functions of n, since the values of k'' are so, from which they are derived; an obvious fact when it is considered that each value of k'' is determined by the intersection of the "n" lines—Figs. 2 to 6—with the axis of abscissæ.[1] Their arrangement according to the categories, in the order of the radii, or in the order of the values of n, fails to indicate any very definite relation. What indication there is of variation, is in favour of the assumption that k' varies with n, which after all is tantamount to a variation with the category. This indication may be noticed when the results of Table A. are plotted, or when the mean of series are taken, as in the table hereunder (K) and shewn in the illustrative plot, Fig. 9. The values k'_{14} (a) are calculated with m constant: (b) with it variable: only the (a) results are shewn in the figure.

Table K.

Nos. in Table A.	1.2	4.7	5.9	10.6.8	11.13	17.12	19.15	14.20.18
Mean value R.	0·47	1·34	5·92	6·95	1·29	13·16	5·41	6·02
,, ,, n.	1·70	1·77	1·78	1·81	1·84	1·87	1·91	1·97
,, ,, $\log k'_{14}$ (a)	4·63	4·61	4·62	4·65	4·64	4·70	4·74	4·72
,, ,, $\log k'_{1}{}^{4}$ (b)	4·74	4·80	4·61	4·70	4·70	4·82	4·75	4·76

[1] For when $U = 1$ its logarithm is zero, and $\log k''$ is the quantity which added to $\log I$, gives the position of the axis of ordinates where $I = 1$, and $\log I$ therefore zero.

The mean of these is $n = 1{\cdot}831$, $\log k'_{14}(a) = 4{\cdot}664$, (b) $4{\cdot}735$
Of the whole series (A) ,, $1{\cdot}840$, ,, $4{\cdot}674$

It should be noticed here that the value of k' is *greatly* affected by the index m of the radius, and inasmuch as the value of that index is very uncertain the satisfactory numerical evaluation of k' is impossible until m and its variation-law have been ascertained by sufficiently accurate experiments. In order to learn how far the slight indication of progression in Table K. is affected by considering m constant, formula (33) was applied to the values of k'', m being determined by the general formulæ (37), (38), with the results above shewn, indicating no progression. If however, the results be taken from Table A. in groups of five, arranged with increasing values of n, the means of the very divergent results are as follows:—

Table L.

Mean	n	$1{\cdot}754$	$1{\cdot}796$	$1{\cdot}866$	$1{\cdot}956$	mean $1{\cdot}843$
,,	$\log k'_{14}$	$4{\cdot}651$	$4{\cdot}705$	$4{\cdot}679$	$4{\cdot}768$	,, $4{\cdot}701$

indicating very distinctly an increase with n. These results are shewn by crosses (+) in the figure. Accepting the mean values in the above table, and reducing by formulæ (35) and (36), § 17—q for $n = 1{\cdot}843$ being $0{\cdot}202$—we find $\log k'_\circ$ has the value $4{\cdot}664$, while when $n = 1$ its value is $3{\cdot}836$. Hence in order that the general formula may shew the progression above indicated, and at the same time be true for the first régime, we may put

$$\log k'_\circ = [1 + {\cdot}256\,(n-1)] \log \left(\frac{g\rho}{8\eta_\circ}\right) \ldots\ldots(39)$$

or putting s for $0{\cdot}256$ and k for $g\rho/8\eta_\circ$

$$k'_\circ = k^{1+s(n-1)^w} = k^{1+p} \ldots\ldots\ldots\ldots(40)$$

so that k is the rationalized coëfficient, and $p = s(n-1)^w$ is empirical. The value of k for $\rho = 1$ is 6851 with the centimetre as unit.

Until more accurate experiments are to hand, the relations between p and q cannot be satisfactorily studied. It may possibly be desirable to omit the f term and substitute η for $\eta_\circ$.

19. *The general equation for flow in circular pipes,*—Summing up the results now reached, we may write for the mean velocity of the flow of water in a circular pipe under either régime, at any temperature, and with any radius, 'slope,' or material of pipe,

$$U = \left[\left(\frac{g\rho}{8\eta_o}\right)^{1+p} f^q R^m I\right]^{\frac{1}{n}} \ldots\ldots\ldots\ldots\ldots\ldots(41)$$

in which n depends upon the roughness of the channel, and can be set forth in categories, p and q are functions of the roughness expressed in n, and m is a function of the absolute dimensions of the pipe, sensibly, though perhaps not wholly independent of its roughness, but must be always taken as 2, while $n = 1$. The values of p, q and m are given in formulæ (39), (36) and (38) respectively.

Reviewing the general result it seems evident:—(i.) That n is in some sense a measure of the intensity of the internal agitation developed by the rugosity of the boundary, or a measure of the integrated shear in a section. (ii.) That the decrease of the efficiency of fluidity in producing velocity parallel to the axis of the pipe, arises from the fact that the efficiency of the boundary condition in promoting internal agitation increases with fluidity: this is probably an asymptotic relation, for it seems certain that increase of fluidity continually promotes flow, though in less degree as the rugosity of the boundary increases: this view seems more obvious when a highly viscous liquid is studied: (iii.) That the variation in the index of the radius implies that the surface roughness is relative to the sectional area, throughout which it is the agent in promoting agitation. It may therefore be found, when sufficient exact experiments are to hand, that m is a function of both n and R.

The following are the mean values of n deduced in the preceding investigation, and values of q and q/n corresponding.

The values in Tables IV. and V. are subject, the latter especially, to very great uncertainty as already pointed out; and it has yet to be shewn by experiment that q, in the temperature function f^q, is always positive, that is even when n is greater than 2.

Table III.

Values of the Index of Roughness (n) and of the index of fluidity q.

Pipe.	n	$\frac{1}{n}$	q
Very smooth lead pipes (Reynolds)	1·70	·59	·26
Lead pipes generally (Darcy)	1·78	·56	·23
Sheet iron pipes coated with tar „	1·79	·56	·22
Jointed glass pipe	1·81	·55	·21
Drawn iron pipe	1·85	·54	·20
New cast iron pipe	1·94	·52	·17
Incrusted cast iron pipe...	1·97	·51	·16

Table IV.

Values of $k_0^{\frac{1+p}{n}}$, and of the index of fluidity,[1] etc.

n	1·70	1·75	1·80	1·85	1·90	1·95	2·0
$(g\rho/8\eta_0)^{\frac{1+p}{n}}$	·694	·681	·669	·658	·648	·638	·628
q	·269	·242	·220	·199	·182	·166	·153
q/n	·158	·139	·122	·108	·096	·085	·076

Table V.

Values of the index[2] of the Radius m and of m/q for different values of the Radius (R).

R.	0·5 cm.	1·0	2·0	3·0	5·0	10	20	30
m	1·99	1·43	1·35	1·31	1·26	1·20	1·15	1·12
$m/1·7$	1·17	·84	·80	·77	·74	·70	·68	·66
$m/1·8$	1·11	·79	·75	·73	·70	·66	·64	·62
$m/1·9$	1·05	76	71	·69	·66	62	60	59
$m/2$	1·00	·74	·68	·66	·63	·60	·57	·56

Kutter's formula has been objected to by engineers on the ground that the estimation of his coefficient of roughness is practically difficult and subject to a wide range of uncertainty. The

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[1] These values can be regarded only as tentative. Sufficient experimental data are not yet to hand to permit of the exact amount of the index being known.

[2] These values can only be regarded as tentative. The experimental data do not yet admit of m being accurately determined. m is very probably also a function of n.

case of the general formula (40) is no better. It is impossible, in view of the results shewn in Figs. 2 to 6, to escape from the recognition of the difficulty of estimating the roughness; and evidently, even under apparently identical conditions, it has sensibly different values. Hence all practical computations of velocity are subject to a considerable margin of doubt; for which there appears to be no remedy.

20. *The so-called hydraulic-radius.*—In hydraulic formulæ it is generally assumed that the resistance to flow, propagated from the wetted surface of a pipe or channel, may be always expressed as a function of the *hydraulic-radius* merely—*i.e.*, as the quotient formed by dividing the area of a right section by the wetted perimeter, a quantity which we shall denote by R or r[1]—and that in this way the flow in any form of pipe (or channel) is immediately comparable with the flow in a circular pipe. If the use of the hydraulic-radius *wholly* eliminated the influence of the *form* of the channel, the assumption would be entirely satisfactory: but such is not the case.

21. *Corrected hydraulic-radius for ellipse: rectilinear flow.*—With rectilinear flow in a pipe of elliptical section, the semiaxes being B and C, the variation of velocity with size of pipe—all other circumstances remaining the same—may be expressed by

$$kU = B^2C^2/\tfrac{1}{2}(B^2+C^2) = \xi \text{ say} \quad \ldots\ldots\ldots\ldots(42)$$

The hydraulic-radius analogue of this quantity, S denoting the area of the ellipse and E its circumference, is:—

$$(S/2E)^2 = B^2C^2/(\tfrac{3}{4}B - \tfrac{1}{2}\sqrt{BC} + \tfrac{3}{4}C)^2 = \chi \text{ say} \quad \ldots\ldots\ldots\ldots(43)$$

this last expression being exact up to and inclusive of the sixth power of the excentricity of the ellipse.[2]

Putting

$$\mathrm{R} = \tfrac{1}{2}(B+C) \text{ and } \epsilon = (B-C)/(B+C) \quad \ldots\ldots\ldots\ldots(44)$$

so that

$$B = \mathrm{R}(1+\epsilon) \text{ and } C = \mathrm{R}(1-\epsilon), \quad \ldots\ldots\ldots\ldots(45)$$

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[1] We use these letters to distinguish the quantity from the radius of a pipe, R or r.

[2] The term is $5e^6/256$. For this approximation see Boussinesq, Comptes rendus, t. 108, pp. 695 – 699.

the ratio of the former expression to the latter, becomes identically

$$\frac{\xi}{\chi} = \frac{R^2\,(1 - 3\epsilon^2 + 4\epsilon^4 - 4\epsilon^6 \ldots)}{R^2\,(1 - \frac{5}{2}\,\epsilon^2 + \frac{3\,3}{1\,6}\,\epsilon^4 - \frac{2\,1}{3\,2}\,\epsilon^6 \ldots)} = 1 - \tfrac{1}{2}\,\epsilon^2 + \tfrac{1\,1}{1\,6}\,\epsilon^4 - \tfrac{1\,0}{3\,2}\,\epsilon^6 \text{ etc.} \quad (46)$$

Consequently this last quantity is a *correcting factor* to be applied to the square of the hydraulic radius for the case of rectilinear flow, or taking its square root the hydraulic radius R, of an ellipse, requires to be multiplied as in the following expression

$$R_o = R\,(1 - \tfrac{1}{4}\,\epsilon^2 + \tfrac{5}{1\,6}\,\epsilon^4 - \tfrac{7}{3\,2}\,\epsilon^6 \ldots) \quad \ldots\ldots\ldots (47)$$

R_o denoting what might be called the *corrected hydraulic radius.* It is evident from these last equations that different forms of channels are not comparable unless some correction be applied to the hydraulic radius, or to express this otherwise,—the simple function called the hydraulic radius is not adequate, when precision of a high order is required. If there be a marked departure from the circular form, the hydraulic radius must be modified. The following table will perhaps more clearly illustrate the significance of this statement.

Table VI.

Values of x in the correction, $R_o = R\,(1 + x)$ for pipes of elliptical section.

Value of ϵ	·05	·10	·15	·20	·25	·30	·35	·40
,, x —	·0006	·0025	·0055	·0095	·0144	·0200	·0258	·0320

22. *On the investigation of the law of flow in channels.*—Unfortunately the magnificent series of experiments made by Bazin on flow in channels, were with a few exceptions, made with rectangular instead of with triangular channels; consequently the results for different hydraulic radii are not immediately comparable, inasmuch—as is evident from the preceding section—the unknown correction to the hydraulic radius systematically changes throughout any series of experiments. The only exception to this is Series 23, with a wooden triangular channel, and these, made with the one slope, permit of the law of variation of velocity with increase of hydraulic radius being determined. In order to find the law of slope, it is necessary to have experiments in which the radius is kept constant and the slope varied. These can only be obtained from Bazin's experiments by interpolations.

23. *The index of roughness (n) probably a function of the slope (I) in open channels.*—We may test this as above indicated. From an extensive series of interpolations from series 6, 7, 8, 9, 10, 11, 18, 19 and 20, of Bazin's experiments with channels formed of ordinary boards, after *very small* corrections for hydraulic radius and temperature, I have taken the following results :—

Form of channel = depth/breadth = $\frac{1}{2}\frac{1}{0}$; log R 2·867. water 11° C.

log I	$\bar{3}$·176	$\bar{3}$·318	$\bar{3}$·690	$\bar{3}$·771	$\bar{3}$·916	$\bar{3}$·924
log U	1·757	1·862	2·081	2·133	2·213	2·219

This gives as a mean result $n = 1{\cdot}643$, but there is some indication of n increasing with I.

Again, Series 6, 7, and 8 were made at the temperatures 7, 8½, and 8½° C. respectively, the breadth of the channel—199 cm.—and materials—boards—being the same in each case. Forming by logarithmic interpolations, the values of log U for the three slopes, for the hydraulic radii whose logarithms were 1·00, 1·14, 1·08, 1·21, 1·26, 1·28 and 1·29, we find *no indication of variation with the hydraulic radius.* It is therefore legitimate to take the mean of the differences of the logarithms, which gives the following results :—

(a)	log I_2 − log I_1 =	·327	log I_3 − I_2 =	·226
(b)	mean diff. log U =	·222		·120
n =	say a/b =	1·47		1·88

The slopes are ·00208, ·00490 and ·00824 so that apparently n increases with I. A similar indication is also given by series 9, 10 and 11, in which the breadth of the channels and material are the same.

The very small range of slope in Bazin's experiments, and the want of a sufficient number of experiments throughout that range, points out the desirability of hesitating as to the assumption that n varies with the slope in channels though not in pipes. Experiments in order to determine this point are necessary. They should of course be made, as pointed out, preferably with triangular channels of constant inclination of sides, and necessarily of constant

hydraulic radius throughout anyone series of slopes. The best slopes for the sides would be 1 to 1, so that the angle included would be 90°.

24. *Proof that the index of the hydraulic radius varies with the radius.*—On plotting the logarithms of the velocities and hydraulic radii of Series 23, respectively as ordinates and abscissæ, to which reference has already been made (§ 21), it is quite evident that the points lie in a curve, Fig. 10, convex upwards. Hence m', the value of $d(\log R)/d(\log U)$ diminishes as R increases. This index would require to be multiplied by n to be comparable with m in the formula for pipes. It is evident therefore that the law of the indices, m and n, must be thoroughly ascertained in order to deduce anything like an exact expression for velocity of flow in open channels.

25. *Dissimilarity of flow with varying hydraulic radius and dissimilar forms of channel.*—It might be anticipated that when the boundary of a channel is very rough, the dissimilarity of the law of flow with dissimilarity of form of channel, would be most striking. This is well shewn by Bazin's Series 30 and 31—slopes ·0081 and ·0152, breadth of channel (lined with canvas) 10 cm., temperature 10° C.—from which the following results are deduced.

Hydr. Rad.	1·16	1·69	2·05	2·39	2·91
Log U_1	1·338	1·530	1·607	1·662	1·733
Log U_2	1·387	1·595	1·694	1·760	1·833
$\Delta \log I / \Delta \log U$	5·6	4·2	3·1	2·8	2·7

These final figures corresponding to the values of n in the investigation of flow in pipes, indicate that the general formula developed for pipes will perhaps fail when applied to open channels. It is however likely that an analogous derivation of a formula will be practicable: this however I have not yet thoroughly examined.

26. *Indications for further experimental investigation with pipes and channels: conclusion.*—(1) The law of velocity as related to temperature with at least two, better three, pipes of very different roughness requires further experimental investigation, especially with a view to the determination of the influence of temperature

when n is very nearly 2. (2) The variation of velocity with respect to the radius of pipes also needs investigation: this evidently should be done with at least three series, having widely different degrees of roughness, so as to ascertain the influence of the roughness upon the variation, in other words to determine m as a function of both n and R.

(3) In channel investigations it is to be hoped that the triangular shape will be adhered to throughout: the law of flow may then be discovered, and the influence of form constituted a subsequent subject of inquiry.

In conclusion I wish to say that the main object of this paper has been to indicate a scheme of empirical analysis of, and to develope a type of formula for, the flow of water in pipes and channels, especially the former, rather than to determine, with the last degree of possible precision, the constants of the formula itself. By means of tables the general expression supplied, can be rendered easy of manipulation for the purposes of practical calculation. Its general factor $g\rho/8\eta_o$, is based on the deductions of rational mechanics, and the empirical constants supply the apparently hopeless defect which inheres in the complete mathematical solution of the problem. That there must necessarily be variations of the constants from time to time, as more exact experimental data come to hand, goes without saying. If a formula free from systematic misrepresentation of the observations has been educed, the object of the investigation has been completely attained: it is believed that the formula supplied will be found capable of being so adjusted, by giving proper values to its constants, to the results of new and more exact experiments, that is to say it is substantially a *general* formula.

Added 24th December, 1897.

A further reduction, see Table A.—by applying formula (35) and assuming $m = 1{\cdot}27$—of the values of log k'_o gave for the constant in (39) § 18 the value 0·248 instead of 0·256. The plot of values of log k''_o with interpolations for radius (R) and for roughness (n) gave very little indication of a variation of m with R itself. More accurate experiments are needed.

University of Sydney.

EXPERIMENTAL INVESTIGATION OF THE FLOW OF WATER IN UNIFORM CHANNELS.

By S. H. BARRACLOUGH, B.E., M.M.E., and T. P. STRICKLAND, B.E.

[*Read before the Royal Society of N. S. Wales, December 1, 1897.*]

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1. *Introductory.*—In a paper[1] read before the Society, entitled "The steady flow of water in uniform pipes and channels," amongst other things the question of the flow of water in open channels is touched upon, and the applicability generally of certain formulæ proposed by Prof. O. Reynolds,[2] is discussed. The experiments described in the following paper form part of an investigation undertaken with a view of filling in an hiatus[3] in the existing series of experimental results, so as to admit of a

[1] "The steady flow of water in uniform pipes and channels," by G. H. Knibbs.—Proc. Roy. Soc. N.S.W., Vol. XXXI., p. 314.

[2] Phil. Trans., p. 949, 1883.

[3] See Mr. Knibbs' remarks, pp. 352–355. For Ganguillet and Kutter's recognition of the fact, see also their work on "The flow of water in rivers and other channels," p. 105.—Macmillan, 1889.

more satisfactory determination of the degree of accuracy with which such, or similar formulæ, may be made to represent the velocity of flow in channels, when the conditions are varied over a wide range. The suggestion of this investigation is due to Mr. Knibbs, and was the result of his critical study of the history of the subject, and analysis of the deductions of earlier investigators. We take this opportunity of acknowledging our indebtedness to him not only for the fullest access to all his notes, but also for his generous coöperation and counsel in planning and carrying out the experiments. The experimental work itself was made possible by the kind assistance of Prof. Warren, who, when the need of the work was discussed, at once undertook the suitable equipment of his laboratory for the prosecution of these and similar hydraulic experiments. For this, and for his cordial assistance and counsel during the whole course of the work we desire to place on record our grateful thanks.

2. *Objects of experiments.*—The conditions which may be assumed as having the most marked influence on the rate of flow in open channels are—(*a*) slope, (*b*) hydraulic radius, (*c*) temperature, (*d*) roughness, and (*e*) form of channel section. The present experiments were carried out in one channel so that the last two conditions were constant (unless it be supposed that roughness must be considered in relation to the absolute dimensions of the channel) and the first three only were included in the enquiry. The objects in view may be thus stated :—

i. While keeping the temperature and hydraulic radius as invariable as possible, to determine the relation between velocity and slope, over the greatest attainable range of slope.

ii. At certain fixed slopes and with the temperature as invariable as possible to determine the relation between velocity and hydraulic radius.

iii. At certain fixed slopes and with the hydraulic radius as invariable as possible, to determine the relation between velocity and temperature.

Of these three, the first was the point under immediate investigation, the second and third being more especially required for the purpose of correcting the velocities in the first, for small and unavoidable changes of hydraulic radius and temperature.

3. *General plan of apparatus.*—When the object of an investigation is the determination of the law of variation of some particular quantity, rather than the magnitude of coefficients or constants required for practical use, there are decided advantages to be gained by planning the apparatus on a small scale, so that the various conditions of the experiment can be easily controlled. For this reason it was decided to use a comparatively short channel, made of planks the full length of the channel, and to limit the water-way to a small section, so as to ensure the water attaining its uniform régime within a short distance from the entrance. The general disposition of the apparatus is indicated in Fig. 1. The water was drawn from the ordinary service supply into the supply tank, whence it passed by one or more orifices to the tin-lined inlet box at the channel entrance, then along the channel to the gauging tank, where its amount was accurately determined, and finally into the drain. For the temperature tests the water in the tank was heated by the condensation of steam from a neighbouring boiler, the steam being lead into the tank by steam piping, not shewn in the figure. The slope of the channel could be readily altered by raising or lowering its supporting trestles. For convenience of observation and computation the metric system was used, as far as possible, throughout the investigation.

4. *Supply and control of the water*—The details of the supply tank are shewn in Fig. 1. It consists of an ordinary 400 gallon tank with part of the top cut away, and having strong wooden stays bolted to the interior sides to prevent bulging. The water discharges itself from the main horizontally through a rose, and this, together with the series of baffle plates fixed across the tank, effectually checks any disturbance due to influx. Throughout the whole of the experiments nothing in the nature of an oscillation

of the surface was observable. In the bottom of the tank was fixed a stuffing-box through which passed an iron overflow pipe, 2″ in diameter, filed to a sharp edge at the top, and discharging through a canvas hose into a drain below. In each experiment the pipe was so arranged, that, with the necessary head on the orifice, the water flowed over the overflow under a head of about 5 or 6 mm. A slight change in the level of the water surface in the tank, due to a change of pressure in the service main, has, of course, a vastly greater effect on the discharge by the overflow than on the discharge through the orifice, and in this way a very convenient automatic regulation of the head is obtained. Any variation in the head was found to take place very slowly, rarely amounting to 2 mm., and being as a rule very much less. The following table, representing the times and the heads observed during the course of experiment 7, Series II., and which was not exceptional in any way, will serve to illustrate this point.

Table I.

Time. hrs. min.	Head. cm.	Time. hrs. min.	Head. cm.	Time. hrs. min.	Head. cm.	Time hrs. min.	Head. cm.
2 43	82·55	2 50	82·54	3 04	82·53	3 20	82·55
2 45	82·54	2 52	82·54	3 08	82·54	3 21	82·55
2 47	82·52	2 55	82·54	3 12	82·55	3 23	82·55
2 49	82·54	3 00	82·53	3 15	82·55		

These heads were observed by means of a gauge-glass about 12 mm. in diameter, and an attached boxwood millimetre scale, fixed to the front of the tank. The zero of the scale was above the centres of the orifices by the amounts shown in the table below, so that the observed heads have to be increased by these amounts, in order to obtain the height of the water surface above the centres of the orifices. There is probably in addition a small error due to capillary action in the gauge-glass, but as the absolute heads are not required in the investigation, this is a matter of no moment. There are four orifices by one or more of which the water may be drawn from the tank, but the largest of the four was not required. When not in use the orifices were closed by

means of metal discs faced with rubber to prevent injury to the edges of the orifices.

Table II.

No. of Orifice.	Approximate Diameter. cm.	Correction to reduce to zero of scale. cm.
1	0·835	·90
2	2·00	·98
3	3·22	1·04

5. *Entrance conditions.*—The orifices discharged into a tin vessel with a wire gauze bottom, through which the water fell on to a piece of wood floating on the surface of the water in the back compartment of the inlet box, shewn in Fig. 1. From this compartment the water rose under the partition, and thus all disturbance due to influx was prevented. In the front of the box a triangular notch was cut to carry the channel, a watertight and yet flexible, joint between the two being obtained by means of sheet indiarubber. This joint allowed of the slope of the channel being varied through a wide range, without straining the channel in any way. To the top end of the channel and flush with its surface, was attached a piece of sheet tin 'splayed out' in the shape of a semi-conical funnel, through which the water entered the channel smoothly, no ripples appearing on its surface for a distance of about two feet down the channel at the higher slopes, and for greater distances at the lower slopes. By means of bands of coloured liquids it could be seen that the flow was continuous at the top, no vortices being observable.

6. *The experimental channel.*—The experimental channel was constructed of two carefully planed kauri pine planks $1\frac{1}{8}$ inch thick in the rough, neither of which showed the slightest defect in the way of cracks or knots. These planks were simply screwed together at right angles without any special form of joint, and, after the water had been flowing for a short time, proved to be perfectly water-tight.[1] The channel was about six metres long

[1] The right angle section was selected for reasons pointed out by Mr. Knibbs in his paper already referred to, p. 354.

and the sides were 13 cm. deep. At intervals of 75 cm. along the channel notches were cut in the edges of the planks, to carry cross bars which were fixed at right angles to the axis of the channel, and having two opposite faces perpendicular to this axis. On the down-stream face of each cross-bar was fixed a paper millimetre scale, a horizontal line on which was taken as the zero line for measuring the distances to the surface of the water. These measurements were made by means of a boxwood scale 20 cm. in length, having a hole drilled in one end and a needle glued therein. A guide block (illustrated in Fig. 2) was constructed to enable this scale to be slid up and down perpendicularly to the axis of the channel in any position across the channel. Since the surface of the water was, in the nature of things, covered with a multitude of small ripples, it was assumed that the surface of the water had been reached when the needle point was immersed as often as not in the course of a few seconds. It was found possible generally to observe the ordinate to the water surface to ·01 cm. As will be shown subsequently, the error involved in measuring the cross sectional areas is a small one. The stations at which the cross-bars were fixed are lettered A, B,...H, but observations were rarely taken at either A or H, as doubtless the conditions at these points would be considerably affected by the proximity of the channel entrance and exit. During the course of the experiments readings were frequently taken down to the sides of the channel in order to detect any change that might have occurred in the cross-section of the channel due to warping or any other cause. In addition to the support at its upper end, the channel was carried in notched standards attached to trestles and capable of being adjusted to any desired height, so that its slope could be easily and rapidly changed. As the lower end of the channel warped slightly in an approximately vertical plane during the course of the experiments, a weight of 28 lbs. was hung on the end of the channel in the later experiments, and the supports adjusted so as to make the slope as nearly uniform as possible, this latter being estimated by means of an ordinary hand level. The channel

was also levelled transversely, as nearly as possible, by wedges, but a perfectly accurate adjustment could not be obtained at every section and is evidently of small importance. At the lower end of the channel the water discharged without loss into an auxiliary channel through which it passed to a small vessel situated immediately above the gauging tank. From this vessel it could either flow directly into the gauging tank, or, by means of a shoot, to waste.

7. *Measurement of the quantity of water flowing through the channel.*—The gauging of the water was done in a second 400 gallon square iron tank, situated below the floor-line, as shown in the figure. To the sides of this tank also were bolted strong wooden stays so as to prevent any tendency towards bulging. The water was conveyed through a down pipe, from the small well on the top, almost to the bottom of the tank. A couple of air vents were left in the top of the tank. The water was discharged into a conveniently situated drain, through two valves fixed in the bottom. A gauge-glass and boxwood millimetre scale were attached to the side of the tank, in the same manner as already described for the supply tank. The cubic capacity of the tank throughout its entire depth was determined by means of a standard cubic foot, manufactured by Sugg for gas measurement. This was placed near the tank and connected with the water supply. It was alternately filled and discharged into the tank, a reading of the scale being taken before and after each cubic foot was run in. This work was done on perfectly calm days as it was found that any breeze produced slight oscillations of the water surface in the gauge-glass, and so prevented accurate readings being taken. To reduce cubic feet to cubic centimetres the multiplier 28,316 was employed. The zero of the scale was several centimetres above the bottom of the tank, but this was of no importance as in any gauging it was the difference of two readings, and not an absolute reading, that was used. Each cubic foot produced an average elevation of the water surface in the gauge-glass of 1·91

cm., and it was possible to read accurately to ·01 cm., corresponding roughly to $\frac{1}{200}$ of a cubic foot, or say $\frac{1}{3}$ of a pound of water.

The temperature of the water was carefully observed throughout the entire process, but it varied very slightly from 12° C., it being at the time mild and settled winter weather. Any readings which gave differences, not in close agreement with neighbouring differences, were subsequently checked by taking several additional readings over that portion of the scale. By interpolation, Table III. was finally constructed from the observed readings, giving the number of cubic feet in the tank up to any reading on the scale, the zero being taken at 98 cm. To measure the mean rate of flow for any experiment it was then only necessary to observe the reading of the scale before the water was turned into the tank, and after it was diverted to the drain, and to note accurately the length of time the water was flowing into the tank. For the

Table III.

Mean temperature = 12° C.

Scale Readings.	Cubic feet of water in tank	Scale Readings.	Cubic feet of water in tank	Scale Readings.	Cubic feet of water in tank	Scale Readings.	Cubic feet of water in tank
98	0·000	73	13·053	48	26·083	23	39·232
97	0·515	72	13·577	47	26·604	22	39·768
96	1·034	71	14·098	46	27·127	21	40·300
95	1·563	70	14·619	45	27·651	20	40·834
94	2·092	69	15·138	44	28·174	19	41·371
93	2·621	68	15·655	43	28·698	18	41·909
92	3·145	67	16·176	42	29·222	17	42·439
91	3·663	66	16·696	41	29·747	16	42·969
90	4·181	65	17·213	40	30·272	15	43·494
89	4·699	64	17·739	39	30·794	14	44·021
88	5·223	63	18·265	38	31·314	13	44·555
87	5·749	62	18·785	37	31·838	12	45·097
86	6·276	61	19·304	36	32·367	11	45·642
85	6·802	60	19·824	35	32·893	10	46·186
84	7·328	59	20·344	34	33·421	9	46·729
83	7·855	58	20·865	33	33·945	8	47·261
82	8·371	57	21·388	32	34·472	7	47·795
81	8·886	56	21·912	31	35·000	6	48·332
80	9·410	55	22·435	30	35·524	5	48·861
79	9·936	54	22·959	29	36·049	4	49·387
78	10·454	53	23·480	28	36·572	3	49·920
77	10·972	52	24·001	27	37·097	2	50·456
76	11·490	51	24·523	26	37·620	1	50·988
75	12·009	50	25·045	25	38·157	0	51·506
74	12·530	49	25·563	24	38·695		

The scale read from 100 at the bottom to 0 at the top.

earlier experiments the times were measured with a stopwatch, but as its rate was found on close examination to be irregular, a pendulum clock marking seconds, was substituted and its rate determined by daily comparison with the time ball of the Government Observatory. As an alternative method of measuring the rate of flow the coefficients of discharge at various heads for the three orifices were determined, as detailed below, and as the method was found to involve at least in the case of orifice 2, which was the one used in the great majority of the experiments, only a small, and quite negligible error, it was adopted in many of the later experiments and provided a useful check on the earlier ones. In the following table h is the head on the orifice in centimetres, and c is a coefficient representing the value, at the respective heads, of the expression $\frac{\text{cub. cm. per second.}}{\sqrt{h}}$

Table IV.

Orifice 1.		Orifice 2.		Orifice 3.	
h	c	h	c	h	c
59·35	16·10	18·44	84·66	34·00*	218·5
80·85	16·07	29·00	84·64	62·03*	217·6
100·24	16·08	33·98*	84·75	83·66†	217·5
		35·14	84·58		
		37·06	84·44		
		55·86*	83·99		
		57·39	84·01		
		79·83*	83·90		
		83·38*	83·90		
		93·08	83·67		

* These were observations taken merely for determining the coëfficient. † This was an experiment in Series I. The remainder form part of Series II.

In one or two of the experiments at the greatest hydraulic radii and slopes, it was found necessary to open two of the orifices together, in order to supply sufficient water, and it was assumed in reducing the results for such cases that the orifices did not appreciably interfere the one with the other.

8. *Measurement of slope.*—At each station down the channel from B to G, bench marks were established, 749·5 millimetres apart, immediately over the centre of the channel, and levels were

taken to these marks with an 8″ theodolite by Troughton and Simms, which was placed very nearly in line with the channel so that the telescope had to be turned only through a small arc. A level staff was constructed of a boxwood millimetre scale, a metal pin being attached to its end, and a plumb-bob and thread at the back to ensure its being held vertically. It was found possible to read the staff to ·01 cm., so that as will be shown more fully in a subsequent paragraph, the error in the determination of the slope is a satisfactorily small one. At least two sets of readings of the levels were taken for each experiment, usually by two different observers, and the results in nearly every case proved to be practically indentical. If any discrepancy occurred between the two sets of readings, they were always repeated. The vertical distance from the bench mark to the zero line of the scale from which the distances to the water surface were measured, is as follows :—

Section	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Distance (mm)	5·6	5·5	6·7	5·8	6·15	5·6	6·3	6·3

9. *Method of making an experiment.*—The routine of an experiment may be described in general as follows. The channel was adjusted to about the required slope, was approximately levelled in a transverse direction, and any slight lack of uniformity in the gradient from section to section, as revealed by the hand-level before referred to, was as far as possible removed by minor adjustments of the supports. The appropriate orifice was then opened and the water allowed to rise in the supply-tank till the necessary depth was attained in the channel, when the head was adjusted by means of the overflow pipe and by a corresponding regulation of the inlet valve. A set of levels was then taken, during the course of which the head on the orifice was frequently noted in order to detect any tendency to fluctuation. The actual experiment was now begun by reading the scale of the gauging tank and then turning the water so as to flow into it, carefully noting the time at the same moment. The distances of the water surface in the channel from the zero line of the scale

were then read at each centimetre graduation of each section, and the side readings to the edge of the stream were also taken. At the conclusion of a set of readings at any cross section, the time and head on the orifice were observed. A second set of levels was then taken, the temperature of the water was observed, and supposing the gauging tank to be nearly full, the stream was diverted to the drain, the time being again accurately noted. A final reading of the scale on the gauging tank completed the experiment.

10. *Reduction of observations, and degree of precision attained.* —The quantities to be determined from the observations are (1) the mean velocity $= U$, (2) the mean hydraulic radius $= R$, (3) the average slope $= I$, and (4) the temperature $= T$. Of these quantities if A be the mean area, P be the wetted perimeter, and Q/t the rate of discharge, the velocity and hydraulic radius will be respectively

$$U = \frac{Q}{t \times A} \text{ and } R = \frac{A}{P}$$

To determine the velocity therefore Q, t and A have to be measured. The method of measuring Q has been detailed in § 7. Assuming that an error corresponding to ·01 of a cubic foot is made in reading the scale on the gauging tank, and remembering that on an average 30 cubic feet of water were run into the tank for each experiment, the error involved is about 1 in 1500. The time, t, during which the water was running into the gauging tank varied from ten minutes at the greatest slopes to one and a-half hours at the smallest. If it is assumed that an error of one second was made in the measurement of the time interval—an assumption probably erring considerably on the right side—the degree of uncertainty involved varies from about 1 in 600 to about 1 in 5000.

In calculating the area, A, at each section, it was considered as consisting of a series of trapezoids (one centimetre wide) together with three small triangles, viz., one at each side of the stream, and one at the bottom which was constant for any section. This latter area was obtained from an accurate plot of the cross section of the channel at the stations B, C, D, E, F and G. The ordinates

to the water surface, for determining the area, were obtained probably to ·01 cm. (as explained in § 6) so that, on the extreme assumption that the errors were made on the same side all along the surface, the resulting error would be about $8{\cdot}0 \times {\cdot}01 = {\cdot}08$ sq. cm. in the case of Series I., and about $6{\cdot}0 \times {\cdot}01 = {\cdot}06$ sq. cm. for Series II. The average areas for these two cases are approximately 20 sq. cm. and 7 sq. cm.; hence the degree of error involved on the above assumption, in determining the area would be about 1 in 250 and 1 in 120 respectively. The actual errror is probably less than this. The quantity subject to the most uncertainty in the investigation is the wetted perimeter, owing to the difficulty experienced in deciding exactly where the mean edge of the stream occurred. This difficulty of course decreased as the slope was diminished and the corrugation of the surface consequently was less marked. The average error in the side reading would not be greater than ·3 mm. corresponding to an error in the wetted perimeter of about one per cent. The wetted perimeter itself was determined by scaling from the plots of the channel sections previously referred to. The hydraulic radii were then determined for each section, and the velocities were reduced to a common radius of 1·5 cm. in Series I., and 1·0 cm. in Series II., by means of the law obtained from Series *A* and *B*.

The slope, *I*, was assumed to be that of the water surface, the levels to which were obtained as described in § 8 to ·01 cm. In nearly every case the slope was taken over a distance of 300 cm., so that the error of slope involved is about ·000033. The lowest slope used in determining the law of variation of slope with velocity was about ·007 the degree of uncertainty in which is therefore 33 in 7000, or a little less than 1 in 200. As the slope increases the degree of error diminishes, it being reduced to 1 in 2000 at a slope of ·066, which was the greatest slope used. The temperatures were obtained by means of two mercurial thermometers graduated in degrees Fahrenheit and provided with Kew certificates of date June, 1893. The readings were then reduced to degrees centigrade. The maximum correction to be applied to the thermometers was

·2° F. or approximately ·1° C., and it is thought that the temperatures as given in the tables may be relied upon to ·2° C.

11. *Relation between slope and velocity.*—Two series of experiments (I. and II.) were made with nominal values of the mean hydraulic radius of respectively 1·5 cm. and 1 cm., and with a wide range of slopes, in order to determine the method of variation of velocity with slope. As Series II. is the more complete and extensive of the two, it will be considered first. The following table summarizes the essential quantities. The velocities as given

Table V.

SERIES II.—Mean hydraulic radius = 1·00 cm. Mean temperature = 16·2° C.

Number in Series.	Reduced Velocity. cm. per second.	Log of Velocity.	Slope.	Log of Slope.	Channel Sections used.
7	48·2	1·6830	·0071	$\bar{3}$·8513	*E*, *F*
4	64·5	1·8096	·0137	$\bar{2}$·1367	*D*, *E*, *F*
5	73·1	1·8639	·0176	$\bar{2}$·2455	„ „ „
B	81·2	1·9096	·0221	$\bar{2}$·3444	Interpolated
3	81·7	1·9122	·0235	$\bar{2}$·3711	*E*, *F*
1	91·2	1·9600	·0274	$\bar{2}$·4378	*D*, *E*, *F*
6	105·2	2·0220	·0380	$\bar{2}$·5798	„ „ „
2	123·3	2·0910	·0505	$\bar{2}$·7033	„ „ „
11	134·5	2·1287	·0646	$\bar{2}$·8102	*E*, *F*
A	135·7	2·1326	·0663	$\bar{2}$·8215	Interpolated

In the above table experiments *B* and *A* are iuterploted from Series *B* and *A* respectively.

in the second column have been reduced to a common hydraulic radius by the formula obtained in § 12, and to a common mean temperature by the formula obtained in § 13. In Fig. 3, curve "II" in the lower half of the diagram shows the method of variation of velocity with slope under the conditions obtaining in Series II., and its logarithmic homologue is shown by the curve marked "II" in the upper half of the diagram. From the fact that there is a linear relationship between the logarithims of the slope and of the velocity it is at once evident that the function connecting these two quantities is exponential in form. The inclination of the straight line is approximately ·46, so that if U

SKETCH OF APPARATUS

Fig 1.

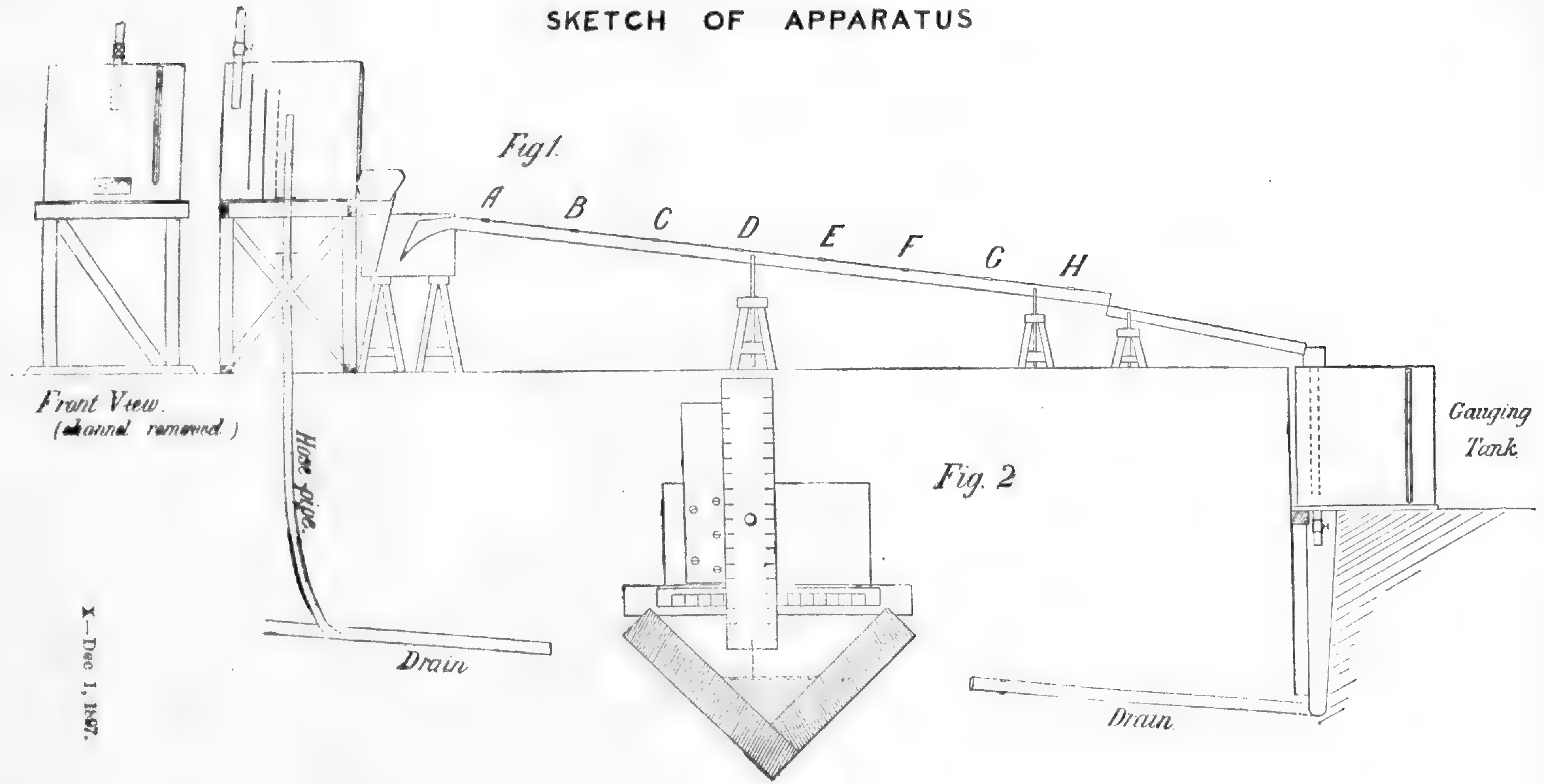


Fig. 2

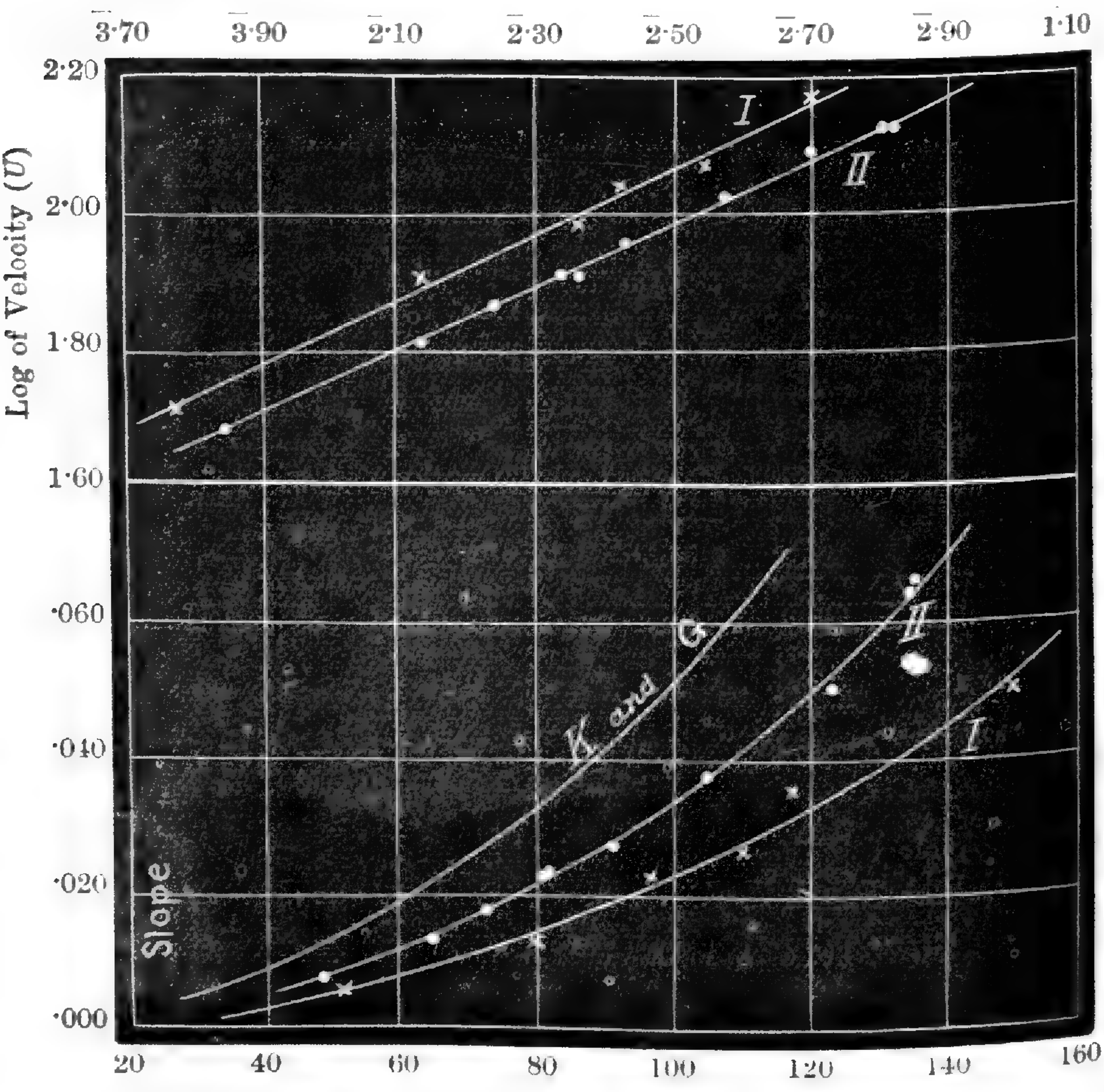
be the velocity and I the slope we have

$$U = k\, I^{\cdot 46}$$

where k is a constant. The degree of accuracy with which this simple expression represents the experimental results renders it unnecessary to enquire whether any other form of expression could not be used for the same purpose.

Fig. 3.

Curves marked "I" correspond to Series I.
" " "II" " Series II.
Curve marked "K and G" shows the results obtained by applying the formula of Kutter and Ganguillet to Series II.



As previously stated the stream did not attain a steady condition of flow immediately on entering the channel but was subject to a marked acceleration for some distance from the channel inlet. In the case of Series II., where the cross section of the stream was small, this distance proved to be comparatively short, the flow being practically steady at Section B, and, except at extremely low slopes, it appeared to be but very slightly affected by the slope. The distance in which the acceleration is complete depends however on the size of the section, and in Series I., where the mean hydraulic radius varied from 1·5 cm. to 1·7 cm., the velocity was found to slightly increase throughout the length of the channel. On the assumption, probably justifiable, that each experiment would be subject to the same percentage error, the line obtained in the logarithmic plot will remain parallel to the true line, and hence the index of the slope in the foregoing expression so obtained, will be almost, if not quite, correct. The necessary quantities for Series I. are given in Table VI., and the two curves marked "I" are shown in the lower and upper portions of Fig. 3, as already described for Series II. In this case, as in Series II., a straight line curve

Table VI.

SERIES I.—Mean hydraulic radius = 1·5 cm. Mean temperature = 13·9 C.

Number in Series.	Reduced Velocity. cm. per second.	Log of Velocity.	Slope.	Log of Slope.	Channel Sections used.
2	51·8	1·7143	·00595	$\bar{3}$·7745	*E*, *F*
3	79 90	1·9025	·0138	$\bar{2}$·1399	*D*, *E*
5	96·65	1·9852	·0230	$\bar{2}$·3617	*E*, *F*
1	110·2	2·0422	·0270	$\bar{2}$·4314	,, ,,
6	116·9	2 0679	·0358	$\bar{2}$·5539	,, ,,
7*a*	150·1	2·1764	·0504	$\bar{2}$·7024	,, ,,

best represents the logarithmic plot, the inclination of the line being approximately ·47. The expression connecting slope and velocity, all other conditions being constant, may therefore be written

$$U = k' I^{\cdot 47}$$

Since, however, the results obtained in Series II. are, as has been shown, more reliable than those of Series I., and since if curve "I" were drawn parallel to curve "II" it would represent the plotted results almost as accurately as in its present position, it will probably be most correct to assume the index to be ·46 for the conditions of the present series of experiments.

12. *Relation between hydraulic radius and velocity.*—As it was impossible to maintain the hydraulic radius absolutely constant throughout the series of experiments on the effect of slope, an auxiliary investigation was made to determine the method of variation of velocity and hydraulic radius. Owing to the acceleration of the rate of flow at the higher value of the hydraulic radius, as described in the preceding section, it was not feasible to make use of a wide range of values, and hence the expression arrived at from these experiments is to be considered, not in the light of a general expression showing the relationship between the hydraulic radius and velocity, but merely as a sufficiently good approximation for purposes of correction. As will be made evident by the accompanying curves (A and B) the approximation obtained is a very close one. Two series (A and B) of experiments were made at slopes of ·0663 and ·02213 respectively. The results are summarized in Table VII.

Table VII.

SERIES *A*.—Slope = ·0663. Temperature = 18° C.

	Number in Series.	Velocity.	Log *U*	Mean hyd. radius.	Log *R*	Sections.
	2	80·3	1·9047	·464	$\bar{1}$·6665	*D, E, F, G*
	1	101·0	2·00432	·639	$\bar{1}$·8055	„ „ „ „
	3	118·2	2·0726	·796	$\bar{1}$·9009	„ „ „ „
II.	11	125·9	2·10009	·884	$\bar{1}$·9464	Interpolated

SERIES *B*.—Slope = ·02213. Temperature = 18° C.

	1	49·7	1·6963	·478	$\bar{1}$·6794	*D, E, F, G*
	4	62·1	1·7931	·658	$\bar{1}$·8182	„ „ „ „
	3	71·7	1·8555	·790	$\bar{1}$·8976	„ „ „ „
II.	5	78·4	1·8943	·952	$\bar{1}$·9786	Interpolated
	2	86·4	1·9365	1·040	·0170	*D, E, F, G*

The mean of the inclinations of the logarithmic curves for Series A and B is approximately ·685, but for the present purposes of correction it will be sufficiently accurate to assume this to be ·7; hence the relationship between velocity and hydraulic radius may, within the range of values covered by the experiments, be approximately expressed as

$$U \propto R^{7}$$

and this is the expression that was employed in reducing the velocities in Series I. and II. to common hydraulic radii of 1·5 cm. and 1 cm. respectively.

13. *Relation between temperature and velocity.*—The temperature of the water being subject to slight variations during the course of the investigation, the following experiments were made with a view of observing in the first place whether the velocity was appreciably affected by changes of temperature, of only a few degrees, and, if it were so, of determining approximately the relationship between the two quantities. The highest temperature attained was about 42° C., which is considerably above any temperature occurring in the experiments of Series I. and II., but which does not provide a range of values sufficiently wide for the precise determination of the above-mentioned relationship. As will be evident from the following table a comparatively small change of temperature produces a distinctly noticeable effect on the rate of flow, and the expression deduced from the observations, although necessarily only roughly approximate, on account of the considerable degree of error involved in each measurement, is yet probably quite accurate enough for the small corrections that have to be made. It was assumed that the change in the coëfficient of discharge of the orifice with increase of temperature would be inappreciable,[1] or at least considerably within the range of experimental error. Further, assuming the coëfficient of superficial expansion of brass to be ·000038 per degree centigrade or ·00076 for the range of temperature adopted in the experiments,

[1] See "Experiments on the discharge of water of different temperatures," by J. G. Mair.—Proc. Inst. C.E., Vol. LXXXIV. p. 424.

it is evident that the error due to the change of area of the orifice is also negligible. In the accompanying table, in addition to the

Table VIII.

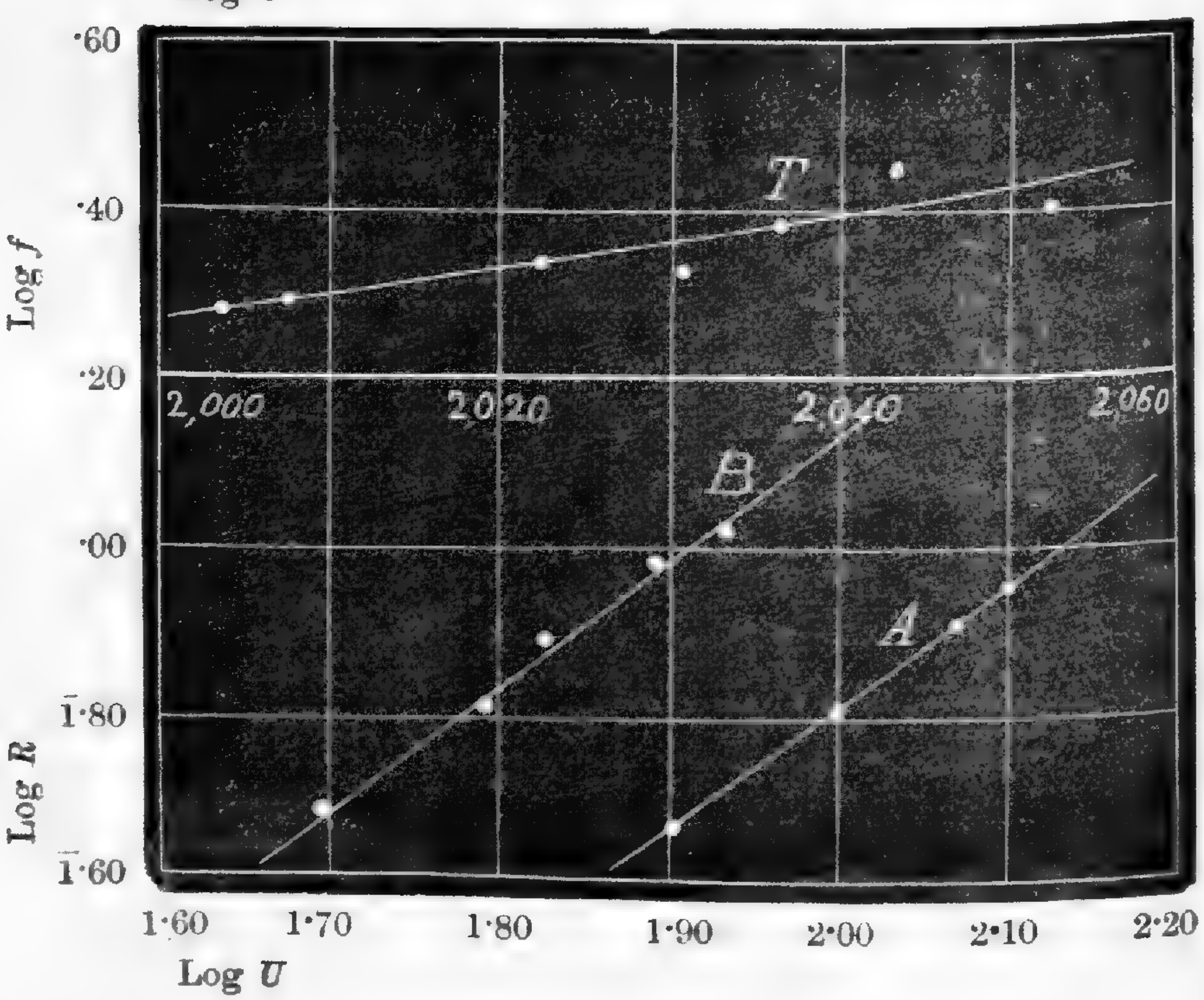
SERIES *T*.—Mean hydraulic radius = ·9 cm. Approximate slope = ·0415.

Number in Series.	Reduced Velocity. cm. per sec.	Log of Velocity.	Relative Fluidity *f*	Log *f*	Temperature C.°
1	100·9	2·00393	1·903	·2794	23
2	101·8	2·00783	1·979	·2964	24·7
3	107·4	2·03088	2·062	·3143	26·5
4	105·5	2·02275	2·178	·3381	29
5	108·7	2·03625	2·404	·3809	33·7
7	112 9	2·05269	2·514	·4004	35·9
6	110·5	2·04351	2·822	·4506	41·7

No. 7 was made at a slope of ·0675, and the velocity was then reduced to the common slope for this series of ·0415.

Fig 4.

Curve *A* corresponds to Series *A*.
" *B* " " *B*.
" *T* " " *T*.



velocity and the temperature of the water, the relative fluidity[1] of the water for each experiment is stated, since it is preferable to introduce the fluidity, rather than the temperature, into an expression for the rate of flow. In the experiments of this series the mean hydraulic radius was in each case almost exactly ·9 cm. and the velocities have therefore been reduced to that common value instead of to an hydraulic radius of 1 cm.

The logarithims of the velocity and the fluidity are co-ordinated in Fig. 4, and the relationship between the two quantities may be represented roughly by a straight line curve having an inclination $q = \cdot 3$ approximately, or in symbols

$$U \propto q^{\cdot 3}$$

This was the expression made use of in reducing the velocities in Series II. to a common temperature.

15. *Comparison of results obtained by the use of the formula of Kutter and Ganguillet.*—Since the formula of Kutter and Ganguillet is probably that most used for the determination of the velocity of flow in open channels, an interesting comprarison may be made between the actual results of the present experiments and those compiled by means of the formula.

In the formula

$$U = c \sqrt{(R I)}$$

the coëfficient is, in metric measure,

$$c = \frac{23 + \frac{1}{n} + \frac{\cdot 00155}{I}}{1 + \left(23 + \frac{\cdot 00155}{I}\right)\frac{n}{\sqrt{R}}}$$

The value of the coëfficient of roughness, n, in this expression may probably be assumed to be ·009 for the circumstances of the present experiments. On this assumption, the velocity has been determined at various slopes throughout the range embraced by Series II., and the resulting curve is shown in Fig. 3, (K and G).

[1] See pp. 318, 319 of this Volume.

It is directly comparable with the curve marked "II." Evidently the formula indicates velocities considerably below the actual ones when applied to conditions such as obtain in the present series. By arbitrarily choosing a smaller coëfficient of roughness for the purpose, the discrepancy could be diminished, but the coëfficient here selected is justified by the results of experiments made on channels similar to the present one, as set forth in the tables published in "The Flow of Water in Rivers and other Channels," by Kutter and Ganguillet.

16. *Experiments at small slopes.*—In carrying out Series II., three experiments (Nos. 8, 10 and 9) were made with slopes of ·0025, ·0020, and ·0012 respectively. Unfortunately the results are not reliable (and are therefore not reported) because the water dit not attain any steady condition of flow. At times the surface of the stream would be "glassy" smooth almost the whole length of the channel, but the slightest disturbance caused it to break, the section increasing, so that the water came down in a series of waves making it impossible to obtain the area with any degree of accuracy.

Appendix.

Since the foregoing paper was written, a second series of experiments on the effect of change of temperature on the rate of flow, has been carried out and the following table summarizes the results:

Temperature C.°	Velocity. cm. per sec.
21·1	105·8
22·8	107·1
26·7	108·5
34·4	110·2
42·5	111·2

It will be seen at once that the effect of change of temperature is very appreciable, but the rate of increase of velocity is considerably less than found in § 13 above, indicating that the correction there determined is too large. The absolute correction is however so small a quantity as to make the error a matter of but little importance.

NOTES ON MYRTICOLORIN.

By Henry G. Smith, f.c.s., Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, December 1, 1897.*]

In a paper[1] read before this Society on the 4th August last, I announced a true dye material found existing in the leaves of the "Red Stringy Bark," *Eucalyptus macrorhyncha*, Having found by the preliminary examination that the material belonged to the quercetin group of natural dyes, I named it myrticolorin, believing it to be the first possible commercial dye-stuff obtained from the natural order Myrtaceæ. In the abstract of the paper published by the Society, it is stated that "it can be obtained in abundance and with a minimum of trouble, and hence its discovery may be of commercial importance."

The object of the present notes is to amplify the above with the following statements :—

(*a*) That myrticolorin is a glucoside of quercetin.

(*b*) That it is to be obtained in large quantities.

(*c*) That the mode of extraction is extremely simple.

(*d*) That in this product Australia has a material of great value, and probably able to successfully compete with quercitron bark from *Quercus tinctoria*, and fustic.

We will consider these statements in the above order.

(*a*) That myrticolorin is a glucoside of quercetin is proved by the fact that on boiling in dilute sulphuric acid it breaks up into quercetin, proved by its reactions, particularly its acetyl derivative, and a sugar or sugars belonging to the glucoses, this being readily fermented by yeast, reduces Fehling's solution on heating, is sweetish in taste and partly crystallises from water in microscopic transparent prisms, probably monoclinic. It therefore differs

[1] On the Saccharine and Astringent Exudations of the "Grey Gum," *Eucalyptus punctuta*, and on a product allied to aromadendrin.

from rutin obtained from Rue *(Ruta graveolens)*, the sugar from that substance being rhamnose.

After making the announcement to the Society, I forwarded a small quantity of myrticolorin, and quercetin obtained from it, to Mr. A. G. Perkin in England, who is so well known as an authority on the natural yellow dyes; he informs me that myrticolorin is certainly a glucoside of quercetin, and that it is quercetin is proved by the formation of acetyl quercetin melting at 189 – 191° C. He also suggested that from its greenish tint it might be identical with rutin; the greenish tinge, however, is not constant, it being wanting in some material I obtained later when this was entirely purified from water. To Mr. Perkin for the assistance so readily given me, and also for his advice and promised help towards making the product commercially known, I wish to tender my sincere thanks.

(*b*) That it is to be obtained in large quantities is indicated by the extent of the range of this species of Eucalypt, it extending over a large portion of this colony and Victoria; and particularly from the fact that the dried leaves contain no less than ten per cent. of myrticolorin. This is the result of quantitative determinations on material obtained from near Rylstone in this colony. As myrticolorin contains from forty-eight to fifty per cent. of quercetin, the actual content of quercetin in the dried leaves may be taken as near five per cent. As only this substance is of use for dyeing purposes, the value is of course judged on the amount of quercetin present.

(*c*) That the mode of extraction is exceedingly simple may be understood when it is stated that all that is required is to carefully dry and powder the leaves, boil the powder in water and pass the boiling liquid through a filter cloth. As the water cools the yellow substance crystallises out, and when cold it is again filtered through a cloth, the yellow myrticolorin remaining behind while the tannic acid and other substances in solution pass away. The myrticolorin can then be washed with clean water, pressed,

and dried, and if desirable powdered. If required it may be purified by dissolving again in boiling water before drying and treating as before. It is most necessary to powder the leaves, as by so doing the extraction is more complete and much quicker, and the finer the powder the more satisfactory the yield. When whole leaves are boiled, little of the material is obtained. As myrticolorin is not very readily soluble in water, even on boiling, it will be necessary to use a good quantity of water ; three extractions appear to be sufficient to remove the whole of the substance providing the leaves are finely ground.

(*d*) That in this product Australia has a material of great value can be readily seen when we consider the commercial importance of quercitron bark and fustic. Quercitron bark is worth in England £6 10s. per ton, and fustic £4 10s. per ton. The quantitative content of quercetin in quercitron bark has not, it appears, yet been determined, but Mr. Perkin thinks it to be about two or three per cent., and when we consider the difficulty of grinding bark in comparison with dried leaves, and the increased percentage of quercetin in the leaves of this Eucalypt, the advantages in favour of eucalyptus leaves are apparent. If the yield of quercetin is taken at three per cent. in quercitron bark, that equals 67 lbs. quercetin per ton, while one ton of dried leaves of *E. macrorhyncha* would give 224 lbs. of myrticolorin, or over 100 lbs. of quercetin.[1] It appears, therefore, that the prospective value of these eucalyptus leaves is very good, and at present they are put to no use whatever. Myrticolorin, too, is easily obtained in comparison with the preparations from quercitron bark. The manufacture of flavin (a dried extract from this bark) appears to be somewhat complicated, and the use of chemicals must necessarily increase the cost of production, while the preparation of myrticolorin can be carried out practically without capital, the only outlay necessary beyond the utensils usually found upon a small homestead being a mill

[1] Myrticolorin contains seven per cent. of water, it probably crystallising with three molecules of water.

for grinding the leaves; the best form of cheap mill will no doubt be forthcoming. Iron utensils for the extraction must not be used.

Although in this industry as in may others, superior advantages are to be gained by carrying out the extraction on a large scale, yet, there is no reason why it should not be done in a small way also. Myrticolorin when dried is not liable to change, so that it is an ideal material for collection and export. The quantity of this class of dyestuffs used annually must be very great, although I have been unable to obtain definite information on that point, but in the Board of Trade Journal for 1894, page 474, it is stated that the export of fustic alone from Mexico, known in that country as "palo-moral" or "palo-amarillo," reaches 9,000,000 kilogrammes a year. This is exported to England, France, and Germany.

It is not to be expected that *E. macrorhyncha* is the only Eucalypt containing myrticolorin in payable quantities in the leaves, and it would be well to bear this substance in mind in future experiments with eucalyptus leaves. It appears necessary for the formation of myrticolorin in the leaves that they be carefully dried, no heating or fermentation being allowed. A few pounds of myrticolorin will now be obtained and forwarded to England for experiment. My thanks are due to my colleague at this Museum, Mr. R. T. Baker, for botanical assistance in the determination of the species.

A SECOND SUPPLEMENT TO A CENSUS OF THE FAUNA OF THE OLDER TERTIARY OF AUSTRALIA.

By Professor RALPH TATE, F.G.S., Hon. Member.

WITH AN APPENDIX ON CORALS, BY JOHN DENNANT, F.G.S.

[With Plates XIX.–XX.]

[*Read before the Royal Society of N.S. Wales, December 1, 1897.*]

SINCE the publication of my supplement to a Census of the Fauna of the Older Tertiary of Australia, in the Proceedings of the Society, there have appeared several important contributions to Australian Tertiary Palæontology. These are:—Cossmann's "Essais Palæoconchologie," parts i., andi i., 1895-6; British Museum Catalogue of the Australasian Tertiary Mollusca, part i., by G. F. Harris (1897); McGillivray's "Tertiary Polyzoa of Victoria";[1] Part iv., "Gastropods of the Older Tertiary of Australia," by the writer, including Naticidæ, Hipponycidæ, Calyptræidæ, Turritellidæ and Vermetidæ;[2] also the "Opisthobranchs" by M. Cossmann;[3] whilst miscellaneous additions to the fauna have been published by Howchin, Pritchard, and others.

M. Cossmann's "Essais," as concerns Australian Palæontology, are classificatory revisions of the families Terebridæ, Pleurotomidæ and Conidæ; and his numerous references to Australian species are based on the study of actual specimens.

Mr. Harris's "Catalogue," which is limited to the Gasteropoda, Scaphopoda and Lamellibranchiata, is largely a reproduction of the diagnoses of species described by McCoy, Tenison-Woods, and myself, sometimes amplified and accompanied by well-executed illustrations, more particularly of the embryonic shell, which for the gasteropods is therein called the *protoconch* and for the lamellibranchs the *prodissoconch*. Thirty-six species are illustrated,

[1] Trans. Roy. Soc., Victoria, 1895.

[2] Trans. Roy. Soc., South Australia, 1893. [3] *Ibid*, 1897.

some of them described as new; though I do not agree with the determinations of a few of them, *e.g.*—*Actæon scrobiculatus*, this is not the species of Tenison-Woods, but represents *A. distinguendus*, Cossmann; *Ringicula lactea* is not Johnston's species, but is *R. Tatei*, Cossmann; *Leptoconus Newtoni*, n. sp., is *L. extenuatus*, Tate; *L. convexus*, n. sp., is *L. acrotholoides*, Tate; and *Drillia oblongula*, n. sp., is *Buchozia hemiothone*, Ten.-Woods *(Columbella)*. In *Scaphander tenuis* and *Umbraculum australe*, the author forestalls *S. Tatei* and *U. australensis* of Cossmann. Moreover Mr. Harris replaces many generic names of long standing by others in accordance with the strict rules of priority, or on the ground of preoccupation; as most of such rectifications are generally accepted by the leading palæoconchologists, I shall indicate these and other proposed innovations in their proper places.

Class Gasteropoda.

Family Muricidæ.

Sistrum, Montfort, 1810, has priority over *Ricinula*, Lamarck, 1816.

Family Lampusidæ.

Triton and *Tritonium* are names that have been in prior use in other departments of zoology, and the application of the priority rule by Mr. R. B. Newton has led him to suggest the employment of *Lampusia*, Schumacher, 1817, in which he is followed by Cossmann, 1896; whilst Mr. Harris advocates *Lotorium*, Montfort, 1810. So also *Colubraria*, Schumacher, 1817, has priority over *Epidromus*.

Genus *Plesiotriton*.

This genus was instituted by Fischer in 1884, uniquely represented by *Cancellaria volutella*, Lamarck, of the Parisian Eocene. The form is that of *Epidromus*, the canal is short and deeply notched, and there are plications on the columella. The type has three principal columellar plaits, but the Australian representatives have only two. I recognise two species in the Eocene strata of Australia, namely, *Cantharus varicosus*, mihi,[1] from Aldinga, and *P. Dennanti*, n. sp., from Cape Otway.

[1] Trans. Roy. Soc., South Australia, 1887, t. 8, fig. 10.

Cossmann,[1] states that my *Epidromus citharellus* "est absolument identique au *Plesiotriton velutella*"; this opinion is based on my figure and description, and not by actual comparison. *E. citharellus* is, however, correctly placed, it being without columella plaits.

I believe it is generally admitted by my co-workers that, whatever ages may be assigned to the main mass of the Older Tertiary, the basal beds of the Aldinga section are Eocene, and the occurrence of *Plesiotriton* in the Aldinga and Cape Otway deposits is one of many evidences of their approximate contemporaneity.

PLESIOTRITON DENNANTI, *spec. nov.* (*Plate* 19, fig. 1.)

Shell elongate conic; pullus relatively small, papillary, of one and a-half smooth turns. Spire-whorls five, moderately convex, closely tessellated by flattish spiral and axial riblets, a little nodulose at the intersections of the primary riblets, slender axial threads crowd the whole surface. The earlier spire-whorls have about seven to ten spiral riblets, and with the revolution of the spire an intermediate riblet appears between them. There are from one to two varices on each whorl. Aperture elongate-oval, rounded behind, narrowed at the front and extended into a short slightly recurved and upturned canal; outer lip varicially thickened externally, crenately dentate on the inner margin; a thin callus covers the parietal wall; columella with two stout spiral plaits, situated in about the posterior one-third. Length 28, breadth 12, length of aperture 17.

Eocene, Cape Otway, Victoria. The species name is in compliment to my coadjutor who brought it to my notice as a species of *Plesiotriton*.

This new species differs from *P. varicosus* by more elongate shape and in the details of ornamentation. In the original description of *Cantharus varicosus*, no reference is made to the columellar plications which were concealed by matrix; subsequent development has revealed two stout plaits.

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[1] Ann. Geol. Univ., Vol. v., p. 1089, 1889.

Family Fusidæ.

Genus *Columbarium*.

In my synopsis of the species of *Fusus*,[1] the reference of certain of them to *Columbarium* was indicated, though I then thought it "convenient to include them under *Fusus*." However, the group offers good characters for generic separation. M. Cossmann,[2] argues for the retention of *Columbarium* in Fusidæ, whilst Mr. Harris[3] refers it to Pleurotomidæ.

Genus *Streptochetes*, Cossmann.

Mr. Harris[4] has referred my *Fasciolaria exilis* to the above genus, but between it and the type-species of the genus I see no resemblance, or also between it and *S. incertus*, with which Mr. Harris compares it. My criticism is the result of comparison with authentically named specimens. However, I would transfer the Australian fossil to *Latirofusus*, because of its long, straight, almost closed canal and by the possession of one or two transverse ridges on the columella; it moreover present great analogy with the Parisian Eocene species *L. funiculosus*.

Genus *Latirus*.

When referring a number of our Australian fossils to *Peristernia*[5] I had recognised the uncertain value of the differences which separate *Latirus* and *Peristernia*—the long recurved canal of the majority of the species influenced me in using the latter name. M. Cossmann[6] and Mr. Harris,[7] applies the former one to those of our species, which they had for study; in this step I follow them, but rather on the ground only of the priority of *Latirus*, because the intermediate characters presented by many of our species render the selection of either name open to dissent.

Peristernia approximans and *P. purpuroides* are conchologically referrable to *Latirus*, but their analogy to the recent *Trophon*

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[1] Trans. Roy. Soc., South Australia, 1887.
[2] Essais, pt. ii., p. 64. [3] Cat. Brit. Mus., p. 51. [4] *Ibid.*, p. 137.
[5] Trans. Roy. Soc. South Australia, p. 1887.
[6] Ann. Geol. Univ., p. 1090, 1889. [7] Cat. Brit. Mus., p. 142.

Paivæ (which has been quoted under *Urosalpinx*, *Fusus* and *Peristernia*, and lately retransferred to its original generic location on anatomical grounds) may make it desirable to view them congeneric therewith.

Subgenus *Latirulus*.

M. Cossmann[1] remarks that my *Peristernia actinostephes* resembles *Latirulus subaffinis*, D'Orb., and consequently, *P. apicilirata* must also be removed thereto.

Family Buccinidæ.

Genus *Tritonofusus*, Beck, 1847,

This name replaces *Sipho*, Mörch, 1852, adopted from Klein, a pre-Linnean author. The Australian species, diagnostically known, are reduced to *T. crebrigranosus* and *T. labrosus*, by removal of *Sipho asperulus* and *S. styliformis* to *Siphonalia*, the former under the changed name of *S. Tatei*, Cossmann.

Genus *Phos*.

Subgenus *Loxotaphrus*, Harris, 1897.

The above name is proposed for a new group with *Phos* (?) *varicifer*, Tate, as its unique type. When describing the species[2] I discussed its affinities with *Phos* and *Nassaria*; the differences of the aperture and protoconch being dealt upon. In *Phos* the protoconch is typically turbinate or even conical, of three or more whorls, whilst in *Loxotaphrus* it consists of one and a half turns, the earlier portion being inflated and implanted obliquely.

Family Volutidæ.

In my arrangement of the thirty-two fossil species of *Volutes*[3] no attempt was made to throw them into groups consonant with those employed for the recent and tertiary species, though incidental references thereto were made as regards a few species. Mr. Harris in his Cat. Brit. Mus. has grouped fifteen of our species into the following genera and subgenera :—

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[1] Op. cit. p. 1090.

[2] Trans. Roy. Soc. South Australia, Vol. x., p. 169.

[3] Trans. Roy. Soc. South Australia, Vol. xi., pp. 119 - 135.

Genus *Volutilithes* includes spp. 29 and 30 ;[1] this generic reference had already been implied by the author of the species.

Genus *Voluta*, subgenus *Aulica* includes spp. 5, 15, 22, 24, 31 and 32.

Subgenus *Volutoconus* includes sp. 10 as referred thereto by me.

Subgenus *Amoria* includes sp. 17 as referred thereto by me.

Subgenus *Pterospira*, this is a new group established for the reception of sp. 1.

Genus *Scaphella* includes spp. 11, 12, and 14.

Subgenus *Eosephœa* includes spp. 21, 25 and 26.

This classification does not meet all the requirements, and I venture to regroup the species. In the first place the subgenus *Pterospira*, which is characterised by a wing-like expansion of the outer lip and by an enormous globose protoconch, is unnecessary; as otherwise other new groups would require to be established for *V. macroptera* and *V. Mortoni*, which have an alate expansion of the lip but have very dissimilar protoconchs. The section *Mamillana* might receive *V. Hannafordi*, as its type has a similar protoconch and an incipient winged outer lip; so also may the other winged species be distributed in a section already constituted.

Genus *Volutilithes*.

Characterised by its small acute protoconch, contains *V. anti-scalaris* and *V. anticingulatus*, both of McCoy.

Genus *Voluta*.

Protoconch mamillate, relatively large.

Section Vespertilio.

Protoconch turbinate, crenulated. Examples *V. Macdonaldi* and *V. uncifera*.

Section Aulica.

Differs from the foregoing by more conic and smooth pullus. Examples, *V. ellipsoidea*, *V. lirata*, *V. costellifera*, *V. Weldii*, *V. strophodon*, *V. cathedralis*, and *V. tabulata*.

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[1] These figures accord with the enumeration of my synopsis of the species.

Section AMORIA.

Shell smooth and polished, protoconch turbinately conic. Examples, *V. Masoni* and *V. capitata*.

Section VOLUTOCONUS.

Shell oblong subcylindrical, protoconch depressedly conoid. Examples, *V. conoidea* and *V. limbata*.

Section MAMILLINA.

Protoconch globulose and large, the tip lateral. Examples, *V. Hannafordi*, *V. heptagonalis*, *V. alticosta* and *V. Stephensi*.

Section ALCITHOE.

V. ancilloides, *V. Mortoni*, and *V. Atkinsoni*. The last recently described by Pritchard.[1]

Section LEPTOSCAPHA, *Fischer*, 1883.

Shell small, oblong-fusiform ; protoconch mamillated, outer lip variced. Example, *V. crassilabrum*, which, by comparison of actual specimens, has much analogy with the type species, *V. variculosa*, Lamk., of the Parisian Eocene.

Section SCAPHELLA.

Smooth shells with a mamillary protoconch. Examples, *V. Maccoyi* and *V. polita*.

Section EOSEPHÆA.

Shell more or less mitraeform, transversely striated and usually longitudinally ribbed ; protoconch papillary smooth with the tip exsert and pointed. Examples, *V. macroptera*, *V. Allporti*, Johnston,[2] *V. lintea*, *V. cribrosa*, *V. sarissa*, *V. pagodoides*, and *V. Tateana*.

The differences which separate the typical members of this group and *Aulica* are somewhat bridged over by *V. cathedralis*, connecting through *V. pseudolirata* to *Aulica*, and making an approach to *V. sarissa* in the section *Eosephaea*.

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[1] Proc. Roy. Soc. Vict., 1896.

[2] Syn. *V. Halli*, Pritchard—Proc. Roy. Soc. Vict., 1896.

V. macroptera and *V. Allporti* have the characteristic protoconch of this group, and it is only the early spire-whorls that have the spiral ornamentation; apart from differences of shape, *V. macroptera* is winged, though it is almost impossible to separate young examples of the two species.

Family Mitridæ.

Mr. Harris locates thirteen of our twenty-four described species of *Mitra* as follows:

Genus *Mitra*.

M. alokiza, *M. uniplicata*, and adds a new species *M. multisulcata*. I would add *M. dictua*, *M. varicosa*, and ? *M. atypha*.

Subgenus *Cancilla*.

M. atractoides.

Genus *Uromitra*, Bellardi, 1887.

M. leptalea, *M. paucicostata*, *M. exilis*, *M. semilævis*, *M. terebriformis*, *M. clathurella*. Three of the foregoing had already been referred by Cossmann (1889) to *Fusimitra (auctores, non* Conrad). And I add *M. biornata*, *M. sordida*, *M. escharoides*, *M. subcrenularis* and *M. citharelloides*.

Genus *Conomitra*, Conrad, 1865.

M. othone, *M. Dennanti*, *M. ligata*. And I add *M. conoidalis*, *M. cassida*, and *M. complanata*, Tate, and *M. anticoronata*, Johnston.

Family Cancellaridæ.

Genus *Cancellaria*.

Cossmann[1] distributes our species as follows:—

Section Cancellaria:—*C. Wannonensis*.

Section Bivetia:—*C. gradata* and *C. ptycotropis*.

Section Sveltia:—*C. epidromiformis* and *C. exaltata;* these species have a conic embryo, not planorbulate, and therefore do not belong to *Uxia*.

Section Merica:—*C. modestina*.

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[1] Ann. Geol. Univ., Vol. v., p. 1091, 1889.

Section NARONA :—*C. turriculata*, *C. Etheridgei*, *C. caperata*, *C. capillata*, *C. micra*, and *C. semicostata*.

Section BIVETOPSIS :—*C. cavulata*, and *C. laticostata;* the last name being preoccupied by Kuster, I had altered to *C. platypleura*, 1893.

C. alveolata is wrongly placed in the genus.

Family TEREBRIDÆ.

M. Cossmann[1] passes under review some of our Australian fossil species, classifying them as follows :—

Genus *Terebra*, sensu stricto.

Example, *T. platyspira*, Tate.

Section NODITEREBRA, Cossmann, 1896.

A new section, characterised by nodulose whorls, diagnosis established after the type species *T. geniculata*, Tate, of the Australian Miocene.

Subgenus *Hastula*.

Includes *T. angulosa* and *T. crassa*, Tate.

Genus *Euryta*.

Subgenus *Spineoterebra*, Sacco, 1891.

Here are transferred by Cossmann, *Terebra subspectabilis* and *T. convexiuscula*, Tate.

Family CYPRÆIDÆ.

Harris arranges some of our fossil cowries as follows :—

Genus *Cypræa*.

Includes *C. scalena* and *C. parallela*.

Subgenus *Bernayia*, Jousseaume.

Characterised by a visible spire and large anterior excavation of the columella. The species of this group are all Eocene, of them *C. subsidua* and *C. contusa* are Australian.

Subgenus *Luponia*.

Here are placed *C. brachypyga*, *C. pyrulata* and *C. leptorhyncha;* and there may be added *C. subpyrulata* and *C. Murraviana*.

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[1] Palæoconchological Essays, Vol. II., 1896.

Subgenus *Erosaria*, Troschel.

This name is in substitution for *Aricia*, Sowerby, 1832, *non* Savigny; it includes *C. gigas*, *C. platypyga*, *C. consobrina*, *C. gastroplax* as indicated by McCoy, also *C. dorsata*, Tate.

Subgenus *Umbilia*, Jousseaume.

Includes as already indicated by me, *C. eximia*, Sow., *C. sphærodoma*, Tate, *C. toxorhyncha*, Tate.

Subgenus *Gaskoinia*.

This is an additional member of the family now recorded for the first time.

GASKOINIA BULLÆFORMIS, *spc. nov.* (*Plate* 19, fig. 5.)

Shell globosely oval, smooth; spire concealed; aperture as long as the shell, with slightly produced extremities, relatively wide, somewhat narrowed and rounded behind, truncate in front with a wide shallow sinuosity; outer lip broadly thickened all round on the inner margin. Length 44·5, breadth 30 mm.

Eocene, Muddy Creek (one example).

Excluded species, *C. ovulatella* is transferred to *Trivia*.

Genus *Erato*.

Subgenus *Eratopsis*.

One species is described from the Victorian Miocene.[1]

Family OVULIDÆ.

The name *Ovula* is for the present expunged from our list and *Simnia (Neosimnia)* takes the place of *Calpurna*, one species is described from the Victorian Eocene.

Family CASSIDIDÆ.

Genus *Morio*, Montfort, 1810.

This name is in substitution for *Cassidaria*, Lamarck, 1812.

Family STROMBIDÆ.

Genus *Strombus*.

Mr. Harris describes a fossil from the Fowler Bay district of South Australia as *Strombus denticostatus;* the horizon is unknown

[1] Trans. Roy. Soc. South Australia, p. 217, 1890.

but is probably Older Tertiary. The genus is new for beds of this age.

Family STRUTHIOLARIIDÆ.

Genus *Pelicaria*.

Harris states that *Buccinum scutulatum*, Martyn, is not the type of Gray's *Pelicaria*, but *B. vermis*, Martyn; and that therefore *Pelicaria* falls in synonymy with *Struthiolaria;* he proposes *Tylospira* as the generic name.

Family CONIDÆ.

Genus *Conus*.

Messrs. Cossmann and Harris have attempted to bring some of our Eocene *Cones* into subgeneric groups as under :—

Subgenus *Stephanoconus*, Mörch. 1852.

The shells of this group are distinguished from *Conus, s.s.*, by a more elongate spire, crowned by obtuse tubercles near the superior suture. Example, *C. Hamiltonensis*, Tate.

Subgenus *Lithoconus*, Mörch.

Distinguished by the absence of sutural crenulations, by the aperture dilated in front and with a rather deep posterior sinus. Examples, *C. Dennanti, C. pullulescens, C. cuspidatus.*

Subgenus *Chelyconus*, Mörch.

Spire elevated, last whorl convex near the suture, rounded at the shoulder, posterior sinus not very deep. Example, *C. Ralphii*, Tenison-Woods.

Subgenus *Leptoconus*, Swainson, 1840.

Examples, *C. heterospira, C. extenuatus, C. acrotholoides, C. Murravianus*, and *C. ptychodermis, C. ligatus*, Tate.

Genus *Hemiconus*, Cossmann, 1889.

HEMICONUS COSSMANNI, *spec. nov.* (*Plate* 19, fig. 11.)

Shell biconic, spire about one-third the total length ; embryo relatively large of one and a half smooth whorls, apex obtuse hemisphæric, the tip somewhat lateral. Spire-whorls five, the first and second concave by the development of a spiral rounded

border at each suture, on the second whorl an interstitial thread appears contiguous with the anterior band. The third and fourth whorls are flat, except for three spiral bands, which ornament it; the two thick marginal bands are rudely crenulated, the medial smaller one is smooth. Last whorl with antesutural angulation, the sutural slope with two spiral ridges, the posterior one is the larger; the anterior surface carries about twelve elevated angulated spiral ridges, which are somewhat unequal in size and not very regularly disposed, the larger ones with coarse blunt crenulations; the whole surface sculptured with somewhat sigmoid closely-set striæ of growth. Length 9, breadth 4·5 mm.

Eocene, Muddy Creek, Victoria (one example J. Dennant).

Among the few European species referred to this genus by Cossmann, which I have had under examination, *Conus scabriculus* Solander, is the one to which our fossil shows the greatest resemblance. It differs from the European species by thick spiral ribs, more numerous on the body whorl, with coarser crenulatures, by relatively shorter spire and larger pullus. The species name is in compliment to M. Maurice Cossmann, who has so ably advanced our knowledge of Australian Tertiary mollusca.

Family Pleurotomidæ.

Subfamily Pleurotominæ.

Operculum with an apical nucleus.

Genus *Pleurotoma*.

Sinus upon the keel, canal long. Example, *P. perarata*, Tate, ms. (apud Cossmann) = *P septemlirata*, Harris.

Subgenus *Hemipleurotoma*, Cossmann.

Canal short, embryo conic. Examples, *P. Samueli* and *murndaliana*, T. Woods, apud Cossmann.

Genus *Drillia*.

Sinus near the suture, canal short curved and emarginate; labrum subvaricose. Examples, *Drillia integra*, *D. stiza*, *D. Trevori*, *Pleurotoma sandleroides* and *P. pullulescens*, Tenison-Woods, *D. vixumbilicata*, Harris.

Genus *Bela*.

Canal short truncate, sinus nearly absent, columella flattened. Examples, *Daphnella tenuisculpta*, Ten.-Woods,[1] (*Bela pulchra*, Tate,[2] *Daphnella pulchra*, Tate);[3] *Bela Woodsii*, Tate,[4] (*Cominella cancellata*, Ten.-Woods,[5] name preoccupied); *Bela sculptilis*, Tate,[6] (*Pseudotoma sculptilis*, Cossmann,[7] *Daphnella sculptilis*, Harris);[8] *Bela crassilirata*, Tate,[9] (*Pseudotoma crassilirata*, Cossmann, *Daphnella crassilirata*, Harris).[10]

Subgenus *Buchozia*, Bayan.

Shell oval, spire very short, embryo subglobose. Examples, *Buchozia hemiothone*, Ten.-Woods (sp.) Syn.:—1879 *Columbella hemiothone*, Ten.-Woods ;[11] 1893 *Pusionella hemiothone*, Tate and Dennant ;[12] 1896 *Buchozia hemiothone*, Cossmann ;[13] 1897 *Drillia oblongula*, Harris ;[14] *Daphnella columbelloides*, Tenison-Woods.

Subgenus *Daphnobela*, Cossmann, 1896.

(*Teleochilus*, Harris, 1897).

Canal wide, truncate.

The type is *Buccinum junceum*, Sowerby, of the Bartonian Eocene, and therewith *Daphnella gracillima*, Tenison-Woods, has been associated by Cossmann and Harris ; these two comprising the group. Of the latter species Cossmann remarks, it has the labrum nearly straight, no sinus, no plications internally, the spire shorter, the columella margin thinner, etc.

Subfamily Borsoninæ.

Columella plicate or subplicate.

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[1] Proc. Roy. Soc., Tasm., p. 106, 1877.
[2] Proc. Roy. Soc. S. Aust., Vol, ix., t. 4, f. 2, 1887; id. Cossmann, Essais, 1896, t. 6, figs. 10, 11, and p. 90, f. 14.
[3] Harris, Cat. Brit. Mus., p. 62.
[4] Op. cit., t. 4, f. 3. [5] Op. cit., p. 107. [6] Op. cit., t. 4, f. 1, ex descr.
[7] Op. cit., p. 146. [8] Op. cit., p. 61 (description) t. 4, figs. 1*a*—*b*.
[9] Op. cit., t. 4, f. 7, ex descr. [10] Op. cit., p. 62, description, t. 4, f. 2*a*—*b*.
[11] Proc. Linn. Soc. N. S. Wales, Vol. iv., p. 14, t. 3, fig. 8.
[12] Trans. Roy. Soc., S. Aust., Vol. xvii., p. 221.
[13] Essais Palæoconch. II., p. 92, t. 6, fig. 8—9.
[14] Brit. Mus. Cat., Tert. Moll. p. 56, t. 3, f. 7.

Genus *Borsonia.*

Sinus near the suture, columella plicate, canal long.

Borsonia protensa, *spec. nov.* (*Plate* 19, fig 6.)

B. protensa, Tate, m.s.[1]

Shell narrowly fusiform ; aperture about equal, more or less, to the spire in length. Embryo globulose of one and a-half smooth whorls, the tip small somewhat depressed and lateral. Spire-whorls eight, the first five roundly costated below the fascial band, most markedly so on the third and fourth whorls, the costation gradually fading away with the revolution of the spire and the whorls becoming more flatly convex. All the spire-whorls closely spirally lined, and more coarsely so transversally. Last whorl ornamented as the penultimate, but with close-set threadlets on the attenuated front portion. Aperture narrow elliptical, narrowed in front into a long straight widish snout, just perceptibly twisted to the right at the tip. Columella straight, with two stout approximate oblique plications, just behind the base of the snout. The fascial band is broad and indicates a shallow sinus at the suture. Length 44, breadth 11 mm.

Eocene, Cape Otway, Victoria.

This species is very typical of the genus, simulating the long snouted species of *Surcula*, but having a slightly different embryo and a biplicated columella.

Borsonia Otwayensis, *spec. nov.* (*Plate* 19, fig. 4.)

B. Otwayensis, ms. op. cit., id. Cossmann.[2]

Shell fusiform, aperture slightly longer than the spire ; embryo as in *B. protensa.* Spire-whorls seven, angulated post medially and broadly costated on the anterior slope (sometimes obsolete on the body-whorl), there are about eight on the penultimate whorl. All the spire-whorls sculptured with spiral threads (increasing to about twenty), crossed by slightly arcuate finer threads. Aperture trapezoidal-elliptic, widest behind, narrowed in front into a

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[1] Trans. Roy. Soc., S. Aust., 1893, p. 111.

[2] 'Essais' Vol. II., p. 98, (fig. 17 of embryo).

relatively short straight open canal. Columella with two oblique plaits just behind the origin of the snout. The sinus of the lip is broad and shallow ; the fascial band occupies the whole antesutural or post-carinal slope. Length 21, breadth 7 mm.

Eocene, Cape Otway, Victoria.

This species is distinguished from the foregoing by its stouter build, angulated and costated whorls, and by more pronounced spiral sculpture.

BORSONIA POLYCESTA, *spec. nov.* (*Plate* 19, fig. 2.)

B. polycesta, Tate, ms., op. cit.

Shell fusiform, aperture as long as the spire : spire-whorls costated and otherwise like *B. Otwayensis*, except that they are convex, the costations more nodulose and the body-whorl not so abruptly narrowed at the front. Length 13, breadth 4·5 mm.

Eocene, Cape Otway, Victoria.

BORSONIA BALTEATA, *spec. nov.* (*Plate* 19, fig. 10.)

Shell fusiform, aperture a little longer than the spire. Embryo globulose, rather large, smooth, of one and a-half turns. Spire-whorls four and a half, medially angulated, distinctly constricted in front of the anterior suture giving rise to the appearance of a narrow convex rib margining the suture. First two nobulose-costated smooth, the costæ evanescent at the antesutural band ; gradually the backward extension of the costæ become restricted to the anterior slope, and traversed by spiral threads, and the posterior slope by arcuate threadlets. Last whorl, the ornamentation consists (1) on the post carinal area, which is slightly concave, of arcuate threadlets, more or less duplicate on the sutural band, and anterior thereto by three or four spiral threads, and of (2) on the antecarinal area of a crenate-dentate keel, and about twenty spiral threads, the posterior four or five crossed by axial threads which produce slight nodulations at the intersections; the axial threads are continued to the front in much reduced strength; the spiral threads are crowded and weaker at the extreme front.

Aperture elongate piriform, columella with two oblique plications. Length 7, breadth 2·5 mm.

Eocene, Belmont, Victoria.

Genus *Cordieria*.

Sinus near the suture, two or more columella plications, canal short.

CORDIERIA CONOSPIRA, *spec. nov.* (*Plate* 19, fig. 12.)

Thala marginata, Tenison-Woods.[1]

The transference of the Table Cape species, described by Tenison-Woods as *Thala marginata*, to either *Borsonia* or *Cordieria* renders a change of specific denomination. *Borsonia marginata* was described by Deshayes in 1864 and was included by Cossmann,[2] in his section *Phlyctænia*, which was subsequently recognised by him to be synonymous with *Cordieria;* in M. Cossmann's[3] work it is listed as *Cordieria marginata*.

C. conospira has considerable analogy with *C. marginata*, Deshayes, both agreeing in having a conic embryo and thus differ from other congeneric species, but otherwise it is nearer to *C. turbinelloides*, Deshayes; apart from its much larger size, *C. conospira* differs particularly by finer costation and the possession of three to four oblique plaits at the anterior part of the columella.

The embryo is conic and consists of four moderately convex, smooth whorls; the first spire-whorl is rather closely costated. An average sized specimen measures long. 12, lat. 4·5 mm., but an extreme form has long. 17 and lat. 7 mm.

Eocene: This species occurs abundantly at most of its localities. Table Cape, Tasmania; Muddy Creek, Mornington and Gellibrand River, Victoria; River Murray Cliffs, South Australia.

Genus *Mitromorpha*, A. Adams.

The shells herein included have the aspect of *Conomitra*, the columella with two strong plaits which do not extend inwards;

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[1] Proc. Roy. Soc., Tasmania, 1877, p. 108.
[2] Cat. Ill. Coq. Foss., IV., p. 248, 1889.
[3] Essais Palæoconchologie, II., p. 100, 1896.

the outer lip is slightly sinuous towards the suture, and interiorly is furnished with small denticles.

My opinion regarding the generic location of certain fossil species herein referred to is the result of a comparison with many specimens of *Columbella alba*, Petterd, a recent species in Southern Australia, which has a very close resemblance to *Mitromorpha lirata*, A. Adams—the type of the genus.

Firstly, there is a distinct, though small, sutural sinus, which demands the relegation of the genus to Pleurotomidæ. Secondly, the columella-ridges are inconstant in number, and though two are usually present, one or both are not infrequently absent. The development of columella-ridges, and denticles on the inner aspect of the lip, belongs to the senile stage of growth, so that immature specimens will not exhibit these characters; but whether or not, the plications and denticles are always produced at the adult stage, I have no means of judging as there are no external developments which might indicate that that stage had been attained. One diagnostically known species, among others, of the Australian Eocene is here referred to the genus. it is :—

Mitromorpha daphnelloides, Ten.-Woods (sp.).

1879 *Mitra daphnelloides*, Tenison-Woods;[1] 1893 *Raphitoma daphnelloides*, Tate,[2] list name.

This species has for an analogue *Buchozia cancellata*, Dantz, and Dollfuss, of the Miocene of Touraine, but differs, apart from more conoid shape and details of ornamentation, in having usually two oblique ridges on the columella, though some specimens of *M. daphnelloides* apparently adult, have the ridges obsolete. However in one of the two specimens of the Touranian species, which I possess, two plaits are discernible, clearly, therefore the two species are congeneric. These determinations prolong the range of the genus into Miocene for France, and Eocene for Australia.

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[1] Proc. Linn. Soc., N. S. Wales, Vol. IV., p. 7, t. 2, fig. 3.

[2] Trans. Roy. Soc., S. Aust., Vol. XVII., p. 221.

Genus *Bathytoma*, Harris and Burrows, 1891.

(*Dolichotoma*, Bellardi, 1875, non Hope 1839).

Columella twisted; sinus removed from the suture, enbryo conoidal.

The species of *Genotia* described in the first supplement of a Census, &c., belong to *Bathytoma*, this position was antecedentally assigned to them, as list names.[1] In my former paper, *Genotia* was used in the belief that *Dolichotoma* might be synonymous, that view being based on the similitude of *G. atractoides*, Watson, with certain of our species of *Bathytoma*; the reconciliation of these discrepancies is made good by Boettger, who affirms that the living species described and figured in the "Challenger Gasteropoda" belongs to *Dolichotoma*. *Genotia* is classed by Cossmann in Conidæ near to *Conorbis*.

The following are diagnostically known:—*Genotia fontinalis*, *decomposita*, *Pritchardi*, and *angustifrons*, Tate; *Pleurotoma paracantha*, Tenison-Woods. *Pleurotoma rhomboidalis*, Tenison-Woods, has no specific characters, it represents the tip of a Bathytoma.

Genus *Asthenotoma*, Harris and Burrows, 1897.

Oligotoma, Bellardi, 1875 (non Westwood, 1836).

Columella with one plication, canal short, sinus large.

Examples, *Pleurotoma consutilis*, Ten.-Woods, and *Asthenotoma Tatei*, Cossmann.[2]

Subfamily MANGILININÆ.

No operculum; sinus at the suture, embryo papillary.

Genus *Clathurella*.

Outer lip varicose, internally plicate; canal short, columella wrinkled. Examples, *Mangilia bidens*, Ten.-Woods, and *C. obdita*, Harris.

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[1] Trans. Roy. Soc, S. Aust., Vol. XVII, p. 221.

[2] Essais, Part II., p. 173, t. 6, fig. 29, 1896.

Genus *Mangilia*.

Outer lip varicose, labrum and columella smooth, sinus distinctly notched.

No typical species have yet been described from the Australian Tertiaries. *M. bidens*, T.-Woods, is transferred by Cossmann to *Clathurella*, and *M. gracilirata* of the same author belongs to *Columbella*.

Subgenus *Cythara*.

Columbelliform, labrum more or less denticulated within.

Examples, *Mangilia obsoleta* and *M. (Cythara) glabra*, Harris.

Family NATICIDÆ.

Genus *Natica*.

Subgenus *Lunatia*, Gray.

This name is substituted for *Naticina*.

Subgenus *Stigmaulax*.

Includes *Natica (Naticina) limata* and *arata*, Tate.

Family CALYPTRÆIDÆ.

Sigapatella is included in *Calyptræa*.

Family SOLARIIDÆ.

Genus *Heliacus*, D'Orbigny, 1842. Syn. *Torinia*, Gray, 1847.

Example, *Solarium Wannonensis*, Ten.-Woods.

Family VERMETIDÆ.

Genus *Thylacodes*.

Six species are referred to this genus by me in Trans. Roy. Soc. S. Aust., 1893, including *Vermetus conohelix*, Ten.-Woods. *Vermetus* is unknown in our Older Tertiaries.

Family EULIMIDÆ.

Subularia is in substitution for *Leiostraca*, if it be worth retaining as a subgenus of *Eulima*.

Family TURBONILLIDÆ.

Odontostomia is the accepted amended spelling of *Odostomia*. *Syrnola*, according to Dall, 1892, is only entitled to subgeneric

rank. *Actæopyramis olivellæformis*,[1] is transferred to *Actæon* in Family Actæonidæ.

Genus Eulimella.

Four minute species are known to me from the Eocene of Aldinga, Shelford, Gelibrand River and Belmont.

Family Littorinidæ.

Genus *Fossarus*.

Fossarus refractus, *spec. nov.* (*Plate* 19, fig. 9.)

Shell minute, turbinate, minutely perforate, test thick not nacreous. Embryo of two whorls, the first papillary, the second rather flatly convex. Spire-whorls two and a half, antemedially augulated, the posterior slope somewhat steep, the anterior one nearly perpendicular; ornamented by rounded relatively high threads, which on the posterior slope are nearly at right angles to the keel, thence backward inclined to the suture; inter-spaces between the axial threads about twice as wide as the width of the threads.

Last whorl with a semi-circular contour in the vertical plane, modified by the four strong keels which encircle the anterior two-thirds of the base. The keels are inequidistant and slightly serrated by the crossing of transverse threads; the first and second are in alignment with those visible on the penultimate whorl, the second peripheral; the second, third and fourth about equidistant. The transverse threads are slightly backward-curved between the suture and the first keel, abruptly bent back between the first and second, thence with a slight backward curvature to the umbilical fissure. Aperture polygonal, peristome entire, outer lip simple; columella concave; umbilical chink minute, bounded by an elevated ridge which joins the basal lip at its junction with the columella, there forming a slight insinuation.

Eocene, Table Cape, Tasmania.

This fossil recalls *Trichotropis* by its umbilical border, but its thick test and absence of distinct basal rostration remove it

[1] Proc. Roy. Soc., N. S. Wales, Vol. xxvii., p. 181.

therefrom ; whilst some species of *Fossarus* offer such similitudes, *e.g.*, *F. lamellosus*, Montrouzier, recent, New Caledonia with which our fossil presents much analogy.

Family Lacunidæ.

Genus *Streblorhamphus*, Tate and Cossmann, 1898.

Etymology: *Streblos*, twisted ; *rhamphos*, a beak ; in allusion to the twist of the columella.

Type: *S. mirulus*, Tate and Cossmann (*spec. nov.*) ; Eocene, Muddy Creek, Victoria. (*Plate* 20, fig. 4.)

Shell very small, short, turbinated, subulate ; embryo obtuse ; whorls five, hardly convex, separated by an indistinct suture ; surface smooth and shining. Body whorl equalling three-fourths of the total length, oval at the base which is perforated by a narrow umbilical chink, circumscribed by a prominent rim. Aperture oval, angular behind, terminating in front by a short narrow snout upon which the umbilical rim is decurrent ; peristome continuous ; labrum arched and deeply insinuated at the front ; columella very arched abruptly and feebly twisted at the front, the twist forms the margin to the anterior beak of the aperture ; columella-border narrow and callous, making an angle at its extremity with the border of the beak.

Streblorhamphus differs from the typical *Lacunæ* by the anterior torsion of the columella, which is not a tooth placed low down as in *Lacunophyxis* ; it has the beak and insinuated basal lip of *Entomope* and the bourrelet of the typical *Lacunæ*. The embryo is that of the Lacunidæ.

Streblorhamphus obesus, *spec. nov.*, Tate. (*Plate* 19, fig. 8.)

Differs from *S. mirulus* by more convex whorls, body-whorl more inflated and relatively very much larger, and is altogether a broader squat shell. Length of four and a-half whorls 3, breadth 2 mm.

Eocene, Mornington, Victoria.

Genus *Dissochilus*, Cossmann, 1888.

DISSOCHILUS VITREUS, *spec. nov.* (*Plate* 20, fig. 5.)

Shell very small, conical, with an obtuse slightly flattened summit; spire whorls five and a-half, semitransparent, shining, slightly convex, separated by a superficial suture, ornamented by engraved spiral lines (twelve to fifteen on penultimate whorl), equal, equidistant, and indistinctly punctate. Last whorl a little more than hålf the total length of the shell. Aperture oval, acuminate behind, a little dilated in front; peristome continuous; columella-border truncated in front, arched, simple, slightly reflected, bordered externally by a narrow umbilical groove which is circumscribed by a thickish rim decurrent at the extremity of the columella; outer lip feebly thickened and slightly arched. Length 3, breadth 1·25 mm.

Miocene, Muddy Creek, Victoria.

Except that there is no parietal plication, this fossil has considerable analogy with *Dissochilus conicus*, Cossmann; it is evidently a member of the Lacunidæ, and is tenatively referred to *Dissochilus*.

DISSOCHILUS EBURNEUS, *spec. nov.* (*Plate* 20, fig. 6.)

Shell ivory-white, smooth and shining, whorls five and a-half. Differs from *D. vitreus* by greater size, more prominent umbilical bourrelet, and aperture not so dilated. Length 3·25, breadth 1·5 mm.

Eocene, Muddy Creek, near Hamilton, Victoria.

Family CERITHIOPSIDÆ.

Genus *Newtoniella*, Cossmann, 1893.

Syn., *Cerithiella*, Verrill (non. *Ceritella*, Morris & Lycett, 1850); *Lovenella*, Sars, 1878 (non. Hicks, 1869); *Newtonia*, Cossmann, 1891 (non. Schlegel, 1866).

Examples, *Cerithium Salteriana* et *C. cribarioides*, Tenison-Woods. But there are a great number of species, belonging to

several subgenera and sections, some of which are yet to be defined.

Genus *Cerithiopsis*.

Cerithiopsis Mulderi, *spec. nov.*

Shell minute. Protoconch styliform of four slightly convex smooth whorls. Spire of four flat whorls, forming a cylindroid cone; the ornament consists of two equidistant stout spiral ribs (sometimes a third small one at the posterior suture), nodulose at the intersection with weaker axial ribs. Suture linear, but apparently channelled by approximation of the adjacent spiral ribs. Last whorl with two nodulose ribs, a smooth rib at the basal angulation and two smooth slender ones on the base. Length of protoconch ·3; length and breadth of spire 1·5 and ·4 mm.

Eocene, Fyansford (several examples).

This species of a genus new to the Eocene fauna of Australia, as previous records belong to *Newtoniella*, is named in compliment to Mr. Mulder, whose untiring researches among the minuter mollusca of the Geelong Eocenes, have yielded such large results.

C. Mulderi resembles *C. ridicula*, Watson, recent in Southern Australia, but it has a longer protoconch, has two primary revolving ribs (instead of three) and has fewer ribs on the base.

Family Rissoidæ.

Genus *Chileutomia*, Tate and Cossmann, 1898.

Etymology : Chilos, lip, *eu*, well, and *tomos*, a cut.

Type : C. subvaricosa, Tate and Cossmann ; Eocene, Victoria.

Shell conical, variced; embryo orthostrophe with an obtuse and oblique nucleus. Aperture expanding at the front, with a continuous thick peristome. Labrum notched at the inferior angle and varicosely thickened at the exterior. Columella slightly excavated; columella-border callous, reflected and detached from the false umbilicus.

Differs from *Rissoina* by the notched labrum, effuse and rounded front aperture, and by the umbilicus. Besides the type, there

exists another species in the Pliocene of Gourbesville (Manche); this species (*C. Tatei*, Cossmann, ms.) has not yet been described, but its form is a little more squat, its whorls less numerous and narrower, its labial notch is a little broader, etc.

CHILEUTOMIA SUBVARICOSA, T. and C., *spec. nov.* (*Plate* 20, fig. 3.)

Shell small, pyramidally conical; embryo orthostrophe of two and a-half whorls with an oblique nucleus. Spire-whorls six of rather rapid increase, somewhat depressed around the posterior suture, thence slightly convex to the front suture; ornamented with oblique growth-lines coincident with the imbricating varices which are about one to each whorl. Last whorl large; aperture oval, angular behind and expanding to the front with a continuous thick peristome; labrum arched, notched at the inferior angle and varicosely expanded; columella slightly excavated; its border callus, reflected and forming a false umbilicus. Umbilical groove bordered by an obsolete rim. Length 8·5, breadth 2·5, length of aperture 3· mm.

Localities: Muddy Creek, Mornington, Curlewis and Fyansford.

Family TROCHIDÆ.

Genus *Infundibulum.*

INFUNDIBULUM LATESULCATUM, *spec. nov.* (*Plate* 20, fig. 10.)

This fossil appears to belong to the Section *Infundibulops*, Pilsbry,[1] which is distinguished by the thin straight columella from its insertion in the centre of the false umbilicus to its union with the basal lip.

Shell widely conical, false-umbilicated; whorls almost planulate, suture not impressed. The sculpture consists of six rounded spiral ridges, narrower than the concave interspaces. Base concave, with eight spiral ridges similar to those on the upper surface. Length 15, breadth 20 mm.

Eocene, Table Cape, Tasmania (one example).

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[1] Man. Conch., Vol. XI, p. 8, 1889.

Genus *Phasianotrochus*, Fischer.

This name is in substitution for *Elenchus*.

Family, FISSURELLIDÆ.

Genus *Lucapinella*, Pilsbry, 1890.

Example, *Fissurella nigrita*, Sow. Recent Australia and Miocene at Muddy Creek, Victoria. This generic name takes the place of *Fissurella* in my Census. The genus is founded on anatomical characters, though conchologically some indication is afforded by the elevated ends of the shell. *Fissurella* as restricted by Pilsbry is not represented in our Older Tertiary.

Genus *Subemarginula*, Blainville.

Shell like *Emarginula*, but the anal slit is more or less obsolete and there is no slit-fascia.

SUBEMARGINULA OCCLUSA, *spec. nov.* (*Plate* 20, fig. 9.)

Shell patelliform, summit a little behind the middle; apex directed backwards, spiral of one and a-half turns, slightly turned to the right. Basal edge of shell approximately level, oval in outline, crenulated. Ornamentation of numerous acute subequal radial ribs, studded with crenatures which are produced by the crossing of imbricating lamellæ of growth; there are about twenty ribs on the anterior half, and about ten primaries with alternating secondaries on the posterior half of the shell. In the young shell, the interstitial ornament is of the usual fenestrated pattern and the ribs are surmounted by denticles. The anal notch is very short in young shells, but obselete in the adult, though the slit band is traceable on the interior. Height 7·5, diameters 20 and 18·5 mm.

Eocene, Muddy Creek (very common); Mornington.

Subgenus *Tugalia*.

Example, *T. crassirecticulata*, Pritchard.[1]

Eocene, Table Cape.

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[1] Proc. Roy. Soc., Vic., 1896, p. 125, t. 3, figs. 4–5.

Genus *Puncturella*, Lowe, 1827.

PUNCTURELLA HEMIPSILA, *spec. nov.* (*Plate* 20, figs. 8 *a*, *b*.)

Shell patelliform; summit subspiral, recurved posteriorly; anal slit in front of the apex, internally separated by a vertical septum from the apical fossa. Basal edge level, oval, plain. Ornamentation of about seven narrow radiating riblets on the posterior half, the rest of the surface smooth. Anal slit narrow elliptic. Height 2, diameters 4 and 2·5 mm.

Eocene, Table Cape, Tasmania (two examples).

This fossil resembles very much *P. Harrisoni*, Beddome, a living Australian shell, but is distinguished by much finer radial ornament, and by the more compressed lateral areas of the shell.

The distribution of *Puncturella* is largely circumpolar and in deep water, and a few fossil species are known dating from the Miocene.

Family SCUTELLINIDÆ.

Genus *Scutellina*.

Scutellina sp. Eocene, Muddy Creek.

A single example only, but too much mutilated for specific determination; it, however, is clearly referable to the genus by the posterior direction of the apex.

Order PULMONATA.

Genus *Siphonaria*.

Example: One specimen, referable to this genus, I have from the Miocene, Gippsland. It has the shape and ornament of the living species *S. diemenensis*, Quoy & Gaimard, but the ribs are not so elevated, and the external ridge corresponding with the pulmonary groove is obselete. These differences may eventually prove to have specific value.

Order OPISTHOBRANCHIATA.

M. Cossmann, in his monograph of the representatives of this order in the Older Tertiaries of Australia,[1] distributes them in

[1] Trans. Roy. Soc., S. Aust., Vol. XXI., 1897.

the following genera :—*Actæon* (this name takes the place of *Tornatella*), six spp. ; *Semiactæon*, one sp. ; *Triploca*, one sp. ; *Tornatina*, three spp. ; *Volvutella*, Newton, 1891, instead of *Volvula*, H. Adams, 1850 (non. O'Ken., 1815), two spp. ; *Scaphander*, one sp. ; *Bullinella*, Newton, 1891, instead of *Cylichna*, Loven, 1846 (non. Burmuster, 1844), ten spp.; *Roxania*, four spp.; *Cylichnella*, one sp.; *Ringicula*, three spp.; and *Umbrella*, one sp. (Harris employs *Umbraculum*, Schumacher, 1817, as antecedent to *Umbrella* of Lamarck.

Order NUCLEOBRANCHIATA.

Genus *Atlanta*.

The only fossil examples of this Order so far known to me from book-knowledge are :—*Carinaria*, three species, Miocene and Pliocene of Italy, and *Eo-atlanta spiruloides*, Lamarck (Cyclostoma), Eocene of Paris. The extreme delicacy of the tests of these gasteropods renders their preservation in a fossil state a matter of extreme improbability. The above-named species are founded on the shell, and it is of interest to be able to record a member of the Order in the form of an operculum in the Victorian Eocene.

ATLANTA FOSSILIS, *spec. nov.* (*Plate* 19, fig. 7.)

Operculum irregularly trapezoidal, nearly flat, but slightly elevated at the two ends ; nucleus nearly marginal and apical, hemisphaeric of one and a half smooth turns ; the expanded surface smooth and shining, but covered with broadish concentric folds. Under-surface with a broad thickened margin extending nearly the whole length of the left side, around the apical margin and half-way down the right side ; there is an umbonal depression corresponding with the nuclear elevation. Length 7·5 mm.

Eocene, Cape Otway, Victoria (one example).

Class PTEROPODA.

Genus *Carolina*.

An example of a species of this genus has occurred to me in the Eocene clays at Mornington, but is now too fractured to admit of specific determination.

Class LAMELLIBRANCHIATA.

Genus *Pecten*.

Subgenus *Pseudamussium*.

Examples, *Pecten Yahlensis*, T.-Woods, and *Pecten Hochstetteri*, Zittel.

Genus *Lima*.

Subgenus *Limatula*.

Examples, *Lima Jeffreysiana* and *polynema*, Tate.

Genus *Plicatula*.

PLICATULA RAMULOSA, *spec. nov.*

Test stout, peripheral outline rhomboid-rotund ; attached valve somewhat convex, surface of attachment relatively large ; free valve flattish ; attached valve ornamented with seven prominent angular ribs, some of which bifurcate at about half way to the front; free valve with similar ornament, the umbonal area, corresponding with the attachment surface of the other valve, without plications except at the margins. Plicæ crossed by foliar lamellæ, raised here and there on the plicæ into squamose scales or into nodulations. Interior unknown, umboventral diameter 13, anteropost. diameter 17 mm.

Eocene, Table Cape (a single example of closed paired valves), J. Dennant.

The fossil resembles the living *P. ramosa*, Lamarck, by comparison of actual specimens, but differs by dense lamellation and closer plications which are a few more in number.

Magaritifera, P. Brown, 1789 (*Meleagrina*) Lamarck.
Nuculana, Link, 1807, (*Leda*, Schumacher, 1817).
Axinæa, Poli, 1791 (*Pectunculus*, Lamarck, 1799).
Axinus, Sowerby, 1821 (*Cryptodon*, Turton, 1822).
Mylitta, D'Orbigny and Recluz (*Pythina, auctores*, non Hinds).

Meretrix, Lamarck, 1799 (*Cytherea*, Lamarck, 1805).

Sunetta, Link, 1807 (*Meroe*, Schumacher, 1817).

Gari, Schumacher, 1817 (*Psammobia*, Lamarck, 1818).

Hemimactra, Swainson, 1840. Example, *Mactra howchiniana*, Tate.

Anapella, Dall, 1895 (*Anapa*, Gray, 1853, non Gray, 1847).

Cuspidaria, Nardo, 1840 (*Neæra*, Gray, 1834, non Robineau-Desvoidy, 1830).

Glycimeris, Lamarck, 1799 (*Panopæa*, Menard de la Groye, 1807.

Solenocurtus (emended from *Solecurtus*).

Genus *Martesia*.

Young shell like *Barnea*, the valves becoming closed anteriorly in the adult; one large accessory valve.

MARTESIA ELEGANTULA, *spec. nov.* (*Plate* 20, figs. 7 *a*, *b*.)

Elongate-conoid, inflated and obtusely rounded in front, attenuated behind; valves closed in front (the gap of the young shell being arched over by a subcallous growth), slightly gaping behind. Exterior of each valve unequally divided into two dissimilar ornamented portions by a perpendicular furrow, extending from the umbo to the ventral margin; the external furrow is reproduced internally as an obsolete rib. The anterior side is further divided into a trigonal area, occupying the extreme front, which is the supplemental growth of the adult, this area is ornamented with fine striæ of growth coincident with sinuate front margin of the adolescent shell; and into a second larger and highly ornate area bounded posteriorly by the antemedian transverse furrow and anteriorly by the sutural line between the two growths. The ornamentation of the second area consists of regular sigmoid acute retroverted lamellæ-like folds, coincident with the margin of the adolescent shell; the superior margin of the lamellæ closely crenulated, the crenulatures passing into granules; in addition there are about ten plicæ radiating from the lunular area, rendered conspicuous by carrying small granulations in place of crenulatures at the intersections with the concentric folds. The part of the

shell posterior to the transverse sulcus carries thickish growth-folds and some coincident striæ. Accessory valve roundly oblong, front margin semicircular, posterior margin truncate, slightly convex and smooth on the outside. Antero-posterior diameter 16, umbo-ventral diameter 8·5, transverse diameter of closed valves 8 mm.; transverse sulcus 5 mm. from the front.

Miocene, Grangeburn, near Hamilton, Victoria; burrowing in coral (*Plesiastræa*).

From figures and description this fossil pholad comes near to *Martesia elegans*, Desh., of the Parisian Eocene; but *M. elegantula* has a longer posterior side, which is not so finely and regularly ridged, and the accessory valve is of a different shape.

Class Polyzoa.

The voluminous monograph by McGillivray already referred to is almost entirely responsible for the very large additions to the genera and species comprised in our Eocene fauna. The census of the class is now eighty-four genera and four hundred and forty-four species representing a gain of forty-seven genera (many new), and two hundred and twenty-nine species. The additional genera are:—

Order Cheilostomata.

Liriozoa, one specimen; *Bigemellaria*, one sp.; *Stenostomaria*, one sp.; *Strophipora*, one sp.; *Microstomaria*, one sp.; *Caloporella*, six spp.; *Claviporella*, four spp.; *Ditaxipora*, one sp.; *Scrupocellaria* one sp.; *Plicopora*, one sp.; *Beania*, one sp.; *Craspedozoum*, one sp.; *Amphiblestrum*, eight spp.; *Farcimia*, three spp.; *Caleschara*, one sp.; *Thalamoporella*, two spp.; *Macropora*, two spp.; *Membraniporella*, two spp.; *Corbulipora*, one sp.; *Hiantopora*, four spp.; *Tessaradoma*, two spp.; *Adeona*, six spp.; *Bulbipora*, one sp.; *Plagiopora*, one sp.; *Gemellipora*, two spp.; *Haswellia*, two spp.; *Bipora*, two spp.; *Adeonella*, one sp.; *Cucullipora*, one sp.; *Pachystomaria*, one sp.; *Phylactella*, one sp.; *Bracebridgia*, one sp.; *Aspidostoma*, one sp.; *Tubicellaria*, two spp.; *Prostomaria*, one sp.; *Bitectipora*, one sp.; *Schismopora*, five spp.

Order Cyclostomata.

Filisparsa, one sp.; *Stomatopora*, two spp.; *Liripora*, three spp.; *Tecticavea*, one sp.; *Discofascigera*, one sp.; *Heteropora*, two spp.; *Frondipora*, one sp.

Retihornera is merged in *Hornera* and *Pustulipora* in *Entalophora; Bimulticava* and *Carbasea* are expunged.

Class Echinodermata.

Genus *Cidaris*.

Subgenus *Stereocidaris*, Schutte.

Example, *Cidaris Australiae*, Duncan. I have compared Duncan's type, which is a single interambulacral plate, with complete interambulacral zones of a *Cidarid* from Aldinga and it is matched with the largest of the tuberculated plates of the Aldinga specimens. These latter belong to *Stereocidaris* and indicate a conic test, the broad base being nearly flat, to about one half the total length of the arc, thence roundly bent backward at about 60°; the basal half consists of four plates in each row having areolar areas, the posterior ones of which are the largest; the four or five posterior plates in each row are without areoles or one or two may show traces of them.

The fossil which has been listed as a widely distributed species under Duncan's name is not that species, but is an undescribed *Goniocidaris*. *Stereocidaris Australiæ* is only known to me from the glauconitic limestone of the Aldinga Cliffs; the type is reported from Cape Otway.

Genus *Echinobrissus*.

An examination of the type of *E. australiæ*, Duncan, proves it, as was long suspected, to belong to *Cassidulus*. The genus is, however, not to be deleted from our list, as *E. Vincentinus*, Tate, is representative.

Scutellina is a misprint for *Scutella*.

Genus *Plesiolampus.*

Example, *Conoclypeus rostratus*, Tate.[1] Additional specimens subsequently acquired permit me to affirm that no perignathic girdle is present, and as a consequence the species is transferred to *Plesiolampus.*

Genus *Eupatagus.*

Subgenus *Macropneustes.*

Example, *Eupatagus decipiens*, Tate. On the authority of Dr. A. C. Gregory, this species is transferred to *Macropneustes.*

Class FORAMINIFERA.

The following additional genera have been recorded by Mr. Howchin,[2] which bring the total of genera to sixty-three and of species to two hundred and nine.

Nubecularia, one specimen; *Sigmoilina*, two spp.; *Clavulina*, two spp.; *Pentellina*, one sp.; *Trillina*, one sp.; *Orbiculina*, one sp.; *Rhabdogonium*, one sp.; *Haplophagmium*, three spp.; *Bdelloidina*, one sp.; *Pavonina*, one sp.; *Calcarina*, one sp.; *Orbitoides*, three spp.

APPENDIX.

By J. DENNANT, F.G.S.

Class ANTHOZOA.

Suborder MADREPORARIA.

The late Professor M. Duncan published descriptions and figures of a few Australian Tertiary corals in the Annals and Magazine of Natural History for 1864 and 1865, and in the Quarterly Journal of the Geological Society for 1870, he dealt systematically with an extensive collection forwarded to him by the Victorian Geological Survey, publishing upwards of thirty

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[1] Proc. Roy. Soc., N.S. Wales, 1893, p. 194, t. 13, f. 1.

[2] Trans, Roy. Soc., S. Australia, 1893, p. 14; Aust. Assoc. Adv. Sc., Vol. v, 1894, pp. 352-361.

species, including those he had already named. Subsequently the late Tenison-Woods, not only diagnosed a number of additional species, but instituted several new genera, the majority of which have been accepted as valid. With his decease, the records of our Tertiary coral fauna have been allowed to fall into arrears, a single species only having been since described, and that by my colleague in his previous paper on "Unrecorded Genera," read before this Society in 1893.

As a result of the persevering manner in which the Tertiary beds of the southern colonies have been searched during the last decade, there is an accumulation of material on hand, which in the absence of other workers I have undertaken to examine. As unrecorded genera for the Australian Tertiary, the following are represented by the species now described.

Family TURBINOLIDÆ.

Genus *Paracyathus*.

PARACYATHUS SUPRACOSTATUS, *sp. nov.* (*Plate* 20, figs. 2 *a*, *b*.)

Corallum almost straight, and gradually tapering from both ends to the slightly constricted middle portion. The base is broad and spreading, and has evidently been attached to some foreign substance. The costæ, which correspond with, and are continuous with the septa, are prominent at the calicular margin, with tolerably deep intercostal spaces in which the wall is visible; they gradually diminish in size to the middle of the corallum and are thence just traceable to the base as faint, scarcely raised lines; towards the calice they are finely granular. Epitheca pellicular and complete. Septa stout but diminishing gradually in size from the primaries to those of the highest order. Systems six, with four cycles. In the figured specimen one system is short in regard to the fourth cycle. The laminæ are very granular with irregular outer edges. The columella is fascicular and highly papillary. There are stout pali before all the septa except those of the last cycle, the youngest reaching higher in the calicular fossa than the secondaries, and these again than the primaries. The tertiary pali are also usually

broader at their superior extremity than the rest. All are granular and much lobed. They are connected with the septa and usually also with the columella by thin, short, and deeply sunken processes. At the extremity of the pali described, and united to them by these processes, a few smaller and more central ones are, I think, separable from the outer papilli of the columella. The calice is slightly elliptical and regularly concave with a tolerably deep fossa. Owing to the stoutness of the septa and pali, as well as to the prominent papilli of the columella, the calice has a crowded appearance. Height of corallum 21, length of calice 8, breadth of calice $7\frac{1}{2}$ millimetres.

Locality:—Very rare in the Eocene beds at Red Bluff, Shelford. Collected by Mr. Swan, to whom I am indebted for the well preserved example figured.

This coral is wholly unlike any species hitherto described from the Australian Tertiary, but from a comparison of actual examples I conclude that, though much larger, it is nearly allied to *P. Turonensis* of the French Miocene.

Some corals lately collected by Professor Tate and myself at Table Cape, Tasmania, though differing slightly in the shape of the corallum, agree with the present species in calicular arrangement. There are two varieties from that bed, each of which may represent a distinct species of the genus. It is proposed to describe them shortly.

Family ASTRAEIDÆ.

Genus *Montlivaltia.*

MONTLIVALTIA VARIFORMIS, *spec. nov.* (*Plate* 20, figs. 1 *a*, *b*.)

Corallum simple and variable in outline from flatly convex to roundly conical; the figured specimen is an intermediate form. There is usually a more or less slight constriction towards the middle of the corallum, but in some examples this becomes so pronounced as to form a neck between its upper and lower portions. The base also varies from broad and spreading to small and rounded,

but in all cases evidence is presented of former attachment. The calice is circular, open and very shallow, with a small axial space. In adult examples this is occupied for a portion, but not the whole of the distance to the base with trabeculæ, which unite the septal ends and form a false columella ; in young specimens these are but little developed, the septa almost joining in the centre of the calice. The septa are slightly exsert at the margin, denticulated, and have an irregular outer surface. There are at least five cycles in six systems, some of which are incomplete. The first three orders extend to the central fossa, and owing to the primaries and secondaries being equally stout the calice really shews twelve main subdivisions. The tertiaries are slightly thinner, and the quaternaries bend towards and usually unite with them at no great distance from the centre: nearer the wall these again are occasionally joined by septa of the highest order.

The endotheca is variable in quantity, some specimens shewing numerous dissepiments, while in others there are scarcely any.

Epitheca thin and seldom complete, usually existing only as transverse irregular folds, between which the costæ are very prominent ; these are also traceable in some examples across the banded epitheca.

The costae are subequal and correspond to the septa, but only the principal orders are at all regularly continuous on the wall, the others sometimes breaking off and reappearing, or not, lower down. There is generally abundant exotheca between the costæ. The peculiar latticed appearance of these corals, especially when much worn, is due partly to the exotheca, but chiefly to the narrow ribbon-like bands of epitheca which cross the costæ.

Dimensions :—Height of type specimen 10, diameter of its calice 14 millimetres. Height of a taller specimen 15 mm. Diameter of calice in a large flatly convex example 18 mm.

Locality :—Abundant in the Eocene at Table Cape, Tasmania. Coll. Tate and Dennant. A much worn coral picked up some

years ago on the surface of the Eocene at Spring Creek is probably an example of the species.

By its septal arrangement and false trabecular columella, this species is linked with *Montlivaltia Vignei*, of the Eocene (or oligocene) of Sind.

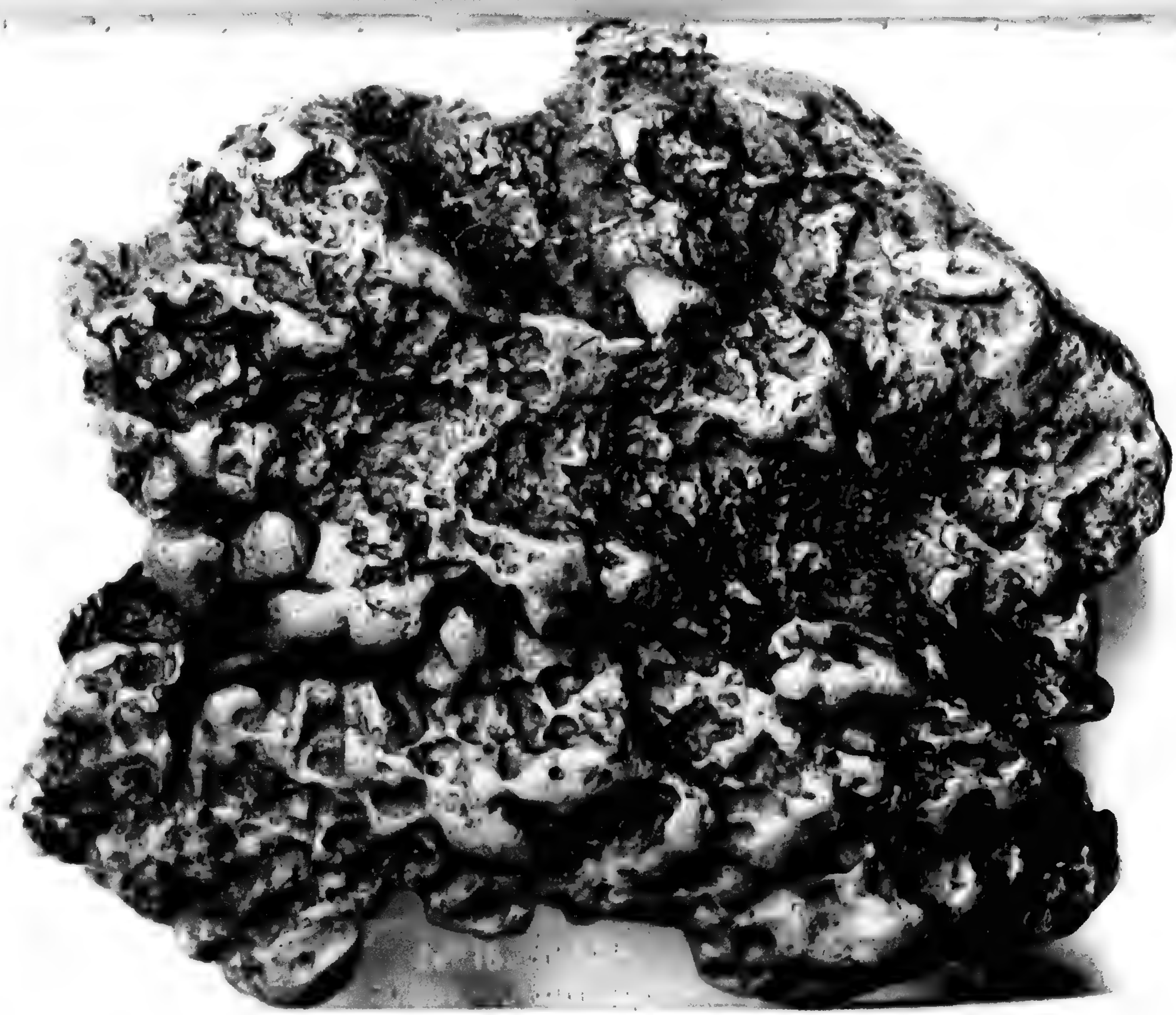
A coral from Muddy Creek was in 1878 referred to this genus by Tenison-Woods as *Montlivaltia discus*, but, as Duncan pointed out in his "Revision of the Madreporaria" (1884), incorrectly so. As shewn in Wood's drawing, synapticulae are present, and Duncan therefore properly placed it with the Fungidæ under Moseley's new genus of *Bathyactis*. A similar coral, and from the same locality, had however, been previously described by Duncan himself, viz., in 1865 and again in 1870 as *Antillia lens*, the synapticulae, if his specimens shewed any, not being noticed. Concerning the identity of Woods' and Duncan's species there can now be no doubt, and by the rule of priority the coral should therefore be known as *Bathyactis lens*, Duncan.

PLATE XIX.

Fig. 1. *Plesiotriton Dennanti*
„ 2. *Borsonia polycesta*
„ 3. *Plicatula ramulosa*
„ 4. *Borsonia Otwayensis*
„ 5. *Gaskoinia bullæformis*
„ 6. *Borsonia protensa*
„ 7. *Atlanta fossilis*—*a*, exterior, *b*, interior aspect.
Fig. 8. *Streblorhamphus obesus*
„ 9. *Fossarus refractus*
„ 10. *Borsonia balteata*
„ 11. *Hemiconus Cossmanni*
„ 12. *Cordieria conospira*—*a*, front aspect; *b*, embryo and first spire-whorl; *c*, side view of body-whorl.

PLATE XX.

Fig. 1. *Montlivaltia variformis*—*a*, corallum 2 diam.; *b*, portion of calice showing two systems, highly magnified.
„ 2. *Paracyathus supracostatus*—*a*, corallum 1·5 diam.; *b*, calice much enlarged.
„ 3. *Chileutomia subvaricosa*—*a*, front view; *b*, lateral aspect of body-whorl.
„ 4. *Streblorampus mirulus*—*a*, front view; *b*, basal view of body-whorl.
„ 5. *Dissochilus vitreus*.
„ 6. *Dissochilus eburneus*.
„ 7. *Martesia elegantula*—*a*, left valve; *b*, accessory valve.
„ 8. *Puncturella hemispila*—*a*, side view; *b*, seen from above.
„ 9. *Subemarginula occlusa*—*a*, seen from above; *b*, enlargement of ornament.
„ 10. *Infundibulum latesulcatum*—*a*, base; *b*, elevation.



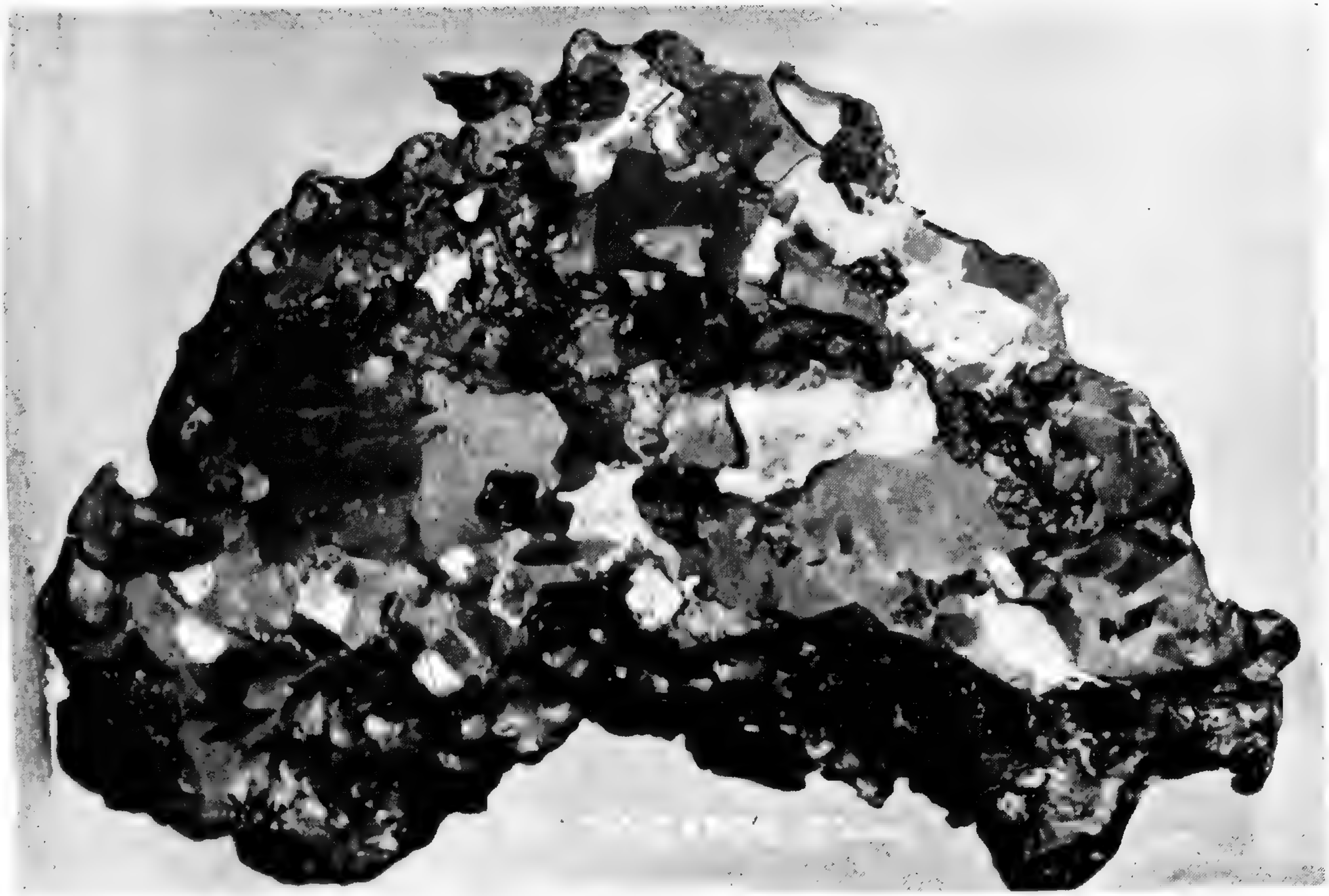
L. Liversidge, 1895

GOLD NUGGET, WEST AUSTRALIA. EXTERIOR, ENLARGED 2 DIAS.

GOLD NUGGET, WEST AUSTRALIA. SECTION ENLARGED 2 DIAS.

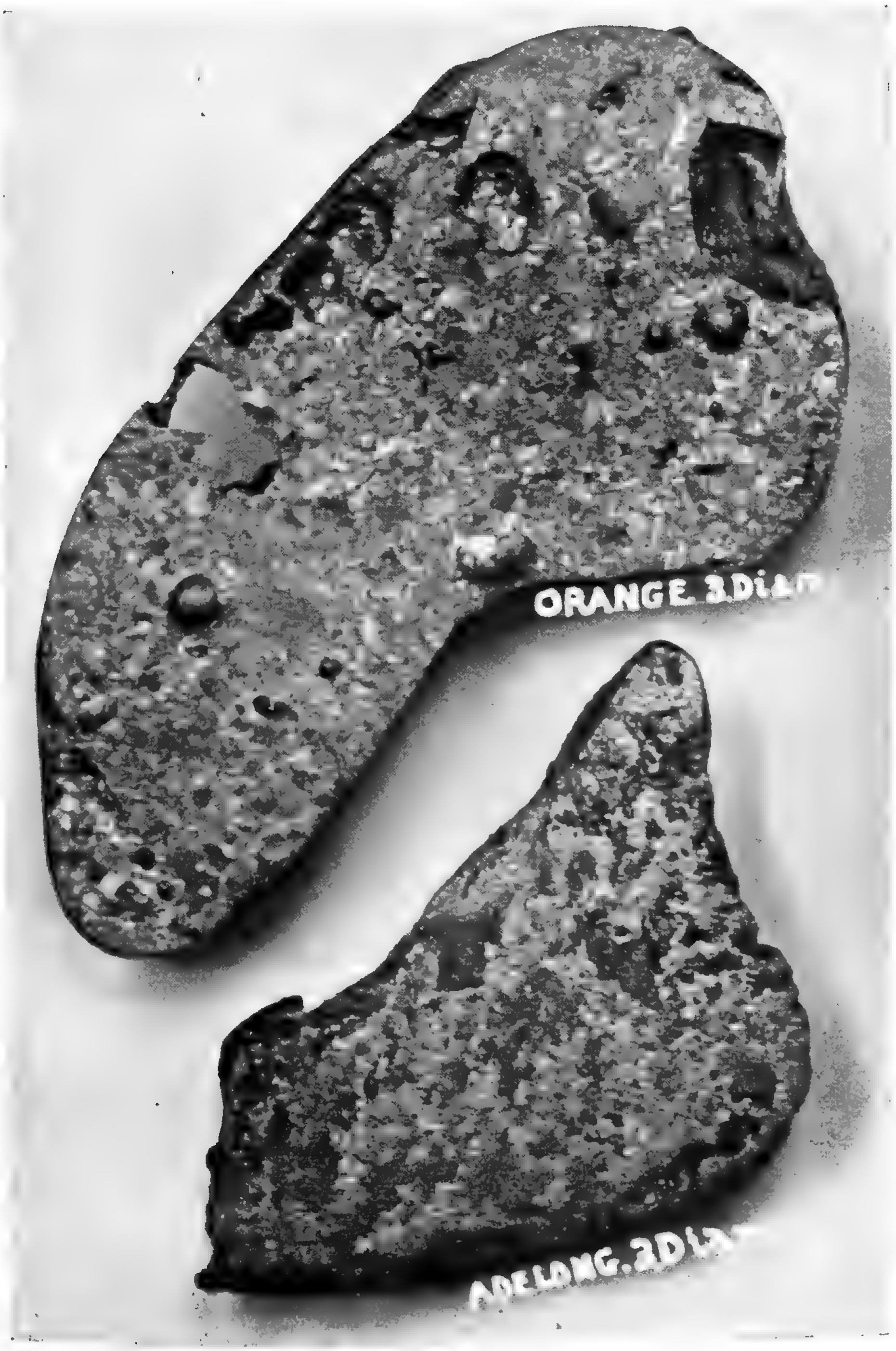
GOLD NUGGET, WEST AUSTRALIA. BACK OF SECTION (PLATE 2).

A. Liversidge, del. 1895.



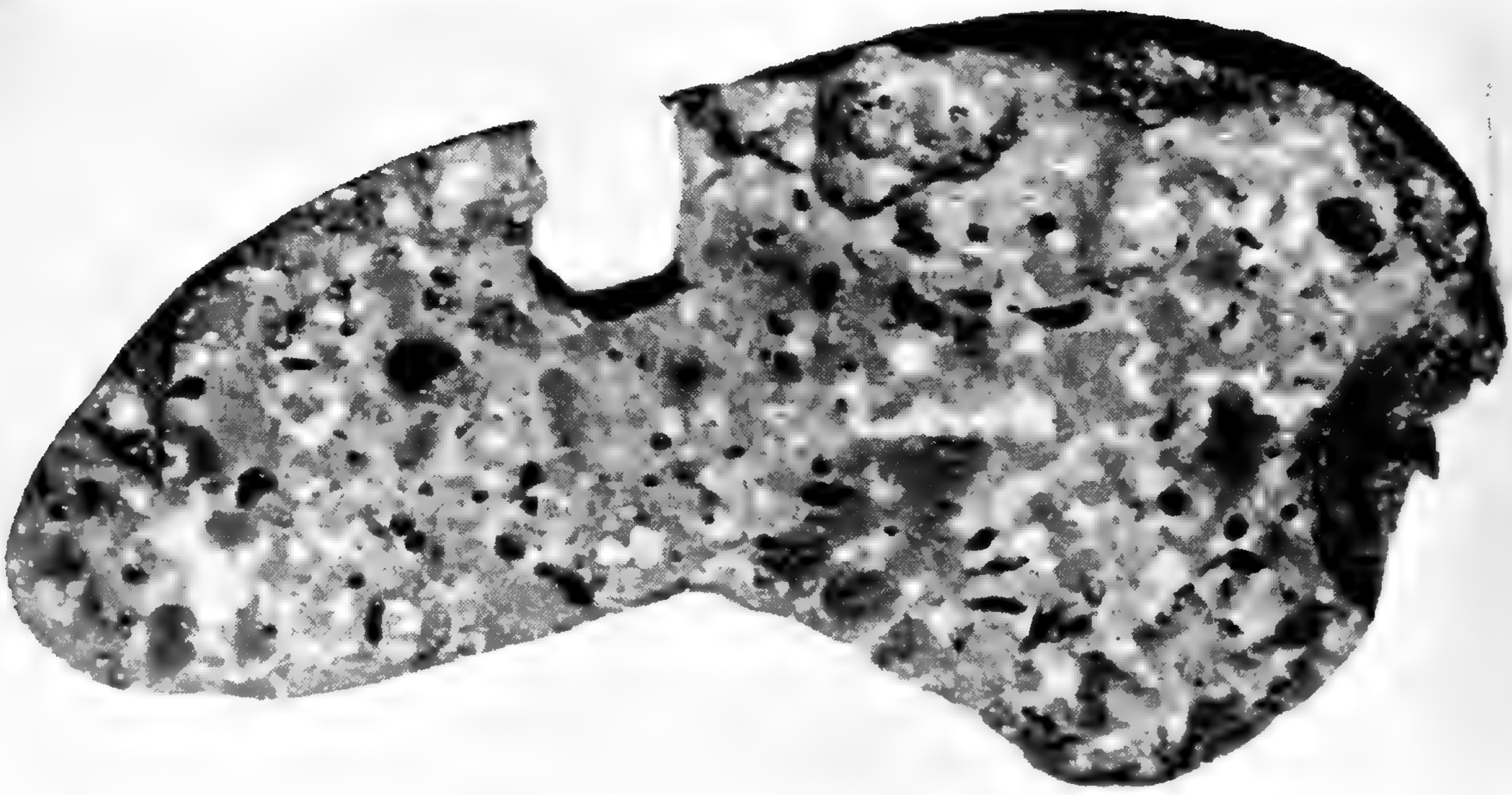
A. Liversidge, 1894.

GOLD NUGGET, WEST AUSTRALIA. No. 2. ETCHED SECTION ENLARGED 3 DIAS.



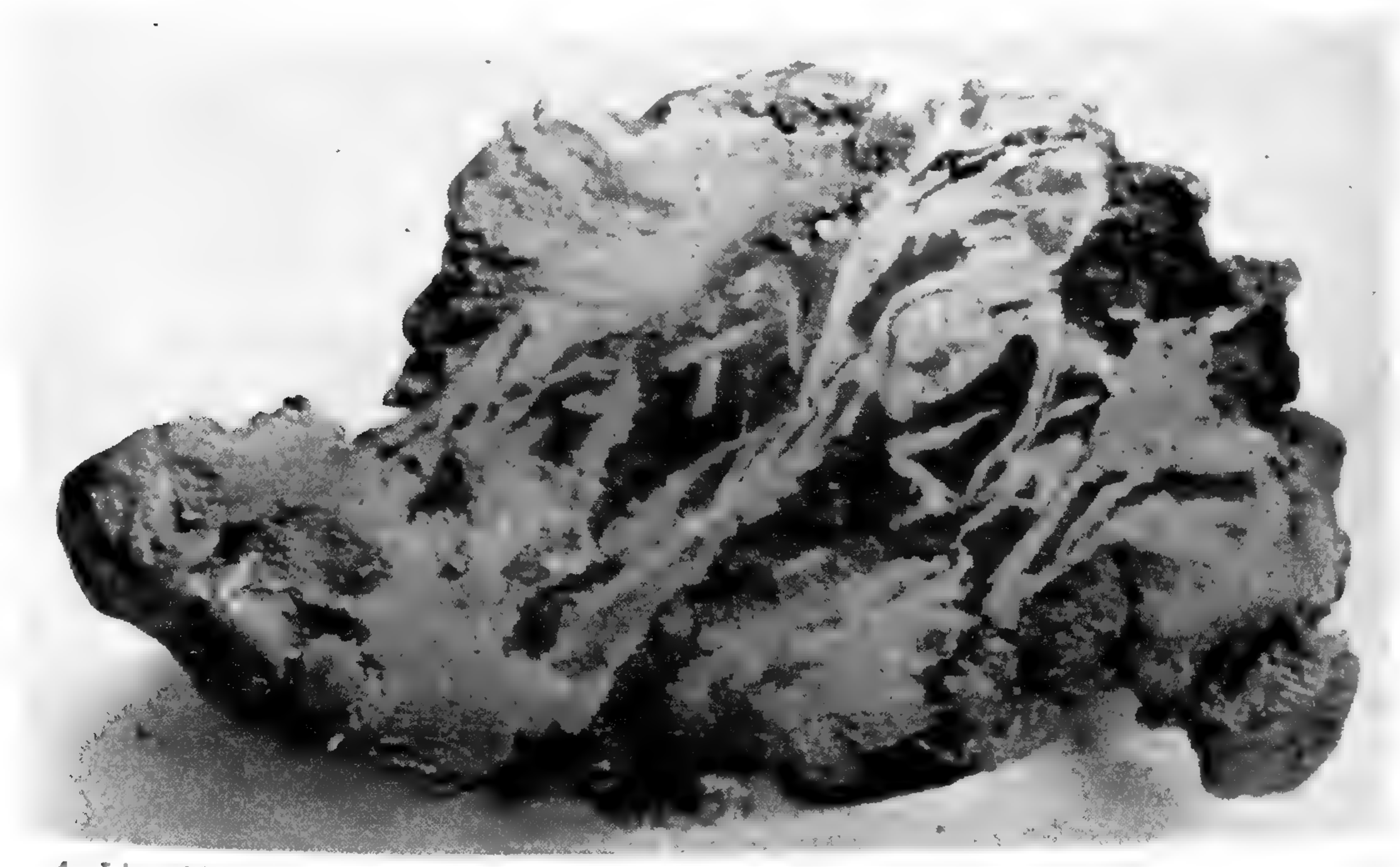
A. Liversidge, 1894.

GOLD NUGGETS, NEW SOUTH WALES. THE UPPER ONE SHOWS BLEBS, AND THE LOWER ONE FERRUGINOUS MATTER.



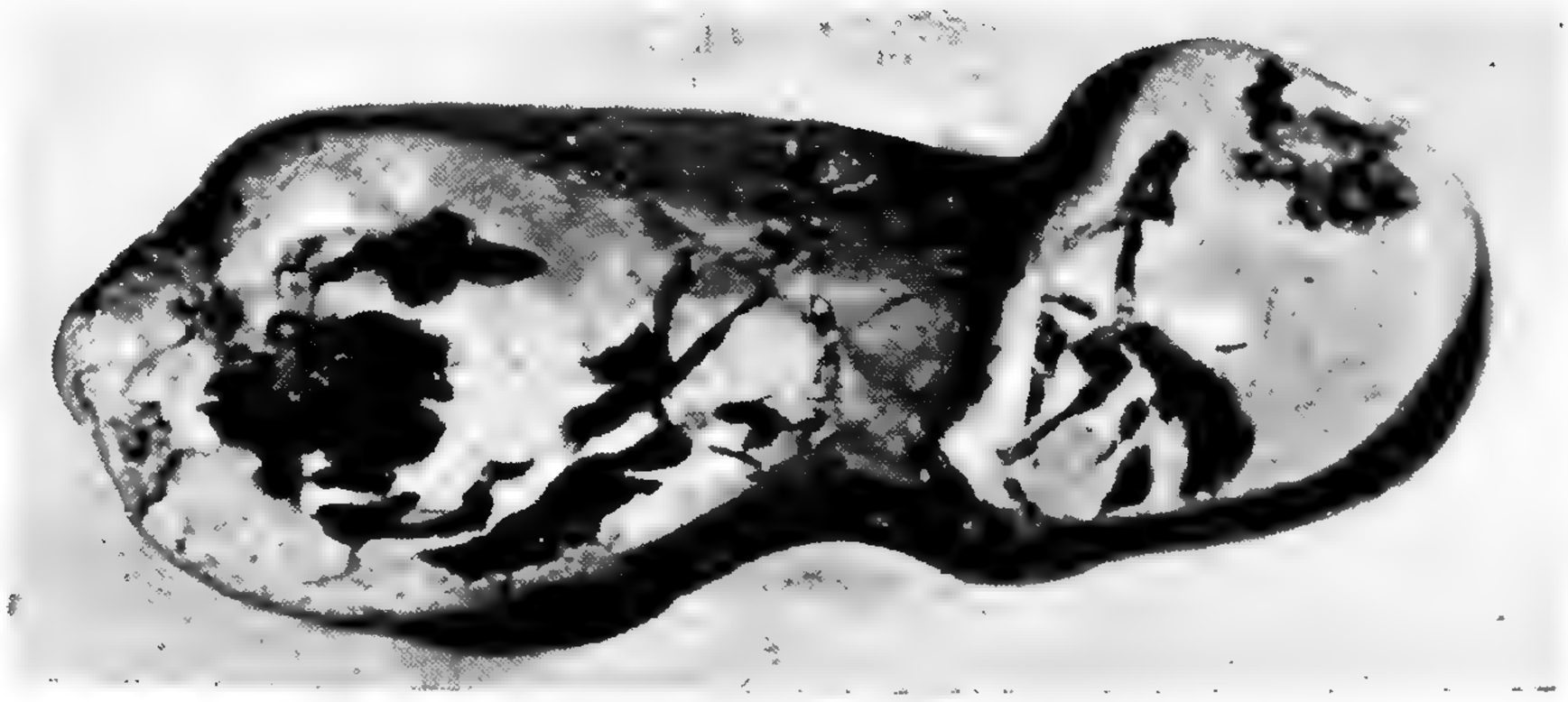
A. Liversidge, 1894.

GOLD NUGGET, ORANGE (SEE PL. 5). ETCHED SECTION SHOWING CAVITIES LEFT AFTER DISSOLVING AWAY THE WALLS OF THE BLEBS.



A. Liversidge, 1895.

GOLD NUGGET, QUEENSLAND. THE DARK PARTS ARE FERRUGINOUS MATTER. SECTION ENLARGED 3 DIAS.



GOLD NUGGET, WELLINGTON, N.S.W. ETCHED SECTION ENLARGED 2 DIAS.
THE DARK PARTS ARE IRON OXIDE.

GOLD NUGGETS. ETCHED SECTIONS ENLARGED 3 DIAS. THE DARK PARTS ARE CAVITIES AND FERRUGINOUS MATTER.

A. Liversidge, 1894.

GOLD NUGGET, PEAK HILL. ETCHED SECTION ENLARGED 3 DIAS.

A. Liversidge, 1895.

GOLD NUGGET, PARKES, N.S.W. ETCHED SECTION ENLARGED 2 DIAS.

A. Liversidge, 1895.

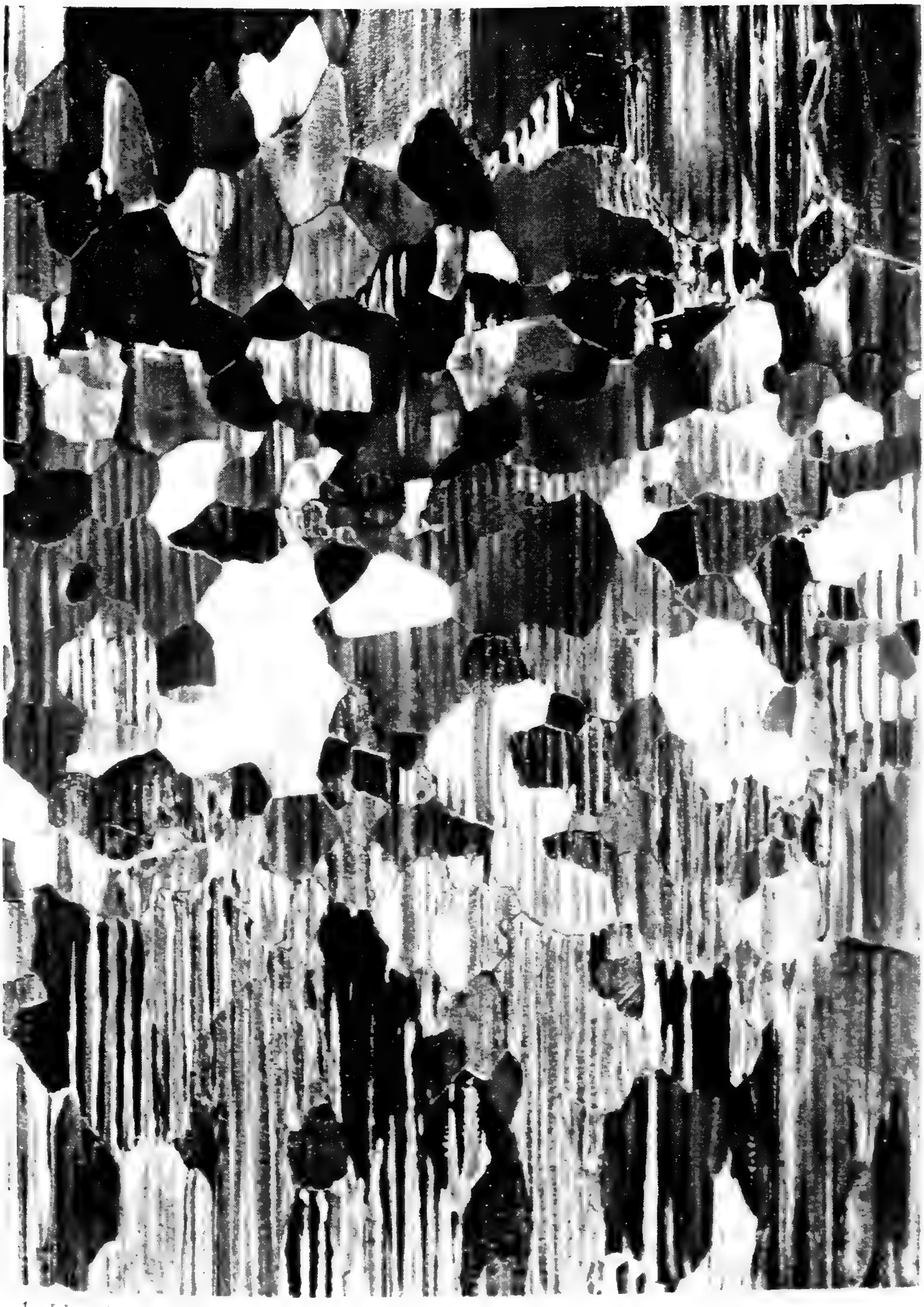
PLATINUM NUGGET. ETCHED SECTION ENLARGED 5 DIAS.

ETCHED SECTION OF INGOT OF GOLD (WEIGHT 1,400 OZ.), ASSAY 1,000. NAT. SIZE.

A. Liversidge, 1895.

A. *Liversidge, 1895.*

PART OF BASE OF 1,400 OZ. INGOT OF GOLD. ETCHED SECTION ENLARGED 2 DIAMS.

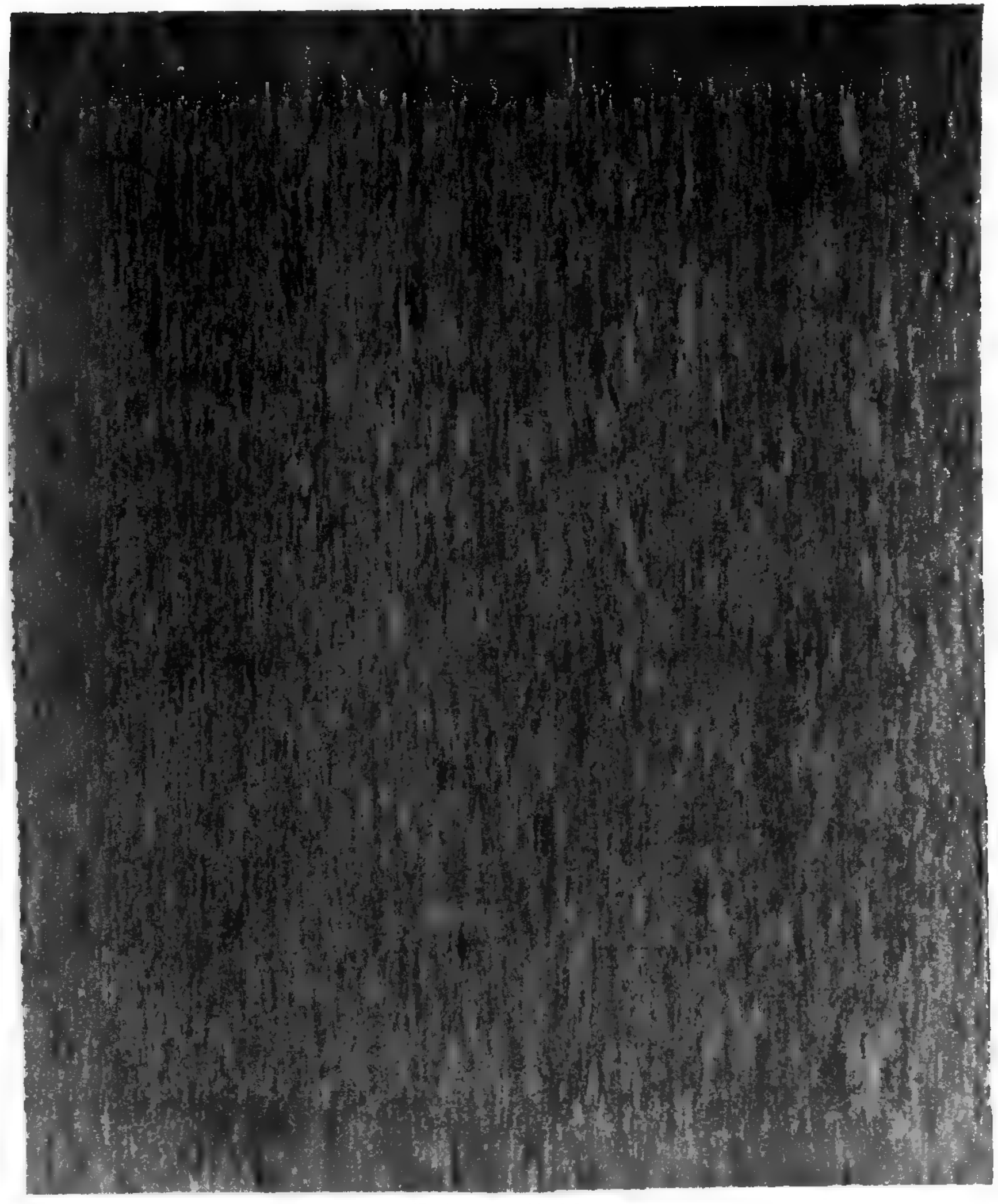


1. *Liversidge, 1895.*

PART OF GOLD INGOT (1,400 OZ.) CUT THROUGH CENTRAL PLANE, A.B. PLATE 10.
ETCHED SECTION ENLARGED 2 DIAMS.

ETCHED SECTION OF INGOT (1,203 OZ.) OF STANDARD GOLD. NAT. SIZE.

A. Liversidge, 1895. Gold (1,000).



Coinage Gold.

ETCHED FILLETS OF ROLLED GOLD.

ROLLED AND ETCHED FILLET OF GOLD (ASSAY 1,000), SHOWING DISTORTED CRYSTALLINE STRUCTURE.
ENLARGED 2 DIAS.

J. Liversidge, 1895

L. Liversidge, 1895.

ETCHED INGOT OF TIN. ENLARGED 2 DIAS.

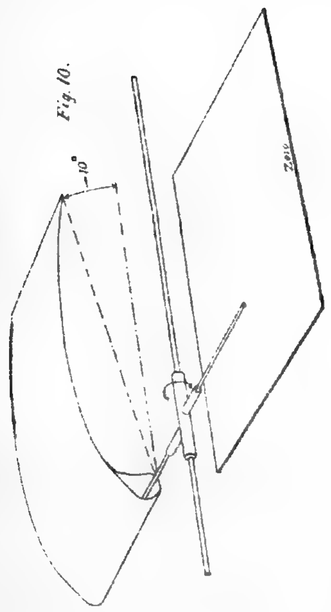


Fig. 10.

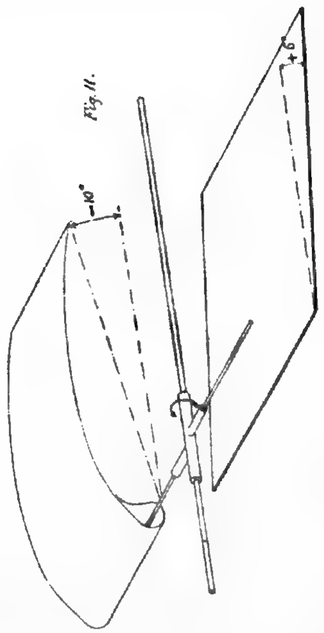


Fig. 11.

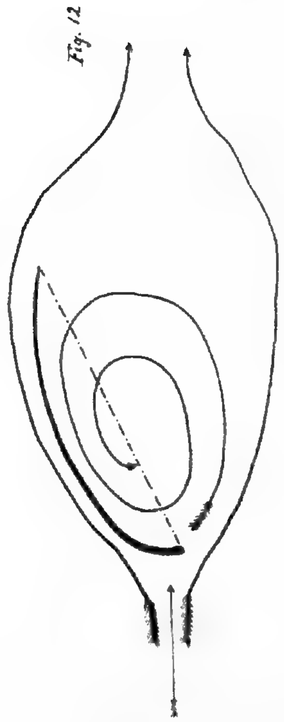


Fig. 12

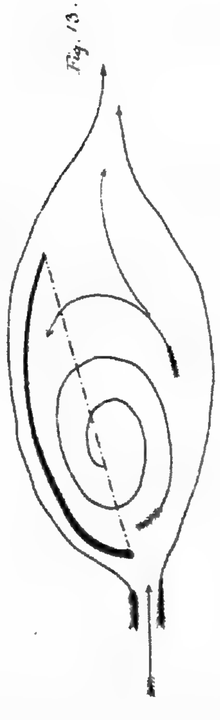


Fig. 13.

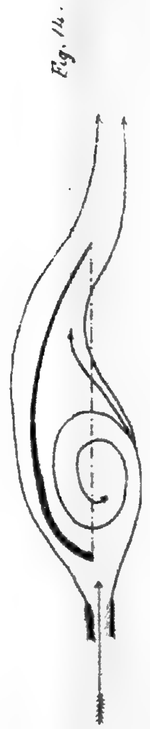


Fig. 14.

Fig. 15.

Fig 16

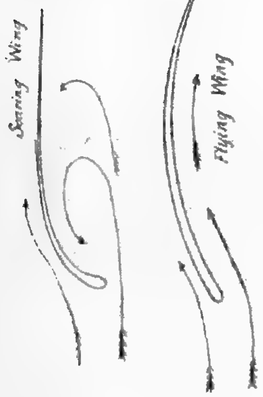


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

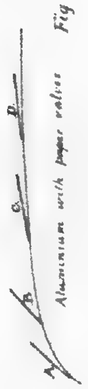


Fig 7.

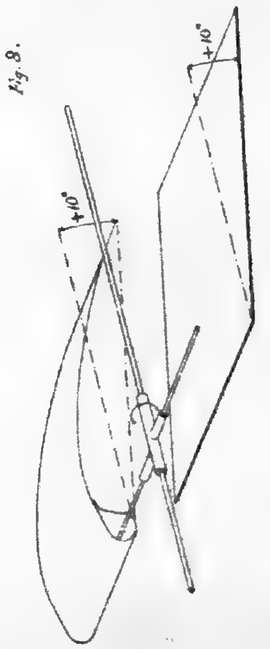


Fig. 8.

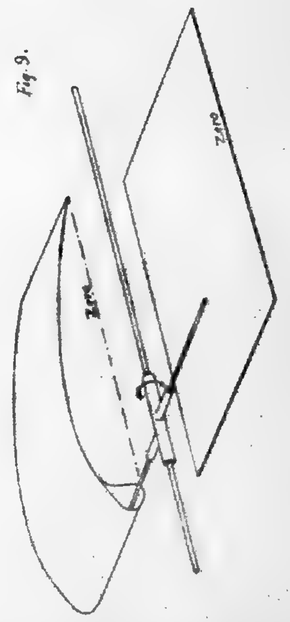
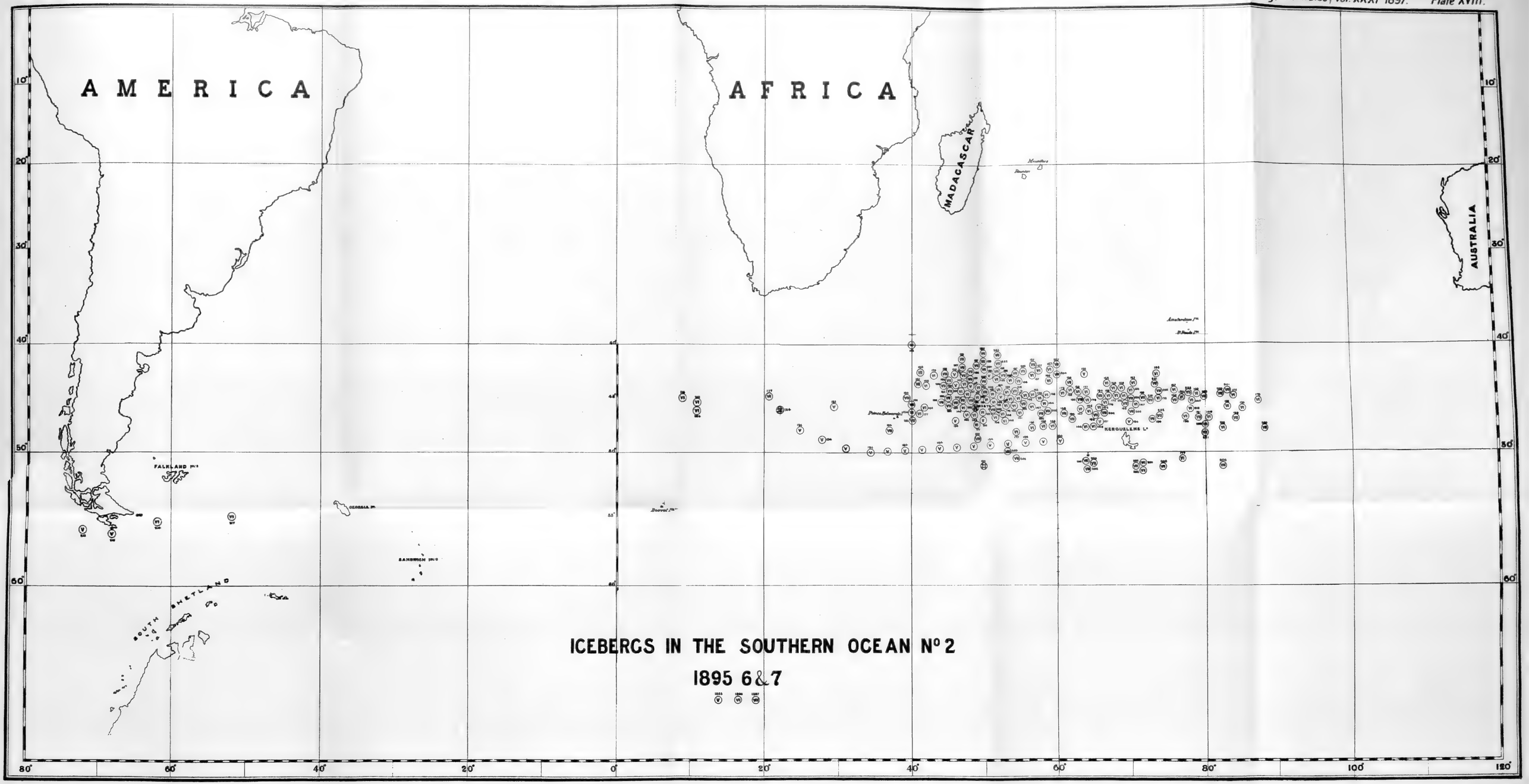


Fig. 9.



ICEBERGS IN THE SOUTHERN OCEAN Nº 2

1895 6 & 7

PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE,
SYDNEY, NEW SOUTH WALES.

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b

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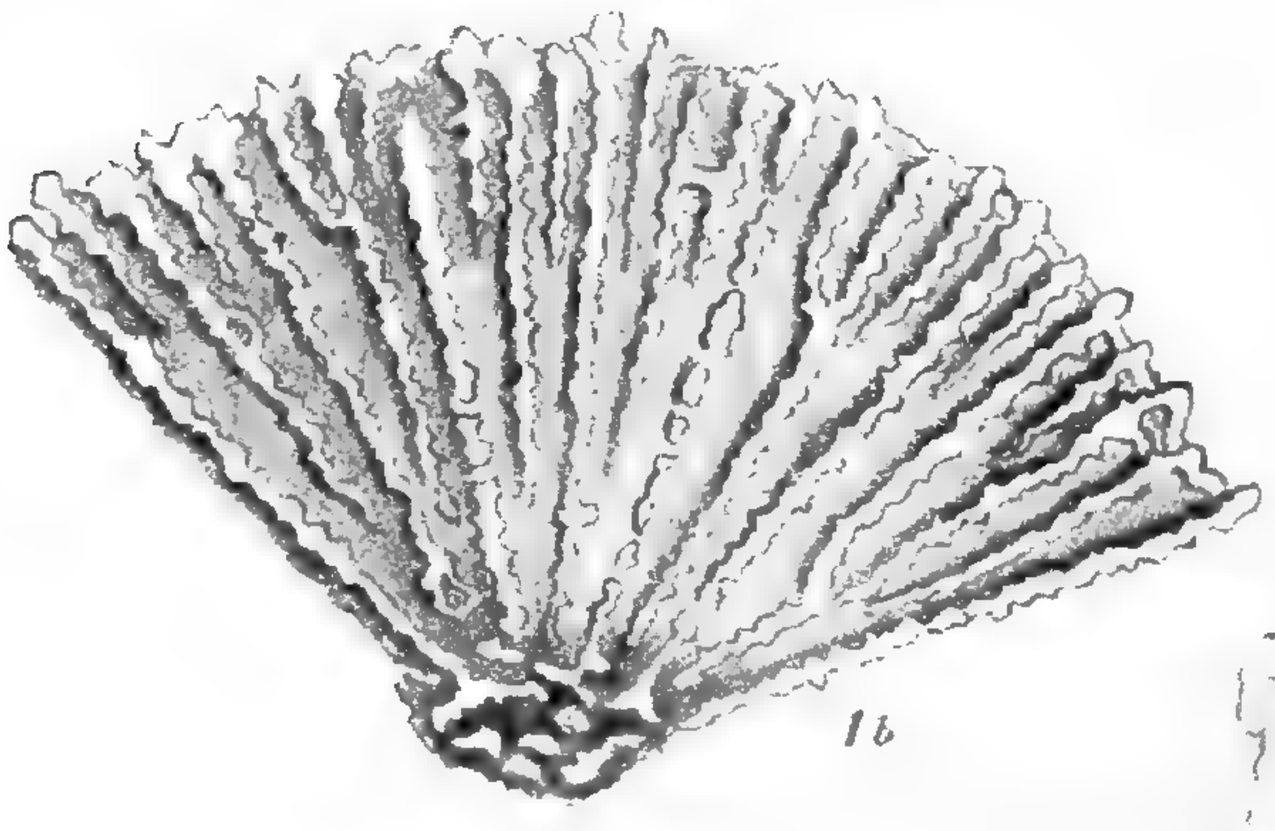
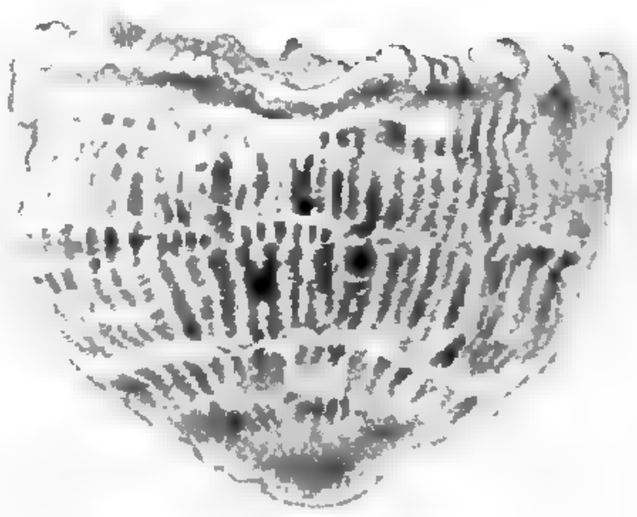
12 *b* *c* *a*



1b



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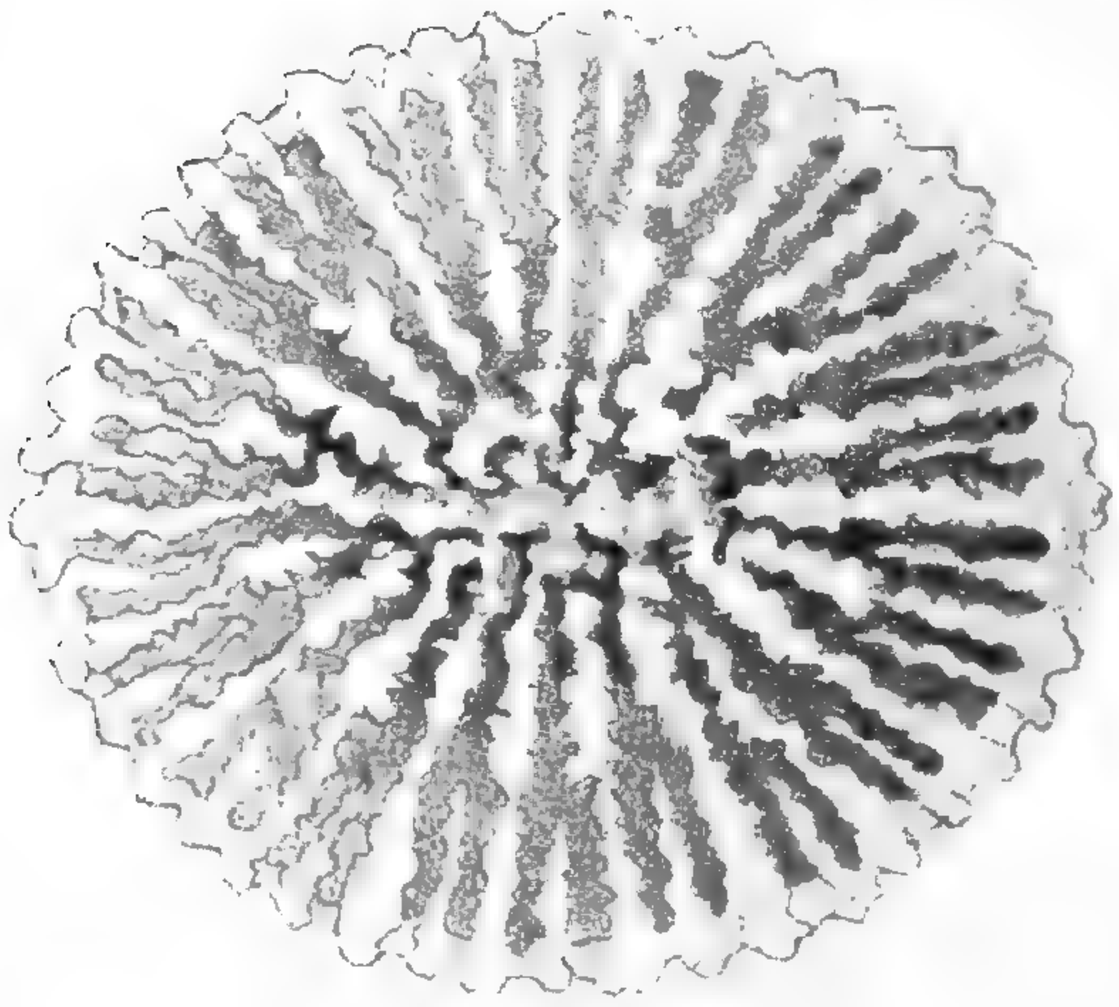

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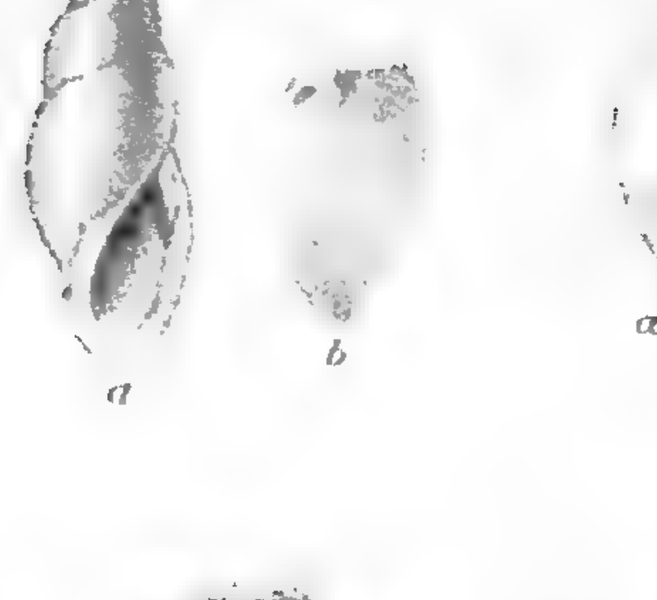

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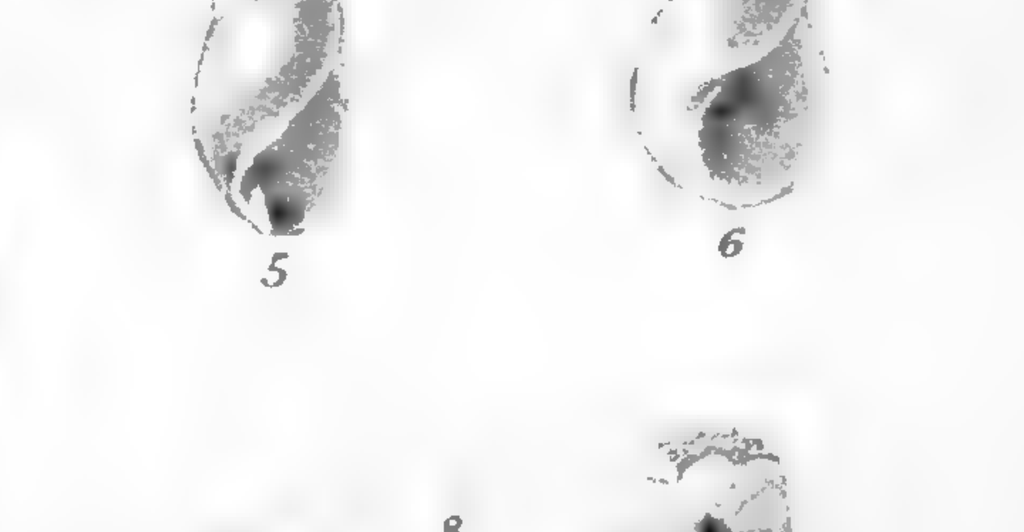

10a 10b

ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 5, 1897.

The Annual General Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street, North, on Wednesday evening, May 5th, 1897.

The President, Mr. J. H. MAIDEN, F.L.S., in the Chair.

Thirty-seven members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ending 31st March, 1897, was presented by the Hon. Treasurer, and adopted:

GENERAL ACCOUNT.

RECEIPTS.	£	s.	d.	£	s.	d.
Subscriptions { One Guinea	118	13	0			
Two Guineas	346	10	0	533	8	0
Arrears	68	5	0			
Entrance Fees				54	12	0
Parliamentary Grant on Subscriptions received during 1896				526	3	0
Rent				21	15	0
Sundries				3	16	7
Repayment of Advance to Building Fund, 31 March, 1896				29	8	2
Advance from Building Fund, 31 March, 1897				8	0	6
Total Receipts				1177	3	3
Balance on 1st April, 1896				46	19	3
				£1224	2	6

			PAYMENTS.			£	s.	d.	£ s. d.
Advertisements						29	15	2	
Assistant Secretary						250	0	0	
Books and Periodicals						113	0	11	
Bookbinding						86	15	5	
Freight, Charges, Packing, &c....						7	1	9	
Furniture and Effects						46	9	6	
Gas						19	14	1	
Housekeeper						10	0	0	
Insurance						12	8	0	
Interest on Mortgage						47	5	0	
Office Boy						23	8	0	
Petty Cash Expenses						14	5	7	
Postage and Duty Stamps						25	10	0	
Printing						24	17	0	
Printing and Publishing Journal						330	18	0	
Prize Essay Award						25	0	0	
Rates						39	11	9	
Reception						17	19	10	
Refreshments and attendance at Meetings ...						24	13	0	
Repairs						28	7	3	
Stationery						10	1	9	
Sundries						22	13	7	
Total Payments									1209 15 7
Balance on 31st March, 1897									14 6 11
									£1224 2 6

BUILDING AND INVESTMENT FUND.

			RECEIPTS.			£	s.	d.	
Australasian Association for the Advancement of Science—									
Balance of Mortgage of £1,400						900	0	0	
Clarke Memorial Fund						376	7	9	
Dr. F. H. Quaife (Donation)						20	0	0	
									£1296 7 9

			PAYMENTS.			£	s.	d.	
Legal Expenses						24	2	6	
Contractors balance of account for additions and alterations						981	0	6	
Architect						42	12	0	
Rent of Temporary Office...						2	10	0	
Rent of Cottage for Housekeeper						4	0	0	
Carried forward									£1054 5 0

PAYMENTS—*continued.*	£	s.	d.
Brought forward	1054	5	0
Nightwatchman	12	0	2
Labour	36	11	1
Sundries	7	16	9
Decorating Hall	46	8	0
Furniture and Effects	88	7	7
Interest on Mortgage	13	10	6
Repayment of Advance from General Account 31st Mar. 1896	29	8	2
Advance to General Account 31st March, 1897	8	0	6
	£1296	7	9

CLARKE MEMORIAL FUND.

RECEIPTS.	£	s.	d.
Interest on Fixed Deposit	8	9	9
Amount of Fund on 1st April, 1896	367	18	0
	£376	7	9

	£	s.	d.
Loan to Building and Investment Fund, Sept. 1, 1896 ...	187	0	3
" " " " Oct. 12, 1896 ...	189	7	6
	£376	7	9

The above amounts to bear interest at current rates from date of loan.

AUDITED, H. O. WALKER.
C. R. WALSH.

SYDNEY, 24th April, 1897.

H. G. A. WRIGHT, *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

Messrs. P. N. Trebeck and J. T. Wilshire were appointed Scrutineers, and Mr. C. W. Darley deputed to preside at the Ballot Box.

A ballot was then taken, and the following gentlemen were elected officers and members of Council for the current year :—

Honorary President:
HIS EXCELLENCY THE RIGHT HON. HENRY ROBERT VISCOUNT HAMPDEN.

President:
HENRY DEANE, M.A., M. Inst. C.E.

Vice-Presidents:
CHARLES MOORE, F.L.S., F.Z.S. | PROF. THRELFALL, M.A.
PROF. ANDERSON STUART, M.D. | PROF. T. W. E. DAVID, B.A., F.G.S.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

G. H. KNIBBS, F.R.A.S., L.S. | J. H. MAIDEN, F.L.S.

Members of Council:

C. W. DARLEY, M. Inst. C.E.

J. GRAHAM, M.A., M.D., M.L.A.

J. W. GRIMSHAW, M. Inst. C.E.

W. M. HAMLET, F.C.S., F.I.C.

S. T. KNAGGS, M.D.

H. A. LENEHAN, F.R.A.S.

Prof. LIVERSIDGE, M.A., F.R.S.

F. H. QUAIFE, M.A., M.D.

H. C. RUSSELL, B.A., C.M.G., F.R.S.

PROF. WARREN, M. Inst. C.E., Wh.Sc.

The following gentlemen were duly elected ordinary members of the Society :—

Gould, Hon. Albert John, M.L.A., Minister of Justice, Sydney.

Portus, A. B., Assoc. M. Inst. C.E., Sydney.

The certificates of three candidates were read for the second time.

The following announcements were made :—

1. That a 'Reception' or 'at home' would be held at the Society's House, probably about the second week in July at which smoking would be permitted.
2. That the Council had decided to send, on behalf of the Society, a congratulatory address to Her Majesty The Queen, on the occasion of Her Record Reign.
3. That the following Sectional Committes had been elected for the ensuing Session and the dates fixed for their meetings :

SECTION MEETINGS.

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ENGINEERING—Wednesday (8 p.m.)	19	16	21	18	15	20	17	15
MEDICAL—Friday, (8·15 p.m,)...	21		23		17		19	

SECTIONAL COMMITTEES—SESSION 1897.

Section H.—Medical.

Chairman—John Ashburton Thompson, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*

Hon. Secretaries—J. A. Dick, B.A. *Syd.*, M.D. *Edin.*, and F. Tidswell, M.B. *Syd.*, and D.P.H., *Camb.*

Committee—W. H. Goode, M.D., D.S.M. *Dub.*, G. E. Rennie, B.A. *Syd.* M.D. *Lond.*, R. Scot Skirving, M.B., C.M. *Edin.*, G. Lane Mullins, M.A., M.D., *Dub.*

Section K.—Engineering.

Chairman—C. O. Burge, M. Inst. C.E.

Secretary and Treasurer—Percy Allan, Assoc. M. Inst. C.E., Assoc. M. Am. Soc. C.E.

Committee—C. W. Darley, M. Inst. C.E., T. R. Firth, M. Inst. C.E., T. H. Houghton, Assoc. M. Inst. C.E., W. Thow, M. Inst. C.E., H. R. Carleton, M. Inst. C.E., J. M. Smail, M. Inst. C.E.

Past Chairmen, *ex officio* Members of Committee for three years: R. R. P. Hickson, M. Inst. C.E., B. C. Simpson, M. Inst. C.E., and Prof. Warren, M. Inst. C.E., Wh. Sc.

Meetings held on the Third Wednesday in each month, at 8 p.m.

Mr. J. H. MAIDEN, F.L.S., then read his address, which was arranged under the following heads and sub-heads:

Part I. HISTORY OF THE SOCIETY DURING THE PAST YEAR:—

1. Roll of Members. 2. Obituary. 3. Papers read during 1896. 4. Sectional Meetings. 5. Reception. 6. Financial Position. 7. Society's Premises. 8. Library. 9. Exchanges. 10. Original Researches.

Part II. PROGRESS OF SCIENCE IN NEW SOUTH WALES DURING THE PAST YEAR:—

1. Physiology. 2. Zoology, including some reference to the Funafuti Expedition. 3. Geology. 4. Chemistry and Metallurgy. 5. Astronomy and Meteorology. 6. Physics. 7. Engineering and Public Works. 8. Public Health.

Part III. SOME BOTANICAL MATTERS:—

1. *Botanical Workers*—*a*. The late Baron von Mueller. *b*. Other Workers.
2. *Agriculture*—*a*. Green Manuring &c. *b*. Some work of the Department of Agriculture. *c*. Mr. W. Farrer's work with Wheats. *d*. Testing of Seeds.
3. *Forestry, &c*—*a*. Arboretum. *b*. Danger of planting inferior species. *c*. Industry of seed-collecting. *d*. Supply of good timbers not unlimited. *e*. Forest-thinning. *f*. Ringbarking. *g*. Noxious Scrub and Prickly Pear.
4. *Australian Timbers*—*a*. School of Timber Research. *b*. Wood-paving. *c*. Special uses of our Timbers.
5. *Botanical Teaching in New South Wales*—*a*. The present state of botanical instruction in the Colony. *b*. An institution for botanical research. *c*. Education of Foresters.
6. *A plea for a Botanical Survey considered in its relations to*—*a*. Pure Botany. *b*. Agriculture. *c*. Forestry. *d*. Horticulture.

A vote of thanks was passed to the retiring President, and Mr. HENRY DEANE, M.A., M. Inst. C.E., was installed as President for the ensuing year.

Mr. DEANE thanked the members for the honour conferred upon him.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of Donors are in *Italics*.)

ANNAPOLIS—U.S. Naval Institute. Proceedings, Vol. XXII., No. 4, 1896; Vol. XXIII., No. 1, 1897. *The Institute*

BIRMINGHAM—Birmingham and Midland Institute. Address by Rt. Hon. G. J. Goschen, M.P., P.C., 22 October, 1896, "International Prejudice," Report of the Council for the year 1896. "

BOSTON, Mass.—American Academy of Arts and Sciences. Proceedings, N.S. Vol. XXIII., O.S. XXXI., 1895-6. *The Academy*

BRISBANE—Colonial Secretary. Annual Report on British New Guinea from 1 July 1895 to 30 June 1896, with appendices. *The Secretary*

Department of Agriculture. A Companion for the Queensland Student of Plant Life and Botany Abridged (2nd Edition) by F. M. Bailey, F.L.S. *The Department*

Geological Survey. Bulletin No. 5, 1897. *The Survey*

BRISTOL—Bristol Naturalists' Society. Proceedings, N.S. Vol. VIII., Part i., 1895-6. *The Society*

CALCUTTA—Asiatic Society of Bengal. Journal, Vol. LXV., Part i., Nos. 1 – 4, Part ii., Nos. 2 – 4, Part iii., No. 1, 1896. Proceedings, Nos. 2 – 10, 1896. "

Geological Survey of India. Memoirs, Vols. XXV., XXVI., 1895-6. Records, Vol. XXIX., Part iv., 1896; Vol. XXX., Part i., 1897. *The Survey*

CAMBORNE—Mining Association and Institute of Cornwall. Transactions, Vol. IV., Part ii., 1895. *The Institute*

CAMBRIDGE—Cambridge Philosophical Society. Proceedings, Vol. IX., Part iv., 1896. *The Society*

CHICAGO—Field Columbian Museum. Publications 10 – 14, 1896. *The Museum*

COLOMBO—Royal Asiatic Society. Journal of the Ceylon Branch Vol. XIV., No. 47, 1896. *The Society*

DUBLIN—Royal Irish Academy. Proceedings, 3 Series, Vol. IV., No. 1, 1896. *The Academy*

EDINBURGH—Botanical Society. Transactions and Proceedings, Vol. XX., Parts ii., iii., 1894-6. *The Society*

Highland and Agricultural Society of Scotland. Transactions, Vol. IX., Fifth Series, 1897. "

Royal Physical Society. Proceedings, Vol. XIII., Part ii., 1895-6. "

Royal Scottish Geographical Society. *Scottish Geographical Magazine*, Vol. XII., Nos. 11, 12, 1896; Vol. XIII., Nos. 1 – 5, 1897. "

Scottish Microscopical Society. Proceedings, Vol. II., No. 1, Session 1895-6. "

ABSTRACT OF PROCEEDINGS, JUNE 2, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street North, on Wednesday evening, June 2nd, 1897.

The President, HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Twenty-nine members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following gentlemen were elected Members of the Society:—

Cardew, John Haydon, Assoc. M. Inst. C.E., Pitt-street.
Low, John S., George-street.
Marden, John, M.A., LL.D., Principal, Presbyterian Ladies' College, Sydney.

The certificates of two candidates were read for the first time.

THE FOLLOWING PAPERS WERE READ :—

1. "A Contribution to the Study of Oxygen at Low Pressures," by R. THRELFALL, M.A., Professor of Physics, Sydney University, and FLORENCE MARTIN.

There is known to be a pressure (about 0·7 mm. of mercury), at which oxygen becomes unstable in its volumes and pressure relations. This instability may plausibly be attributed to a change in the chemical nature of the gas, and during the period of change it is possible that ozone may be temporarily produced. An experiment was made with the object of investigating whether oxygen can form ozone simply by virtue of a reduction of pressure. A suitable indicator having been discovered, an experiment was satisfactorily carried out showing either that no ozone at all is formed, when the pressure falls to from 0·4 to 0·1 mm., or that, if such formation does occur, it is to an extent less than 0·005% of the volume of the gas employed.

2. "Determination of the Orbit Elements of Comet *f* 1896 (Perrine)," by C. J. MERFIELD, F.R.A.S.

The author explained that his deductions were based on observations made in various American and European observatories,

and also on observations made by Mr. John Tebbutt, F.R.A.S., of Windsor, New South Wales. The elements as determined by him agreed substantially with those determined by Dr. Knopf, and would not, in his opinion, be sensibly varied by further investigations.

NOTES AND EXHIBITS.

Mr. F. N. QUAIFE, M.A., M.D., gave a short descriptive account of the action of Röntgen rays, and a demonstration with his apparatus.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*)

FORT MONROE—United States Artillery School. Journal, Vol. VI., Nos. 2, 3, 1896. *The School*

GEELONG—Gordon Technical College. *'The Wombat,'* Vol. II., Nos. 2, 4, 1897. *The College*

GLASGOW—Philosophical Society of Glasgow. Proceedings, Vol. XXVII., 1895-6. *The Society*

HOPTON (Mirfield)—Yorkshire Geological and Polytechnic Society. Proceedings, N.S. Vol. x., (1837 - 1887) 1889; Vol. XI., Parts i., ii., iii., 1888-90; Vol. XII., Parts ii., iii., 1892-93; Vol. XIII., Part i., 1895. ,,

KEW—Royal Gardens. Hooker's Icones Plantarum, 4 Ser., Vol. VI., Parts i., ii., 1897. *The Director*

KINGSTON—Institute of Jamaica. Journal, Vol. II., No. 3, 1896. *The Institute*

LEEDS—Yorkshire College. Annual Report, (22nd) 1895-6. *The College*

LIVERPOOL—Literary and Philosophical Society. Proceedings, Vol. L., 1895-6. *The Society*

LONDON—Anthropological Institute of Great Britain and Ireland. Journal, Vol. XXVI., Nos. 2 - 4, 1896-7. List of Fellows, May 1, 1897. *The Institute*

Geological Society. Quarterly Journal, Vol. LII., Part iv., No. 208, 1896; Vol. LIII., Parts i., ii., Nos. 209, 210, 1897. General Index, Vols. I. - L., Parts i., ii. Geological Literature added to Library during 1896. *The Society*

Institution of Civil Engineers. Minutes of Proceedings, Vol. CXXVI., Part iv., 1895-6; Vol. CXXVII., Part i., 1896-7. Brief Subject Index, Vols. CXIX. - CXXVI. *The Institution*

Institution of Mechanical Engineers. Proceedings, Nos. 1, 2, 1896. ,,

Iron and Steel Institute. Journal, Vols. XLVII., XLVIII., 1895; Vol. L, 1896. *The Institute*

LONDON—*continued.*

Linnean Society. Journal, Botany, Vol. XXXI., No. 218; Vol. XXXII., Nos. 220-227, 1896: Zoology, Vol. XXV., Nos. 164, 165. 1896. Proceedings, Nov. 1895 to June 1896. List of Fellows, 1896-7. *The Society*

Meteorological Office Report of the Meteorological Council for the year ending 31 March, 1896. *The Office*

Mineralogical Society. *Mineralogical Magazine*, Vol. XI., No. 51, 1896. *The Society*

Pharmaceutical Society of Great Britain. Journal, Fourth Series, Vol. III., Nos. 1374-1383, 1896; Vol. IV., Nos. 1384-1407, 1897. Calendar 1897. ,,

Physical Society of London. Proceedings, Vol. XIV., Parts x.-xii., Nos. 73-75, 1896; Vol. XV., Parts i.-iii., Nos. 76-78, 1897. ,,

Royal Agricultural Society of England. Journal, Third Series, Vol. VII., Part iv., No. 28, 1896; Vol. VIII., Part i., No. 29, 1897. ,,

Royal Astronomical Society. Monthly Notices, Vol. LXI., No. 10, Supplement 1896; Vol. LXII., Nos. 1-6, 1896-7. General Index, Vol. XXX.-LII, 1869-1892. ,,

Royal Geographical Society. *The Geographical Journal*, Vol. VII., No. 4; Vol. VIII., Nos. 4, 5, 6, 1896; Vol. IX., Nos. 1-6, 1897. ,,

Royal Historical Society. Transactions, New Series, Vol. X., 1896. The Domesday of Inclosures, 1517-1518, Vols. I. and II. ,,

Royal Meteorological Society. Quarterly Journal, Vol. XXII., No. 100, 1896, Vol. XXIII., No. 101, 1897. The Meteorological Record, Vol. XVI., Nos. 61, 62, 1896. ,,

Royal Microscopical Society. Journal, Parts v., vi., Nos. 114, 115, 1896; Parts i., ii., Nos. 116, 117, 1897. ,,

Royal United Service Institution. Journal, Vol. XL., Nos. 224-226, 1896; Vol. XLI., Nos. 227-229, 1897. *The Institution*

Sanitary Institute of Great Britain. Journal, Vol. XVII., Parts iii., iv.; Vol. XVIII., Part i., 1896-7. *The Institute*

Society of Arts. Journal, Vol. XLIV., Nos. 2292-2295, 1896; Vol. XLV., Nos. 2296-2321, 1897. *The Society*

Zoological Society of London. Proceedings, Parts iii., iv., 1896; Part 1, 1897. Transactions, Vol. XIV., Parts ii., iii., 1896-7. List of the Animals, 1896. ,,

MADRAS—Madras Government Museum. Bulletin, Vol. II., No. 1, 1897. *The Museum*

MANCHESTER—Conchological Society of Great Britain and Ireland. Journal of Conchology, Vol. VIII., Nos. 9, 10, 11, 1896-7. *The Society*

Manchester Geological Society. Transactions, Vol. XXIV., Part x., 1895-6; Vol. XXV., Parts i.-vi., 1896-7. ,,

Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol. XLI., Parts i.-iii., 1896-7. List of Members and Officers, 1781-1896. ,,

MELBOURNE—Australasian Journal of Pharmacy, Vol. XI., No. 132, 1896; Vol. XII., Nos. 133–138, 1897. *The Editor*

Broken Hill Proprietary Co. Reports and Statements of Accounts for Half Year ending 30 Nov., 1896. *The Secretary*

Field Naturalists' Club of Victoria. The Victorian Naturalist, Vol. XIII., Nos. 8–11, 1896-7; Vol. XIV., Nos. 2, 3, 1897-8. *The Club*

Royal Society of Victoria. Proceedings, Vol. IX., (New Series) 1896; Vol. X., (New Series) Part i., 1897. *The Society*

NEWCASTLE-UPON-TYNE—North of England Institute of Mining and Mechanical Engineers. Transactions, Vol. XLV., Parts iv., v., 1895-6; Vol. XLVI., Parts i.–iii., 1896-7. Annual Report &c. for 1895-6. *The Institute*

NEW YORK—American Chemical Society. Journal, Vol. XVIII., Nos. 11, 12, 1896. *The Society*

American Geographical Society. Bulletin, Vol. XXVIII., No. 3, 1896. ,,

New York Microscopical Society. Journal, Vol. XII., No. 4, 1896. ,,

School of Mines, Columbia College. The School of Mines Quarterly, Nol. XVIII., No. 1, Nov. 1896. *The School*

OXFORD—Radcliffe Library Catalogue of Books added during 1896. *The Library*

PARIS—Académie des Sciences de l'Institut de France. Comptes Rendus, Tome CXXIII., Nos. 15–26, 1896; Tome CXXIV., Nos. 1, 2, 3, 1897. *The Academy*

PORT LOUIS—Royal Alfred Observatory. Annual Report of the Director for 1894. Results of Meteorological Observations during 1895. *The Director*

PHILADELPHIA—Academy of Natural Sciences. Proceedings, Part ii., 1896. *The Academy*

American Entomological Society. Transactions, Vol. XXIII., No. 3, 1896. *The Society*

PHILADELPHIA—American Philosophical Society. Proceedings, Vol. XXXV., Nos. 151, 152, 1896. *The Society*

Franklin Institute. Journal, Vol. CXLII., Nos. 851, 852, 1896; Vol. CXLIII., Nos. 853 - 855, 1897. *The Institute*

PERTH, W.A.—Department of Mines. Gold Mining Statistics for 1896. *The Department.*

SCRANTON, Pa.—The Colliery Engineer Co. The Colliery Engineer and Metal Miner, Vol. XVII., Nos. 2, 3, 4, 1896. *The Proprietors*

SYDNEY—Australian Museum. Memoir III., Parts i., ii., iii., 1896-7. Records, Vol. III., No. 1, 1897. *The Museum*

Department of Agriculture. *Agricultural Gazette of N.S.W.*, Vol. VII., Part xi. and Index, 1896; Vol. VIII., Parts i. – vi., 1897. *The Department*

Department of Public Instruction. The New South Wales Educational Gazette, Vol. VI., Nos. 7, 8, 9, 11, 12; Vol. VII., Nos. 1, 2, 1896-7. ,,

ABSTRACT OF PROCEEDINGS, JULY 7, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street North, on Wednesday evening, July 7th, 1897.

The President, HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Twenty-seven members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two candidates were read for the second time.

The President announced that the council of the University Medical Society cordially invited the members of the Royal Society to attend a lecture to be delivered on the 9th instant by Professor Krause, of the University of Berlin, on "The Remains of '*Pithecanthropus erectus*' (Dubois) recently discovered in Java."

The President called on Mr. R. H. Mathews to read his papers.

Mr. H. G. Smith raised the point of order that Mr. Mathews' papers not having been announced at the previous meeting could not, under Rule xx., be received, and that while the President might under that Rule vary the order of business, he could not allow the reading of Mr. Mathews' papers to be proceeded with.

The President asked (*a*) if Mr. Smith intimated that section 14 of Rule xx. prevented the reading of Mr. Mathews' papers, and (*b*) whether Mr. Smith was aware of any rule prescribing that notice of the reading of papers should be given at a previous meeting?

Mr. Smith having replied to (*a*) in the affirmative and (*b*) in the negative.

The President decided that as the rule in question prescribed the order of business only, and as no rule existed requiring that notice of papers should be given at the meeting previous to that at which it was intended the papers should be read, Mr. Mathews' papers were properly before the meeting, having been submitted to, and accepted by, the Council as required by Rule xxvi.

Mr. R. T. Baker stated that he desired to read a paper by himself and his colleague, Mr. H. G. Smith, the title of which he had forwarded to the Hon. Secretaries. He and his colleague were unaware that the rule relating to the submission of papers to the Council would be enforced.

The President, after pointing out that the provisions of Rule xxvi. were in the interest of the Society, decided that the paper would not be received, as it had not been submitted to the Council as required by that rule.

THE FOLLOWING PAPERS WERE READ:—

1. "The Burbung, or Initiation Ceremonies of the Murrumbidgee Tribes," by R. H. MATHEWS, L.S.

The paper described the burbung of the aboriginal tribes occupying that portion of the Murrumbidgee River which is situated between Jugiong and Hay. When it has been decided to hold a burbung for the purpose of inaugurating some of the youths into the status of manhood, the head man of one of the tribes sends out messengers to the chiefs of adjoining tribes forming the community, inviting them to participate in the ceremonies. Each of these tribes will probably have a few boys to be initiated. When the whole community has thus been gathered at the appointed place, the boys are separated from their mothers, and are taken away into the bush by the head men. During this ceremony they are taught the sacred traditions of their forefathers, their duties and responsibilities as tribesmen are inculcated, and they are instructed in the laws relating to the totemic divisions of their tribe. An important part of the ceremonies is the extraction of one of the central pair of upper incisor teeth of each youth. The feet of each boy operated on are inserted in small holes dug in the ground for the purpose, and a man stands beside him to hold him steady. The tooth extractor then places a hard wooden chisel against the tooth and gives it a smart blow with a mallet, which forces it out. Each youth is warned that if he reveals any part of the secret ceremonies to women or the uninitiated he will be punished with death.

2. "The Totemic Divisions of Australian Tribes," by R. H. Mathews, L.S.

The paper dealt chiefly with the Kamilaroi and Wiradjuri communities. These natives are divided into four sections, called Murri, Kubbi, Ippai, and Kumbo. Every man and woman in the tribe is born under one or other of these four sections. Each section is composed of a number of families bearing the names of different animals, such as kangaroo, iguana, emu, codfish, grasshopper, &c., which are called *totems*. The descent of the children is reckoned on the side of the mother only—the names of the father having no influence in the matter. The paper concluded with numerous examples of the rules of marriage, descent and relationship, established in connection with the tribal divisions above stated.

NOTES AND EXHIBITS.

Professor W. H. Warren, Wh. Sc., M. Inst. C.E., read a note on "The apparatus used for ascertaining the minute strains which occur in materials when stressed within the elastic limit." He stated that the coefficient of elasticity was usually defined as the ratio of the stress to the strain which it produces. It is necessary to know the coefficient of elasticity whenever it is desired to calculate the deformation or strain produced by a given load or stress, or to calculate the stress from an observed deformation. Such calculations are of frequent occurrence in connection with the design of structures and machinery. The deformations produced by the stresses under normal working conditions are exceedingly minute and require very delicate instruments to measure them accurately. This remark is more especially true in connection with the determination of the elastic coefficients of brittle materials such as stone, concrete, and cements, and involves measurements as small as 1-10000ths in. He then explained the theory of the measuring instruments in use in the engineering laboratory, and exhibited two very delicate appliances made by Mr. Böhme, instrument maker to the Royal Testing Laboratory in Berlin, for the Engineering Laboratory at the University of

Sydney. Both these instruments were invented by Professor Martens, of Charlottenberg. In one known as the Martens' mirror apparatus it is possible to measure deformations as small as 1-250,000ths in. with certainty. The other instrument is a roller extensometer, and measures 1-2500ths in.

H. C. RUSSELL, B.A., C.M.G., F.R.S., exhibited a series of records by a new Thermograph.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*.)

SYDNEY—Department of Mines. Records of the Geological Survey of N.S. Wales, Vol. v., Part ii., 1897. *The Department*

Engineering Association of N.S.W. Minutes of Proceedings, Vol. IX. 1893-4. *The Association*

Government Printer. The Statutes of New South Wales (Public and Private) passed during the Session of 1896. *The Government Printer*

Government Statistician. Statistical Register for 1895 and previous years (Bound copy); 1896, Part ii.; and Parts v., vi. appendix. vii., x. - xii. The Wealth and Progress of N. S. Wales, 1895-6, Vol. I. *The Government Statistician*

Institution of Surveyors, N. S. Wales. *The Surveyor*, Vol. IX., No. 12, 1896; Vol. x., Nos. 1 – 7, 1897. *The Institution*

Linnean Society of New South Wales. Proceedings. Vol. XXI., Part iii., No. 83; Part iv., No. 84, 1896. Abstract of Proceedings, March 31, April 28, May 26, June 30, July 29. *The Society*

New South Wales Medical Board. Register of Medical Practitioners for 1897. *The Board*

Observatory. Results of Rain, River, and Evaporation Observations made in New South Wales during 1895, by H. C. Russell, B.A., C.M.G., F.R.S., Government Astronomer. *The Government Astronomer*

Royal Geographical Society of Australasia. Journal, Vol. VI., Nos. 3, 4, 1896. *The Society*

University of Sydney. Calendar for the year 1897. *The University*

United Service Institution of New South Wales. Journal and Proceedings, Vol. VI., 1894; Vol. VIII., 1896. *The Institution*

TAIPING—Perak Government Gazette, Vol. IX., Nos. 25 - 30, and Index 1896; Vol. x., Nos. 1 – 14, 1897. *The Secretary*

TOKIO—Imperial University of Japan. Journal of the College of Science, Vol. IX., Part ii.; Vol. x., Part i. *The University*

WASHINGTON—Navy Department. Report of the Surgeon-General U.S. Navy 1896. *The Department*

U. S. Geological Survey. Annual Report (16th) Part i., 1894-5. *The Survey*

WELLINGTON N. Z.—Polynesian Society. Journal, Vol. v., No. 4, 1896; Vol. VI., Nos. 1, 2, 1897. *The Society*

A "reception" was held at the Royal Society's House, No. 5 Elizabeth-street North, on Wednesday, July 14th, 1897.

The hall and staircase were decorated with ferns, palms, &c., kindly supplied by Director of the Botanic Gardens.

About one hundred and fifty guests were present; there were but few exhibits, inasmuch as the principal object of the gathering was to bring members and their friends together for a kindly chat and smoke.

Professor THRELFALL delivered a short lecture on the electrolytic deposition of zinc at the Cockle Creek Sulphide Works; some plates were shown illustrating the process. Acetylene gas illumination, and the calcium carbide from which the gas is produced were shown by the Technical College. A large number of samples of etched gold and sections of nuggets showing the crystalline structure of the metal, were shown and explained by Professor LIVERSIDGE, who also exhibited a series of photographs of the etched sections.

Mr. HAMLET shewed a spectroscope for use in chemical analysis, and gave demonstrations of the spectra of the rarer or more interesting metals.

Professor HASWELL's biological exhibit illustrated some features of more than ordinary interest to biologists.

Photographs of the moon, taken at the Lick Observatory, at the Paris Observatory, and by the Bruce telescope at Harvard College, Cambridge, were shown by Mr. RUSSELL, illustrated and rare botanical works by Mr. MAIDEN, and an autograph letter of Lord Nelson announcing the victory of the battle of the Nile, by Dr. H. G. A. WRIGHT. Mr. LAWRENCE HARGRAVE exhibited one of the latest forms of his cellular kite, and explained the recent developments in aeronautical science, and the results of his later experiments. Messrs. WILLOUGHBY and LANE exhibited one of the latest phonographs and microphone, the performances of which were much appreciated.

Mr. HENRY DEANE, M.A., M. Inst. C.E., President, presided.

ABSTRACT OF PROCEEDINGS, AUGUST 4, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 4th, 1897.

The President, HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Twenty-nine members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The following gentlemen were duly elected ordinary members of the Society :—

Boucher, Arthur Sackville, Sydney

MacDonald, C. A., Sydney.

The certificates of two candidates were read for the first time.

THE FOLLOWING PAPERS WERE READ :—

1. "The Theory of the Reflecting Extensometer of Prof. Martens," by G. H. KNIBBS, F.R.A.S., Lecturer in Surveying, University of Sydney.

When the extensions measured by this instrument are large, the scale-readings require corrections which become considerable toward the end of the scale. If e denote the extension resulting from applied stress, R the scale-reading, l the width of the prism, L the distance between the mirror and scale, ω the rotation of the prism, and E the length of the contact piece, then it is shewn that

$$\frac{e}{R} = \frac{l}{2L} \cdot \frac{\cos 2\omega}{\cos \omega} \left(1 + \frac{l}{2E} \sin \omega \mp \frac{3}{4} \frac{L}{l} \tan^2 \omega\right)$$

The factor following the . may be treated as a correction of the approximate expression preceding it. Tables are supplied with the arguments R and E. It is shown that the disposition of the apparatus, indicated by Prof. Martens, eliminates errors due to longitudinal shift or small rotations of the test piece. The best disposition and proper adjustment of the apparatus is discussed.

2. "On the Saccharine and Astringent Exudations of the 'Grey Gum,' *Eucalyptus punctata*, D.C., and on a product allied to aromadendrin," by HENRY G. SMITH, F.C.S., Technological Museum, Sydney.

The principal sugar contained in some of these exudations was found to be raffinose (melitose), and is identical with that obtained from beet. Naturally formed Eucalyn was also found. The new substance "Eudesmin" was isolated from the kino in fine crystals 5-6 mm. in length. Aromadendrin is not present in this kino. A true mordant yellow dye-stuff was isolated from the leaves of the "Red Stringy Bark" of N. S. Wales, *Eucalyptus macrorhyncha*, F. v. M., and has also been investigated. The author has named it Myrticolorin. It is somewhat allied to Aromadendrin found in some Eucalyptus kinos. Myrticolorin belongs to the quercetin group of natural dyes; it can be obtained in abundance, and with a minimum of trouble, and hence its discovery may be of commercial importance.

3. "On the Essential Oil and the presence of a solid Camphor or Stearoptene therein, of the Sydney 'Peppermint,' *Eucalyptus Piperita*, Sm," by R. T. Baker, F.L.S., Assistant Curator of the Technological Museum, and Henry G. Smith, F.C.S., Technological Museum.

This is the commencement of a projected research on the oils of each species of Eucalyptus in New South Wales. The essential oil contains 24·5% of Eucalyptol, a rather low percentage compared with that of *E. globulus*, and much less than that of *E. punctata*. An important discovery concerning this oil was the presence of a stearoptene or solid camphor in the fifth fraction boiling between 265° and 270° C. It was detected first on the corks of the bottle containing the distilled oil. The stearoptene crystallises in acicular forms, and most probably belongs to the rhombic system. It has not yet been isolated chemically. This species is the Eucalyptus from which Eucalyptus oil was first obtained, viz., in 1788, by Dr. White, of the first fleet under Governor Phillip. That officer spoke highly of the therapeutic properties of the oil. The yield of oil is good, ·784 per cent. being obtained from leaves and branchlets. The oil is lævo-rotatory $(a)_D - 2{\cdot}97$.

NOTES AND EXHIBITS.

1. Mr. Lawrence Hargrave exhibited some models and made a preliminary announcement of a discovery of importance to aerial navigation. He had, he intimated, made experiments that showed—(1) That the profile of a soaring bird's wing, and pieces of metal of a somewhat similar curve, generated vortices on their concave surfaces when the chord of the curve made a negative angle with the direction of the wind. (2) That all the concave surfaces were in contact with air moving towards the mean direction of the wind. (3) That the mean pressure on the concave surface was higher than that on the convex side. (4) That the chord of the curved metal might make a negative angle of ten degrees with the direction of the wind, and still have a higher pressure on the concave side than on the convex. The direct inference was, he said, that gravity could be entirely counteracted by a volume of disturbed air moving in a horizontal direction, and that flying machines of great weight could be held suspended in a horizontal wind, and rise vertically without the expenditure of any contained motor force.

2. Mr. R. T. Baker exhibited specimens of "Oliverian" oil obtained from the bark of *Cinnamomum Oliveri*, Bail.—a species of *Cinnamomum* he has recently recorded as new for this colony, and which has now been shown to extend over a large area of the coastal district from the Tweed River to the Illawarra. The percentage of oil from the bark was nearly 1 %, an excellent result. It is a light golden-coloured oil, with a specific gravity of 1·00105, highly aromatic and persistent, contains *cinnamic aldehyde*, *eugenol*, together with other constituents. Its commercial possibilities are favorable. Botanical specimens of the species and the fungus *Melampsora nesodaphnes* were also shown.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*).

Des Moines—Iowa Geological Survey. Annual Report, 1895, Vol. v. *The Survey*

FLORENCE—Società Italiana di Antropologia, Etnologia &c. Achivio, Vol. XXVI., Fasc. 2, 3, 1896. Classification Decimale per Biblioteche, Schedarii &c. *The Society*

FORT MONROE, Va.—U. S. Artillery School. Journal, Vol. VII., Nos. 1, 2, 1897. *The School*

LONDON—Mineralogical Society. *Mineralogical Magazine*, Vol. XI., No. 52, 1897. *The Society*

MARSEILLE—Faculté des Sciences de Marseille. Annales, Tome IV., Fasc. 4; Tome V., Fasc. 1, 2, 3; Tome VI., Fasc 4, 5, 6; Tome VIII., Fasc. 1, 2, 3, 4. *The Faculty*

MINNEAPOLIS—Geological and Natural History Survey of Minnesota. Second Report of the State Zoologist, Zoological Series II., November 1895. *The Survey*

Minnesota Academy of Natural Sciences. Bulletin, Vol. IV., Part i., No. 1, 1892-94. *The Academy*

NANTES—Société des Sciences Naturelles de l'Ouest de la France. Bulletin, Tome V., Trimestre 2–4, 1895; Tome VI., Trimestre 1–3, 1896. *The Society*

NAPLES—Società Reale di Napoli. Rendiconto dell' Accademia delle Scienze Fisiche e Matematiche, Ser. 3, Vol. II., Fasc. 8–12, 1896; Ser. 3, Vol. III., Fasc. 2–4, 1897. *The Society*

NEW YORK—American Chemical Society. Journal, Vol. XIX., Nos. 1–6, 1897. ,,

American Museum of Natural History. Bulletin, Vol. VIII., 1896. *The Museum*

New York Academy of Sciences. Annals, Vol. IX., Nos. 4, 5, 1897. Transactions, Vol. XV., 1895-96. *The Academy*

New York Microscopical Society. Journal, Vol. XIII., No. 1, 1897. *The Society*

PARIS—Académie des Sciences de l'Institut de France. Comptes Rendus, Tome CXXIV., Nos. 4–26; Tome CXXV., No. 1, 1897. *The Academy*

Ecole d' Anthropologie de Paris. Revue Mensuelle, Année VI., Nos. 10–12, 1896; Année, VII., Nos. 1–6, 1897. *The Director*

Ecole Polytechnique. Journal, Serie II., Cahier 1, 1895. ,,

La Feuille des Jeunes Naturalistes. Revue Mensuelle d' Histoire Naturelle, Ser. 3, Année XXVII., Nos. 313–321, 1896-7. Catalogue de la Bibliothèque, Fasc. 18–21, 1896-7. *The Editor*

Ministère de l'Instruction Publique. Bibliographie des Travaux Scientifiques (Sciences mathematiques, physiques et naturelles) publiès par les Sociétés savantes de la France, Tome I., Liv. 1, 1895. *The Minister*

Ministère des Travaux Publics. Statistique de l'Industrie Minérale et des appareils à vapeur en France et en Algérie pour l'année 1895. ,,

Muséum d'Histoire Naturelle. Bulletin, Nos. 1–7, 1896. *The Museum*

Observatoire de Paris. Rapport Annuel pour l'année 1896. *The Observatory*

Revue de l'Aeronautique. Année VI., Liv. 4, 1893; Année VII., 1894; Année VIII., Liv. 1, 1895. *The Director*

ABSTRACT OF PROCEEDINGS, SEPTEMBER 1, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street, North, on Wednesday evening, Septemper 1st, 1897.

Mr. CHARLES MOORE, F.L.S., Vice-President, in the Chair.

Twenty-eight members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two candidates were read for the second time, and of two for the first time.

THE FOLLOWING PAPERS WERE READ :

1. "Outburst of Springs in time of Drought," by W. E. ABBOTT.

After briefly noticing the principal explanations which have been put forward, the author indicated his own opinion, based upon frequent observations, extending over a large number of years, of the phenomenon. The theory advanced was that the exhaustion by capillary action, and rapid evaporation, occurring through the characteristic dryness of the air in prolonged drought, of the water in underlying water-bearing strata, prevents it ever reaching the terminal ends of the strata, at which discharge on to the surface takes place. When the condition of dryness of the air passes away, the evaporation diminishes and the exhaustion indicated does not continue, hence the reappearance of water on the surface. Variations of barometric pressure are, in themselves, not a cause.

2. "The possibility of Soaring in Horizontal Wind," by LAWRENCE HARGRAVE.

This paper deals with some experiments connected with those perplexing observations that have received the name of "Aspiration." Many careful observers have noted birds of various kinds moving through the air and ascending when no movement could be detected in their wings. This has often been seen where the conditions were such that no upward trend in the mean direction of the wind could possibly exist. It is therefore correct to say

that birds of certain form *ascend* when there is a horizontal wind, whereas according to their weight and the velocity of the wind they ought to *descend*. The act of ascending is termed "Aspiration." Numerous sections showing the profile of wings have been published from time to time, and Mr. O. Chanute, C.E., of Chicago, U.S.A., has pointed out the distinction between the soaring and flying wing profile. The writer, whilst experimenting with metal bent similarly to a soaring wing, has discovered—1. That the profiles of a soaring bird's wing and pieces of metal of a somewhat similar curve, are such that they generate vortices on their concave surfaces when the chord of the curve makes a negative angle with the direction of the wind. 2. All the concave surfaces are in contact with air that is moving *towards* the mean direction of the wind. 3. That the mean pressure on the concave surface is higher than that on the convex side. 4. That the chord of the curved metal may make a negative angle of ten degrees with the direction of the wind, and still have a higher pressure on the concave side than on the convex. The practical effect of these discoveries is that birds, and therefore flying machines of suitable form may rest on an air current, generated by their shape, that is ascending and moving towards the mean direction of the wind; and that the aggregate normal pressure exerted by the wind on a soaring wing is not upwards and inclined to leeward, but upwards and inclined more than 10° to windward.

3. "On 'Grey Gum,' *Eucalyptus punctata*, DC., particularly in regard to its essential oil," by R. T. Baker, F.L.S., Assistant Curator, and Henry G. Smith, F.C.S., Technological Museum, Sydney.

The paper deals with several forms of this species of Eucalyptus, which extends over the greater part of the coastal districts and also over the Dividing Range. In addition to the economic and systematic notes the histology of the leaf was also given and illustrated. The essential oil, obtained by the authors was shown to be of excellent quality, whilst the yield was also very good. It contained (unrectified) 46 to 64% of Eucalyptol and a

fraction from a first class sample, representing 60% of the crude oil, gave 79% Eucalyptol: the average the whole oil distilled (nine samples) was 62% of this principle. The authors pointed out that the results of their research on this oil were of importance to the commercial world, because of the very high character of the oil, which does not appear to have been previously obtained.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of Donors are in *Italics*.)

AACHEN—Meteorologische Station I. Ordnung. Ergebnisse der 1896. *The Director*

ADELAIDE—Royal Society of South Australia. Transactions, Vol. XXI., Part i., 1897. *The Society*

BALTIMORE—Johns Hopkins University. Circulars, Vol. XVI., Nos. 127, 129, 130, 131, 1896-97. American Chemical Journal, Vol. XVIII., Nos. 6 – 10, 1896; Vol. XIX., Nos. 1, 2, 1897. American Journal of Philology, Vol. XVII., Nos. 1 – 3, 1896. American Journal of Mathematics, Vol. XVIII., Nos. 3, 4, 1896; Vol. XIX., Nos. 1, 2, 1897. Historical and Political Studies, Vol. XIV., Nos. 6 – 12, 1896; Vol. XV., Nos. 1, 2, 1897. *The University*

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Société de Biologie. Comptes Rendus, Nos. 1 – 22, 26, 28 – 32, 1897. ,,

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Société Entomologique de France. Annales, Vols. LXIII., LXIV., 1894-5. ,,

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Société Géologique de France. Bulletin, Vol. XXIII., Nos. 4 – 10, 1895; Vol. XXIV., Nos. 1 – 7, 1896. Compte Rendu des Séances, 3 Ser., Tomes XXIII., XXIV., 1895-6. ,,

Société de Spéléologie. Tome II., Nos. 6 – 8, 1896. ,,

Société Zoologique de France. Bulletin, Tome XX., 1895. Mémoires, Tome VIII., 1895. ,,

ABSTRACT OF PROCEEDINGS, OCTOBER 6, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street North, on Wednesday evening, October 6th, 1897.

The President, HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Twenty-seven members were present.

The minutes of the preceding meeting were read and confirmed.

The following gentlemen were duly elected ordinary Members of the Society:—

Callender, James Ormiston, Sydney.

Fell, David, Sydney.

The certificates of two candidates were read for the second time, and of one for the first time.

The President announced that the Council had set apart the front room on the first floor as a 'Smoke Room' for the use of members.

The following letter was read :—

Government House, Sydney, 17th Sept., 1897.

Sir,—I have the honour to inform you that His Excellency the Governor has been advised by the Secretary of State for the Colonies that Her Majesty has received an Address from the Royal Society of New South Wales, on the occasion of the completion of the Sixtieth Year of Her Reign. 2. I am to add that Her Majesty has commanded that Her cordial thanks are to be conveyed to the members of your Society for their loyal and dutiful Address, which she gratefully appreciates.

I have, etc.,

A. F. H. FERGUSON, Captain,

Private Secretary.

The President of the Royal Society of N. S. Wales,

Elizabeth-street, Sydney.

THE FOLLOWING PAPERS AND NOTES WERE READ:—

1. "Note on mutilations practised by Australian Aborigines," by T. L. BANCROFT, M.B. *Edin.*

Anyone having read through Professor Anderson Stuart's paper "The "Mika" or "Kulpi" operation of the Australian Aborigines,"

(read before the Society on June 3rd, 1896), would, in all probability, have gathered "That the operation did not appreciably limit the population; its object was doubtful, and it could scarcely be regarded as practised from a Malthusian standpoint. The "kulpi" took precedence over those who were not "kulpi" and were privileged to appear in the nude state before the women, and further were intrusted with matters of moment to the tribe." Now having had the opportunity, during 1892, of travelling over the watershed of the Cooper, Diamantina, Georgina, and Mulligan Rivers (over the whole of which territory the "kulpi" obtains), and having taken some interest in the mutilations practised by the aborigines, I hope it will not be considered presumptuous of me to state to the Society what conclusions I have formed, although these differ so greatly from what might be inferred from Professor Stuart's paper. The mutilation of the sexual organs of both sexes is apparently practised to limit population; it is undoubtedly severe, but infinitely better than that of castration, for the men, at least, do not lose their virility. I cannot agree with those, who regard the practice as barbarous, and believe that it might with advantage be imitated by the more civilized races of mankind. In each camp that I visited, there were one man and two, or sometimes three, women upon whom no operation had been performed; they appeared to be the chief and his queens, and were evidently regarded with very great respect by the mutilated members. Those, who have considered "that the "kulpi" operation could not be regarded as practised to limit population on account of scarcity of food," have probably done so after having visited the country in a good season, when there was abundance of food, and in ignorance of the fact, that dry seasons, during which great scarcity of food prevails, follow upon good seasons. In 1892 there had been a drought for two years, and had it not been that the camps of blacks contained few members, I am afraid the whole race would have become extinct from starvation; few as they were it was as much as they could do to exist. It appears that sexual mutilations are practised in those parts of Australia

alone in which the food supply is precarious. In camps of blacks removed a few miles from towns all the members, men, women, and children are always in the nude state. The "kulpi" are very reluctant to shew their mutilation, feeling much ashamed of themselves and their inferiority to men in whom the parts are normal. During micturition they squat down, avoiding as far as possible being seen by the white man in the act. In the cases in which I was permitted to view the parts operated upon, the urethra had been slit open from the meatus to the scrotum, and there was in no instance any prepuce, so that I supposed circumcision had also been performed, although the natives themselves did not lead me to understand that such was so. Those, who have had much experience of the blacks, will bear with me in stating that it is extremely difficult to get information of a reliable character from them ; they either do not understand the question thoroughly, or conclude that you are in some way making ridicule of them, and purposely deceive you ; they are always reluctant, even to white men who have learned to speak their language, to impart information concerning their private affairs. So far as I was able to ascertain from the civilized blacks at the stations, as to what had been done to the women to prevent their child bearing, it would appear that it is during infancy that an operation is performed upon them by introducing a rough grass stalk into the uterus, twisting this round and round until it has firmly grasped the walls, when the organ is dragged down, but whether the uterus is then cut away or only the grass stalk forcibly pulled out, carrying with it the mucous lining, was not known to them ; all they could further tell me was, that the operation was done by a particular man of the tribe and caused great loss of blood.

DISCUSSION.

Mr. R. H. Mathews said that as far as his investigations in reference to the "mika" operation had gone, he was of opinion that it was not designed to prevent procreation, since there are well authenticated cases of mutilated men being the fathers of families. The custom was in force in districts where food was

comparatively plentiful, and was not found in many parts of the continent which were more or less sterile. Infanticide, also practised by these tribes, was an effective method of controlling the population. As regarded the mutilation of females, he thought that from the ignorance of the aborigines about castration, it was unlikely that they would understand the more difficult operation upon the female. In some tribes, however, the vagina is lacerated. The practice of circumcision, and other mutilations of the genitals, probably had their origin in ancient rites of an initiatory or religious character, and are still carried on in accordance with long established custom.

2. "On a Cordierite-bearing Rock from Broken Hill," by J. Collett Moulden, Assoc. R.S.M., F.G.S. (Communicated by E. F. Pittman, Assoc. R.S.M.)

This is believed to be the first time that cordierite has been recorded in Australia. It has a somewhat extensive development in the metamorphic rocks of Broken Hill, and is described in detail from two parallel exposures of granulitic rock about half a mile S.E. by E. from Block 14 Mine. The cordierite occurs in large crystals and also in grains through the granulite. A description of the physical and optical properties of the mineral is given, and reference made to the other constituents of the rock, which it is decided to name *cordierite-granulite*. Mention is also made of the occurrence of cordierite as a nucleus to the felspar "augen" of an augen-gneiss three miles and a half east of Block 14 Mine.

3. "Note on the occurrence of a nickeliferous opal near Tamworth, N. S. Wales," by D. A. Porter.

Several years ago, a specimen of opal brought to the writer, was said to have been obtained in the "Never-never" ranges on the head waters of Attunga Creek, and not far distant from Mount Gulligal, Parish of Attunga, County of Inglis. Some little while ago, being in the vicinity, Mr. Porter found the locality and secured a few small specimens, one of which he forwarded to be exhibited before this Society. The mineral occurs in the form of small veins in serpentine rock, and is accompanied by

veins of a pinkish or salmon-coloured chalcedony, exhibiting a porcelain-like texture and broken surfaces. The veins of opal vary from $\frac{1}{16}$″ to $\frac{1}{2}$″ or more in thickness, and in colour from the palest to the deepest apple-green. A fair proportion of the mineral is translucent, but much of it is clouded and opaque. The powdered mineral—selected fragments of the deepest colour—gave a strong nickel reaction. The veins of opal and associated chalcedonic veins have as yet been opened only for about eighteen inches from the surface.

Some observations were made by Professor Liversidge.

4. "Icebergs in the Southern Ocean, No. 2," by H. C. Russell, B.A., C.M.G., F.R.S.

This paper was prepared as a continuation of one read before the Royal Society, Sept. 4, 1895. It deals with the reports of icebergs seen since the end of July 1895. One hundred and two ships have reported ice in the interval, nearly the whole of the ice so reported, was within the area enclosed between 40° and 86° east longitude and 40° to 62° south latitude; very few reports of ice outside that area have been received. It was shewn that the Thermopylæ steamed for 1,000 miles amongst icebergs, and that the ocean was clear one hundred to one hundred and twenty miles north of this track. Some idea of the number of icebergs may be gathered from the fact that the officers of one ship counted 977 bergs, and those of another ship 4,500. This and the previous paper cover a period of six years, and it was shewn that at times the icebergs come into, or leave the track of vessels in a few days; three instances in which there had been sudden disappearances were shown to be coincident in point of time with the advent in Australia and the ocean between the Cape and Australia of strong north to north-west winds.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*.)

Albany—New York State Library. Annual Report (108th) of the Regents of the University of the State of New York, Vols. I. and II., 1894; Annual Reports (2nd and 3rd) of the Examination Department 1894-5. *The Regents*

BATAVIA—Directeur de l'Instruction Publique, des Cultes et de l'Industrie aux Indes Néerlandaises. Description géologique de Java et Madoura par Dr. R. D. M. Verbeek et R. Fennema, Tome I., II., and Carte géologique et Feuilles Annexes 1896. *The Director*

Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indië. Natuurkundig Tijdschrift voor Nederlandsch-Indië, Deel LVI., Negende Serie, Deel V., 1897. Boekwerken, 1896. *The Society*

BERGEN—Bergens Museum. An account of the Crustacea of Norway by G. O. Sars, Vol. I., Isopoda, Parts iii., iv., 1897; Vol. II., Isopoda, Parts i., ii., 1896. Bergens Museums Aarbog for 1896. *The Museum*

BERKELEY—University of California. Department of Geology, Bulletin, Vol. I., Nos. 12, 13, 14, and Index 1895-96; Vol. II., Nos. 1, 2, 3, 1896 Library of the University of California, Contents-Index, Vol. I., 1889-90. Register 1895-96. Biennial Report of the President 1894-96. Annual Report of the Board of State Viticultural Commissioners for 1887, Appendix E. to Report for 1891-92; Appendix A. to Report for 1893. Agricultural Experiment Station—Report of the Viticultural Work during the Seasons 1887 – 93. Report of Work of the Agricultural Experiment Stations for 1894-95 Bulletins Nos. 110, 111, 113, 114, 115, 1896. The Vine in Southern California, 1892. The Vineyards of Southern California 1893. The Vineyards in Alameda County 1893. The White Wine Problem 1895. On the Correlation of Elementary Studies by Prof. G. H. Howison 1896, Special University Edition of the Berkeley Daily Advocate, 31 October, 1896. *The University*

BERLIN—Gesellschaft für Erdkunde. Verhandlungen, Band XXIII., Nos. 6 – 10, 1896; Band XXIV., Nos. 1, 2, 1897. Zeitschrift, Band XXXI., Nos. 3 – 6, 1896. *The Society*

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BERNE—Département de l'Interieur de la Confédération Suisse (Section des Travaux Publics) Graphische Darstellung der Lufttemperaturen und der Niederschlagshöhen, Bl. I., II., III., 1895. Graphische Darstellung des schweizerischen hydrometrischen Beobachtungen, Bl. I. – XVI., 1896. *The Department*

BOLOGNA—R. Accademia delle Scienze dell' Istituto di Bologna. Memorie, Serie 5, Tomo IV., 1894. *The Academy*

BONN—Naturhistorischer Verein der preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück. Verhandlungen, Jahrgang LII., Hälfte 2, 1895; Jahrgang LIII., Hälfte 1, 1896. *The Society*

Niederrheinischen Gesellschaft für Natur-und Heilkunde. Sitzungsberichte, Heft 2, 1895; Heft 1, 1896. ,,

BOSTON, Mass.—American Academy of Arts and Sciences. Proceedings, Vol. XXXII., Nos. 1 – 14, 1896-97. *The Academy*

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BREMEN—Meteorologische Observatorium. Ergebnisse der Niederschlags-Beobachtungen im Jahre 1894. Ergebnisse der Meteorologischen, Beobachtungen, Jahrgang, III., 1892; Jahrgang VII., 1896. *The Director*

BRISBANE—Colonial Secretary. Annual Reports (6) on British New Guinea from 1 July 1889 to 30 June 1895. *The Colonial Secretary*

BUDAPEST—Hungarian National Museum (Zoological Department). Természetrajzi Füzetek, Vol. XX., Parts i., ii., 1897. *The Museum*

BUENOS AIRES—Direccion General de Correos y Telegrafos. Jurisprudencia Postal y Telegráfica, Vol. VIII, 1895. *The Director General*

Instituto Geografico Argentino. Boletin, Tome XVII., Nos. 7 – 12, 1896. *The Institute*

CAEN—Académie Nationale des Sciences, Arts et Belles-Lettres. Mémoires, 1895, *The Academy*

CALCUTTA—Geological Survey of India. Records, Vol. XXX, Part ii., 1897. *The Survey*

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CAPE TOWN—South African Philosophical Society. Transactions, Vol. VII., Part ii., 1896. *The Society*

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CASSELL—Vereins für Naturkunde. Abhandlungen u. Bericht, XLI., 1895-6. *The Society*

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COPENHAGEN—Société Royale des Antiquaires du Nord. Mémoires, Nouvelle Série, 1896. ,,

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DRESDEN—K. Sächs. Statistische Bureau. Zeitschift, Band XLII., Heft 1–4, Jahrgang 1896. *The Bureau*

Vereins für Erdkunde. Jahresbericht, XXV., 1896. *The Society*

EDINBURGH—Royal Scottish Geographical Society. *Scottish Geographical Magazine*, Vol. XIII., Nos. 6, 7, 1897. ,,

FLORENCE—Società Italiana di Antropologia, Etnologia, &c. Archivio, Vol. XXVII., Fasc. 1, 1897. ,,

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HAARLEM—Koloniaal Museum te Haarlem. Bulletin, March 1896; June, July 1897. Handleiding . . door H. Veen. Tijdschrift der Nederlandsche Maatschappij ter bevordering van Nijverheid Nieuwe Reeks, Deel I., Feb.–July 1897. *The Museum*

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HAMBURG—Deutsche Seewarte. Archiv der Deutschen Seewarte, Jahrgang XIX., 1896. Deutsche Ueberseeische Meteorologische Beobachtungen, Heft VII., 1890-93. Ergebnisse der Meteorologischen Beobachtungen, Jahrgang XVIII., 1895. Ergebnisse der Meteorologischen Beobachtungen für das Lustrum 1891–1895. Jahres-bericht über die Thätigkeit XVIII., für das Jahr 1895. *The Observatory*

Geographische Gesellschaft in Hamburg. Mittheilungen, Band XIII., 1897. *The Society*

ABSTRACT OF PROCEEDINGS, NOVEMBER 3, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street, North, on Wednesday evening, November 3rd, 1897.

The President, HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Thirty-three members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following gentlemen were duly elected ordinary Members of the Society:—

Ronaldson, James Henry ; Darlinghurst.

Russell, Harry Ambrose, B.A.; Ashfield.

The certificate of one candidate was read for the second time.

THE FOLLOWING PAPERS AND NOTES WERE READ:—

1. "The effect of temperature on the Tensile and Compressive properties of Copper," by Prof. WARREN, M. Inst. C.E., and Mr. S. H. BARRACLOUGH, M.M.E.

This investigation was carried out on some fifty copper test pieces supplied by Mr. W. Thow, M. Inst. C.E., Chief Mechanical Engineer to the N.S. Wales Government Railways. The test pieces were immersed in a very heavy cylinder oil, contained in a cast iron bath, which was provided with a loosely fitting stuffing box at each end to allow of the necessary connection being made with the test piece. The temperature range attained was from 25° F. to 535° F., the temperatures being measured by certified mercurial thermometers. The extensions and compressions were measured by Kennedy's lever extensometer and Martens' mirror apparatus. The chief conclusions arrived at were :—(*a*) The relation between the ultimate tensile strength and the temperature may be very closely represented by the equation $f = 32{,}000 - 21\,t$, where "f" is the tensile strength expressed in pounds per square inch, and t is the temperature expressed in degrees F. (*b*) Temperature does

not affect the elongation or contraction of area in any regular manner: and at any one temperature the variation in these two quantities is so variable for different specimens that no particular percentage could be included in a specification for the supply of copper. (*c*) The elastic limit in tension occurs at about 5,400 lbs. per square inch: this limit probably decreases rapidly with increase of temperature, but the differences in the behaviour of individual specimens are so great as to prevent the determination of the relationship between the two quantities. (*d*) The elastic limit in compression occurs at about 3,200 lbs. per square inch: it decreases with increase of temperature, the relationship between the two being more regular than in the tensile tests. (*e*) The rate of permanent extension and compression increases rapidly with increase of temperature.

2. "Aurora Australis," by H. C. Russell, B.A., C.M.G., F.R.S.

This paper contained a list of auroral displays in the southern hemisphere during 1897, also a detailed account of one which was observed by the captain and officers of the R.M.S. "Aorangi," on April 20th, 1897, when the ship was in Long. 96° W. and Lat. 47½° S. It was first seen as a diffused white glow over the southern horizon at 6·30 p.m.; shortly after this, white rays shot out from the white glow in all directions, many of them along the eastern horizon, and it was observed that these rays rose above the horizon and drifted across the sky to the west. Closer inspection revealed the fact, that every ray and patch of light, including the zenith ring that was seen later was drifting to the west. Every part of the auroral light, rays and patches was white up to 8·30 p.m., then suddenly the white gave way to colours, and every ray and fragment of light was tinted with brilliant shades of red, green, and yellow. Then an arch appeared above the southern horizon, brilliant with yellow and green in its central parts and roseate hues near the horizon. As this arch rose higher another followed it until at last six of these beautifully coloured arches spanned the sky from the southern horizon to within 60°

of the northern horizon. These again broke up into fragments in all parts of the sky, and electric flashes darted from one to the other, making with all the colours a magnificent display, all of which was moving to the west like a panorama, with varying intensity the aurora lasted until 9·30 p.m.

3. "The Basalts of Bathurst and the neighbouring districts," by W. J. Clunies Ross, B.Sc., Lond. F.G.S. (Communicated by J. H. Maiden, F.L.S.)

In this paper the character of the basalt occurring in the neighbourhood of Bathurst, on the Bald Hills, and other hills in the vicinity, is described. Specimens from various localities have been obtained, microscopic sections cut from them, and chemical analysis made. It has been found that there are some differences in the microscopic structure of the rocks from hills close together, but the chemical analysis shews them to be all closely related. The silica was found to be about 47 per cent., but reached 50 per cent. on Mt. Pleasant. The alumina, oxide of iron, lime, and magnesia were also determined. For comparison with the Bathurst basalt, which no doubt originally flowed as a lava from some centre of volcanic activity, and in order to trace the source from which it came, specimens were examined from all the places within forty miles of Bathurst, where basalts are known to occur. There are three such localities—(1) Blayney and Carcoar, (2) Orange district, (3) Oberon and Swatchfield. The rocks from Blayney and Orange were found to differ considerably from the Bathurst basalt, the Orange rock yielding 55 per cent. of silica. The character of the country also renders it unlikely that a lava would flow from either district to Bathurst. Oberon and Swatchfield, on the other hand, are on the Macquarie River system, upon which river Bathurst is situated. It was, therefore, interesting to find that basalt from Oberon agreed more closely in chemical composition with the Bathurst rocks than either of the others did, and was of the same type microscopically. The late Mr. C. S. Wilkinson was of opinion that the Bathurst basalt

came from Swatchfield, and this view is confirmed by the investigations of the writer of the paper. A basalt, similar to that of Bathurst, has also been found lower down the Macquarie, at Rock Forest.

NOTES AND EXHIBITS.

Mr. HEDLEY, who had just returned from New Caledonia, exhibited a few articles of ethnological interest which he had collected there. The Kanakas use there an implement called by the French a "doigtière," and by the Owbatche tribe the "hooeng," which is almost, if not quite, peculiar to the island. It consists of a cord about six inches long, with a ball at one end and a loop at the other. The loop is fitted to the forefinger of the warrior, who holds the spear with the remaining fingers, the palm upwards, and the ball end is passed round the spear and caught under the cord. Whereas the womerah of Australia is used to increase the velocity of the spear, the "doigtière" merely imparts a rotatory motion to the projectile, adding little to the speed but much to the aim.

Another instrument of offensive warfare is the sling, in the use of which the New Caledonians are most expert. Their ammunition consists of ovate stones, an inch and a half long, ground to a point at either end. These are carried in a woven pouch tied by a belt round the waist, the belt itself being a knitted sack capable of holding additional ammunition when necessary. Any European who has crossed mountain and jungle armed with revolver, knife, and cartridge belt, would acknowledge that the kanaka's mode of carrying his sling stones excelled ours of carrying cartridges in rough and broken country.

The method of handling both sling and "doigtière" was demonstrated.

The following donations were laid upon the table and acknowledged :—

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(The Names of the Donors are in *Italics*.)

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ABSTRACT OF PROCEEDINGS, DECEMBER 1, 1897.

The General Monthly Meeting of the Society was held at the Society's House, No. 5, Elizabeth-street North, on Wednesday evening, December 1st, 1897.

The President, HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Thirty-four members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following gentleman was duly elected an ordinary member of the Society :—

Webb, Frederick William, C.M.G., J.P., Clerk of the Legislative Assembly, Sydney.

Messrs. C. R. WALSH and DAVID FELL were appointed Auditors for the current year.

The President announced that a Conversazione would be held at the University on the 14th January 1898, and that members not in arrears with their subscriptions would receive cards of invitation.

A letter was read from the Mueller National Memorial Committee, inviting subscriptions.

THE FOLLOWING PAPERS AND NOTES WERE READ :—

1. "On the steady flow of water in uniform pipes and channels," by G. H. KNIBBS, F.R.A.S., Lecturer in Surveying, University of Sydney.

The paper dealt generally with the nature of the two régimes under which flow takes place, and of the instability of the rectilinear flow in pipes. In the first or linear régime, the velocity formula for a pipe of elliptical cross-section is,

$$U = \frac{g}{8}\frac{\rho}{\eta}\frac{H}{L}\frac{B^2C^2}{\frac{1}{2}(B^2+C^2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

in which g is the acceleration of gravity, ρ the density of the fluid, by means of a column of which the height H—the difference of the pressures, at two sections of a horizontal tube, the distance

L apart—are measured, B and C are the semiaxes of the ellipse, and η is the viscosity of the fluid. Tables of the values of viscosity and fluidity were given.

It was pointed out that Prof. Reynolds had, in respect to the witnessing of the two régimes in glass tubes, been anticipated in 1853 by Hagen, who recognised exactly the influence, on the velocity of translation parallel to the axis of the pipe, of the internal agitation that succeeds the condition of minimum shear—the first régime. Reynolds' factors, in his empirical and supposed general formula, were shewn to lead to the same result as the formula above given, which is based on rational mechanics.

That the index 2 in the expression $U^2 \propto I$, the latter denoting H/L, was too great, was proved to have been recognised by DuBuat Woltmann and Eytelwein at the end of last and beginning of this century, as also by St. Venant, Hagen, and Gauckler, in 1850, 1853, and 1867, so that Reynolds' direct statement in 1883, that no one had recognised the law $U^n \propto I$, was not supported by fact. Not only was that so, but St. Venant in 1850 had employed the method of logarithmic coördinates, as also Hagen in 1853 and 1867. Prof. Reynolds' supposed general empirical formula given in the Phil. Trans. in 1883—which might be written

$$M f^2 R^3 I = (N f R U)^n \ldots\ldots\ldots\ldots (7)$$

M and N being constants for all classes of pipe, f the relative fluidity, and R and U the same meanings as usually—was shewn not to be experimentally indicated for the second régime, while it it might be replaced by the simpler rational formula, already given, for the first.

It was shewn that $U^n \propto f^q$, and also that $U^n \propto R^m$, but that q and m were not respectively $2-n$ and $3-n$, as required by Reynolds' formula. For these indices the following were proposed as sufficiently interpreting experimental data, viz.

$$q = \frac{x}{a\,(n-1)^z + x} \ldots\ldots\ldots\ldots\ldots (35)$$

in which $a = 1$, $x = 0{\cdot}18$, and $z = 2$, and

$$m = 1 + \frac{x}{x + R^z} \quad \ldots\ldots\ldots\ldots\ldots\ldots(37)$$

in which x = about 0·77 and $z = \frac{1}{2}$. In order that m however, should be entirely general it is necessary to give it some such form as

$$m = 1 + \frac{x}{x + b\,(n-1)^y\,R^z} \quad \ldots\ldots\ldots\ldots\ldots\ldots(37a)$$

so that it may be always 2 when $n = 1$ exactly. Experiment may therefore shew that it is always a function of the roughness.

The general formula proposed is, for the mean velocity of the flow of water in a circular pipe under either régime, at any temperature, and with any radius, 'slope,' or material of pipe,

$$U = \left[\left(\frac{g\rho}{8\eta_o}\right)^{1+p} f^q\, R^m\, I\right]^{\frac{1}{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(41)$$

in which n depends upon the roughness of the channel, and can be set forth in categories, p and q are functions of the roughness expressed in n, and m is a function of the absolute dimensions of the pipe, sensibly, though perhaps not wholly independent of the roughness, but must be always taken as 2 when $n = 1$. The value of p is 0·256 $(n - 1)$; or more generally $p = c\,(n-1)^w$. The defect of the Chezy, of the Darcy and Bazin, of the Ganguillet and Kutter, and of the Reynolds formulas, is that each systematically departs from what may be called the general trend or indication of the experiments upon which they are founded.

The hydraulic radius is shewn, even in the case of the ellipse, not to be an absolutely satisfactory function in regard to eliminating the influence of the form of a pipe or channel. What may be called the corrected hydraulic radius, is for the ellipse,

$$R_o = R\,(1 - \tfrac{1}{4}\,\epsilon^2 + \tfrac{5}{16}\,\epsilon^4 - \tfrac{7}{32}\,\epsilon^6 \ldots) \quad \ldots\ldots\ldots\ldots(47)$$

in which

$$\epsilon = (B - C)/(B + C).$$

The general method of analysis of the flow in open channels was indicated, and the fact noticed that in this case n seems to increase with I. It is also noted that m increases with R which is clearly shewn in Series 23 of Bazin's experiments.

In regard to the type of the general formula, the author believes that it will be found capable of being so adjusted, by giving proper values to its constants, as to represent not only all old, but also new observations of flow in pipes, that is to say, it satisfies the requirements of a *general* formula; and that probably an analogous analysis will yield an equally general formula for flow in channels. The paper was accompanied by tables for the purpose of facilitating computations.

2. "Experimental investigation of the flow of water in uniform channels," by S. H. BARRACLOUGH, B.E., M.M.E., and T. P. STRICKLAND, B.E.

This investigation was suggested by Mr. G. H. Knibbs, as a result of his examination of the work of previous investigators, an account of which appears above, and the experiments were carried out in the laboratory of the P. N. Russell Engineering School, with the cordial co-operation of Prof. Warren. Its main object was to fill in an hiatus in the existing series of experimental results, by determining the effect of change of slope upon the velocity of flow, when the slope is varied over a wide range. Since in making these experiments it was impossible to maintain the temperature and hydraulic radius absolutely constant, two subsidiary enquiries had to be undertaken to determine approximately the effect which these two quantities have upon the velocity, in order to allow of corrections being applied to the observations in the main series of experiments. The apparatus used included (1) a four hundred gallon supply tank, fed from a water main, and having a special device for automatically maintaining a constant head; (2) a wooden channel having a triangular section, and provided with means for ensuring undisturbed entrance conditions; (3) a four hundred gallon gauging tank, the capacity of which at various points throughout its depth was carefully determined by comparison with a standard cubic foot. It is estimated that the experimental error involved was less than 1%. The chief conclusions arrived at were that (*a*) the expression $v^{2\cdot14} \propto i$ represents very accurately the relationship between velocity and slope for

this particular channel; (*b*) other conditions being the same, the velocity increases as $R^{\cdot 7}$, where R is the mean hydraulic radius; (*c*) the velocity increases with increase of temperature, this indicates (when taken in conjunction with (*a*) above, where $n = 2{\cdot}14$) that the exponent $(2 - n)/n$ in Prof. Reynolds' formula is inapplicable to the present experiments, since it would make the correction for temperature negative. The propriety of this formula had been challenged by Mr. Knibbs, and the value $2 - n$ shewn not to be supported by existing experiments when n was less than 2. This result disposes of any uncertainty that might be conceived to have remained.

3. "Current Papers, No. 3," by H. C. Russell, B.A., C.M.G., F.R.S.
(This paper will be printed in Vol. xxxii., for 1898.)

4. "Notes on Myrticolorin," by Henry G. Smith, F.C.S., Technological Museum, Sydney.

In the abstract of proceedings for August 4th, a paper by Mr. Smith is noticed wherein is announced a new dye-stuff obtained from the leaves of the "Red Stringy Bark," *Eucalyptus macrorhyncha*. This material, which in some respects is allied to aromadendrin, was stated to belong to the quercetin group of natural dyes. It was named by the author Myrticolorin as it was supposed to be the only true dye substance obtained from the Myrtaceæ. This note amplifies previous statements by recording the results arrived at since the announcement above referred to. Myrticolorin is a glucoside of quercetin, and it breaks up on boiling with dilute sulphuric acid into quercetin and a sugar. Quercetin is proved by its reactions, and the formation of acetylquercetin 189 – 191° C. It has also been proved to be quercetin by Mr. A. G. Perkin of Leeds, the well known authority on the natural yellow dyes. The sugar belongs to the glucoses, it partly crystallises in microscopic transparent prisms, probably monoclinic. It is readily and entirely fermented by yeast, and reduces Fehling's solution on heating. Myrticolorin contains 48 – 50 per cent. of quercetin, and quantitative determinations on

leaves from near Rylestone in this colony, proved them to contain no less than ten per cent. of myrticolorin, or about five per cent. of quercetin; one ton of dried leaves, therefore, gives two hundred and twenty-four pounds of myrticolorin, and this crystallised with seven per cent. of water over one hundred pounds of quercetin per ton. As quercitron bark probably does not contain more than three per cent. of quercetin or sixty-seven pounds per ton, the advantages are decidedly in favour of these Eucalyptus leaves, in the increased percentage of quercetin, in the ease with which the leaves may be ground, and the simplicity of extraction. The powdered leaves are boiled in water to remove the myrticolorin, and this crystallises out on cooling, and may be thus easily removed. Myrticolorin may be obtained in large quantities, as this particular species of Eucalypt extends over a large portion of New South Wales and Victoria. It is not to be supposed, however, that this species is the only one containing myrticolorin in its leaves.

5. "A second supplement to a Census of the Fauna of the Older Tertiary of Australia," by Professor RALPH TATE, Hon. Memb.; with an appendix on "Corals," by JOHN DENNANT, F.G.S.

Professor Tate begins his paper by giving references to the principal contributions to Australian Tertiary Palæontology which have appeared since the publication of his first supplement in the Journal of this Society for 1888. He notes a number of genera hitherto unrecorded as being represented in Australia, notably *Plesiotriton*, represented by two species from the Eocene, viz.:— one from Aldinga, S.A., and the other from Cape Otway, Victoria. *P. Dennanti* (a new species) from the latter locality, is then described. Also *Gaskoinia*, represented by a new species *(bullæformis)* from the Eocene of Muddy Creek. Prof. Tate also records a new species of *Hemiconus (H. Cossmanni)* from Muddy Creek. The genus *Borsonia* is represented by no less than four species, viz.: *B. protensa*, *B. Otwayensis*, *B. polycesta*, all from the Eocene, Cape Otway, and *B. balteata*, from the Eocene, Belmont, Victoria.

Tenison-Woods' *Thala marginata* from Table Cape is transferred to *Cordieria*, under the name *C. conospira*, the name *Borsonia (Cordieria) marginata* being preoccupied. The species occurs abundantly in the Eocene in Tasmanian, Victorian and South Australian localities. *Fossarus refractus* is a new species from the Eocene of Table Cape, Tasmania. *Dissochilus vitreus* is a new species, described from the Miocene of Muddy Creek, and *D. eburneus*, from the Eocene of Muddy Creek, near Hamilton, is also described for the first time. *Infundibulum latesulcatum* is a new species from the Eocene of Table Cape. *Subemarginula occlusa* is a new species from the Eocene of Victoria (Muddy Creek and Mornington). *Puncturella hemipsila* is described as new from the Eocene of Table Cape. *Atlanta fossilis* is described as new from the Eocene of Cape Otway. The genus *Plicatula* also has one species, viz.: *P. ramulosa* from the Eocene of Table Cape. *Martesia elegantula* is also described as new. It is from the Miocene of Grangeburn, near Hamilton, Victoria, burrowing in coral *(Plesiastræa)*.

In the Polyzoa, a synopsis is given of McGillivray's work, this author being almost entirely responsible for the very large additions to the genera and species of our Eocene fauna. Prof. Tate also intimates that he has discovered a representative of *Cerithiopsis*, a genus not hitherto represented in our fauna. The following genera are described as new :—*Streblorhamphus*, Tate and Cossmann—*S. mirulus*, from the Eocene of Muddy Creek, Victoria, and *S. obesus* from Mornington being described. *Cheleutomia*, Tate and Cossmann—the new species described being *C. subvaricosa* from the Eocene of Victoria (Muddy Creek, Mornington, Curlewis and Fyansford).

Mr. Dennant's appendix is prefaced by a brief resumé of recent work on Australian Tertiary Corals. He then proceeds to record two hitherto unrecorded genera for the Australian Tertiary Corals; these are represented by the species now described for the first time, viz.:—*Paracyathus supracostatus*, from the Eocene at Red Bluff, Shelford, Victoria. *Montlivaltia variformis*, from the Eocene of Table Cape, Tasmania.

NOTES AND EXHIBITS.

Prof. LIVERSIDGE exhibited some mineral specimens. Amongst them was a sapphire from Ceylon, which is of a fairly deep red or amethyst tint by candle or gas light, but of a blue colour by day-light, by the electric light and by magnesium light. The change in colour was exhibited to the members. These gems are being sold at Colombo as blue alexandrites (chrysoberyl). Many sapphires show this dichroism; but good specimens are not common. He also showed the strongly marked fluorescence of some green fluor-spar (chlorophane) permeated with plates of native copper, collected by Mr. Edgar Hall, F.C.S., from the Bald Nob Copper Mine, Emmaville, which he is working. Mr. Hall states that the native copper occurs at a depth of about eighty feet, where the fluor is two feet wide. At lower depths the fluor carries molybdenite and above the fluor it is a deep blue colour carrying red oxide and the carbonates of copper. Cassiterite also occurs in the lode in a gangue of quartz and felspar; but it is there quite free from copper and copper minerals. Also some very good crystals of mispickel from New England, collected by Mr. D. A. Porter of Tamworth, and other specimens.

Mr. E. F. PITTMAN, Government Geologist, exhibited a number of specimens of "telluride ores" from Kalgoorlie, and gave a brief description of the geology of those parts of Western Australia recently visited by him. The Perth artesian basin was described as consisting of deposits of very porous calcareous sandstone of æolian origin. The basin is a one-sided one, sloping from the flanks of the Darling Ranges on the east to the sea coast on the west, the total width of the section being about fifteen miles. The rain water collected in these porous rocks evidently leaks into the ocean. The Perth basin also differs from most other known artesian basins in that the porous rocks are not overlain by impervious beds. It appears therefore that the rising of the water above the surface from the bore holes must be due to the resistance offered by the sand rock to its passage into the ocean.

The Collie Coalfield (about one hundred and thirty miles south of Perth) presents but few opportunities to the geologist, as the coal measures have suffered much from denudation, and are not now exposed at the surface. The coal has been obtained by boring and sinking, and the best seam is said to be about thirteen feet thick. The coal contains about eleven per cent. of water, and does not form coke. In character it very much resembles the Clarence River coal of New South Wales. The coalfield forms an artesian basin, and water under pressure is flowing from all the bores which have been put down. This fact taken in conjunction with the appearance and quality of the coal, point to its being of Mesozoic Age. Fossil plant remains are very scarce, but portions of two were obtained, and Mr. R. Etheridge, junr., after some hesitation, pronounced them to belong to the genus *Sagenopteris*, thus confirming the impression that the measures are Mesozoic.

The Darling Range lying twenty miles to the east of Perth attains an altitude of 1,000 feet, and beyond this the country gradually rises to an altitude of 1,400 feet at Coolgardie and Kalgoorlie. The geological formation of this elevated tableland is granite and crystalline gneiss, with occasional belts of metamorphic schists. At Coolgardie there is a considerable development of hornblendic rocks (amphibolites, diorites, &c.) and near the junction of these with the granite occur auriferous quartz reefs, such as Bayley's and the Londonderry. At Kalgoorlie the gold occurs in micaceous schists, which, in depth, pass into quartz felsites (?) containing veins, splashes and pockets of calaverite (telluride of gold) and native tellurium. It appears that the matrix of the tellurides is an intrusive dyke of felsite (?) which has been much crushed and foliated, and that the micaceous schists at the surface (which contain free gold) are the result of the decomposition of this crushed intrusive rock. The felsitic rocks are themselves intruded by dykes of diorite, and fissures or reopenings in them have also been filled by quartz. No lithological distinction can be observed between the rich and the barren por-

tions of the dykes, and consequently, the boundaries of the so called "lodes" can only be defined by assay.

Extremely salt water occurs at a depth of about two hundred feet in the mines, owing to percolation of rain water through the zone of oxidised or porous rocks. The quantity is however small, and the want of a water supply is one of the most serious difficulties in connection with this rich and remarkable field.

The following donations were laid upon the table and acknowledged :—

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(The Names of the Donors are in *Italics*.)

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PROCEEDINGS OF SECTIONS.

PROCEEDINGS OF THE SECTIONS

(IN ABSTRACT.)

ENGINEERING SECTION.

At the provisional meeting held 14th April, the following officers were elected for the 1897 Session:—Chairman: C. O. BURGE, M. Inst. C.E. Secretary and Treasurer: PERCY ALLAN, Assoc. M. Inst. C.E., Assoc. M. Am. Soc. C.E. Committee: C. W. DARLEY, M. Inst. C.E., T. R. FIRTH, M. Inst. C.E., T. H. HOUGHTON, Assoc M. Inst. C.E., M.I.M.E., W. THOW, M. Inst. C.E., M.I.M.E., H. R. CARLETON, M. Inst. C.E., J. M. SMAIL, M. Inst C.E.

The *ex officio* members of the Committee being R. R. P. HICKSON, M. Inst. C.E, B. C. SIMPSON, M. Inst. C.E., and Prof. WARREN, M. Inst C.E., Wh. Sc.

The Hon. Treasurer presented the balance sheet showing a credit of £2 16s. 6d., in connection with the Reporting Fund, which after being audited by Messrs. NANGLE and WARD, was adopted.

Monthly meeting held May 19.

Mr. C. O. BURGE in the Chair.

Thirty members and visitors were present.

The Chairman then delivered his presidential address.

Monthly meeting held June 16.

Mr. C. O. BURGE in the Chair.

Sixteen members and visitors were present.

Professor WARREN read a paper on "The Unification of Methods of Testing Materials of Construction and precautions necessary in the accurate determination of the various Co-efficients of Strength and Elasticity," the discussion being adjourned to the next meeting.

Monthly meeting held July 21.

Mr. C. O. BURGE in the Chair.

Twenty-three members and visitors were present.

Mr. T. H. HOUGHTON read a paper on "Low Lift Pumping Machinery."

The discussion on Professor WARREN's paper on "The Unification of Methods of Testing Materials of Construction and precautions necessary in the accurate determination of the various Co-efficients of Strength and Elasticity," was opened by Mr. Deane, and continued by Messrs. Haycroft, Shaw, Selman, Barraclough, and Sinclair, and adjourned to the next meeting.

Monthly meeting held August 18.

Mr. C. O. BURGE in the Chair.

Twenty-one members and visitors were present.

The discussion on Professor WARREN's paper on "The Unification of Methods of Testing Materials of Construction and precautions necessary in the accurate determination of the various Co-efficients of Strength and Elasticity," adjourned from the previous meeting, was continued by Messrs. Selman, Barraclough and Knibbs, and replied to by the author.

Mr. C. J. MERFIELD then read a paper on "The Cubic Parabola applied as a Transition to small Tramway Curves," the discussion being adjourned to the next meeting.

The discussion on paper by Mr. T. H. HOUGHTON on "Low Lift Pumping Machinery," was adjourned to the next meeting.

Monthly meeting held September 13.

Mr. C. O. BURGE in the Chair.

Fifteen members and visitors were present.

Mr. HOUGHTON moved and Mr. GRIMSHAW seconded the following alteration in the date of election of officers :—

i. That the Engineering Section elect their Committee and Officers for the Session 1898 and subsequent Sessions, at the

meeting to be held in December; such Committee to take office from the first day of the following January.

ii. That in the case of the death or resignation of any member of the Committee, or of his ceasing to be a member of the Royal Society, the Committee may elect another member of the Section to the vacant place on the Committee, such election to be confirmed at the next Sectional meeting.

Mr. HAYCROFT moved and Mr. Ross seconded "that the mode of election of officers be altered so that the ballot papers be sent out without any recommendation being made by the Committee, leaving to individual members the nomination of Committee." This was ruled out of order by the Chairman, and the motion moved by Mr. Houghton was then carried with the substitution of the word "shall" for "may" in par. ii.

Mr. HERBERT E. Ross then read a paper on "Belt Power Transmission, with some Notes on a new form of Brake Absorption Dynamometer," and the discussion was adjourned to the next meeting.

The discussion on paper by Mr. HOUGHTON on "Low Lift Pumping Machinery" was opened by Mr. Norman Selfe, a letter from Mr. Pridham on the subject of the paper was read, and Mr. Grimshaw having contributed to the discussion, the author replied.

The Chairman opened the discussion on paper by Mr. C. J. MERFIELD, on "The Cubic Parabola applied as a Transition to small Tramway Curves," and after Mr. Shaw had spoken the discussion was adjourned to the next meeting.

Monthly meeting held October 20.

Mr. C. O. BURGE in the Chair.

Thirty-four members and visitors were present.

Mr. H. R. CARLETON then read a paper on "Light-houses in New South Wales," the discussion on which was adjourned to the next meeting.

The discussion on Mr. C. J. MERFIELD's paper on "The Cubic Parabola applied as a Transition to small Tramway Curves," adjourned from the previous meeting, was continued by Messrs. Cowdery and Knibbs, and replied to by the author.

The discussion on paper by Mr. HERBERT E. ROSS, on "Belt Power Transmission, with some notes on a new form of Brake Absorption Dynamometer," was adjourned to the next meeting.

Monthly meeting held November 17.

Mr. C. O. BURGE in the Chair.

Sixteen members and visitors were present.

The Chairman announced that the Committee would be pleased to receive suggestions from the members as to nominations for the new Committee, any suggestions to be sent to the Hon. Secretaries in writing.

Mr. G. R. COWDERY read a paper on "Tramway Rail Joints," and the discussion was adjourned to the next meeting.

The adjourned discussion on Mr. H. E. Ross' paper on "Belt Power Transmission, with some notes on a new form of Brake Absorption Dynamometer," was then resumed, Messrs. Ludowici, How, Deane, Grimshaw, Barraclough, and Houghton, taking part in it; the author then replied.

A conversational discussion then took place on Mr. COWDERY'S paper, Messrs. Ross, Deane, Houghton, How and the Chairman taking part in it; Mr. Cowdery replying.

Monthly meeting held December 15.

Mr. C. O. BURGE in the Chair.

Nine members were present.

Messrs. COWDERY and Ross were appointed Scrutineers to conduct the ballot for the election of the Officers and Committee for the following year.

Mr. HAYCROFT proposed that the formality of a ballot be dispensed with, but the Chairman decided that according to the rules

a ballot was necessary, and it was accordingly proceeded with. The ballot having been taken the Chairman announced that the following were duly elected :—Chairman : T. H. HOUGHTON, Assoc. M. Inst. C.E., M. Inst. M.E. Secretary and Treasurer : S. H. BARRACLOUGH, M.M.E. Committee : H. DEANE, M. Inst. C.E., T. R. FIRTH, M. Inst. C.E., W. THOW, M. Inst. C.E., M. Inst. M.E., H. R. CARLETON, M. Inst. C.E., NORMAN SELFE, M. Inst. C.E., M. Inst. M.E., PERCY ALLAN, Assoc. M. Inst. C.E., Assoc. M. Am. Soc. C.E.

Mr. HAYCROFT moved and Mr. Ross seconded that it be noted on the minutes of the meeting that eight (8) members voted in the ballot. The motion was carried.

The Hon. Treasurer's balance sheet, as audited by Messrs. Ross and Cowdery, was read and adopted.

A discussion then ensued on Mr. G. R. COWDERY's paper on "Tramway Rail Joints," the following members taking part :—Messrs. Haycroft, H. E. Ross, Barraclough, Grimshaw, and the Chairman. Mr. Cowdery replied.

Before vacating the Chair, the Chairman congratulated the Section on its having had a more than ordinary successful Session.

Mr. GRIMSHAW proposed a vote of thanks to the retiring Chairman (Mr. C. O. Burge), which was carried by acclamation.

MEDICAL SECTION.

The First General Meeting of the Session was held in the Large Hall of the Society's House, on May 21st, 1897, at 8 p.m., when Dr. ROBERT SCOT SKIRVING, the retiring Chairman, presided.

The following members were elected to the various offices according to the By-laws :—Chairman : JOHN ASHBURTON THOMPSON, M.R.C.S. *Eng.*, M.D. *Brux.*, D.P.H. *Camb.* Honorary Secretaries : J. ADAM DICK, B.A. *Syd.*, M.D., C.M. *Edin.*; FRANK TIDSWELL, M.B., C.M. *Syd.*, D.P.H. *Camb.* Committee : W. H. GOODE, M.D., D.S.M. *Dub.*; G. LANE MULLINS, M.A., M.D. *Dub.*;

GEORGE E. RENNIE, B.A. *Syd.*, M.D. *Lond.*; R. SCOT SKIRVING, M.B., C.M. *Edin.*

The dates of the meetings of the Section were fixed.

Dr. E. J. JENKINS, exhibited a patient showing Freidreich's Disease.

Dr. C. P. B. CLUBBE showed a patient with Charcot's Joint Disease.

Dr. SYDNEY JAMIESON exhibited several pathological preparations preserved in formalin glycerin.

The Hon. Secs. exhibited numerous radiographs of surgical and medical interest, taken by Mr. F. Schmidlin.

The Address from the Royal Society to Her Gracious Majesty the Queen, congratulating her upon the sixtieth year of her reign, was on view and was inspected by the members.

SECOND GENERAL MEETING.

The Second General Meeting was held in the Large Hall of the Society's House on Friday, July 23rd, at 8·15 p.m. The evening was very stormy and wet. Present: Drs. ASHBURTON THOMPSON, (in the Chair), W. J. MCKAY, W. H. GOODE, FRANK TIDSWELL, J. ADAM DICK.

Dr. MCKAY requested leave to withdraw his paper, "Notes on Fifty Cases of Abdominal Section" from the business sheet of the Section. Agreed.

THIRD GENERAL MEETING.

The Third General Meeting of the Section was held in the Large Hall of the Society's House, on Friday, September 17th, at 8·15 p.m. In the absence of the Chairman of the Section, Dr. P. SYDNEY JONES was elected to preside over the meeting. About thirty members and visitors were present.

Dr. E. T. THRING exhibited a fresh specimen of Carcinoma Uteri and explained the operative procedure necessary for the

removal of the uterus and the neighbouring glands. Drs. Neill, Crago, and Sydney Jones discussed the method of operation.

Dr. C. P. B. CLUBBE read a paper "On Fifteen cases of Intussusception."[1]

Drs. E. T. Thring, and J. Adam Dick discussed certain points in the paper. Dr. Clubbe replied.

Dr. G. E. RENNIE read a paper "On a Clinical and Pathological Criticism of Hereditary Ataxy, and Locomotor Ataxy." The paper was illustrated by numerous micrographs, and by slides prepared for the microscope.

Dr. Crago, and others discussed the paper. Dr. Rennie replied.

Dr. SYDNEY JAMIESON exhibited several specimens from the Sydney University Museum of Morbid Anatomy.

FOURTH GENERAL MEETING.

The Fourth General Meeting of the Section was held in the Large Hall of the Society's House, on Friday, November 19th, at 8·15 p.m. There was an attendance of about forty members and visitors. The Chairman of the Section, (Dr. J. ASHBURTON THOMPSON) presided.

Dr. W. H. GOODE exhibited several prepared tubes displaying the application of "Wright's modification of Widal's test for Typhoid Bacilli."

Dr. SYDNEY JAMIESON exhibited several interesting recent additions to the University Museum of Morbid Anatomy.

Dr. J. ASHBURTON THOMPSON, the Chairman of the Section, read a paper entitled, "A Note on the Application of the Tuberculin Test to Bovine Animals."[2]

Copies of a table drawn up by the New South Wales Board of Health for use in cases where tuberculin is applied were exhibited.

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[1] Vide British Medical Journal, 1897.

[2] Vide "Australasian Medical Gazette," December 20, 1897.

The subject was discussed by Drs. J. Adam Dick, W. Camac Wilkinson, Frank Tidswell, and G. Lane Mullins and others. Dr. Ashburton Thompson replied.

Dr. GEORGE E. RENNIE read a paper entitled, "Some Recent Work on the Cerebellum, its Connections and Functions,"[1] with exhibits.

Drs. Frank Tidswell, Spencer, Scot Skirving, and others discussed the subject. Dr. Rennie replied.

A paper entitled "Notes on an Interesting Cerebral Case," by Dr. J. Adam Dick was postponed owing to the lateness of the hour and the sultriness of the weather.

The Chairman announced that this was the last meeting of the Session.

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[1] Vide "Australasian Medical Gazette," December 20, 1897.

ANNUAL ADDRESS.

By C. O. BURGE, M. Inst. C.E.

[*Delivered to the Engineering Section of the Royal Society of N. S. Wales, May 19, 1897.*]

GENTLEMEN,—My first duty is to thank you, not only for electing me to the chair for the ensuing session of this important section of the Royal Society of New South Wales, but also for providing me with the assistance of a strong Committee and Secretary. I hope that the ordinary members will add their strength to the section by furnishing suitable papers, and by good attendance and discussion. It must not be forgotten that the youngest of members can help us in the submission of papers, as these not only help other younger members, but frequently the elder ones also Any one who has looked through the students' papers, contributed to the minutes of the Institution of Civil Engineers, can see that information is often given in them which is valuable to older members, who may possibly have missed the particular experience which they illustrate.

I find myself confronted, as my predecessors have been, and as my successors will be, no doubt, with the difficulty of finding a suitable subject for an opening address, and I have decided that, as a definite step forward has been taken this year towards the Federation of the Australian Colonies, it would be appropriate to refer to engineering works recently completed, in progress, and in more or less immediate contemplation, in those colonies.

Though one of the smallest in population of the group, Western Australia stands one of the first in the importance of the works coming under these heads—the two great breakwaters at the mouth of Swan River at Freemantle, more than a mile in aggregate length, are complete, and, when this is combined with the extensive deepening of the river itself now in hand, it is anticipated

that Freemantle will supersede Albany as the port of call for the mail steamers.

The Coolgardie water supply about to be begun is also a large work. A concrete dam one hundred feet high will impound 3,300 million gallons at Greenmount Ranges, near Perth, three hundred feet above sea level, from whence the water will be pumped to a distance of three hundred and thirty miles, and to a height of 1,400 feet to a service reservoir near Coolgardie. This project is probably the most remarkable referred to in this address, owing to the combination of the great distance between source and delivery, and the height of the latter. Suppose Wyalong, which is eight hundred feet above the sea, raised to double that height, and supplied by pumping from Prospect, and you have an idea of the magnitude of the work. It is to cost two and half millions. The confidence in the permanency of Coolgardie which is implied by this undertaking, is also a noteworthy feature.

In railway extension this western colony is progressing rapidly, three hundred and fifty-seven miles of new lines were estimated in the railway report of June, 1896, to be opened between that date and December 1897, and certainly, if results in the past are to be relied upon, enterprise in this direction is justifiable, as the existing Government railways have been paying the unprecedented dividend of 12½% on the capital invested.

In South Australia the only important work to be mentioned is the Adelaide water supply scheme, which is just finished. It consists of a weir across the Onkaparinka River, from which the supply is drawn, a tunnel from thence through the Mount Lofty range, over three miles long, a storage reservoir at the Happy Valley, of four hundred and forty acres water surface, retained by a dam over half a mile in length, and seventy-two feet in height, and finally an outlet tunnel and steel main to Adelaide, the whole distance covered being nearly sixteen miles.

Coming to Victoria, the only really large work is the sewerage of Melbourne, which is well advanced, all the larger tunnels being

finished or nearly so. The northern suburbs direct railway, largely in tunnel and viaduct, though at present only in the form of a project, will, no doubt, be carried out in the near future. The proposal for narrow gauge branch railway feeders recently favoured by the Victorian Standing Committee for Railways, does not seem to have advanced much. Notwitnstanding the volume of evidence before them, perhaps because of it, this Committee do not seem to understand the question. Isolation from workshops for ordinary repairs to their rolling stock is one of the great objections to short narrow gauge branches to a broad gauge line, yet the Committee, by their report, seem to think that repairs are only wanted in the exceptional instance of an accident, and, therefore, that this objection is trivial. They seem to think that a locomotive, for instance, is like a human being who, if fed, watered, and exercised will keep his own organs in ordinary repair, and not, as it really is, like a pair of boots, continually wearing and requiring new soles and patches.

In Tasmania, there is being constructed, in connection with the Mount Lyell mines, a short but heavy length of railway construction.

Turning to the mother colony, harbour engineering is very active. Important works at the Tweed, Richmond, Clarence, Bellinger, Nambucca, Macleay and Manning Rivers, also at Trial Bay, and at Newcastle are being carried out, while at Hastings River, Darling Island in Sydney, and Port Kembla, large works are in immediate prospect. Light railways from Jerildeie to Berrigan, Narrabri to Moree, Parkes to Condobolin, Berrigan to Finley, Nevertire to Warren, and Tamworth to Manilla, are either just finished, in hand, or about to be begun. These represent about two hundred miles. There are also considerable improvements, by deviations being made in grades and curves, on the Great Western and Great Southern main lines.

I really do not know whether I ought to include or not, as impending, the extension of the railway into the city of Sydney, and its suburban connections. The proposal seems to crop up

periodically like our Astronomer's weather cycles. This is a matter which should be settled on the evidence of special experts in the departments of engineering, traffic, and property valuation, and only those of them who have practical acquaintance with city work in these branches; more than this only serves to darken counsel and delay results. When, therefore, we find that over forty witnesses were examined and thirty-five different schemes, by all sorts of projectors, were considered by the Royal Commission in 1891, besides what has been done since, and no result arrived at, we must come to the conclusion that the Horatian maxim, so often followed in modern times, *interdum vulgus rectum videt*, is not applicable to the city railway question.

Four electric tramways in Sydney and suburbs, as well as the conversion of several steam tramways to the same system, are in the category of recently completed or authorised works. In connection with this matter, I might mention, incidentally, that out of three hundred and ten miles of proposed light railways in Great Britain, forming the first batch lodged with the Commissioners under the new English Light Railways Act, no less than one hundred and eighteen miles are to be worked by electricity. The large works at Cockle Creek near Newcastle for the treatment of Broken Hill ore by the sulphide process should also be mentioned. The lock and weir at Bourke on the Darling now in hand presents some novel features, and is certainly important enough to be referred to in the present summary. As to Queensland, a large railway bridge is being constructed over the Burdekin River. Another large one over the Bremer River at Ipswich is complete, while the contract for another at Rockhampton has been let. About one hundred and fifty miles of railway are under construction, and the Brisbane horse-tramways are being converted to electricity as a motive power.

The railway gauge question is one that will before long come before the public, with particulars as to what it will cost as a more or less complete scheme, together with the corresponding estimated gain. To some people the alteration appears to be only

a matter of shifting a rail, and to them the whole difficulty is over when an agreement is come to by the various colonies, and an order issued to give effect to it; but to those better acquainted with the subject it is a very different affair, requiring much consideration. The matter now stands thus—Queensland has the 3′ 6″ gauge, New South Wales the 4′ 8½″, generally called the standard gauge, Victoria has the 5′ 3″, and South Australia has partly the 5′ 3″ and partly the 3′ 6″, while Western Australia has adopted 3′ 6″. Tasmania being separated from us by sea need not be considered.

There appears to be a consensus of professional opinion that the future assimilated gauge is to be the standard one of 4′ 8½″, which is that of New South Wales. Not only is this gauge preferable as being that of the greater part of the world's system, but either of the other possible alternatives, viz. adopting the 5′ 3″ of Victoria and part of South Australia, or the 3′ 6″ of Queensland, and the rest of South Australia, would be objectionable, because in the former case, increasing a gauge is a very much more expensive process than decreasing it, and in the latter, though for the reason just mentioned the cheapest, the capacity of the 3′ 6″ gauge would be insufficient for main line traffic in the larger colonies. As the whole of the colonies concerned in the alteration must pay for it, the question of the most suitable gauge need not be hampered by other considerations than those of general ultimate economy and convenience.

The non-adoption of a uniform gauge in Australia, originally, was undoubtedly a great blunder, (and I understand it was done in spite of professional advice) but it having been made, and thousands of miles of railway having been since constructed and rolling stock provided, it does not necessarily follow that the entire correction of that blunder is now commercially advantageous. The principal evils of break of gauge are as under :—

1. Cost of transhipment of goods and live stock, and demurrage of rolling stock while transhipment is going on.

2. Separation of rolling stock from repairing shops other than those situated on lines of its own gauge.
3. Inconvenience arising from inability to transfer rolling stock of one gauge to the lines of another one in case of a temporary local pressure of traffic.
4. Delay in transfer of troops and material in time of war.

Now in the case of local branches of a main line, which it has been occasionally proposed, in Australia, to construct on a smaller gauge in view of apparent economy, all of these four evils would operate to a greater or less degree, but in the question now under consideration, where one large system on one gauge consisting of thousands of miles of lines, meets another of similar magnitude on another, transhipment and demurrage, as regards goods and live stock in time of peace, and delay in transfer of troops and material in time of war, would be much more important than the isolation of rolling stock. The cost of the latter, though impossible to put into figures, would be certainly appreciable, even in large systems, as its abolition would enable a temporary extra demand for trucks etc., at one locality to be satisfied, without limit as to direction, by a possible superfluity in another, but it is not likely that the whole area of a colony would be under pressure of this sort at one time, and if not, there would be generally sufficient area to draw from, without going outside of it. Apart from the military question, transhipment and demurrage, therefore, are the main evils arising from allowing the present breaks to remain.

According to the official evidence given before the Victorian Committee of 1895 on narrow gauge railways, the average cost of transhipment in South Australia is about four pence per ton, and taking the value of the time of delaying trucks of average loading while transhipment is going on, deduced from the evidence of the Victorian Locomotive Superintendent and Acting Commissioner of Railways, the demurrage will be about another fourpence per ton; adding another fourpence for extra shunting, isolation, etc., we cannot be very far wrong in taking one shilling per ton trans-

ferred,[1] as a rough estimate of the amount to be gained by assimilating the gauges of two large systems in Australia.

Taking Queensland first, and its southern system only, which is alone at present connected with the general Australian group, 1,375 miles would have to be altered and corresponding new rolling stock provided. Mr. Horace Bell, M. Inst. C.E., Consulting Engineer for the State Railways of India, who had the spending of nearly £4,000,000 in such work, is a good authority in this matter, and, though he is referring to an alteration from 3′ 3″ to 5′ 6″ gauge as against the lesser change now in question, this difference does not affect the matter so very much.

He says in his work on "Railway Policy in India," "The conversion from the metre to the standard (5′ 6″) gauge has so far shown that the cost, *exclusive of rolling stock* will be from £3,000 to £3,500 per mile, allowing for the sale, in a very limited and decreasing market of the metre gauge material; the operation is one, therefore that cannot be lightly entertained."

A rough estimate based on Australian rates and *allowing for rolling stock* would show that £4,000 per mile is the least that should be allowed. The cost would at this rate, for southern Queensland alone, be £5,500,000, and the interest at three and a half per cent. £192,500, so that to pay the interest alone, no less than 3,850,000 tons at one shilling per ton, saving in transhipment etc. would have to be assumed as crossing the border annually. If we turn to the New South Wales Railway Commissioners' last report, we find that the whole of the goods and live stock loaded up in this colony for the year was about 4,000,000 tons, so the supposition that anything like that amount would cross the northern border annually is absurd. The merest glance at the figures show that the alteration even of the southern Queensland system is not within measurable distance. It might be said that the main connection Brisbane to the Border only, two hundred and

[1] This is corroborated by the evidence of the manager of the Silverton Tramway Co. before the Public Works Committee of N. S. Wales on the proposed Broken Hill extension railway.

thirty-three miles, might be converted; but there is very heavy work below Toowoomba and at the Little Liverpool Range, with numerous five chain curves, and the cost would be probably be over a million; moreover, it would only be shifting the break to another place. Should this connection ever become worth the while on a uniform gauge, a better way would be to connect the colonies at Tweed Heads, the present Queensland lines running south from Brisbane being in easy country, and the New South Wales connections being partly already made, while the missing links in both colonies have been approved for their own sake independently of the gauge question, so far as to have reached the stage of survey and estimate.

Mr. H. Stanley, Engineer-in-Chief for Queensland Railways, told me some years ago that he did all he could to persuade his Government to adopt the standard gauge, at all events south of Brisbane, in view of ultimate connection with the mother colony, but to no purpose.

Coming to Victoria, the alteration would be much less costly per mile, but a complete scheme involves the alteration of no less than 3,122 miles, including the conversion of rolling stock, a great deal of which mileage, especially the Melbourne suburban system, which of course has necessarily a very large rolling stock, would gain very little by the change—the amount of this suburban rolling stock is a very serious factor in the question, and may be judged by the fact that in the Sydney suburban system, the rolling stock, according to the latest returns in which it is shown apart, cost about £30,000 per mile. Even taking a very low mileage cost for the conversion, including rolling stock, of the whole 3,122 miles, it would take a border traffic of dimensions that could hardly be realized for many years to come, to save sufficient on transhipment and demurrage to pay the interest alone. And the same would apply to a greater degree if the four hundred and ninety miles in South Australia of 5′ 3″ gauge were converted, and this would still leave the South Australian narrow gauge lines, 1,231

miles, isolated, a mileage nearly as great as the Southern Queensland section already referred to.

Another scheme would be to convert, to the standard gauge, the Albury to Melbourne main line, but this would be only to destroy the one break at the border, while creating new ones at the numerous points where this line connects with the whole of the Victorian North Western system, thus hampering a large proportion of Victorian local traffic. It would be robbing Peter to pay Paul.

If then the complete unification of the gauges is nothing but a happy dream, impossible now of practical realization, the probable trend of traffic under future conditions will chiefly be the guide in estimating where, and to what extent, partial unification should be carried out, leaving such breaks as are unavoidable in any partial scheme, in as unobjectionable places as possible. There are serious constructional objections to a mixed gauge, especially when the two are so much alike as the 4′ 8½″ and 5′ 3″ —6½″ only being the difference, while there are others connected with the working which are of importance; nevertheless, owing to the future direction of the traffic, I am convinced that in this mixed gauge lies the best present solution of the question. When, after Federation, the traffic is absolutely unhampered by border duties, preferential rates and unequal import duties at Sydney and Melbourne, which now chiefly operate in obstructing intercourse between the south and west of New South Wales and the city and port of Melbourne, a third rail southwards from Albury, and from Deniliquin, to Melbourne and its harbour, will abolish the break of gauge as regards this large and, no doubt, increasing traffic. Of course trade between the places away from these two main Victorian lines and New South Wales, would still have to be transhipped, but rather than pay the large amount of annual interest on the outlay necessary for the conversion of over 3,000 miles of Victorian railways and rolling stock, it would be better for the general treasury to pay the extra tonnage rates incurred by the transhipment of this comparatively speaking small traffic.

The principal difficulty in the mixed gauge project is the running of the 4′ 8½″ line through the points and crossings and interlocking work of the larger gauge, and probably the least objectionable way of overcoming it would be to divert the standard line round the back of the present stations, clear of all points, and by making annexes (and this would be the difficulty of the proposal) which would be practically new stations on the 4′ 8½″ gauge, at Melbourne and its port, to deal with the intercolonial traffic. This standard gauge line would not pick up any goods traffic intermediately in Victoria, and no intermediate sidings would be required, except for passing places, and access to engine sheds, etc.

A great deal of the through traffic thus dealt with would be that diverted from traffic now going to Sydney, so that, as far as that is concerned, new rolling stock would not be required, it need only be transferred—traffic expenses on the new line also would be, to a great extent, a diverted, and not an additional, item. This proposal would also be an instalment of future more complete unification.

As to the approximate cost, allowing £600 per mile for the third rail and partial conversion of rolling stock, for three hundred and ten miles, alterations and resumptions at nine large stations at £6,000 each, fifty smaller ones at £2,000 each for the deviations etc. referred to, and £160,000 for extra terminal accomodation, the total would be half a million, the interest on which would be undoubtedly saved by the avoidance of the break. This arrangement would do away with the through passenger break at the border, but not that for other intercolonial passenger traffic, but the question is not really a passenger one; it is inconvenient no doubt, to oblige people to change carriages, but most branch line passengers, as a rule, have now and will always have to do it, and, commercially speaking, it is not likely that the railway administrations would lose a single passenger by not making unification complete.

The military aspect of the question, being a matter which can only be dealt with by a military expert, is beyond the scope of

this address, but it is evident that even a partial assimilation would get rid of many of the defects, from this point of view, now existing.

Of course much more data would be required, and an accurate estimate of cost and result made, which I understand is now being done, before any determination could be come to, but enough has been said to show that such a modified scheme, as has been just sketched out, is worthy of consideration.

It is universally conceded that, as mentioned before, whatever is expended in the matter should be at the charge of the entire Commonwealth, if established, and as a complete unification of gauge will no doubt be found to be financially impracticable, the only apparent fair way of dealing with the question would be to carry out at the general expense the partial change, whatever it may be, which is financially justifiable, and also to charge the central exchequer with the annual additional working expenses caused by the breaks remaining elsewhere. When, if ever, this latter charge, by increase of traffic at any break, shall become so great as to exceed the interest on the cost of abolishing it, the alteration might be made and complete unification would be advanced another stage.

As to the past, there may have been some justification for Queensland wholly, and South Australia partially, breaking away to a smaller gauge, owing to pressing necessity for cheap extension, but, even without the present feelings of Federal gush and brotherly love, which are supposed to animate us at present, it is inconceivable, either for the sake of the slightly increased capacity of the extra six inches on the one hand, or the infinitesimal economy of reducing the gauge by that amount on the other, that Victoria and New South Wales should have deliberately adopted a difference which has resulted in no practical advantage whatever to either of them.

I have dwelt in this address perhaps, too largely on the gauge question, but the explanation is, besides its immediate importance

at the present time, the fact that one naturally leans to matters familiar, and a connection of now nearly forty years with railway construction of nearly all the gauges from 2′ to 5′ 6″ gives me some authority to speak on this subject.

In conclusion, though I do not represent specially here the Institution of Civil Engineers, still, as a large majority of the Section belong to it, I think this a good opportunity to put on record the thanks of the Institution to the Royal Society, for their courtesy in lending the use of these premises for its meetings. One of our past chairmen, Mr. Deane, is the chief representative of the Institution of Civil Engineers in this Colony, and he is also this year President of the Royal Society, I would suggest therefore, that he, in the former capacity, thank himself in the latter capacity, for the favour I have mentioned. With this I shall end this address, wishing the Section a prosperous session, and hoping that with your assistance and co-operation it may end with still greater vigour than that with which it has begun.

The UNIFICATION of the METHODS of TESTING MATERIALS used in CONSTRUCTION, and the Precautions Necessary in the Accurate Determinations of the various Coefficients of Strength and Elasticity.

By W. H. Warren, M. Inst. C.E., M. Am. Soc. C.E., Wh. Sc.,
Challis Professor of Engineering, University of Sydney.

[With Plates 1 and 2.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, June 16, 1897.*]

The importance of establishing a uniform system of tests for construction materials is now fully recognised in all civilized countries. In America an attempt has been recently made under the auspices of the Society of Mechanical Engineers, to secure the adoption of uniform methods of testing materials A similar attempt was also made about the same time in France, but probably the most important Society established for this purpose is that which was originated by the late Prof. Bauschinger, which held its first meeting in Munich in 1884, under the title "The International Union for the Unification of the Methods of Testing Materials." The scope and importance of this society at present is due largely to the energy and ability of Prof. Tetmaier of Zurich, who was the president for last year, This year the meetings are to be held at Stockholm, and in the year 1900 they will be held in Paris. So far the matters dealt with are fundamentally important and have done much to place the testing of materials upon a a scientific basis.

The author proposes in future papers to publish the most important of the investigations made at the University Engineering Laboratory on the materials of construction, so that this paper is intended to serve as an introduction to those which are to follow.

It is proposed to consider the nature of the mechanical tests rather than the results obtained, and generally to deal with the

subject in regard to the data which it is sought to obtain in the tests, and the precautions to be taken in order to eliminate disturbing influences. It is also proposed to endeavour to establish the sizes and proportions of test pieces which are most suitable for the particular test in question, with reference to the data which it is the object of the test to furnish; and, moreover, to secure uniformity in the results, and render their comparisons with those obtained in other countries much more satisfactory than at present.

Tension.

Tensile tests are by far the most general in connection with the commercial testing of construction materials, and, when they are correctly made, furnish reliable data for the determination of the quality in regard to the suitability or otherwise of the material in guestion. It is essential that the following points be accurately determined :—

a. The tensile strength per unit of area.
b. The yield point.
c. The ductility as measured by the percentage of elongation or construction of area after rupture.

For accurate scientific testing, the limit, and coefficient of elasticity should be also determined, as well as the distribution of the elongation over the tested length in order that the general extension may be separated from the local, and that the elongation may be corrected when fracture occurs on one side of the centre of the tested length between the reference points. When the fracture does not occur in the centre the elongation is doubled for a distance equal to half the length of the test, counting from the section of rupture on the side, where it is possible to measure it, in such a manner as to render the same conditions as would have obtained had the rupture occurred in the middle of the test piece, and had the elongation been produced freely on both sides. This result increases slightly the effective elongation measured directly on the real test piece. The method is rather troublesome as the test piece should be marked before testing in $\frac{1}{2}''$ or $\frac{1}{4}''$ spaces

between the reference points, and the result is only approximate, as the elongations are produced, during the course of the test in an irregular manner along the length of the test piece, and are probably not necessarily uniform at the ruptured section, even when that is in the middle of the test piece. The resolutions of the Conventions recommend the rejection of all test pieces which break outside the middle third of the distance between the reference points, which appears desirable in accurate testing unless some such expedient as the foregoing is adopted.

Dimensions of test pieces.—The Conventions agree that the test length should be proportional to the square root of the cross-section, but the American Society adopt for circular sections an area of test piece of 600 square millimeters for a useful length of 200 millimeters, which gives a diameter of 27·64 millimeters, whereas, the European standards give lengths respectively of 100, 150, 200, and 250 millimeters for diameters of 10, 15, 20, and 25 millimeters. These standards are recommended for all metals. In English measure these proportions become lengths of 4″, 6″, 8″ and 10″ for diameters 0·4″, 0·6″, 0·8″ and 1·0″ respectively, *i.e.*, the length should be ten times the diameter. It is also provided in order that the proximity of the heads shall not interfere with the observed results, especially in the measurement of elongation, the actual length of the cylindrical portion of the test piece should be increased by at least 10 mm., it was formerly made 20 mm.

In testing plates or pieces of square or rectangular cross section, the law of similarity of form should be applied as far as possible, but with due regard to convenience of preparation. It is therefore desirable to make the width constant in each series, and to vary the length and thickness thus :—For plates between $\frac{1}{4}$″ and 1″ in thickness, the width should be 1·2″, over 1″ in thickness, the thickness should be considered as breadth, and the width made 0·8″. The useful length or that over which the elongations are measured should be 8″ for a standard section of 1·2″ × 0·4″.

For testing thin plates under $\frac{1}{4}$″ in thickness, such as are now frequently used for water pipes, the law of similarity probably

does not apply, and the useful length should be 4.″ *Plate* 1, figs. 1 to 6. Test pieces cut from plates should be taken from the longitudinal and transverse sides, and when uncut plates are used at least 1″ in width should be cut away to waste. The skin left by the rolls in plates should not be removed, and with rails the bars detached should have square sections, and contain the exterior fibres of the rail. The foregoing rules for the sizes and proportions of test pieces are almost exactly the same as those adopted by the various Conventions which have considered the subject, the slight alterations made being necessary in consequence of the reductions from the metric system used in Europe, these are represented more fully in *Plate* 1, figs. 1 to 6.

In regard to the accuracy of the machines and the errors permissable, the Conventions state that they will accept an error of one-tenth of a kilogramme per square millimeter corresponding to the elastic limit and to that of rupture, which is 1422·32 pounds or 0·635 of a ton per square inch. This necessitates accurate testing machines and skilful handling.

All authorities agree that the test piece should be accurately placed in the axis of the machine; this can generally be more easily accomplished with round than with rectangular specimens, and in all cases the rectangular specimens held by a pin passing through a hole in the heads of the test piece is preferable to the ordinary serrated wedge holders. Again the threaded ends *Plate* 1, figs. 4 and 5, are not so good as the standard form for round pieces shown in fig. 3.

In regard to the rate of testing, the Conventions while admitting its importance, recommend further study before establishing rules. The American Society consider that the duration of the test should be in a certain measure, a function of the volume of the test piece, and recommend that the time should be from one to six minutes.

The use of autographic apparatus for drawing a diagram of tests is generally recommended, and the Conventions require that their

area should be calculated up to the limit corresponding to rupture. Where such diagrams are not used, it is recommended that as many observations as possible should be made during the test from which diagrams may be plotted. In specifications intended to govern the supply of steel for works of construction, it is usual to specify an upper and a lower limit of tensile strength, and to state also the minimum percentage of elongation. It generally happens with ductile materials that high tensile strengths are accompanied with smaller elongations, and that the lower tensile strengths give correspondingly greater elongations.

In order to express the value of a material under these circumstances, Prof. Tetmaier has proposed a coefficient of quality which is based upon the following considerations :—

Plate I. fig. 10, represents an autographic diagram such as would be produced in testing a piece of mild steel, but somewhat distorted from o to e and e to y in order to show more clearly the characteristic points in the diagram. The loads are represented as ordinates and the elongations by abscissæ. The point e indicates the elastic limit, and the line is straight from o to e; from e to y the line curves slightly from the straight portion and then takes a horizontal direction; y indicates the yield point or the commencement of the permanent elongations, *i.e.*, the commencement of the plastic state of the material. The test piece elongates considerably and the point m denotes the maximum load supported, local contraction of area then occurs as shown by the line mr, after which rupture takes place.

Let Le denote the load sustained at the elastic limit
„ Ly „ „ „ „ yield point
„ Lm „ „ „ „ maximum load
„ Lr „ „ „ „ load at rupture
„ Δl, denote the elongation at the elastic limit
„ $\Delta l_{''}$ „ „ „ maximum load
„ $\Delta l_{'''}$ „ „ „ rupture

Let A_1 denote the area of the portion $o\,e\,e_{,}$

„ A_2 „ „ „ „ $e'\,e\,y\,m\,m'$

„ A_3 „ „ „ „ $m'\,m\,r\,r'$

Then these areas may be expressed as follows :—

$$A_1 = \tfrac{1}{2}\,L e\,\Delta l_{,}$$

$$A_2 = \alpha\,L m\,(\Delta l_{,,} - \Delta l_{,})$$

$$A_3 = \rho\,L m\,(\Delta l_{,,,} - \Delta l_{,,})$$

Where α and ρ are coefficients depending on the shape of the diagram.

The total work applied to the test piece up to the moment when fracture occurs is—

$$A = A_1 + A_2 + A_3 = \tfrac{1}{2}\,L e\,\Delta l_{,} + L m\,(\Delta l_{,,} - \Delta l) + \rho\,L m\,(\Delta l_{,,,} - \Delta l_{,,})$$

The elastic elongation $\Delta l_{,}$ is very small, and moreover does not depend upon the ductility of the material, *i.e.*, it has no reference to the total elongation at rupture, it may therefore be neglected. Again $(\Delta l_{,,,} - \Delta l_{,,})$ is not large even in ductile materials, and approaches zero as the material becomes more brittle, hence we may write approximately—

$$\Delta l_{,,} = \Delta l_{,,,} = \Delta l \text{ and } L m = L r$$

The expression for the work done then becomes—

$$A = \alpha\,L m\,\Delta l$$

If l denotes the length of the test piece in millimeters and x the area of the section in square millimeters, the work done per unit of volume will be—

$$a = \alpha\,\frac{L m\,\Delta l}{x\,l} = \alpha.\beta.\lambda$$

where β is the load per unit of area of section and λ the elongation per unit of length. Now α can be determined experimentally, and Professor Tetmaier has proved by a numerous series of experiments that for the same class of materials the value of α is very sensibly constant. It follows then that the coefficient—

$$c = \beta\lambda$$

is proportional to the work done upon the test piece per unit of volume. The values of c enable us to classify the various kinds of ductile materials upon their capacity of work, and the factors β and λ are determined in the ordinary testing of materials. If we adopt the English ton, and the inch as units in the place of the kilogramme and the metre, we may express Tetmaier's coefficient in the following manner. Let β denote the tensile strength in tons per square inch, and let λ denote the percentage of elongation measured on a length of 8″, then—

$$c = \beta\lambda$$

represents the coefficient as before in inch tons per unit of volume. For thirty-two ton steel giving 20% elongation, the coefficient becomes 6·4, or we may use the coefficient to determine the elongation, having decided the tensile strength of the material beforehand. The author proposes to introduce the coefficient in his reports of tests in order to enable engineers to judge of the quality of materials when the strengths and elongations vary. In specifying the quality of steel, however, the upper limit of strength should always be stated in order to prevent the use of too great a percentage of carbon in the manufacture, but the lower limit need not be stated if either a coefficient of quality or the elongation be given.

Tetmaier's coefficient of quality was first adopted, on his recommendation, by the Swiss Government, about twelve years ago, it was afterwards adopted by the Austrian Government, and last year, also by the Committee of the American Society of Civil Engineers. It applies to compression and transverse tests as well as tension.

This Committee of the American Society of Civil Engineers recommend for all grades of structural steel from 56000 to 74000 pounds per square inch, *i.e.*, 25 to 32·6 tons per square inch, shall have the following elongations and reduction of area at fracture—

$$\text{Per cent of elongation in } 8'' = \frac{1500000}{\text{ultimate strength in lbs.}}$$

$$\text{Per cent of reduction of area} = \frac{2800000}{\text{ultimate strength in lbs.}}$$

This gives for 28 tons per square inch an elongation of 24% nearly and a contraction of area of 44·6%. Tetmaier's coefficient of quality becomes 6·72 inch tons per unit of volume of the test piece.

A recent specification by the Association of American Steel Manufacturers (Aug. 9th, 1895) is as follows :—

Name of Grade.	Tensile Strength.	Per cent. of Elongation.
Soft Steel ...	52000 to 62000	25
Medium Steel	60000 to 70000	22

The product 62000 by 25 is 1550000, and the product 70000 by 22 is 1540000.

If we prefer to use the English ten instead of pounds then the above rule becomes—

$$\text{Per cent. of elongation in } 8'' = \frac{670}{\text{strength in tons per sq. inch}}$$

$$\text{Per cent. of reduction of area} = \frac{1250}{\text{strength in tons per sq. inch}}$$

The pound is however, a better unit than the ton, and the latter is only introduced in order to render the results more in accordance with British practice.

The following table gives Tetmaiers system of recording the various coefficients of strength, elasticity and quality:—

Tests of Elasticity and Tensile Strength made on a round specimen of basic ingot iron (fer fondu).

Diameter of test piece $d = 25$ mm. Sectional Area $F = 491$ mm.^{2}

Detail Test.

No. of Test.	Total Load applied in kilogrammes	Primitive Sectional area F in mm^2	Observed Length l in mm.	Elongations Δl $\frac{1}{100}$ mm.	Differences.	Remarks.
16	 3000	491	150	... ... 4·20	4·20	Dimensions of the ruptured section $d_e = 15{\cdot}1$ mm. $F_e = 879$ mm.^{2}
	... ...			... ...	4·25	
	3000			4·25		Mean elastic elongation
					1·41	under a load of 1000kils $\Delta l = 0{\cdot}01415$ mm.
	4000			5·66		
					1·40	Coefficient of elasticity $e = 21590$ k. per mm.
	5000			7·06		
					1·41	Coefficients of work corresponding with—the
	6000			8·47		
					1·44	limit of elasticity $y =$ 19·4 kg. per mm.^{2}
	7000			9·91		
					1·41	the yield point $\sigma = 27{\cdot}7$
	8000			11·32		
					1·42	at rupture $\beta = 41{\cdot}2$
	9000			12·74		
		—Limit of Elast icity—			1·54	Elongations measured after rupture upon—
	10000			14·28		
					1·68	100 mm. $\lambda_1 = 32{\cdot}0\%$
	11000			15·96		200 mm. $\lambda_2 = 22{\cdot}0\%$
					2·16	
	12000			18·12		
	13000	Yield Point and				Contraction $6 = 63{\cdot}5\%$
	13650	Commencement of the permanent elongation.				Tetmaier's Coefficient of quality—
	20300	Maximum Load.				$c = \beta\lambda = 91$ kg. mm.
	15800	Load at Rupture.				

In regard to the Elongation. The usual way to record the elongation is as follows :—The total length of the test piece before and after the test is measured between the reference points, the latter is subtracted from the former, and the result multiplied by the length first measured and divided by 100. This method

gives the percentage of elongation, which it is the custom to record in test reports on materials in ordinary commercial testing. The error in the method and the divergence in the results when made on test pieces of different lengths is now well understood, the percentage of elongations increasing as the length of the specimen decreases, for the same diameters. The method of expressing the true percentage of elongation has been investigated by Mr. J. H. Wickstead in 1890, also by Professors Dwelshauvers, Derry, and Tetmaier, and it is generally admitted that the elongation up to the point of maximum load supported by the test piece should be used, and the local elongation or 'necking' which occurs afterwards should be rejected as it has nothing whatever to do with the length of the specimen, increasing with the diameter in circular sections, and with the ratio of breadth to thickness in rectangular sections. In *Plate* I fig. 10, the extension up to the point m is proportional to the length of the test piece, but the portion between m and r is the local extension or necking. The true extension per unit of length may however be obtained from the test piece in the following manner :—

Let the local extension be denoted by Δlo, the elongation per unit of length by λo. Then for a test piece of length $l = 8''$ and total elongation Δl_2 we have :

$$\Delta l_2 = \Delta lo + 8\,\lambda o \ldots\ldots\ldots (1)$$

If now we measure the total elongation over a length of $4''$ in the same test piece (or over any other convenient length containing the local elongation) we have :

$$\Delta l_1 = \Delta lo + 4\lambda o \ldots\ldots\ldots (2)$$

From these two equations we can find the two unknown quantities Δlo and λo thus :

$$\Delta lo = 2\,\Delta l_1 - \Delta l_2 \ldots\ldots\ldots (3)$$

and

$$\lambda o = \frac{\Delta l_2 - \Delta l_1}{4} \ldots\ldots\ldots (4)$$

The elongation at rupture is therefore for a length of $8''$:

$$\Delta l = 8\,\lambda o = 2\,(\Delta l_2 - \Delta l_1) \ldots\ldots\ldots (5)$$

This method, which is due to Prof. Tetmaier, gives the true elongation independently of the length of the test piece. The test piece should be divided along its useful length into spaces $\frac{1}{2}''$ apart to facilitate the measurement of Δl_1 and this has been the practice for several years in the Engineering Laboratory of Sydney University in all tests in which the author has not been restricted by the specification of tests accompanying the test pieces.

It can be shown however, that the total elongation measured in the usual way may be made to give approximately uniform results in diverse sections, if the length is suitably chosen thus :

Let the following proportions be adopted for a useful length of $8''$, viz., 0·8 diameter for circular sections, and $b : t = 3$ for rectangular sections. Then to find the length of test piece which will give the same value for the total elongation divided by the length as the normal section, we assume that the local extensions are proportional to the diameters in circular sections, and to the ratio of the breadth to the thickness in rectangular sections.

Experiments on different proportions of test pieces for the same material show that this assumption is practically true. Hence the following method may be used :—

Let x be the useful length over which the elongations are measured, then—

$$x\,\lambda o + \Delta lo = \Delta l_2$$

$$\therefore x = \frac{\Delta l_2 - \Delta lo}{\lambda o}$$

The general expression for the elongation after rupture is—

$$x\,\lambda o + \Delta lo = \Delta l$$

For a test piece of normal proportions having a length of $8''$ we have—

$$8\,\lambda o + \Delta lo' = \Delta l_2$$

$$\therefore \lambda o + \frac{\Delta lo}{x} = \frac{\Delta l}{x}$$

$$\lambda o + \frac{\Delta lo'}{8} = \frac{\Delta l_2}{8}$$

Imposing the condition—

$$\frac{\Delta l}{x} = \frac{\Delta l_2}{8}$$

We have—

$$x = 8\,\frac{\Delta lo}{\Delta lo'}$$

But $\frac{\Delta lo}{\Delta lo'}$ is proportional to the diameters in circular sections, and to the ratio of b to t in rectangular sections, hence we have the following proportions :—

Circular Sections—

Diameter	$d =$	0·3″	0·4″	0·5″	0·6″	0·7″	0·8″	1·0″
Useful length between reference points ...	$x =$	3″	4″	5″	6″	7″	8″	10″

Rectangular Sections—

Ratio b to t	$\frac{b}{t} =$	1·0	1·5	2·0	2·5	3	4	5
Useful length ...	$x =$	4″	5″	6″	7″	8″	8″	10″

Compare these results with *Plate* 1, figs. 1 to 7.

Compression.

For the determination of the elastic limits and yield point the French Commission recommend a diameter of 27·5 mm. (600mm^2 in cross section) with 100 mm. of useful length. The American Society suggest that the length should be from 10 to 20 diameters. For the resistance to crushing the French Commission suggest cubes or short prisms 25 mm. side, and the American Society cylinders 1″ in diameter and 2″ high.

In regard to the test of long pieces which fail by buckling, the Commission recommend that the ratio of length of the test piece to the minimum radius of gyration should be constant, and they propose a value which shall be multiples of 5 or 10, *Plate* 1, figs. 7 and 8. They recommend that the tests shall be made under well defined conditions, either complete clamping or perfect hinging. It appears to be preferable to adopt the latter method as clamping is unsatisfactory.

Prof. Bauschinger has expressed the compression strength of a test piece by the formula—

$$\sigma = \alpha + \beta \frac{\sqrt{f}}{l}$$

in which α and β are constants to be determined by experiment, f is the sectional area, and l the length. For prisms of dissimilar cross sections, he proposes the following formula—

$$\sigma = \left(\alpha + \beta \frac{\sqrt{f}}{l}\right) \sqrt{\frac{4\sqrt{f}}{u}}$$

where u is the circumference of the cross section.

Prof. Martens after investigating these experiments has deduced the following formulæ for cast iron of the same quality but different cross sections.

For rectangular sections $\sigma = 4400 \sqrt{\frac{\sqrt{b}}{\frac{1}{2}(b+1)}} + \frac{\beta}{n}$
sides a and b

For square sections ... $\sigma = 4220 + \frac{1497}{n}$

For circular sections ... $\sigma = 4320 + \frac{1417}{n}$.

For hollow sections
outer and inner diameters $\sigma = 4230 + \frac{1380}{n} \sqrt{\frac{d-d_1}{d}}$
d and d_1 respectively

$n = \frac{l}{\sqrt{f}}$, Prisms and cylinders of similar geometrical form have the same strength.

Experiments by Rondelet on different kinds of stone proved that the total strength of similar geometrical test pieces varies as the square of the homologous sides. The strength of a prism of square section is 0·98 times that of a cylinder of the same height and sectional area. In testing building stones it is necessary to cut it into the desired shape, otherwise the results will not be uniform. Chipping will affect the strength of small cubes more than large. All tests of this kind should be made on accurately prepared specimens with the opposite surfaces exposed to crushing, rubbed to true parallel planes, and one of the bearings should be spherical to ensure uniform distribution of stress. This applies to cements, concrete, bricks, etc., but the true planes may be produced by applying a thin coat of plaster of Paris.

The strength of cubes placed one on the other varies with the number of cubes, thus: for one, two and three cubes Rondelet found in one series the strengths to be 1 : 0·61 : 0·5 respectively, in another series 1 : 0·80 : 0·75 respectively.

In tension, compression, and transverse tests made on ductile materials there are three successive changes of state more or less clearly defined, which mark the limit of elasticity, the commencement of the plastic period, and the limit of cohesion or completion of the plastic period. The first change shows itself in tension tests and in compression tests, when the pieces are sufficiently long, by the elongations or shortenings of the specimen ceasing to be proportional to the loads producing them, and by the disappearance of the deformations when the loads are released. In transverse tests of beams the first change is marked in a similar manner by the deflections ceasing to be proportional to the loads producing them.

The second state is marked in tension and in transverse tests by the commencement of the permanent elongations, and deflections respectively; but in compression tests this change is shown by the commencement of the swelling of the piece in the form of a barrel, termed by the French refoulement. It is not necessarily however, the limit of cohesion. In order that it may be developed in the test piece the length must not greatly exceed the diameter or buckling will be produced.

The third change marking the limit of cohesion is shown in tension by the rupture of the specimen, in transverse tests of beams also by rupture, unless the material is so soft and ductile as in some kinds of mild steel, that the beams fail to support the loads by bending. In compression of short pieces the third change is shown by a decided swelling of the piece, although the load is perfectly supported.

The following shows the details on one of the tests made by Prof. Tetmaier on ingot iron, and is given as a specimen sheet for recording the results made to determine the relative elastic compression coefficients.

Size of test piece 200 mm. in length, 32·8 mm. in diameter.

Total loads in kilogrammes	Sectional Area F in mm^2	Observed length l in mm.	Compressions of piece Δl in $\frac{1}{100}$ mm.	Differences.	Remarks.
... ...	845	149·4	... ...		
				4·10	Compressions for a load of 1000 kilogrammes
5000			4·10		
... ...			... ...		0·81 mm.
				4·08	$\frac{}{100}$
5000			4·08		Mean elastic
				1·62	
7000			5·70		Compression for a load of
				1·63	
9000			7·33		1000 kilogrammes.
				1·60	
11000			8·93		$\Delta l = 0{\cdot}0082$ mm.
... ...			... ...		Coefficient of elasticity
				8·92	
11000			8·92		$e = 21560$ kg. per mm^2
				0·83	
12000			9·75		
				0·83	
13000			10·58		Coefficients of work
				0·81	
14000			11·39		corresponding with
				0·84	
15000			12·23		Limit of elasticity
				0·85	
16000			13·08		$\gamma = 21{\cdot}9$ kg. per. mm^2
				0·82	
17000			13·90		
				0·80	
18000			14·70		Maximum load supported
—Limit of Elasticity—				0·93	
19000			15·63		$\beta = 25{\cdot}1$ kg. per mm^2
				0·98	
20000			16·61		
				1·20	
21000			17·81		
21500	This load was not supported and rupture occurred by buckling.				

The following shows a similar test sheet made to determine the commencement of swelling of the test piece (refoulement) and the resistance to compression in ingot iron of the same quality as in the foregoing test.

Test piece 20 mm. in length and 20 mm. in diameter.

Total load applied in kilogrammes	Sectional Area F in mm²	Length observed l in mm.	Reading in 1/40 mm.	Differences		Remarks.
				Absolute	Per load of 500 kg.	
... ...	314	20	20·2			
5000			20·2	...		
6000			20·3	0·1	0·05	
7000	—Commencement of the refoulement		20·3	0·0	0·00	
7500			21·5	1·2	1·20	
8000			26·3	4·8	4·80	Commencement of bulging. $\sigma = 23{\cdot}1$ k. per mm²
8500			30·0	3·7	3·70	
9000			33·4	3·4	3·40	
10000			40·6	7·2	3·60	
11000			47·6	7·0	4·00	Resistance to compression $\beta = 39{\cdot}8$ k. per mm²
12000			54·8	7·2	4·90	
12500	—Pronounced change of state (resistance to compression)		58·8	4·0	5·10	
13000			63·7	4·9	5·30	
14000			73·9	10·2	6·00	Shortening or compression for 39·8 k. per mm²
15000			84·5	10·6	6·40	$\Delta l = 0{\cdot}96$ mm. or $\lambda = 4{\cdot}8\%$
16000			96·5	12·0	6·10	
17000			109·3	12·8	6·50	
18000			121·5	12·2	6·80	
19000			134·5	13·0		
20000	Load still perfectly supported.		148·1	13·6		

The author would like to have included some considerations on tests of columns by excentric loading, but he has decided to leave this for a future paper.

Transverse Tests.

In regard to castings, the Convention recommends that bars be used 110 centimeters in length by 3 centimeters side, giving a useful length of 100 centimeters. (*Plate* I, fig. 9). The faces of the bars should be left in their rough condition. The resistance to flexure should be measured up to the point of rupture, and the corresponding work on three pieces. The American Commission recommends that the faces of the bars should be shaped by a machine, and the edges rounded by a file, also that the time of testing should be comprised between one and two minutes. The sizes of the test bars are recommended to be 2″ on a side, or $2\frac{1}{2}$″ in diameter and the useful length of 16″ or 20″. The large size is used to avoid the effect of superficial quenching.

The usual test bar adopted in New South Wales, namely 2″ × 1″, with a useful length of 36″ would be improved by making the bars 2″ square, the length of 36″ or 40″ as recommended by the Convention is immaterial. If rectangular bars are used the coefficient of strength will be lower as the section is larger, and a wide bar gives a higher coefficient than a deep bar. The same span may be adopted for transverse tests of spring steel, taking care to test the steel plate after it has been prepared under the same conditions as to quenching and annealing as the springs. It is important to observe that the deflections should be measured from a fixed and invariable base, and that the load applied should be exactly in the middle, and normal to the axis of the piece.

In regard to tests on finished or whole pieces there is a difference of opinion as to the intensity of the test, but it appears to the writer that the maximum working load should be applied, and the deformation due to that load should be accurately measured. The working conditions may be represented by a steady pressure or by shock, but in either case it should be applied

as nearly as possible in accordance with these conditions. In testing beams, axles and rails, the loads necessary to produce this elastic limit and commencement of the permanent deformation should be determined, as well as the elastic and permanent deflections.

Impact Tests.

The importance of impact tests are fully recognized by the various Conventions, and continued study in this direction is recommended. The standard weight of hammer adopted by the Conventions is 1000 kilogrammes, but in certain exceptional cases hammers of 500 kilogrammes are permitted. The striking surfaces should be of forged steel, the vertical axis of the hammer should be perfectly symmetrical with the plane of the leads, and the guided length should be at least double the clear width between the guides. The weight of the anvil block shall be at least ten times the weight of the hammer, and the foundations shall be inelastic. The American Society however, recommend that the weight of the anvil block alone or embedded in solid masonary should form a solid mass of at least fifteen times the weight of the hammer. The leads should be lubricated with plumbago, and the frictional resistances should not exceed 2%.

In order to determine the effect produced by various heights of fall the work done by the hammer upon standard copper cylinders should be carefully studied. The maximum height of fall recommended is six metres. A sliding scale should be used, arranged so that the zero coincides with the level of the top of the test piece. It has been suggested that a short flexible cord or chain should be fixed between the detaching device and the hammer. The point of suspension should be on the vertical axis passing through the centre of gravity of the hammer. Impact tests are used at present in connection with the testing of tyres and axles, also for rails, but the apparatus used is rough and the results necessarily inaccurate. At the same time they give a good, rough indication of the suitability of the material for the purpose intended. Systematic tests made with apparatus designed to

record accurately the effect of the shock would furnish most valuable information not merely on railway axles, tyres, and rails, but on nearly all materials used in construction ; they would give information which could not be obtained in any other way, and they offer a very promising field for scientific investigation.

Superficial penetration and perforation by shock are recommended by the various Commissions, also tests of hardness by scratching and by resistance to wear and tear, but the methods most suitable have not been definitely decided.

Torsion Tests.

Torsion tests should be made with machines arranged in such a manner that all disturbing influences such as transverse stresses and longitudinal tension should be prevented. The test pieces and the collars or holders should be concentric cylinders, and keyways should be cut in the test piece at each end to secure it to the holders, which should be capable of sliding longitudinally when the piece is under stress. Very delicate observations on the elastic twist may be made by means of a telescope fixed to the test piece reading on to an upright scale placed at some distance from the telescope. Mixed tests (shearing and punching) are recommended by the Commissions for study—they say mild steel and ingot iron should not be punched.

Folding, curving, and bending tests are recommended, in which strips 250 x 40 millimetres are used, excepting in the case of copper and its alloys, in which the length may be reduced to 150 millimetres. The apparatus should be slow moving, and expose clearly the weakest portion of the test piece, and the bending should be made round a mandrel 25 mm. in diameter. The test pieces cut from plates should have a width of three times the thickness with rounded edges. One American society recommends that the diameter of the mandrel should be twice the thickness of the plate.

These tests may be made upon the material cold or heated to a standard temperature, or after quenching from a red heat in water

of a certain temperature, they may be applied after cold hardening, or after cutting. Closely allied with the foregoing tests are those made by forging, stamping, bending into hooks, boring, pressing, flattening, welding, and enlarging upon mandrels.

Special Tests.

Special tests, such as those made upon finished pieces, wire ropes, chains, pipes, tubes and boilers.

In the case of wire ropes the wires should be tested in tension, folding, winding, and torsion. The folding should be done on a mandrel, twice the diameter of the wire, by bending the wire alternately in opposite directions. Tests of the wire rope should also be made to ascertain its strength and flexibility, and the Commissions have suggested also a shock test applied along the axis of the rope. Tests of chains are of two kinds.—First: A gradually applied load continued up to the point of rupture, stopping merely to obtain measurements of the elastic and permanent deformations. Secondly: A proof load equal to the maximum working load, with careful examination and measurements to ascertain the change in form of the links under stress. Tests of pipes, tubes, and boilers should be made with hydraulic pressure up to the maximum working loads, and the deformations under stress should be carefully measured.

Temperature tests are very important and further experiments are necessary, but time will not allow of their consideration in this paper. The author hopes to be able to discuss these tests in a future paper.

Discussion.

Mr. Deane said he fully recognised the great value of the paper contributed by Prof. Warren, that there should be a uniform method of testing materials adopted was a matter of deep importance. The paper was worthy of careful study. He was thoroughly in accord with Prof. Warren in the main points brought under notice, but it appeared to him (Mr. Deane) that one thing had been omitted, and that was the chemical tests of materials, of which no mention was made in the paper. It might be said that we can do without chemical tests; but he could not agree to this. We wanted to be safe on all sides. We might specify certain tensile stresses and tensile strength, but if not subjected to chemical tests, we could not be certain as to the quality of the material we were getting—he referred specially to steel rails. Some steel for instance, was practically nothing but iron of a certain kind, and carbon, he might also mention nickel steel, and other descriptions which were really manganese. He supposed Prof. Warren would not object to make some reference to the question of chemical tests; he (Mr. Deane) would like to hear his views in regard to the same in connection with steel. He could not regard a specification as complete unless provision were made for chemical tests. As regards the drop test and deflection—it is of course very interesting to know what the deflection would be under certain conditions, but what is more important to the railway engineer is to be certain as to what his rail will stand in respect of the hammering to which it will be subjected. In a specification which he had been preparing recently in conjunction with Mr. T. R. Firth, they had adopted the drop test without deflection. He recognised the fact that more information was needed on these subjects, as comparatively speaking, in the history of mechanical engineering, steel was almost a new substance. He should very much like to see some uniform method of testing adopted, and should be highly pleased if Prof. Warren's recommendations were adopted by the Public Works Department and the colony at large.

Mr. J. I. Haycroft said that though every engineer did not or could not possess a testing machine, still he should be as far as possible conversant with the details of testing, as treated in the paper, in order to be in a position to write a sensible specification. At the outset, he might point out that the sequence, as set out in the paper, of the various bodies investigating this subject might be improved, as follows: the idea originated in 1884 at Munich as stated, the same technical convention meeting in subsequent years at Dresden, Berlin and Vienna. The American Society then took the matter up, and within the past two years a Commission of Research was authorised to make investigations in France. Not a single step in this forward movement had, as is usually the case in such matters, been taken in England, either by the Institution of Civil Engineers or other scientific bodies, though valuable individual research has occurred, and one could not look to the Board of Trade for any help in this matter.

The investigations of the Commission of Research in France, were in his opinion, by far the most important of the several that have taken place, due both to the well known scientific character of the nation, the eminence of their professional men, and lastly, but most important fact, to their having analysed the proceedings of the former conventions held elsewhere.

He wished to add to the paper some facts gathered from the French investigations, not in any way criticising the manner in which the paper has been compiled, or indeed in supplying what might be termed deficiencies, but with the object of making the members of the section acquainted with facts, and thereby adding, if possible, further value to the already valuable paper of the author. As regards dimensions of test pieces, the author stated that the American Society adopted for circular sections an area of test piece of 600 square millimeters for a useful length of 200 millimeters, which gives a diameter of 27·64 millimeters. This mode of procedure should have been credited to the French Commission who, in order to make a comparison of the total elongations taken after rupture on circular test pieces of different design, decided to

establish a fixed relation between the transverse section and the useful, or test, length of the piece. This relation, deduced by the law of similarity, shewed that the test length should be proportional to the square root of the cross section ; this law, as the author states, was agreed to by the convention, but it was not pointed out that the convention and the French Commission differed as to value of the coefficient, but the American Society ignored these formulæ, in as far, that they preserved a constant of 8″ for the length of test piece. The French formula was $L = 8{\cdot}16\ \sqrt{s}$, whilst the convention formula was $L = 11{\cdot}3\ \sqrt{s}$; the former gave a diam. of 27·64 millimetres for a test length of 200 millimetres,[1] whilst the latter gave 20 millimetres for same test length, or a proportion of 10 to 1 as stated by the author : the latter formula recommended itself on account of its simplicity due to the above mentioned proportion, but the former or French formula had this advantage, that the area, the first item deduced in using the formula, was a simple number (in the present case 600 square millimeters). Now in order to simplify calculations, the adoption of a simple number to express the area of cross section which is the function used in calculations of strength, was more advisable than simplicity in expressing the diameter, the difficulty of measuring which was always the same. The American Society on the other hand used the dimensions credited by the author to the Conventions or rather European standards.

The French dimensions were as follows—test lengths of 70, 100, 141, and 200 millimetres ; cross sections of 75, 150, 300 and 600 square millimetres ; and diameters deduced from above of 9·77, 13·82, 19·55, and 27·64 millimetres : the convention standards were those where the proportion of length to diameter is as 10 to 1, the length ranging from 100 to 250 millimetres. The American Society, as previously mentioned, preserved a constant test length of 8 inches, thus ignoring the difference which must occur in the measurements of total elongation, by testing with a uniform length and variable diameter. This length of 8 inches was chosen

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[1] $200 = 8{\cdot}16\ \sqrt{s}\ \therefore\ \sqrt{s} = 24{\cdot}51\ \ s = 6000$ mm. $d = 2\sqrt{\frac{s}{\pi}} = 27{\cdot}64$ mm.

by the American Society, as well as the decimal part of an inch diameters, for the purpose of approaching as nearly as possible the measures of the metric system.

As regards the accuracy of machines and errors permissible, the American Society made no recommendation, but the French adopt a rule not quite so exacting as that suggested by the Conventions.

As regards the rate of testing, it was the French Commission, not the American Society, who considered that the duration of the test should be, in a certain measure, a function of the volume of the test piece; the Convention, whilst making no recommendation on this subject, strongly urged the necessity of noting with what rapidity the diagram was traced. The resolutions of the Convention and the American Society provided for the use of diagrams similar to that exhibited by the author, but the French Commission did not consider them necessary, at least in current practical tests with a view to ascertaining the quality of the metal tested from a determination of the useful surface they present, and this is the opinion of some English scientists, amongst others Prof. Unwin. This remark of course only applies to diagrams taken by one or other of the autographic recorders. He uses diagrams however, which are plotted from the known stresses and the various observed elongations.

Under the heading of compression, the author for the first time referred directly to the results of the French Commission; the first recommendation was correct, as far as the elastic limit is concerned, but the mention of cubes or prisms of 25 millimeters a side should have been given as a recommendation of the Convention and not of the French Commission, whose recommendations on this head were that the diameters be reduced to 19·56 millimeters equal to a cross section of 300 square millimeters, and the useful length to 20 millimeters. As regards tests on long pieces, which fail by buckling, the Convention had issued no instructions, but the French Commission recommended the requirements as stated by the author, but the reason for which he omitted, said

reason being that that condition was all that was necessary to to make two tests comparable on bars or rivetted pieces. The American Society in this class of tests required that the process should be the same as in tensile tests dividing the useful or test length into small sections in such a manner that the loss in value sustained, might be determined from its elements, and that the calculation of the modulus and coefficient of elasticity should be made under like conditions.

As regards mixed tests (shearing and punching) the Convention was silent, but as stated by the author, the French Commission recommended further study ; the Convention only recommended that certain plates, such as those for boilers, of wrought iron, should be submitted to the punching test, but claimed that such a test was useless for plates of mild steel or ingot iron, neither of which should ever be punched.

The author stated, *inter alia*, "it is proposed to consider the nature of the mechanical tests rather than the results obtained, and generally to deal with the subject in regard to the data which it is sought to obtain in the tests and the precautions to be taken in order to eliminate disturbing influences." The author then proceeded, under the clause headed "Tension," to enumerate the various points which it was essential should be accurately determined in connection with the commercial testing of materials of construction, and enumerated under the sub-head (*b*) "the yield point," adding in a further paragraph as apparently distinct from being essential that for accurate scientific testing the limit and coefficient of elasticity be also determined.

On this point, Mr. Haycroft could not agree with the author, as he considered it was much more essential to know the limit of elasticity than it was to know the yield point. He was of course aware of the considerable difference of opinion which existed amongst engineers with regard to this branch of the subject, and was of opinion that it merited further and very careful consideration. It was well known that great difficulty has always existed in determining on a stress diagram the exact point where the limit of

elasticity was reached, and where permanent deformation commenced. Just to illustrate the differences of opinion which existed amongst engineers as to the elastic limit, he would bring under the notice of members the following facts corroborating his opinion on that point. The French Commission made use of three terms :—

(1) The elastic limit or the unit stress beyond which a portion of the deformation remains as permanent set.

(2) The proportional elastic limit, corresponding to the point where the deformation ceases to be proportional to the loads.

(3) The apparent elastic limit corresponding to the point where the deformations increase rapidly without any increase in the force exerted : all these points lay between *e* and *y* of the author's diagrams.

The Conventions required that during the elastic period there should be sought the yield point and the limit of proportional elongation, appearing to admit that these two limits were blended. The American Society required the determination of the same information, insisting especially upon the importance of the yield point, which measurement it claimed should be made with the greatest precision. The American Society did not however seem to be very sure as to their actual requirements, as it defined the yield point as the load which produced a modification in the rate of elongation, thus seeming to identify it with the proportional limit of the French Commission ; but further on in the American Society's report, in an illustration, it required that the limit (yield point) should be determined by noting the point at which the elongation was suddenly augmented, thus identifying it with the apparent limit of the French Commission.

Prof. J. B. Johnson of Washington University in his recent book on "Materials of Construction," went very fully into this matter with a view to put an end to these differences amongst professional men. The Professor referred to was a recognised authority, and the very fact that he had made upwards of 40,000

tests on timber alone for the United States Government, was sufficient guarantee that he was reliable. Professor Johnson in dealing with the definition of the French Commissions shewed that none of them could be used in practice, and that they were absolutely indeterminate or wholly dependent on the delicacy of the measuring apparatus rather than on the qualities of the material tested. When the most delicate apparatus was employed, several specimens from the same bar of the most uniform material might give elastic limits of either of the first two kinds which differed widely from each other, and hence were materially contradictory. In other words, such delicate tests were worthless for practical purposes, the results obtained not being characteristic.

The third definition, that of apparent elastic limit was also indefinite since it remained a question which load was to be taken, the higher load at which the first great permanent elongation occurred, or the lower load under which this elongation continued to spread throughout the entire length of the bar: these often differed by as much as from $1\frac{1}{2}$ tons to 3 tons per square inch. Prof. Johnson was also seized with the want of knowledge on this subject, and stated: "The fact is something must be done in this matter, since no one knows what is meant by elastic limit, without an explanation, which explanation is not usually given.

Prof. Johnson proposed as a way out of the difficulty, the adoption, in the future by members of the profession, of an arbitrary definition which he styled the "apparent elastic limit," and defined as being that point on the stress diagram where the rate of deformation was 50% greater than it was at the origin. This point, in all tension stress diagrams, would be found to mark a well defined point, whose coordinates were practically fixed and constant for the same material. Although this point was slightly beyond the true elastic limit it would mark a point corresponding to a permanent set much less than could be measured on any scale by the naked eye and hence might be regarded as the true elastic limit for commercial purposes. This point also served to classify material as to the maximum loads they could resist without receiv-

ing deformation which would injure them for continued service, being the real "ultimate loads" for all practical purposes. It marked therefore, the most valuable and important property of all engineering materials. It was thus the most essential characteristic point on the stress diagram. After this last opinion surely the author of the paper would make an alteration where he put the value of the yield point in priority to that of the elastic limit as regards essentiality of determination. It may be very interesting to know the so-called yield point of a certain material, or its percentage of elongation, but Mr. Haycroft was of opinion that definite information as regards the limit of elasticity alone, was of infinitely greater value to a professional man when designing, and marked its most valuable and important property.

Members of the profession who took an interest in this subject could not do better than read Prof. Johnson's book and the various Continental and American reports, from which latter the paper and these remarks have been freely compiled. In conclusion he was of opinion that the use of the decimal system was more appropriate for physical measurements, such for instance as those mentioned in the paper, than the duodecimal or English method, and would be glad to see it more generally used in the future. In connection with this matter he might state that a paper on "The decimal system in engineering methods" had been read before the Institution in London last May, and a bill was being put through the United States Senate making the use of the decimal system compulsory in the United States from the commencement of the Twentieth Century, in all transactions, except land measurements. It existed at present in their coinage and in measurements of the Coast and Geodetic Survey.

Mr. SELMAN said he had carefully perused the recommendations of both the American Society of Mechanical Engineers and the French Convention in regard to the testing of materials, from which sources the author had drawn so largely in compiling his paper, and to those interested in this matter he commended for study a recently issued American State paper dealing with the

whole subject, and the various decisions arrived at. Although no formal action of a similar character had yet been taken in this matter in England, still a very large amount of attention had been given to it both scientifically and commercially, and he failed to discover in the recommendations anything that was not well known and in many cases the practice there for the last ten years or more, he could not see how Professor Warren's paper had in any way improved matters other than from an educational point of view. The author had stated in the paper that it was essential to accurately determine three factors in each tensile test, one of which was the "yield" or "breaking-down" point, but nothing had been said as regards the determination of an apparent limit of elasticity, though several purely physical points had been touched on. Mr. Selman, however, contended that the "yield point" was a very unsatisfactory criterion of the elastic properties of materials. If was true that it was generally a well defined point on the diagram, and by no means difficult of fairly exact determination; but as the range of its exact position, as regards its distance from the limit of elasticity was so very variable, it was no safe indication of the exact value or position of the latter. Notwithstanding that a number of most elaborate instruments had been designed, having for their object the determination of the elastic limit, yet the writer believed that it was still an indeterminate quantity, and that the only practical solution of the difficulty would be to adopt some definite and convenient point lying between the true elastic limit and the yield point.

Quite recently in America, Professor Johnson, an authority on this matter, had proposed an "apparent limit of elasticity" based on the determination of a tangent point on the diagram at which the rate of elongation was 50% greater than what it was at the origin. No doubt this was a practical step in the right direction, but the writer had found the method difficult of application from the uncertainty of being able to locate the exact position of the tangent point on account of the personal error and the smallness of curvature at the tangent point. Mr. Selman proposed as a

"standardising limit of elasticity" the point of intersection of the stress diagram with a line making an angle with the axis of stress whose tangent was 5% greater than that due to the rectilinear portion of the diagram.

Such a point was exceedingly easy of determination and always lay between the true elastic limit and the yield point; being sufficiently near the former in most cases to ensure that the rate of elongation was not more than 5% above its normal value. All difficulties as regards errors of observation would practically be removed, and he was of opinion that such a "limit" would be found very uniform in all tests from the same bars, and sufficiently near the commencement of the plastic action for all engineering purposes. Such a standard limit would be fair both to the engineer and the manufacturer, and probably prevent materials from being unfairly condemned. He had known materials rejected by one engineer as bad and accepted by another as of good quality, simply through a descrepancy in the tests.

He had applied his proposed "standardising limit" method to the test of the bar of basic ingot iron given in the paper in illustration of Tetmaier's system of recording a test, by plotting the figures with the result shewn in the diagram.

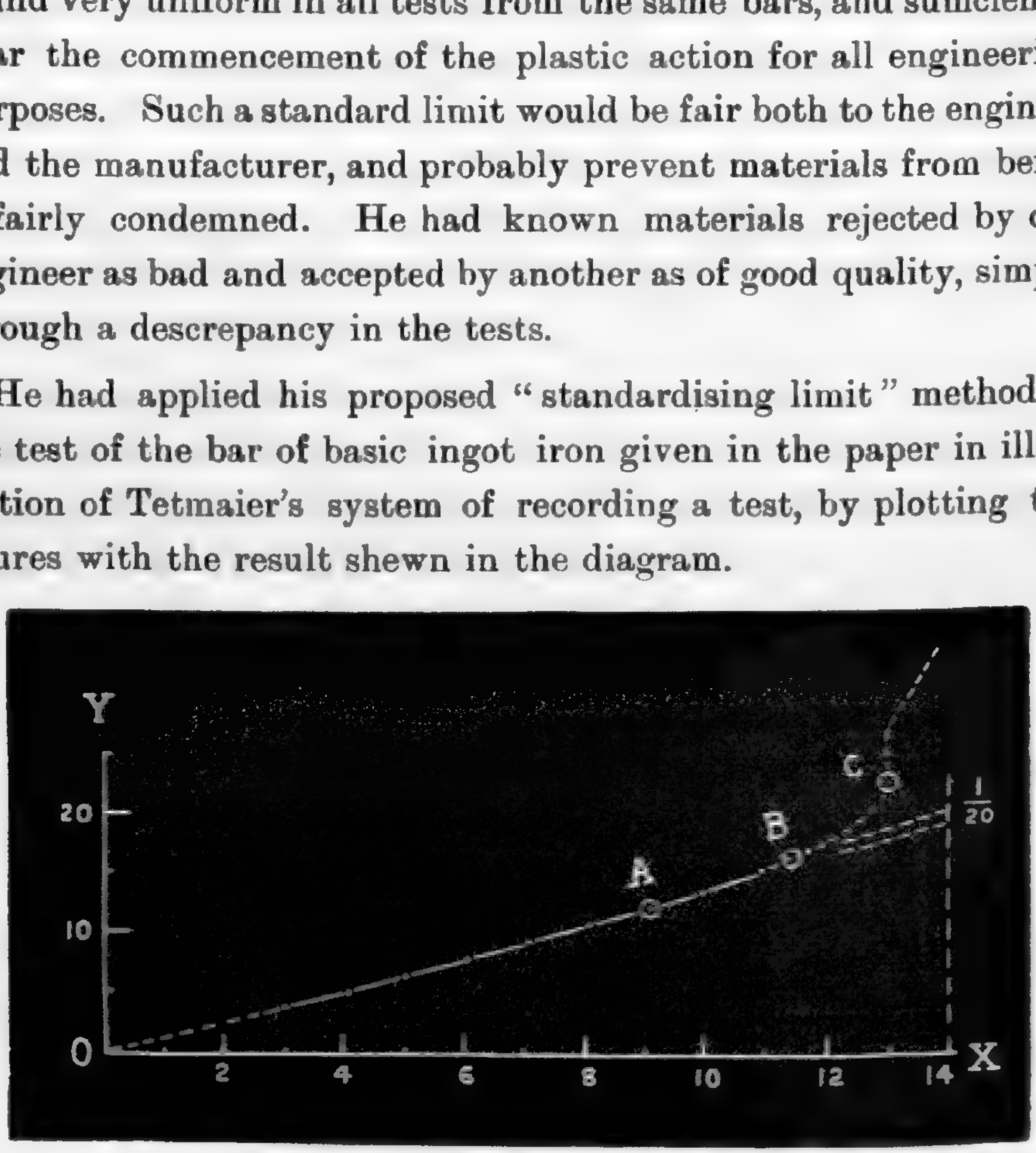


Fig. 1.

O X = Load in "Tonnes." O Y = Percentage Elongations.
A = Apparent limit of Elasticity according to Tetmaier.
B = Standardising limit of Elasticity. (Selman).
C = Yield Point.

It would be seen that the apparent limit of elasticity as given by Tetmaier was about 9,000 kilogrammes, and the yield point about 13,000 kilogrammes; the standardised limit being about 11,400 kilogrammes with a very slightly augmented rate of elongation above the normal value. These values in tons per square inch were Tetmaier's limit of elasticity about 11·3 tons, standardised limit of elasticity about 14·5 tons, and the yield point abopted by the author 16·7 tons. Mr. Selman was of opinion that the 11·3 tons was much too low. For similar iron a number of Bauschinger's tests gave an average of about 13·5 to 14 tons per square inch, a result strikingly in accord with that given by the method proposed by himself. It was quite easy for inertia in the testing machine to give abnormal values near the elastic limit, and this may probably have been the case in the present instance. It would also be noted that the differences of elongation as given in the table referred to were very small and fairly regular, except at 6,000 kilos., until about 11,000 kilogrammes was reached when there was evidence of the commencement of plasticity, the difference being 2·16 against 1·68 for the previous loads. This also confirmed his contention. There were many other points in the paper open to discussion, but he regretted that he had not had sufficient time at his disposal to criticise them.

Mr. SHAW said he would like to make a few remarks with regard to the "impact test." Prof. Warren makes use of copper cylinders for regulating the strength of blow. He had a drawing of a small testing machine he had designed some time ago, which might be of interest to some of the members. This was designed for testing steel cylinders subject to very high strains such as are used in ordnance. The ram shown was turned to a very accurate fit, and fitted with a copper bush, and had a chamber containing the main body of the water round this bush. At the base of the pedestal there was another ram sealed by a small copper disc which acted on the top of the copper cylinder. The copper cylinder was of known size, diameter and length—the weights were allowed to fall on the disc and it in turn acted on the

cylinder—an aperture, as shown, being left to admit of the free entry of air, as the blow fell. The copper cylinder was then taken out, measured, and a piece from the same bar taken and cut from the original put into the machine, and tested to the exact length as it was when it came out—giving the exact momentum of the blow. The machine is of course only useful where high concussive strains have to be dealt with.

Mr. SINCLAIR said that one point that appealed to him in the paper was in reference to the "test load" as applied to tubes and boilers—he (Prof. Warren) only recognised "maximum working load." He (Mr. Sinclair) thought that this data would be of little value for getting out any alterations that would take place in the boiler for showing any weakness of the boiler, cylinders, etc. He thought in this case no deformation would be produced, although a slight deformation was anticipated in such structures—it might for instance come in an unstayed end. The Board of Trade and kindred bodies in the old country, in dealing with this question, allowed a hydraulic test of $1\frac{1}{2}$, although a great many engineers still adhere to twice the working load; and in one instance that came to his mind, he had to put a boiler up to 3·20, not due to any weakness of the boiler, but through a faulty joint. It would be a great advantage if something uniform could be decided upon in regard to the maximum test stresses to be put on structures.

Mr. G. H. KNIBBS said that the behaviour of materials under stress might be treated either from the point of view of the physicist or from that of the engineer. As however, approach was made to exactness, the former or theoretical view became more and more important, and when questions like the limit of elasticity were touched it was necessary to have regard to facts which might have otherwise appeared purely theoretical and of little practical moment. An ordinary rough stress-strain diagram, it was true, shewed a trace, which for some length was *sensibly* straight, and hence this portion might be taken as *sensibly* representing that portion of the deformation which was proportional to the applied stress, and moreover independent of the time during

which the application of the stress was continued. But experiments shewed that in addition to this, there was a secondary deformation depending upon the time during which the stress was maintained, but which appeared to approach a limit. Consequently the trace in the stress-strain diagram was not exactly straight anywhere; and its curvature would slightly vary with the time of stress-application. A proposal therefore to produce the straight part of the curve, and adopting an arbitrary increase of the tangent or arc, to draw a second line, the intersection of which, with the trace, was to be taken as the arbitrary elastic limit, could not be regarded as having any distinct advantage over Professor Johnson's proposal, viz., to draw a tangent to the curve with an arbitrary increase on the ratio of the deformation to stress. And his method had very little advantage over the older practice of marking the point where the trace commences to sensibly curve. The difficulty of ascertaining the point where the molecular constraints resisting deformation were so relaxed that the rate of plastic flow becomes very large, relatively to the elastic extension, was a difficulty inherent in the behaviour of the material and one which could not be avoided. Probably a higher order of accuracy of measurement now possible by such instruments as Prof. Martens' extensometer, would, when thermal changes due to the stress were measured and discussed, indicate the solution of this question. It might be of interest to mention that in a test made to-day by Mr. Barraclough and himself with the instrument referred to, disposed as recommended in the paper recently read by the latter to the Royal Society, the evidence of plastic flow was noticed even in 20 seconds and in 30 seconds. The loads in thousands of pounds, and the differences of the deflections in ten-thousandths of millimetres, were :—

Load	5	7	9	11	13	15	17	19	21	22	23
Diff. Extension	116	126	123	123	124	123*	138	181†	145	310	

* Flow in 20 seconds 4. † Flow in 30 seconds 4.

It would be seen that while the rate extension was apparently uniform, plastic flow appeared to have occurred. In conclusion,

he would like to say that the continuation of observation of the 'yield point' was desirable, because although the phenomena of its occurrence might not be fully elucidated, they were worthy of study, since it marked a critical change in the behaviour of the material. In general it was desirable that the results of testing should be of value not only from the view of the engineer but also from that of the physicist.

Mr. S. H. Barraclough said the discussion had largely centered around the question as to what point on the stress diagram should be chosen as a measure of the elastic properties of the material under test. The whole question was, in the present state of our knowledge, almost entirely a matter of personal opinion. He could not agree with some of the previous speakers in their opposition to the use of the yield point as a satisfactory measure of the elastic properties for all "practical" purposes, and he thought that in attempting to altogether discredit the worth of this point a rather unjustifiable use had been made of Professor Johnston's lately published book, for on page 306 of that work it was stated that "in practical or commercial testing it will be found sufficient to observe the third one only. . ." *i.e.*, the yield point. Further the fact that the stress-strains diagram obtained from a test of certain materials such as cast iron and some grades of steel did not show any yield point, was no argument against its use for such materials as did show it. An examination of the results of tests made at the University for some years past would show that in the great majority of cases the yield point is well marked, and constitutes a thoroughly characteristic point on the diagram. The yield point is of course considerably above the elastic limit, and, as the author of the paper states, should always be called the yield point and not the elastic limit, when reporting a test. To illustrate the positions of these two points and of the two arbitrary elastic limits which had been proposed during the course of the discussion, the speaker had prepared two stress-strains diagrams representing the results of tests made with the aid of Marten's mirror extensometer, by which the extensions of the test

pieces are measured to four millionths of an inch. It would be noticed that the limit proposed by Mr. Selman was considerably higher than that of Prof. Johnson, both of course being above the so called true elastic limit. There was no apparent advantage to be gained by adopting the limit proposed by Mr. Selman. It was simply a question as to how nearly parallel you could draw two lines and still have a definite point of secancy. At the previous meeting Mr. Selman had proposed that the one line should be made to slope ten per cent. more than the other, at the present meeting he substituted five per cent., and there seemed nothing to prevent some one else using three per cent. or one per cent. It was merely a question of draughtsmanship.

With regard to Prof. Johnson's proposed "apparent elastic limit," it was to be regretted that a more detailed demonstration was not given in his book of the reliability of the statement that when the apparent elastic limit is located in the manner directed "it will be found at practically the same point on all tests of like kind on similar materials. It is therefore *characteristic of the material.*" Judging from some of the figures given in the book, (for example fig. 249), this particular elastic limit was subject to about the same variation as were the others. Prof. Johnson probably used the term "characteristic" in a somewhat loose and general sense.

Professor WARREN in reply to the discussion, said, in answer to Mr. Deane that in regard to chemical tests, it had generally been accepted that, if the physical tests as fixed by the specifications were satisfied, then, also, would the chemical composition be satisfactory, but this was not universally true. At the same time it was desirable to interfere as little as possible with the province of the steel manufacturer, whose business it was to produce steel in accordance with the requirements of the physical tests specified, which should be sufficiently comprehensive in character to develope the real nature of the material as applied to the particular purpose for which it is intended to be used. There were however, some few exceptions to this rule, such as for example in the case of

steel rails, where the physical tests should be very thorough if they were to be relied upon entirely, such as the careful determination of the elastic limit in cross-bending, and the exact measurements of the strains within and beyond the elastic limit, which should be compared with standard deformations under stresses in rails of a known satisfactory quality similarly tested. In this way the hardness and durability of the rails when laid in the road would be sufficiently accurately determined. Again the drop test carefully conducted with measurements of the deflections produced by the blows of the hammer, and also of the elongations produced by the bending of the rail on the tension side, would give reliable data as to the quality of the rails.

Prof. Tetmaier, who had devoted considerable attention to the subject, recommended that the rails should not take a permanent set with less than 19·35 tons per square inch at the most strained fibre, and he gave a formula for rails tested on supports and loaded in the centre. Reduced to English units his rule would be thus—

Let W = the load in the centre which will not produce a permanent set

M = the moment of resistance of the section with an extreme fibre stress of 19·35 tons per square inch

l = the span in inches

Then $W = 4\frac{M}{l}$

After removal of this load the rail should spring back to its original shape. The load was afterwards to be increased up to a fibre stress of 32·25 tons per square inch, using autographic apparatus, on plotting the various deformations to scale. For comparisons as to relative hardness, the formula for the load up to this stress was

$$W = 6{\cdot}7\frac{M}{l}$$

This should be increased until the rail became permanently twisted and deformed, but it must not fracture.

In the case of some rails recently tested at the Engineering Laboratory, welghing 45 and 58 lbs. per yard respectively, the

author used Tetmaier's formula thus, the moment of resistance calculated in the usual way was found to be—

$$\text{For the 45 lbs. rail } M = \frac{fI}{y} = \frac{7{\cdot}57}{1{\cdot}91} f = 3{\cdot}96\, f$$

$$\text{For the 58 lbs. rail } M = \frac{15{\cdot}67}{2{\cdot}284} f - = 6{\cdot}86\, f$$

The spans for each rail were 67 and $33\frac{1}{2}$ inches.

At the elastic limit where $f = 19{\cdot}35$ tons per square inch

$$\therefore W = \frac{4M}{l} = \frac{3{\cdot}96 \times 19{\cdot}35 \times 4}{67} = 4{\cdot}56 \text{ tons for the 45 lbs. rail}$$

$$\text{and } W = \frac{6{\cdot}86 \times 19{\cdot}35 \times 4}{67} = 7{\cdot}92 \text{ tons for the 58 lbs. rail.}$$

For the $33\frac{1}{2}$ inches span the results were proportional. The rails were carefully loaded and the deflections measured until the elastic limits were reached in each case, which occurred with loads of 4·5 and 5 tons for the 45 and 58 lbs. rail respectively. Hence the 58 lbs. rail was considered to be too soft. Pieces cut from the heads and flanges and tested in tension, as well as the results obtained by testing the rails under the drop hammer, confirmed the bending tests. There was no doubt that physical tests could be thoroughly relied upon to give reliable data as to the quality of all construction materials, provided that the testing was properly conducted and suitable tests were chosen.

The question raised by Mr. Deane did not however, apply to the reliability of physical tests in the determination of the quality of any material, but rather how this was governed by the chemical composition, and as to the most reliable method which an engineer should adopt in ordering a quantity of rails in order to ensure that the quality should be suitable for the purpose. The chemical composition governed the quality of the material as delivered to the rolling mills from the furnaces in the shape of ingots or blooms. The reheating of the blooms, and the design of the rolling mills influenced the resulting product; it was desirable also that the rail should be finished at as uniform a temperature as possible throughout its length, and that the metal should be practically uniform in quality. No doubt these requirements were fully

realized and more or less obtained in a well organized establishment; if it was not, the rails would be of unequal hardness. This would be more likely to occur where a high percentage of carbon was used, which was very desirable in order to secure durability in the road and resistance to deformation.

It appeared therefore that the practice of the American engineers was the best to follow in regard to rails, and this was well exemplified in the specifications of Mr. Walter Katte, Engineer-in-Chief of the New York Central and Hudson River Railway, to whom the author is indebted for the following particulars—

Chemical Composition.

	65 lbs.	70 lbs.	75 lbs.	80 lbs.	100 lbs.
Carbon	0·45 to 0·55	0·47 to 0·57	0·50 to 0·60	0·55 to 0·60	0·65 to 0·75
Silicon	0·15 to 0·20	0·15 to 0·20	0·15 to 0·20	0·15 to 0·20	0·15 to 0·20
Manganese ...	0·80 to 1·00	0·80 to 1·00	0·80 to 1·00	0·80 to 1·00	0·80 to 1·00
Sulphur not to exceed ...	0·069	0·069	0·069	0·069	0·069
Phosphorus not to exceed...	0·060	0·060	0·060	0·060	0·060
Rails having Carbon below will be rejected	0·43	0·45	0·48	0·55	0·60
Rails having Carbon above will be rejected	0·57	0·59	0·62	0·65	0·75

Test ingots were also cast from each heat from which bars about 18″ long and half an inch square were rolled, these were afterwards bent cold through a right angle of 160°. These test bars should not fracture, and the elongation on the stretched side should be 12% per inch. The rails were tested on supports three feet apart, under the drop hammer weighing 2,000 lbs., the heights being as follows :—

Weight of rail in pounds per yard	60	Height of drop	16 feet
,, ,, ,,	65	,, ,,	16 ,,
,, ,, ,,	70	,, ,,	16 ,,
,, ,, ,,	75	,, ,,	20 ,,

Weight of rail in pounds per yard			80	Height of drop		20	feet
,,	,,	,,	85	,,	,,	20	,,
,,	,,	,,	90	,,	,,	20	,,
,,	,,	,,	95	,,	,,	20	,,
,,	,,	,,	100	,,	,,	20	,,

Ninty per cent of such tests should stand without fracture, and when fracture occurred the rails must show 5% elongation on the most strained inch on the tension side. The high percentages of carbon and manganese used would be considered too great by English engineers, but the results obtained by this specification so far have been very satisfactory. In the case of railway tyres and axles, also propeller shafts, armour plates, guns, etc., the object aimed at was to produce a material of the greatest strength and elasticity consistent with sufficient ductility to enable it to resist the shocks and general rough usage to which it was subjected. Chemical composition must be carefully attended to by the manufacturer in such cases and subsequent treatment, but it did not appear wise for the engineer to fix the proportions of the ingredients which were necessarily better understood at the works, more especially as the quality can be completely ascertained by suitable physical tests. Moreover, the mechanical processes to which the ingot is subjected differed in the various steel works, to such an extent, that if the chemical composition were the same in each case, the resulting products would be by no means uniform. The subject of physical tests of steel and chemical composition was now attracting considerable attention, and the effect of carbon, manganese, silicon, phosphorus, and sulphur, on the strength, elasticity, and ductility of the metal was fairly well understood.

Mr. Cunningham has given some results of Mr. Campbell's investigations as to the strengthening effect of the various components of steel,[1] which are of considerable interest in regard to the question of chemical and physical tests. He says that, the strength of puro iron, as far as it can be determined from the

[1] Proc. American Society of Civil Engineers, Vol. XXIII., No. 5.

strength of steel is about 38,000 or 39,000 lbs. per square inch, and the formula for acid steel is—

38600 + 121 carbon + 89 phos. + R = tensile strength

For basic steel—

37430 + 95 carbon + 8·5 mang. + 105 phos. + R = tensile strength.

The carbon manganese and phosphorus are expressed in units of 0·001%, and the value of *R* given in accordance with the conditions of rolling and the thickness of the plates or pieces. The formulæ were derived from experiments on structural steels ranging from 0·02 to 0·35% of carbon, and probably do not apply to steels of harder quality or special alloys.

Mr. H. M. Howe, a high authority on this subject says, "The structure and physical properties appear to depend chiefly—1. On the ultimate chemical composition. 2. On the mechanical treatment it has undergone. 3. On the conditions under which it has been heated or cooled, *i.e.*, its "heat treatment" which may induce the ultimate components of the mass to regroup themselves in new combinations, thus causing one set of minerals to give place to another. Just as the character of granite rock may be judged from the character of its mineral constituents, as proximate chemical compounds, and very imperfectly from ever so exact a determination of its ultimate elements, so we must learn to rely with less assurance on the ultimate chemical analysis of iron and steel, and more on the proximate chemical compounds formed therefrom. Unfortunately these latter are difficult of determination, or even of identification, and hence we know very little about them. It is for this reason that we are as yet unable to infer with any great assurance the mechanical properties from the chemical analysis."

The author considered that the form of the cross section of rails was very important, and that the relatively thin flanges adopted by English engineers were unsuitable for steel containing a high percentage of carbon. The American section appeared to be much more satisfactory in every way.

In reply to Mr. Haycroft's thoughtful discussion of the paper, only those points would be referred to in which he appeared to differ from the author. Since the paper was read, an excellent book on materials had reached this country written by Professor Johnson in which many of the points under discussion were fully treated. Mr. Haycroft appeared to prefer Prof. Johnson's proportions on test pieces, and his method of locating a so-called elastic limit to the recommendations of the author. After carefully reading Prof. Johnson's views on these points, the author was unable to alter his opinion or modify it in any way for the following reasons. In regard to the proportions of test pieces pieces shewn in Figs. 1 to 6. The object of the paper as expressed in the title was to secure unification of the methods of testing materials, and the proportions given have been shown to give uniform results by Prof. Tetmaier and other eminent authorities, and have moreover been endorsed by the practise of the majority of the laboratories in Europe. Professor Johnson proposed proportions intermediate between those of the French and Germans, which have not, so far at least, been adopted by the International Union,— necessarily the highest authority on these matters. Until this was done the author saw no reason to modify these proportions, as they were so simple that they could readily be remembered by anyone interested in the subject.

In regard to the term Elastic Limit. A definition of this was given in the paper, and there can be no question that it was of more importance to determine this point than the yield point, but it was absurd to expect to locate it accurately on an ordinary autographic diagram.

Professor Kennedy had succeeded in making an appliance which drew the stress-strain diagram for the elastic period fairly well. Mr. Olsen, of Philadelphia, had showed the author, about eighteen months ago, a very fair piece of apparatus for producing a similar diagram in connection with his testing machine; it was illustrated on page 349 of Johnson's book. The Grey extensometer apparatus on some of Mr. Richle's machines was equally good.

Probably the most perfect apparatus for producing this part of the diagram would consist of mirrors attached to the test piece, whose angular displacements were proportional to the deformations, and the light from which was focussed by means of a camera with the sensitised plate made to slide at a rate proportional to the stress on the test piece. Such an instrument could easily be constructed, and its advantages over every other so far constructed were obvious. Professor Johnson proposed, however, to locate a point on the ordinary small scale autographic diagram which he had defined as the relative elastic limit, thus adding another kind of elastic limit to the three referred to by Mr. Haycroft. Such autographic diagrams are exceedingly useful and instructive, and should be drawn for every test which is continued to the point of failure, but it appeared to the author undesirable to push the data so obtained too far. The yield-point was perfectly well defined on such diagrams for ordinary ductile materials, and it was usual, although incorrect, to record this point as the elastic limit. The author proposed to record the yield-point, as the yield-point or commencement of the large plastic deformations, as he considered the practice of recording it as the elastic limit is misleading, also that it was preferable to any arbitrary point such as Professor Johnson's, which lay somewhere between it and the elastic limit, which latter is very imperfectly defined on an ordinary autographic diagram. If the elastic limit were desired—and this should always be obtained in an important test—then it was imperative that an accurate extensometer be used, such as the one exhibited by the author at the June meeting of the Society—"The Martens mirror apparatus." It was absurd to say that fine measurements were useless for such a purpose, and that rough ones are preferable. None of the methods described by Professor Johnson, in conjunction with American tests, were as exact as the records produced by Professor Martens' apparatus.

The subject of impact tests have only been referred to by Mr. Shaw, who explained a very ingenious application of the use of copper cylinders in connection with such tests.

In reply to Mr. Sinclair on the tests of pipes and boilers by means of hydraulic pressure, the author recommended the test to be continued up to the working loads, as he considered that the practice of testing a boiler to double the working load might produce permanent strains; but he saw no objection to one and a half times the working load if ordinary care is used in making the test, or even a higher pressure if care is taken to avoid overstraining. As the paper was not intended to deal with boiler tests, the remarks should have been restricted to pipes.

In regard to Mr. Selman's remarks, the author was astonished at the statement referring to the practice in England ten years ago. The object of the International Union for the Unification of Tests had been sufficiently explained in the paper, but according to Mr. Selman there would appear to be no necessity for such a society, or of the various other societies in America and France, he appeared to have misunderstood the paper in various particulars. In regard to his remarks on the elastic limits and yield points, it was incorrect to say that no reference had been made to the apparent elastic limit. There is also no justification for the statement in which he implied that the author considered the yield point a criterion of the elastic properties of the material. Surely no one reading the paper carefully could draw such an extraordinary conclusion as to the meaning of the author. The statement as to whether the elastic limit is determinate or not should have been explained more fully, as it was not clear enough for the author to reply to. The standardizing limit proposed by Mr. Selman appeared to be decidedly inferior to the relative limit proposed by Professor Johnson. In regard to his reference to Professor Tetmaier's tests, the author wished merely to state that Professor Tetmaier was acknowledged to be one of the most eminent authorities on the testing of materials, and had a world-wide reputation.

NOTE ON THE CUBIC PARABOLA APPLIED AS A TRANSITION TO SMALL TRAMWAY CURVES.

By C. J. MERFIELD, F.R.A.S.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, August 18, 1897.*]

Introduction.—In a paper by the author, published in the Proceedings of this Society during the year 1895,[1] it is shewn how the cubic parabola may be applied as a transition curve for connecting the straight to the circular curve. Appended to the discussion there are tables to facilitate the field operations, the abscissa having a fixed numerical value.

If the angle ϕ, contained between the abscissa and the tangent to the curve at the point of contact with the circular curve, be made constant, then other tables may be constructed by simply taking a suitable multiple for the case required.

On tramways it is often necessary to use small radii curves when connecting the straights. The shock received by the rolling stock, due to the sudden change from the straights to these sharp curves, is very noticeable even at low rates of speed, but this concussive motion is reduced to a minimum, by adopting a curve of varying radius to connect the straights with the circular curve. Theoretically all circular curves should have transitions applied, but usually in practice, transition curves are not used, when the adopted elevation of the outer rail of the circular curve is small.

It is the object of this note to demonstrate how the method, explained in the previously mentioned paper, may be easily extended to any case required, by the aid of three tables.

Method of preparing the tables.—The three tables appended are computed from the equation

$$y = mx^3$$

[1] Vol. xxix., p. 51.

A numerical value is given to the coefficient m so that the radius of curvature of the curve represented by this equation, will be the same as the circular arc at the point of tangency.

The method of deriving this coefficient, so that the above condition shall be fulfilled, has been explained by the author in the paper referred to, but the following abstract will be compatible with this note, the same notation being adopted as formerly.

From the equation to the curve we have

$$\tan \phi = 3mx^2 = dy/dx \ldots\ldots\ldots\ldots 3$$

and if this be substituted in the equation

$$\rho = \left\{1 + \left(\frac{dy}{dx}\right)^2\right\}^{\frac{3}{2}} \div \frac{d^2y}{dx^2},$$

it will be found after reduction that

$$x/2\rho = \sin \phi \cos^2 \phi \ldots\ldots\ldots\ldots 5$$

Making ρ equal to unity and adopting a suitable value for x, denoted by x_c and which should not exceed $0{\cdot}68\ldots\rho$, then putting β in place of $x_c/2$ and writing u for $\sin \phi$, the above cubic becomes

$$u^3 - u + \beta = 0 \ldots\ldots\ldots\ldots a$$

from which u may be found, and hence $\sin \phi$. The angle ϕ may then be obtained from a table of trigonometrical ratios, as well as the tangent of this angle. Using the adopted value of x_c and $\tan \phi$ just found, we can obtain the necessary value of m from equation (3).

Referring now to the diagram[1] it will be seen how the various quantities given in the tables are obtained, and how the curve is applied. A complete explanation is given in the former paper, so that it is here unnecessary to enter into the details.

The length of the transition curve may be computed from the following series

$$s = x\left(1 + \frac{1}{10}\tan^2\phi - \frac{1}{72}\tan^4\phi + \frac{1}{108}\tan^6\phi - \ldots\text{etc.}\right).$$

Method of using the tables.—Having decided upon the value of ρ, which is taken equal to R the radius of the circular curve, we

[1] See Plate 10, Journal Royal Society of N. S. Wales, Vol. XXIX., 1895.

multiply all quantities, given in either of the tables, by this value with the exception of ϕ, also K and log. m. The quantity K is simply the circular measure of 2ϕ. The value of log. m may be found for the radius R, by subtracting twice the logarithm of R from the tabulated value of log. m. A practical example will perhaps make the preceding remarks more explicit.

Let R equal 4, then if we multiply each value of x in the first column of Table I. by four, we obtain the several lengths along the axis X, where the ordinates y of the second column are to be set out, these values being also multiplied by four; thus—

$$R = 4$$

x	y
0·20	0·00018 68
0·40	0·00149 32
0·60	0·00503 92
etc.	etc.
$x_c = 2·00$	$y_c = 0·18664$ 04

We also have the following

$$\begin{aligned} \phi &= 15^\circ\ 38'\ 24''·50 \\ x' &= 1·07837\ 80 \\ \mathrm{H} &= 0·03853\ 52 \\ s &= 2·01550\ 96 \\ \kappa &= 0·54594\ 38 \\ \text{Log. } m &= 8·36791\ 52 \end{aligned}$$

Should a longer transition be required, then use Table II. or III., so that with the above value of R we have the choice of three transitions namely

R.S.—Cubic Parabola 2

$$\begin{aligned} 0·50 \times 4 &= 2·00 \\ 0·60 \times 4 &= 2·40 \\ 0·68 \times 4 &= 2·72 \end{aligned}$$

and similarly in other cases. It is not necessary that R be integral, but any value may be taken.

Limits of application.—The angle of deflection ω of the straights must either be equal to or greater than 2ϕ; if less than this angle then the transitions will overlap, this will be inadmissible; when 2ϕ equals ω, then the circular curve disappears, the points c and c' becoming one and the same, and such a case is admissible.

Further, it is not desirable that the radius of curvature at any point on the transition should be less than the radius of the circular curve. It is for this reason that the application of the cubic parabola, as a transition curve is limited. If this were not so, then it would be admissible to eliminate the circular arc in all cases. This could be done by taking the angle $\omega/2$ and a value of ρ, hence obtaining x_c and the coefficient m, but it will be found, if a certain limit is exceeded, that the radius of curvature will be less at some point on the parabola than at x_c y_c.

This limit is reached when "H" has a maximum value and may be obtained thus

$$H = y - y' = mx^3 - R + R \cos \phi \ldots\ldots\ldots b.$$

Eliminating mx^3, also putting R equal to unity and reducing, we have

$$H = \tfrac{2}{3} \sin^2 \phi \cos \phi + \cos \phi - 1 \ldots\ldots\ldots\ldots\ldots c$$

from this equation it will be observed that H has a maximum value when

$$\cos \phi = \sqrt{\frac{5}{6}}$$

The angle ϕ corresponding to this cosine is $24^\circ\ 5'\ 41''{\cdot}45$ and the congruous value of x_c being $0{\cdot}6804\ldots\rho$. It is therefore advisable not to exceed this value of the angle ϕ, or the objection mentioned will become evident.

Remarks.—When eliminating mx^3 from equation (b) it will be noticed that a very useful form of the original equation is obtained namely

$$y = \tfrac{2}{3} R \sin^2 \phi \cos \phi \ldots\ldots\ldots\ldots d$$

we have also at the same time

$$x = 2R \sin \phi \cos^2 \phi \ldots\ldots\ldots\ldots 5$$

By this method of procedure we may fix a point c on the circular curve, and hence the angle ϕ becomes known, which should not exceed the limit previously mentioned. The solution of the equations (d) and (5) will give the rectangular cartesian co-ordinates of the point c relative to the axes of the parabola. The remaining qnantities required being obtained in a similar manner as explained in the paper previously referred to.

Table I.

$\rho = 1$	$x_0 = 0{\cdot}50$
$\phi =$	15° 38′ 24″·50
$x' =$	0·26959 45
H =	0·00963 38
$s =$	0·50387 74
$\kappa =$	0·54594 38

x	y
0·00	0·00000 00
0·05	0·00004 67
0·10	0·00037 33
0·15	0·00125 98
0·20	0·00298 62
0·25	0·00583 25
0·30	0·01007 86
0·35	0·01600 44
0·40	0·02389 00
0·45	0·03401 52
0·50	0·04666 01

Log. m = 9·57203 52

Table II.

$\rho = 1$	$x_0 = 0{\cdot}60$
$\phi =$	19° 48′ 43″·48
$x' =$	0·33893 63
H =	0·01286 15
$s =$	0·60765 28
$\kappa =$	0·69157 20

x	y
0·00	0·00000 00
0·05	0·00004 17
0·10	0·00033 36
0·15	0·00112 58
0·20	0·00266 86
0·25	0·00521 21
0·30	0·00900 65
0·35	0·01430 20
0·40	0·02134 87
0·45	0·03039 69
0·50	0·04169 68
0·55	0·05549 84
0·60	0·07205 21

Log. m = 9·52319 25

Table III.

$\rho = 1$	$x_0 = 0{\cdot}68$
$\phi =$	24° 4′ 8″·04
$x' =$	0·40783 49
H =	0·01430 10
$s =$	0·69321 48
$\kappa =$	0·84016 31

x	y
0·00	0·00000 00
0·05	0·00004 02
0·10	0·00032 20
0·15	0·00108 67
0·20	0·00257 60
0·25	0·00503 12
0·30	0·00869 38
0·35	0·01380 55
0·40	0·02060 76
0·45	0·02934 17
0·50	0·04024 93
0·55	0·05357 18
0·60	0·06955 08
0·65	0·08842 77
0·68	0·10124 53

Log. m = 9·50784 80

Discussion.

Mr. C. O. Burge said that the adaptation of the cubic parabola to transition curves had been first brought before the Royal Society by Mr. Walter Shellshear, M. Inst. C.E., about nine years ago. Since then, the author of the present paper had communicated a paper on the subject, with tables, which had been adopted by the Railway Construction Department, and he would like to explain how these tables were utilised in the Government Railway surveys, all curves of twenty chains radius and under being transitioned.

There were usually two surveys for every line: first, the trial survey, on which the estimates were based, and secondly, the permanent staking, on which construction was carried out. Formerly the trial survey was very sketchy in character, and the final selection was left to the later one. Now, however, the trial survey was carefully aligned, and the second one was in many cases more or less of a mechanical operation. In the trial survey, however, the transitions were not set out, but four chains, as a minimum, of straight was left between the sharper reverse curves. This gave room for the insertion afterwards, in the permanent staking, of a four chain transition to each curve, half of each transition being absorbed by half of the straight, and half on two chains of the circular curve. The four chain transition was adopted almost without exception for all the curves dealt with.

Mr. Burge was of opinion, however, that though it was a good thing to have the simplicity gained by a uniform length of transition, this length was not enough for main lines where high passenger speeds were to be expected, and that, if the Department had to deal with such lines, the transitions should be lengthened. It should be remembered that, at high speeds, four chains would be passed over in less than four seconds, and the sudden oscillation, above the springs, set up by the rise in the outer rail, in the four chains, would be very severe. In a short curve the fresh oscillation set up by the descent of the rail, at the end of the curve, might synchronise with the original one, and thus intensified

might go on for a considerable time, to the detriment of the rolling stock and the discomfort of the passengers.

The ideally perfect curve would be one in which the centrifugal tendency would be met by a uniform rise in the outer rail from the springing to its maximum at the centre of the curve, and a similar fall to the end. The minimum of oscillation above the springs would then occur, there would only be the gentle rise and fall in the whole vehicle due to the flat gradients of the outer rail.

This would only be completely gained by lengthing the transitions so that they should meet, absorbing the circular curve altogether, and though this would be probably impracticable in very long curves, the ideal ought to be approached as nearly as possible in high speed lines. Complete parabolic curves were in use on the little two feet gauge Festinnög lines, on the extension of which he had been employed, and though the great lateral overhang of the rolling stock, due to the narrow gauge, promoted oscillation, and the curves were exceptionally sharp, and the speeds high, he never travelled on a smoother line.

The present paper referred to small tramway curves, but what he had said would, to a large extent, apply to these, because though the speed was much less on tramways than on railways, the curves on the other hand were much sharper.

Mr. P. W. Shaw said the necessity of easement or transition curves, on both railways and tramways, had been more fully recognised by engineers in recent than in former years, when they were left to be put in by the platelayers, and came to be known as "platelayer's curves," which curves may be all very well for large radii, but when dealing with small ones, something more definite is required to minimise the shock on the rolling stock, and there can be little doubt but that the cubic parabola will be found to answer that purpose in most cases to the fullest extent. He was sure the excellent papers the author had communicated to this Society on the subject, would be the means of bringing that particular curve into more general use. On tramways, where

the curves employed were frequently as small as from 50 lks. to 100 lks. radius, requiring superelevations of between 2″ and 3″ the necessity of transition curves becomes very apparent, but the selection of the best transition to fulfil the requirements was not always an easy matter. About four years ago he pegged out what he believed was the first transition curve on tramways in this city, adopting the system so much in vogue in America, viz., the spiral curve, but has used the cubic parabola in preference ever since the author's paper on that subject in 1895. Spiral curves are made up of radial arcs with increasing radii from the point of contact with the curves to the point of contact with the straight. The number of radii, and the length of chord employed, determine the character of the transition. In practice six or seven arcs are generally used, with equal chords 4 lks. to 10 lks. in length, according to the requirements, and they can be set out on the ground, either by offsets or angles, as may be found most convenient. Some very good examples of spiral curves were published in October 1895 in the *Engineering News and American Railway Journal*, by C. A. Alden, C.E., in which he gives tables, ranging from 30′ to 1,700′ radius, with short transitions 15′ to 43′ in length. He had plotted down the first three examples given in that journal for a curve of half chain radius, against the three given in the author's paper to the same radius, to show the comparison between the two systems, when the ratios were similar. The two systems agreed very closely in the first and second, but in the third example shown, there was a considerable difference, one of which was, the distance between the two main curves, amounting to about 2′ 6″, which would be of great value, when endeavouring to keep away from the kerbing, on the convex side of the curve; which could not be attained by using the cubic parabola, as it would require a length of transition greater than ·68 of the radius, which the author has shown to be inadmissible. One great advantage the cubic parabola has over the spiral, is that neither the radius of the main curves R, nor the length of the transition x_c have any appreciable effect on the curve at the

P. of C. with the straight, the nominal radius at that point always being very large, giving an extremely easy entrance to the curve; whereas in the spiral, shortening x_c without introducing a great number of radii, has the effect of bringing the curve to more or less an abrupt termination, as in the case of No. 1 on the diagram shown, the radius at P. of C. with the straight is only 3·18 chains, giving a curve which in itself might be said to require a transition. In America he found engineers seldom made the transitions on tramways longer than about 60 lks. for curves up to about 9 chains, but he considered 80 lks. a very good maximum length for the cubic parabola on curves over 1·5 chains radius where it could be used, but often found it was not a matter of choice, but rather one of necessity, in using the one which would comply with the conditions.

Referring to the author's tables for tramways, while fully appreciating the work done, he would like to have seen them worked out somewhat on the principle of the author's first paper on transitions, viz., with fixed lengths of transitions for different radii. The tables given, were very limited in their usefulness, because the length of the transition x_c increased in proportion with the radius R, making it too long to use in most cases, also as the angle of deflection ω must be greater than $2\,\phi = 31^\circ\ 16'$ before the tables could be applied. A greater variety of transitions and curves was required on tramways than on railways, to enable the engineer to comply with the limited conditions.

LOW LIFT PUMPING MACHINERY.

By T. H. HOUGHTON, A.M.I.C.E., M.I.M.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 21, 1897.*]

THE question as to which is the most suitable pump to adopt, is one that has to be carefully considered by any one proposing to raise water for irrigation, on a large scale, and the author has in the following paper ventured to bring before the Society, the results obtained with various types of pumps, and the cost of installing and working them.

It may be taken for granted, that except in a few places, a maximum lift of 100′ is, as high, as it is profitable to raise water for irrigation purposes, and the author does not propose to discuss pumping machinery in general, but only such types as are suitable for lifts not exceeding 100′. The selection of a pump is governed not only by the engineering problems involved, but by the number of days a year it has to work, cost of fuel, and first cost, these latter constitute the financial problem, and frequently have more influence upon the selection than the engineering one.

Seven different types of pumps will be considered, viz. :—

a. Scoop wheels.
b. Archimedean screws.
c. Chain pumps.
d. Rotary pumps.
e. Centrifugal pumps.
f. Direct acting reciprocating pumps.
g. Flywheel reciprocating pumps.

Each of the first three types of pumps, is suitable for pumping water to only a very moderate height, the next two have been used for lifts of 100′, but not with economy, the height to which the last two types will raise water is only limited by the strength of the materials used in their construction. The most economical

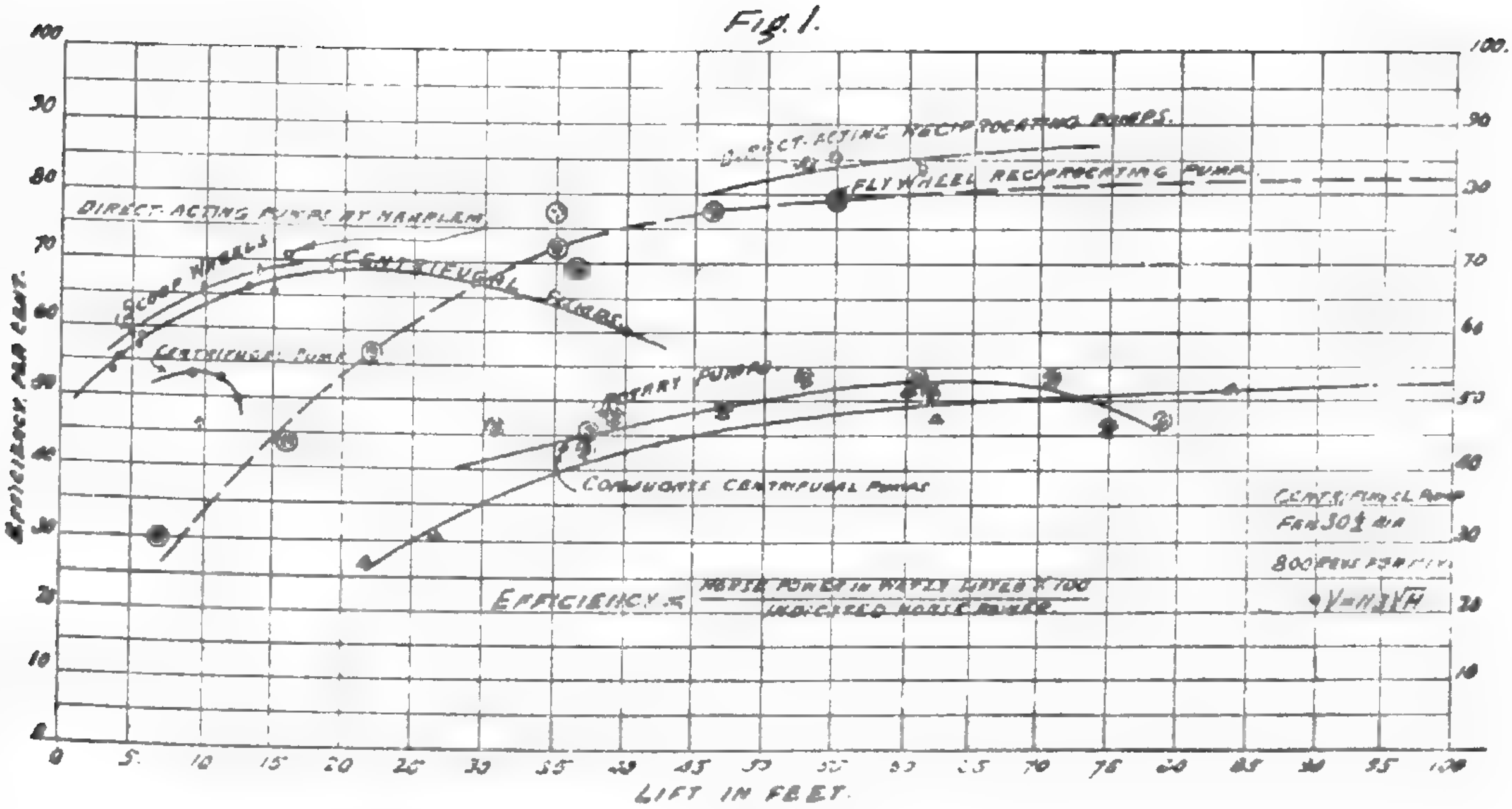
pump is naturally that one which turns the greatest amount of the power put into it into effective work, and in Figure 1, are shewn the efficiency curves of various types for different lifts, from this it will be seen that although the reciprocating pumps are very economical as regards power wasted at lifts greater than 30′, yet at lower lifts the centrifugal pump gives better results, and for lifts up to 15′, a well designed scoop wheel has about the same efficiency, as the centrifugal pump. The first three types are not suited for places where there is a very great variation in the levels of either the suction water or of that in the delivery channel such as occur in most of the Australian rivers, but there are probably many places in which they could be used, and the author has consequently included them in the paper.

Scoop wheels are largely used in the Fen lands of England, and in Holland for low lifts, but are going out of favour. Figure 2 shews the form first used, this has been superseded by those with the improved form of bucket shewn in Figure 3.

The defects of the wheel are the liability for a large waste of water by leakage at the sides, and if straight buckets as in Figure 2, are used, the water is raised much higher than necessary, and as frequently erected, a considerable loss is incurred owing to defective construction of the races for the ingress and egress of the water, a wheel constructed as in Figure 3 and properly installed will utilize about 70% of the power developed by the engine, whereas those of the older make rarely give more than an efficiency of about 46%, and in Figure 1 is shewn at *H*, the efficiency obtained on four tests of a wheel 33′ 6″ diameter with a width of 25″, raising 71½ tons of water per minute 9·8′ high, few of the wheels are giving this efficiency, but there is no reason why properly constructed wheels should not be used, where the lift does not exceed 15′, and the lower water level is fairly constant.

Archimedean screws if made on Mr. Wilfred Airey's system give good results, but owing to the angle at which they have to be fixed,are not suitable for a lift of more than 20′, as the length and consequently the weight and cost mount up very rapidly.

Fig. 1.



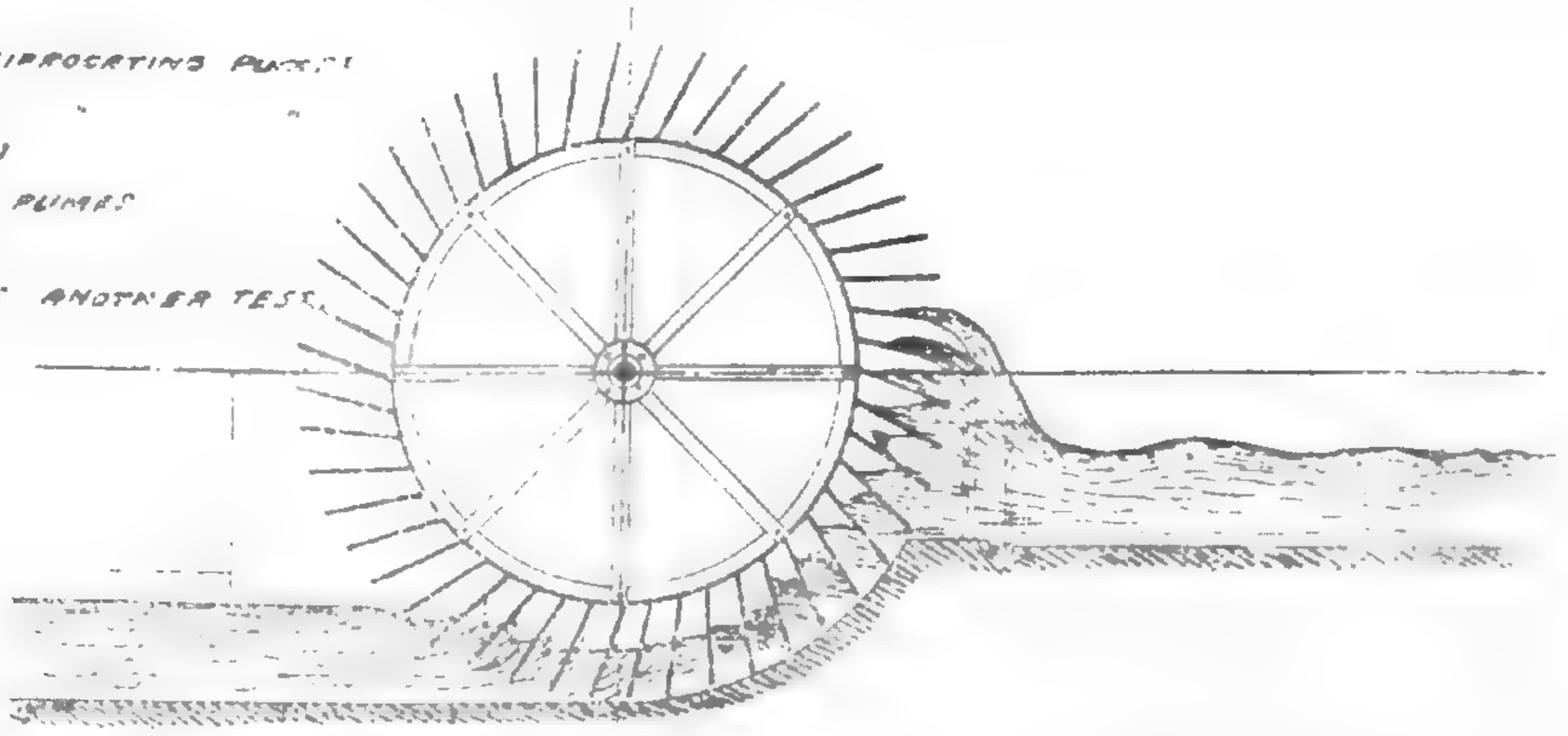


Fig 2.

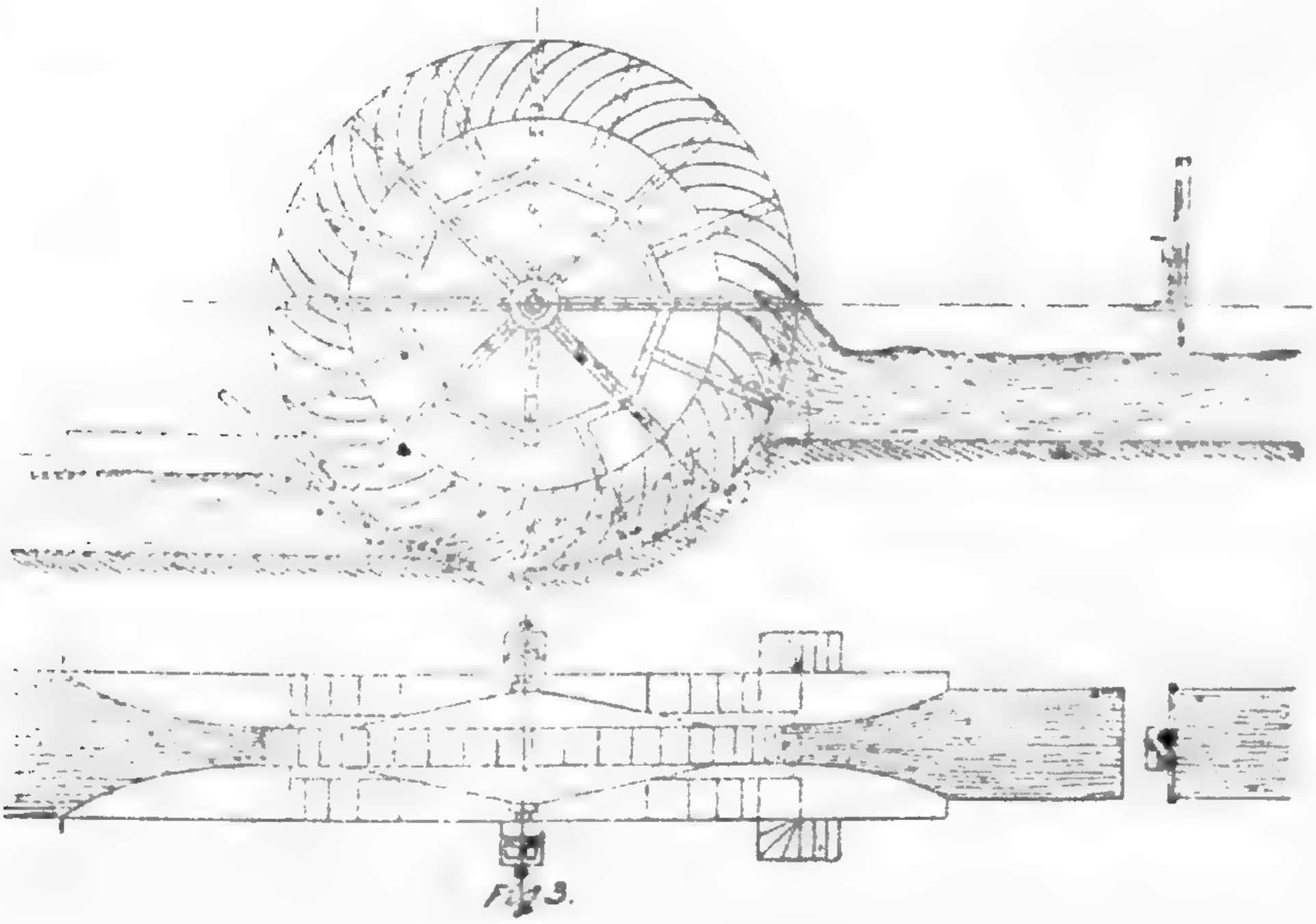
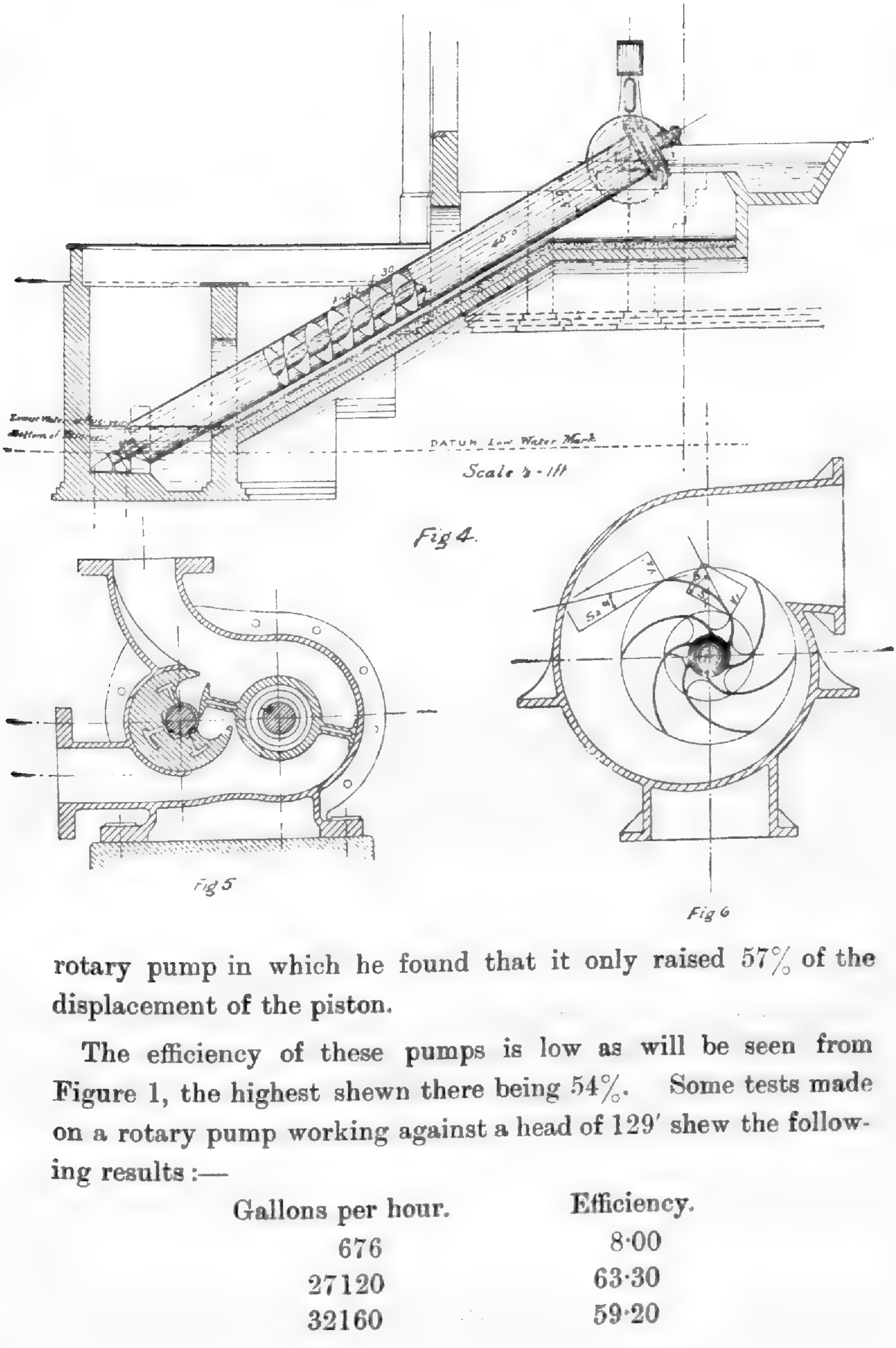


Fig 3.

The method of construction adopted by Mr. Airey is to attach a screw of one, two, or three threads formed on a core, to a cylindrical casing, and revolve the whole, in the older types the screw simply revolved in a stone or timber trough, rather higher than the centre line of the worm, a considerable leakage takes place between the screw and the trough, and although cheaper to construct, the efficiency is less. Figure 4, shews one similar to the screws used at the Antwerp Water Works for raising water into the filter beds. They are not suitable for a variable height in the delivery channel, as the outlet of the pump must be above the highest level, and any fall in the level of the water in it, reduces the efficiency of the machine, through the water being raised to a greater height than is required by the difference between the top and bottom water levels.

Chain pumps are largely used for raising small quantities of water, and when made with buckets that are a good fit in the barrel give fairly good results, for large quantities of water, say 1000 gallons per minute, the diameter of the rising barrel would be great, as the speed at which the buckets can be raised is not more than two feet a second, the efficiency of this class of pump, if well constructed is about 55%, but its use is limited, both as to quantity and height to which the water has to be raised. With a varying height in the delivery channel the efficiency becomes less as the level falls.

Rotary pumps have been used for pumping small quantities of water for some years, but the author is not aware of any at work on a large scale, some large ones were erected about ten years ago, at one of the London Water Works for pumping water on to the filter beds, they proved a failure, and were removed by the contractors, three throw pumps being erected in their place. One of the many makes of this class of pump is shewn in Figure 5, a great difficulty is experienced in keeping the pistons tight against the sides of the casing, and as a consequence there is either undue friction, or leakage. Mr. Isherwood U.S. Navy records in the Journal of the Franklin Institute for 1889, some tests made on a



rotary pump in which he found that it only raised 57% of the displacement of the piston.

The efficiency of these pumps is low as will be seen from Figure 1, the highest shewn there being 54%. Some tests made on a rotary pump working against a head of 129′ shew the following results :—

Gallons per hour.	Efficiency.
676	8·00
27120	63·30
32160	59·20

This is better than those plotted on the diagram, but the height of lift is beyond the limit to which it was intended to refer in this paper.

Probably more centrifugal pumps are used for low lifts than any others, and when properly designed for the work they have to do, none are more efficient when raising water to heights not exceeding 30′ to 40′, beyond that height the efficiency falls off. In Figure 1 are shewn the results of a number of tests of these pumps by good makers, and it will be noted, that they give for lifts up to 30′ better results than reciprocating pumps, each pump however, only does its best at a certain lift and delivery any variation in either quantity or lift reducing the economy. The best results that have been obtained with centrifugal pumps are in Egypt, with some large pumps made by Messrs. Fariot of Paris,[1] which gave an efficiency of 65%, and some pumps made by Gwyne for the drainage of Haarlem Meer, which on 15′ lift shewed an efficiency of 65·7%.

Since the centrifugal pump was introduced by Mr. Appold at the 1851 Exhibition, many experiments have been made to determine the most suitable form of casing, and shape of the vanes, and at the present time the best results are generally obtained with the spiral casing and curved vanes, pumps with radial vanes giving a much lower efficiency. Figure 6, shews a section through a pump with spiral casing, and curved vanes. In order that the water may pass through the fan of the pump without shock, it is necessary that the angle of the vanes with the inner and outer circumference, should be the resultant of two forces, namely, one the direction and velocity of the radial flow of the water entering or leaving the wheel, and the other the tangential velocity of the circumference, this is shewn in Figure 6, where v^1 and v^2 are the radial velocities of the water entering and leaving the wheel respectively, and s^1 and s^2 the tangential speed of the circumference, completing the two parallelograms, the

[1] Engineering, Jan. 28, 1887.

resultant shews the direction of the vanes at the circumference, the intermediate portion being filled in with any flat curve. These angles are not always adhered to for practical reasons, but it will be seen from the diagram that any variation in the speed of rotation or velocity of flow through the wheel, requires a different angle of vane to enable the pump to work without shock.

The fan has to rotate at a peripheral velocity not less than $\sqrt{2gh} = 8\sqrt{h}$ per second, h being the height to which the water has to be lifted, this speed does not cover any losses in the pump, and the revolutions have to be increased, so as to give a peripheral speed in excess of that given by the formula $s = \sqrt{2gh}$, where $s =$ velocity in feet per second of the outer circumference of the pump.

This speed $c\sqrt{2gh}$ varies with the velocity v at which the water passes through the fan, and also depends upon the angle α, which the outer ends of the vanes make with the circumference. Figure 7, shews the result obtained by the author on a large pump when delivering varying quantities of water, the different values of c being plotted as abscissæ and the cubic feet of water delivered per second as ordinates.

In a valuable paper by Professor Unwin on the "Centrifugal Pump,"[1] are given the formulæ connecting the speed of rotation, rate of delivery of water and efficiency for different angles of vanes for a pump with spiral casing, and also with whirlpool chamber, and in it he shews that the smaller the angle made by the vanes with the outer circumference up to 30°, the greater the theoretical efficiency will be, but that the speed at which the pump has to be driven also increases; the angle made by the vane with the inner circumference does not enter into the question of speed, but effects the efficiency, for with radial vanes that is $\beta = 90°$, the water entering the wheel has its direction suddenly changed, whereas if β is as drawn in Figure 6, there is no change in direction.

Many attempts have been made to use the centrifugal pump for high lifts, but it has either meant a large fan, or an excessive

[1] Proceedings Inst. C.E., Vol. LXIII.

Fig 7

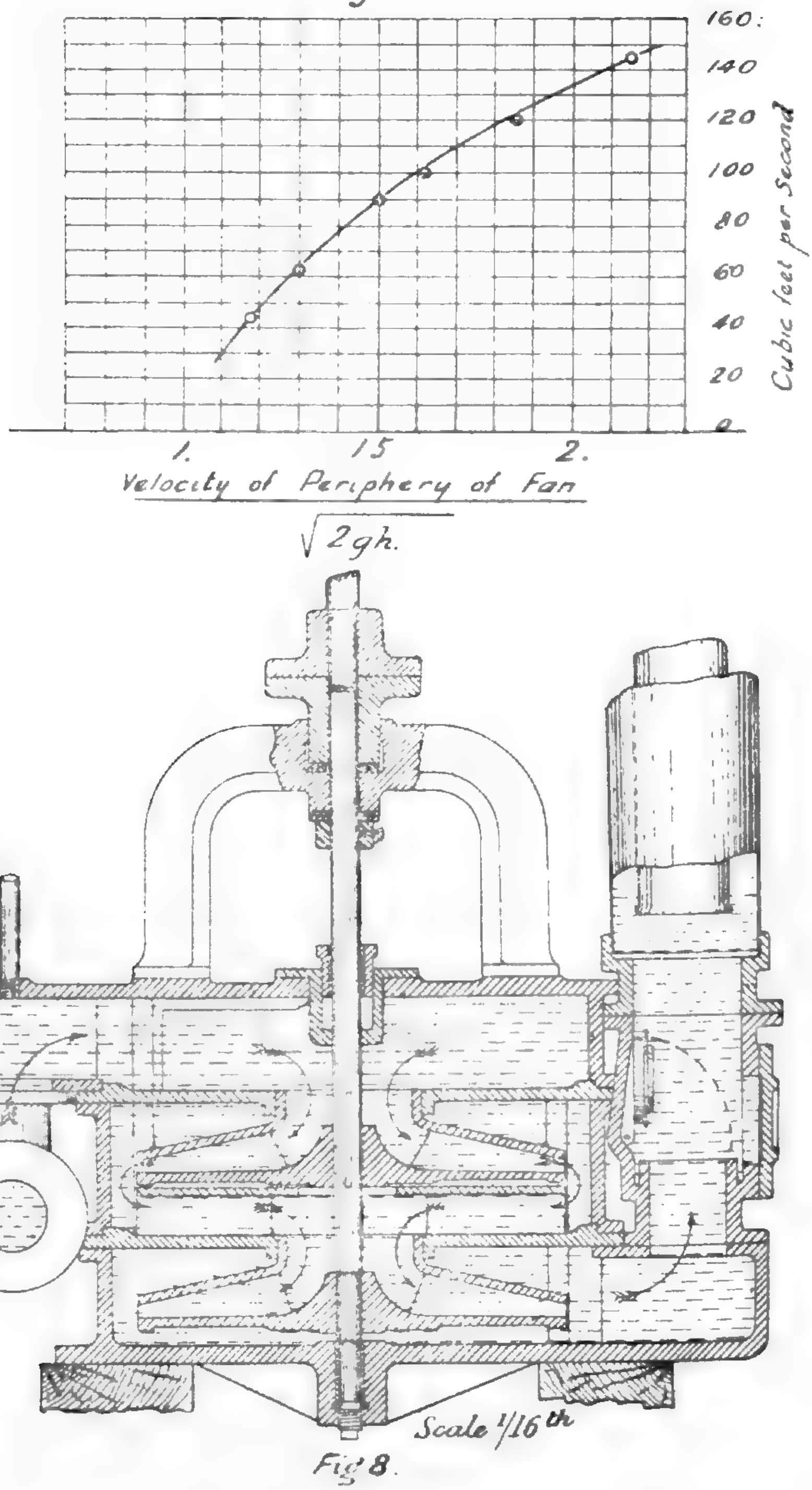


Fig 8.

number of revolutions per second for a small one, taking for example a lift of 64′, $\sqrt{2gh}$ would be 64 and assuming that $c = 1{\cdot}25$ the peripheral velocity would be 80′ requiring a fan 5′ in diameter to make 306 revolutions per minute, or else a fan 3′ in diameter making 510 revolutions per minute, to overcome this difficulty two ordinary pumps are often used, the first one dis-

charging into the suction of the second. An improved form of conjugate pump is shewn in Figure 8, which is taken from a paper by Mr. Richards on "Irrigating Machinery on the Pacific Coast."[1]

With large diameter fans, unless for large quantities of water, the opening between the sides becomes very small so that it is not practicable to use them, and there is besides the extra skin friction, for taking the sizes given above $\pi/4\ D^2 \times N$ is for the 5′ fan 69% greater than for the 3′ fan, and the friction of the rotating discs is almost three times as great for the large fan as for the small one. The use of two pumps or two fans in one casing naturally very considerably reduces the efficiency of the pumps, a test made with one on a lift of 36′ only shewed an efficiency of 43·6%, in the author's opinion it is not advisable to use centrifugal pumps for a greater height than 40′, and then only when the quantity of water is such as to enable the mouth of the fan to be not less than $\frac{1}{12}$ the diameter in width.

The direct acting reciprocating pumps are well known, and as shewn in Figure 1, their efficiency is high, the author is aware of only one reliable test of these pumps, made when working on lifts of less than 25′ and that is of the great pumps used for draining Haarlem Meer in Holland, which on a lift of about 16′ gave an efficiency of 70%, but judging from the experiments made with flywheel reciprocating pumps the efficiency will fall below that of centrifugal pumps, at about 25 to 30′, they have, however, the advantage over the latter in that, if required, small quantities of water can be raised by a pump whose normal duty is much greater.

In direct acting pumps are included the ordinary Cornish beam engines, as well as what are more commonly termed direct acting pumps.

The non-compound direct acting pumps with the exception of the Cornish and Davey pumps, are very properly classed as steam eaters, but no engineer would think of using them for permanent

[1] Proceedings Inst. M.E., 1886.

works, requiring more than 20 to 25 horse power, as the additional boiler power required, would almost equal the difference in price between a compound, and a non-compound engine.

Flywheel reciprocating pumps do not give as good a result, in water lifted per indicated horse power, as direct acting pumps, owing to the friction of the greater number of moving parts, they are besides rather more expensive for moderate powers. One of the principal losses in reciprocating pumps, beyond those due to the friction of the engine, arises from the friction of the water passing through the valves, and as this is constant, other things being equal for all heads, it follows that the lower the head the less the efficiency, and it is to the improvements in the valves that any increase in efficiency is to be looked for.

Professor Reidler has for some years been using both for water pumps, and air compressors mechanically moved valves, and has found a great improvement from their use, being able to increase the speed of the pump piston to as much as 420′, or 60 revolutions per minute, without any shock occurring on the closing of the valves.

The first cost and working expenses of the various pumps differ considerably as may be expected, and the following table condensed from a paper by Mr. Cuppari, "On the practical results obtained from various water raising machines in Holland,"[1] is interesting.

TABLE I.

Type of Pump.	Cost of building per H.P.	Cost of machine per H.P.	Total.
Wheels and Engines, average of seven pumping stations	£46	£46	£92
Centrifugal pumps, average of five pumping stations	£34	£37	£91
Archimedean screws, average of two stations	£37	£42	£79
Piston pumps, average of three stations	...	...	£72

The conclusions arrived at by Mr. Cuppari are, that no general rule can be given as to the adoption of any one type, but that

[1] Proceedings Inst. C.E., Vol. LXXV.

each case must be considered on its merits, but he evidently favours the adoption of centrifugal pnmps.

A Dutch engineer Mr. Korevaar has investigated the question as to the best pumps to adopt, and he states that the following is the efficiency obtained

Scoop wheels 67%
Reciprocating pumps 70%
Centrifugal pumps 45%

And taken over a period of two years, the fuel consumption of the various types was in the follow proportions for equal work performed

Scoop wheels 100
Reciprocating pumps 100
Reciprocating pumps combined with wheels 98
Centrifugal pumps 167

These results are not borne out by others, for the substitution of the centrifugal pumps for wheels, has in all cases with which the author is acquainted resulted in a saving of fuel, but the wheels removed were of old make so that this cannot be taken as representative.

The following table shews the actual horse power required for raising one inch of water for various areas per twenty-four hours

TABLE II.

Actual horse power required to raise water at different lifts to deliver at the rate of one inch per acre per twenty-four hours.

Lift in feet.	Actual Horse Power.									
						Acres.				
	100	200	300	400	500	600	700	800	900	1000
10	4·8	9·6	14·3	19·1	23·8	28·6	33·4	38·2	42·9	47·7
20	9·6	19·1	28·6	38·2	47·7	57·3	66·8	76·4	86·0	95·5
30	14·3	28·6	42·9	57·3	71·5	86·0	100·3	114·4	128·9	143·1
40	19·1	38·2	57·3	76·4	95·5	114·4	133·7	152·8	172·0	191·0
50	23·8	47·7	71·5	95·5	119·0	143·3	167·1	191·0	214·5	238·6
60	28·6	57·3	86·0	114·4	143·3	172·0	200·6	229·2	257·9	286·5
70	33·4	66·8	100·3	133·7	167·1	200·6	234·0	267·4	300·8	334·0
80	38·2	76·4	114·4	152·8	191·0	229·2	267·4	305·6	343·8	382·0
90	42·9	86·0	128·7	172·0	214·5	257·9	300·8	343·8	386·8	429·7
100	47·7	95·5	143·1	191·0	238·6	286·5	334·0	382·0	429·7	477·5

for different heights, the indicated horse power varying of course with the type of pump used. Or if the work to be done is expressed in million gallons per twenty-four hours, the actual horse power = millions per day × height of lift in feet × ·21.

The costs of pumping plants of any one of the types described in the paper naturally vary very considerably, and the circumstances of each case have to be considered before deciding which is the best pump to adopt. In the following tables the author has given the average cost per actual horse power, but they can only be considered as approximate, for a pump delivering a large quantity of water against a low head, costs more than one raising only one-third the quantity, to three times the head, although the horse power is the same.

The prices include engines, but not boilers, and delivery in Sydney, it generally follows that the cheaper the pump for any particular work, the greater the cost of the boiler, and also of the fuel bill. The average steam consumption per actual horse power is also given in the tables for each type.

TABLE III.

Average cost of Pump and Engines per Actual Horse Power.

Actual Horse Power.	Centrifugal Pumps		Rotary Pumps.	Reciprocating Pumps.		
	1	2		1	2	3
5 – 10	£25	...	£17	£15	...	...
10 – 20	20	...	14	12	...	£49
20 – 30	16	...	13	11	...	39
30 – 40	14	...	12	...	£25	31
40 – 50	12	...	...	...	22	28
50 – 75	10	£17	...	...	19	25
75 – 100	...	15	...	...	17	24
100 – 150	...	14	...	...	16	23
150 – 200	...	12	12	...	15	22
Steam consumption 70 to 60lbs per actual H.P. per hour.						
Steam consumption 43 to 38lbs per actual H.P. per hour.						
Steam consumption 70 to 60lbs per actual H.P. per hour.						
Steam consumption 100lbs per actual H. P. per hour.						
Steam consumption 54 to 48lbs per actual H.P. per hour.						
Steam consumption 32 to 28lbs per actual H.P. per hour.						

A few cases have been worked out, as to the cost per annum per actual horse power of different types, including interest and depreciation, and are given below.

TABLE IV.

Cost of an Actual Horse Power per Year of 2,500 hours working.

Size of Plant.	Type of Pump.	Interest at 6 per cent. on engine, pump, boiler piping, buildings, and foundations. £	Maintenance and Depreciation at seven and a half per cent. £	Coal at 12s. per ton and of an evaporative value of 9000 T.U. £	Oil and miscellaneous stores. £	Labour. £	Total cost of one horse power for 2500 hours. £
20 – 30 P.H.P.	Centrifugal Pump. 1	2·7	3·4	6·0	0·5	6·3	18·9
	Centrifugal Pump. 2						
	Rotary Pump	2·6	3·2	6·0	0·5	6·3	18·6
	Reciprocating Pump. 1	2·8	3·5	9·3	0·5	6·3	22·4
	Reciprocating Pump. 2						
	Reciprocating Pump. 3	3·3	4·1	3·5	0·5	6·3	17·7
50 – 75 P.H.P.	Centrifugal Pump. 1	2·1	2·6	5·4	0·4	5·2	15·7
	Centrifugal Pump. 2	2·3	2·9	3·9	0·4	5·0	14·5
	Rotary Pump						
	Reciprocating Pump. 1						
	Reciprocating Pump. 2	2·6	3·2	4·7	0·4	5·3	16·2
	Reciprocating Pump. 3	2·7	3·4	2·9	0·4	5·0	14·4
100 – 150 P.H.P.	Centrifugal Pump. 1						
	Centrifugal Pump. 2	2·1	2·7	3·7	0·4	3·2	12·1
	Rotary Pump						
	Reciprocating Pump. 1						
	Reciprocating Pump. 2	2·3	3·0	4·5	0·4	3·2	13·4
	Reciprocating Pump. 3	2·7	3·4	2·8	0·4	3·2	12·5

Nothing has been said as to the engines used for driving the various pumps, but it has been assumed that equally efficient engines are available for any of the types referred to, in the tables of prices the probable steam consumption per actual horse power per hour has been given, and it will be noticed the great saving in fuel due to using engines of rather higher first cost.

The author has laid this paper before the Society with considerable diffidence, as he is fully aware that little, if anything new can be written on such a subject, but it may bring out in the discussion much valuable information from members who have had to deal with this class of machinery.

Discussion.

Mr. Pridham said that the method of raising water by means of the "air lift" had not been touched upon by the author. Although the efficiency is small compared with any of the pumps and lifts mentioned, being only about 50% with a lift of 10′, diminishing to 20% with a lift of 200′ (as pointed out by Mr. E. E. Johnston, M. Am. Soc. M.E.), yet this plan might be used with great success for increasing the yield of some of our flowing artesian wells. At Asbury Park, New York, the yield of two wells, about 1000′ in depth, was stated to have been increased by about $2\frac{1}{2}$ times the natural flow by the "air lift," but in these cases the air pipe was extended to a depth of 200′, necessitating a pressure of nearly 90 lbs. per square inch.

Mr. Norman Selfe said that he considered the diagram illustrating the falling off in efficiency of centrifugal pumps as the lift increased, was of special value; and he had only recently had occasion to ask the author for data similar to that now furnished. The scoop wheel, shewn in Fig. 2, could only have a low efficiency because the wave of water was raised so much above the level of the head race as to cause a waste of power. He was of opinion that a practical scoop wheel could be made with feathering or folding buckets, that would lie close against the drum of the wheel as they approached guide vanes, so fixed and curved as to deflect the water horizontally at the delivery level, and that a wheel so constructed would reduce the loss by at least one-half, or, in other words, increase the efficiency to say 75%. The loss of efficiency in the Archimedean screw through the delivery not being adapted to variable heads could be got rid of by making the whole screw adjustable in the direction of its axis, so that while the lower end was more or less immersed the delivery would be always at the exact height required. The efficiency of 55% set down for the chain pump seemed extremely low, certainly some of the Melbourne makers of this class of machinery claimed a very much more effective result, and the rotary pump giving only 57% efficiency, did not seem of the highest type.

The reference to Mr. Appold's pump at the Exhibition of 1851 as the introduction of that system of raising water, might mislead perhaps; and as he (Mr. Selfe) had a most vivid recollection of that portion of the machinery department where those pumps were shewn at the Crystal Palace in 1851, he could say that Gwynne was equally as well represented there as Appold, but as Appold delivered the water from his pump in a broad waterfall it attracted more attention from the public. The Appold pump itself was out of sight in a wooden casing, but the Gwynne pump was very similar to the pumps of the present day. It was here, in the trials of these two pumps, that the difference as to the merits of radial versus curved vanes first came under his (Mr. Selfe's) notice.

With regard to the use of centrifugal pumps for high lifts, the author shows that it either means large fans or an excessive number of revolutions, or conjugate pumps, one delivering into the other; in either case lowering the efficiency to such an extent that he does not consider it advisable to use the centrifugal pump for greater heights than 40′. Now he (Mr. Selfe) from a cursory examination of the conjugate or duplex pump exhibited by the author, considered it was so extremely badly designed that he was glad to find the author was in no way connected with the design. He further considered that the fact that centrifugal pumps are not yet used for higher lifts, simply shows that up to the present time the requisite inventive talent has not been developed to make them efficient, or that the occasion has not arisen yet to justify such machines being constructed. Mr. Houghton shows that Farcot of Paris has constructed centrifugal pumps to give 65% efficiency, and states that up to 30′ the results are better than those for reciprocating pumps. If such be so, then if thirty-one tanks were fixed, at intervals of 30′ apart, on the Eiffel Tower, the bottom one on the ground and the top one on the 900′ stage of the tower, and thirty centrifugal pumps were fixed to lift the water through the intervening stages, is it not certain that the work of each pump would be similar, and

that if 10 HP were required to lift a given quantity of water the first stage from tank to tank, the same amount of power would suffice for the second stage, and 300 HP would raise the load to the top? The percentage of efficiency would be unaltered, whatever the number, with similar pumps, similar engines, and similar heights. Such being the case, there does seem scope for the design of a pump in which the thirty vanes might be all arranged in one casing, producing a machine something after the manner of the "Parson's" steam turbine, with reversed action, so that instead of thirty pumps 30′ apart, with their respective deliveries and following suction pipes connected by tanks, we might have one machine.

With regard to the author's statement that fly-wheel pumps do not give quite as good results per 1 HP as direct-acting ones, owing to the extra friction of the moving parts, there was plenty of scope for difference of opinion. The Leavitt pumps recently constructed by The Blake Co. for the Boston, Mass., waterworks, gave 140 million duty, and they can no doubt keep that up and drive a fly-wheel too. Rotative engines always give full stroke to their pump pistons. It is possible that the efficiency of rotative pumping engines may be still further increased by putting the fly-wheel shaft on roller bearings. Having used roller bearings for many years, and seen the efficiency of machines increased from 55% to 85% by their introduction, there did not seem to be any insuperable objection to their introduction into pumping machinery. Direct acting pumps seldom, if ever, work the full stroke they are supposed to do, after their trial is over; rotative pumps are obliged to do so.

As the title of the paper was "Low" lift pumping machinery, the discussion had perhaps strayed a little away from the core of the subject, and he would conclude by saying that the ideal pump for low lifts would probably be found to be in the nature of the "Downton" or "Stone" pump, with one or two valve pistons working in one barrel, but so arranged and connected to the motive power that the speed of the flow of the water would be uniform,

the bottom and top of the delivery barrel being trumpet-mouthed so that no water would be lifted an unnecessary inch and no contraction of the vein take place at the bottom. In all pumps there are losses from—(*a*) The friction of the machinery; (*b*) The friction of the water. In reciprocating pumps there is the further loss due to—(*c*) The loss of inertia from alteration of motion as the chambers fill and empty, which is absent in centrifugal and rotary pumps. And in low-lift pumps—(*d*) The needless height to which the water may be lifted. Now, with a large vertical barrel and a continuous stream of water delivered at a trumpet-head, the losses from (*c*) and (*d*) would be absent altogether, (*b*) would be reduced to a minimum, and only the question of (*a*) is open. This point offers a very wide scope for inventive talent to devise a motive power that would ensure one bucket or piston always being in motion at its normal velocity and on the up stroke; another piston would be commencing its ascent at normal speed before the other slackened in speed or commenced the return stroke downward. Without doubt 90% efficiency could be got if this principle was well worked out.

Mr. GRIMSHAW considered that little could be added to this extremely useful paper. He agreed with Mr. Selfe that improvement in the design of the scoop wheel by feathering the scoops should very materially increase its efficiency for very low lifts. If, as the author states, the efficiency of the centrifugal pump for a lift of 30′ was greater than the reciprocating pumps, then by arranging these pumps at different levels the same efficiency might be obtained for a greater lift. If, for example, the efficiency was 65% for 30′ lift, it would with two pumps at different levels give the same. At the same time the complication of pumps on different levels would not always be economical. He had an opportunity of seeing a Riedler pump at work in Rotterdam and was much impressed with the advantage resulting from the high speed it is enabled to run through the valves being mechanically controlled instead of left to take care of themselves as in the ordinary pump. One of the great advantages of direct-acting

pumps was that if any stoppage in the main occurred the pump would probably be stopped without accident, while in the case of a fly-wheel the stored energy might cause a complete wreck of the pumping plant.

Mr. HOUGHTON in reply to the discussion said, in answer to Mr. Pridham, that he had not mentioned the "air-lift" method of raising water as it was not one that could be utilised with economy except in very rare cases; it was of no doubt of great benefit for the purpose described by Mr. Pridham. Mr. Selfe had made several suggestions as to the manner in which the efficiency of some of the types of machines described could be increased, but it might complicate machines whose great advantage was simplicity to endeavour to obtain a greater efficiency. Mr. Grimshaw and Mr. Selfe both pointed out how the centrifugal pump can be adopted for high lift, but in his (Mr. Houghton's) opinion this would not be so economical as ordinary ram or bucket pumps. The type of reciprocating pumps advocated by Mr. Selfe, in which the water has a continuous upward flow, have already been used; Messrs. Mather & Plott make them for pumping from wells, and the Southwark and Vauxhall Water Works Co. have a large plant at work on a somewhat similar system. Mr. Selfe introduced the question of duty when speaking of the relative merits of rotative and direct-acting pumps, the author had purposely left this out and referred only to efficiency; but he is not aware of any published accounts of reliable tests in which the ratio of actual work done to indicated power developed was not higher for direct-acting pumps than for rotative pumps when working against similar pressures of water, no doubt the adoption of roller bearings would increase the efficiency of the rotative pumps as suggested by Mr. Selfe.

BELT POWER TRANSMISSION WITH SOME NEW FORM OF BRAKE ABSORPTION DYNAMOMETER.

By HERBERT E. ROSS.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, October 20, 1897.*]

THE history of the use of belting as a power transmitting device has apparently no beginning. The custom of the ancient historian to chronicle the arts of war rather than the industries of peace, has left no record of the earliest part of the subject behind the veil of antiquity. Tolerably certain it is, however, that in modified forms the use of flexible cords was well known to the pioneers of engineering over three thousand years ago. The author has, therefore, some hesitation in putting forward a paper on a matter which has already received so much attention.

The subject is however, one eminently suited to discussion, and even at this late date, there would appear to be no reliable data of the comparative efficiency of all the various kinds of belting now in general use. And while leather and rope have received much attention, the less common belts, in gutta percha, india rubber, canvas, balata, raw-hide, and hair, have either had no reliable values assigned to them, or where coefficients have been determined, they are the results of investigation under such various conditions as to render comparison incomplete.

At the recent Engineering and Electrical Exhibition Buildings the author had undertaken a number of tests dealing with the classes of belts enumerated. The tests were made under working conditions, the same tension, speed and pulleys being used for each particular case to establish due comparison. As it was necessary to cause the belt to definitely slip on the pulley, a special absorption brake dynamometer was designed, a transmission apparatus not meeting the requirements of the case without means of even application of an increasing load.

The dynamometer used was specially designed by the author to carry out the following conditions :—

1. Capability of taking various lengths of belt.
2. Capability of adjusting the tension on the belt at rest to known amounts.
3. Of gradually and evenly adding load to the brake to a definite slipping point of belt.
4. Of recording the relative speed of the driver and driven pulleys.
5. Of recording the load, speed, and duration of experiment.
6. Of automatic tension and release of brake.

The dynamometer brakes hitherto in use would not meet all the desired conditions, more especially (3) and (6), and the common difficulty of absorption brakes of the heating and consequent expansion of the brake pulley, and the variation of the friction on the same, due to imperfect lubrication would have been a factor in unsatisfactory working.

The machine as designed consisted of two 12″ × 6″ steel beams, true on bed and edge, laid lengthwise on two 12″ × 6″ oregon beams and bolted thereto. The pair of girders were distanced parallel apart 3′ by cast iron distance brackets. The first receiving pulley (A) and the driver pulley (B) were mounted on a 3″ shaft at one end of the bed guides. Upon the steel beams, and traversing the greater part of their length upon friction rollers, was the trussed wooden frame (*c*). This frame carried the brake shaft and brake pulley (D), and driven pulley (E), and all the recording gear of the machine.

The brake wheel was 36″ diam and 7″ face and carried the brake of tallow-wood blocks secured by a link belt, one end of which was attached to the trussed lever (F), and the other was coiled round in the direction of rotation and brought up to a yoke or bridle which was lifted by a small ram acting upward in the cylinder (G), also attached to the trussed lever (F). The cylinder G was connected by a small and flexible copper pipe to the pressure cylinder of the plungers (J) under the end of the lever.

At the end of the lever the two cylinders of H and J, with a common axial centre, received the direct connected plungers (H and J), one, the larger, acting upward into the cylinder with air chamber attached, and the other downward into a cylinder connected as before stated to the tension cylinder (G). The end of the lever passed through an eye in the plungers (H and J). The rotation was to lift the lever ; in so doing the pressure was released (G) and the brake slackened.

The load was applied by admitting water under pressure to the top cylinder (H) the pressure was partly transmitted to (J) thence to the tension cylinder (G) by oil in the connections. Any tendency of the lever to fall by more than the load applied was counteracted by the tightening of the brake, conversely any tendency of the lever to rise by more than the load applied at its end was to release the pressure in the tension cylinder and to slacken the brake. Thus the brake was automatic in action. All that the observer had to do was to admit water slowly into the air cylinder (H) till the tension on the brake caused the belt to slip. The load in pounds on the end of the lever was read off a specially graduated pressure gauge calibrated to the exact area of the larger plunger (H), and from this reading was deducted the pressure transmitted to the lower plunger (J) as shewn by a similarly specially calibrated gauge.

The friction on the plungers (H, J) was almost entirely obviated by giving the plungers a semi-rotary movement during the application of the load. The error due to this source apparently did not exceed one per cent.

The machine was driven by a portable twin-cylinder engine, developing by reference to an electric output nearly fifty (50) horse-power. During the tests the engine was driving a dynamo on reduced output, which served admirably to steady the engine. The engine-driver, standing by the throttle valve during the experiment, was guided by the reading of a voltmeter and was able to keep the speed fairly constant. The speeds on the dynamo-

meter were however, taken separately for each test by means of mechanism to be described.

The speed recording apparatus consisted of a small case (L) containing a pair of clockwork indices each indicating revolutions and fractions from 1 to 1,000, and driven by cords from the driver and driven shafts, which were dimensioned to give the same readings on each index at a low belt tension without load. The case also contained a split seconds stop watch, the watch and counters were simultaneously started or stopped by the rising or falling of a lever.

A small 10 volt dynamo was attachèd to the traversing frame, and was driven by a small 2″ friction pulley bearing against the rim of the driven pulley. The current from this dynamo excited an electro magnet in the recording box and supported a soft iron yoke, and the lever was supported till the yoke fell by cessation of the current.

The obvious effect of any slip of the belt was a reduction of the speed factor in the brake friction; the brake, unable to lift the trussed lever with the same energy, allowed the lever to be forced downwards by the air in the air chamber and thus additional pressure was communicated to the tension cylinder (G) causing the brake to seize the pulley fast. The operation when slip occurred being practically instantaneous. The cessation of the current consequent terminated the speed and time records. It was found possible to increase the load from nil to twenty horse-power in a space of 10 (ten) seconds, to count the revolutions and accurately take the duration in that time. To remove any effects of momentum however, the load was distributed over about sixty seconds, and the recording apparatus put in motion during about the last twenty seconds of the test. The pulleys used were 30″ diameter and 12″ flat turned face, and were such as are ordinarily used in mill gearing.

The application of fluid pressure to the automatic control of the brake in place of the compound differential levers on similar

devices having proved satisfactory, the author has dwelt on the construction of the machine at some length. The method of reducing the friction of the hydraulic leathers by rotary movement in a plane normal to the stroke though obvious, is thought to be novel, The practical effect being to reduce the internal static friction due to the leathers from 26% to less than one per cent. Thus at 100 lbs. pressure on a plunger 1·12″ diameter the friction was 28 lbs.

Agreeing with a formula $F = \frac{P\ C}{D}$ where

F = Total Friction
P = Total pounds pressure on ram.
C = a coefficient 0·3
D = diameter of plunger

whereas on rotary movement the friction was represented by slightly under one pound.

It will be noted that the friction of this plunger does not agree with the coefficient of John Hicks,[1] estimated at from 0·03 to 0·09 for leathers under similar circumstances.

A large number of transmission tests were made at each particular tension, and for convenience of comparison the whole were reduced from varying speeds to 1000′ per minute by direct proportion.

Table shewing the comparative transmission of horse power at 1000′ per minute. Cast iron pulleys arc of contact 180°.

Double leather belt, 6″ wide, cemented only, oak tanned, grain side to pulley, dry, and not dressed. Endless.

Lbs. tension of combined parts of belt.	Horse power.	Nearest coeff.
275	5·2	0·45
400	7·6	,,
490	8·7	,,
650	12·1	,,

[1] *The Engineer*, June 1, 1866.

Double leather belt, 6″ wide, cemented only, oak tanned, grain side to pulley. Endless. Dressed day previously with castor oil.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	6·3	+ 0·6
400	9·3	,,
490	11·5	,,
650	14·9	,,

Rawhide belt, 6″ wide, grain to pulley. Endless.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	6·2	0·6
350	7·7	,,
400	9·1	,,
490	11·3	,,
650	14·9	,,

Woven hair belt, patent edge, new, with manufacturer's surface in best condition. Wire lacing.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	5·6	0·5
400	8·4	,,
490	9·8	,,
650	13·0	,,

Rubber belt, 6-ply, 6″ wide, new. Wire lacing.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	5·5	0·5
400	8·5	,,
490	9·9	,,
650	13·2	,,

Dry single leather belt, 6″ wide, cemented only, grain side to pulley. Endless.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	5·0	0·45
400	7·5	,,
490	8·8	,,
650	12·0	,,

Dry single leather belt, 6″ wide, cemented only, flesh side to pulley. Endless.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	4·6	0·4
400	6·9	,,
496	8·2	,,
650	11·1	,,

Balata, 5-ply, 6″ wide, new. Wire lacing.

Lbs. tension as before.	Horse power.	Nearest coeff.
275	3·8	0·3
400	5·4	,,
490	6·5	,,
650	8·7	,,

The coefficients are deduced to the nearest first place of decimals.

The belts were new in each case. The pulleys were smooth with the ordinary turned surface and were kept clean from any adhesive substance due to any previous test.

In the above experiments the results would appear to confirm the practical superiority of leather, and this more especially applies as leather is not in its best condition when new, whereas the woven and rubber belts with the adhesive substances applied to them externally in manufacture are at their best, and will lose efficiency as the substance wears off.

From the data derived from the experiments, and following a graphic system which the author first noticed in the *American Machinist*, the diagrams have been prepared, shewing size of pulley, speed per minute, width of belt, and horse power transmitted ; assuming a total tension on the tight side of the belt of 60lbs. per inch of width, this being as great as can be recommended for durable effect.

As far as the author is aware, the only examination of the comparative efficiency of belts and ropes was made by the Society of Industry of Northern France in 1895, when careful comparison

was made in a transmission of about 160 h.p. at about 4000′ per minute. The rope system and belt system each being tested at what was believed to be the best working conditions. The result was that the efficiency appeared to be the same for both ropes and belts. The question of working cost was not examined in the case mentioned. It would generally appear, however, that ropes are more costly to maintain, for, though costing less, the wear is excessive and renewals are comparatively frequent. The use of heavy grooved pulleys adds to the cost of installation, and the efficiency being no greater, no doubt accounts for the limited application of this system of driving, except for great loads, or high speeds up to 6000′ per minute.

While the subject of belts at low speeds may be readily examined by existing formulæ, additional factors enter into considerations of high speeds which very considerably modify the results. It is an American contention that an air pressure, due to rarefication of air near the pulley rims, causes a greater pressure normal to the belt on the pulley than that due to the tension only. And the contention is borne out by results, notwithstanding the counter influence of centrifugal effect, which is easily subject to calculation.

Again, at high speeds adherent air is carried under the belt and so reduces the friction coefficient. This has led to a system of perforating the belt or the pulley with satisfactory results. There is little doubt that the efficiency of the link-belt at high speed is as largely due to its open texture as to its superior flexibility. Thus the system of high-speed driving, brought about by modern electric generation, has opened up a new field for investigation.

The use of link belting is advocated for high speeds rather than for high tension and heavy loads, being favoured for its smooth running qualities, and capacity for large transmission at high speeds. Its low tensile strength renders it unsuitable for slow driving, except for governors and mechanism absorbing small power but demanding easy running.

Link belts are commonly secured by steel pins, and in more recent construction are flexible longitudinally to afford better grip in crowned pulleys. For high speed machinery with constant load driven by variable speed motor such as a gas engine, or constant power driving a variable load, the leather pin link belt will give most satisfactory results. This class of belt would appear on cursory examination to be incapable of long wear and durability, but as a matter of fact, its durability and elasticity is remarkable. It is customary to drive link belts at much higher tensions per unit of sectional area than is permitted by solid leather bands. Link belts are found to stretch to 15% in excess of their original length without damage, and may be safely used at very high speeds on pulleys as small as 9″ diameter, and being weighty for its capacity, it usually runs free from shaking-waves.

Where the distances between centres are short, and the arc of contact consequently small, the link belt is commonly applied. The author is, however, of opinion that in all such cases a system of leading pulleys permitting the use of a longer belt—the main distance between centres remaining the same—is much preferable. Both pulleys being then embraced to 180° and greater elasticity of belt obtained.

The author has observed cases where the tension in belt and stress in journals could have been reduced more than 50% by this simple expedient, with the same transmission of load.

In situations where the excessive heat or dryness, leather is found to become dry and hard, the use of raw-hide belting is advisable. It has a high efficiency and wears well, being subject however to a greater stretching than leather. During use it has a tendency to exude the stuffing used in its manufacture and clog the pulley face, and while the transmitting efficiency is increased the pulley becomes uneven and the durability of the belt affected. The pulleys should be kept clear of such adhesions. Among the simple belts, a class known as "Patent Edge" has much favour among electrical engineers; it consists of a single belt with a double edge, and has practically the flexibility of a single with

the strength of a double ply. The double belt with flexible back is used for larger pulleys with much crown, thus giving a better grip on the pulley.

Is has been customary to refer to the slight movement of the strap with reference to the pulley as slip. The author would prefer to designate this action as creep, leaving the former definition to represent the actual failure of the belt.

The creep in belts examined by the author varied as follows, from no load to maximum :—

Leather	0 to 2·4%
Rubber	0 „ 2·8
Hair	0 „ 2·0
Balata	0 „ 1·7

From the comparison already referred to, the creep in ropes may be taken at 1%.

For durable life the most economical speed for leather belts may be taken at :—

3000′ per minute for triple.
2500′ „ „ double.
2000′ „ „ single.

The maximum speeds for any degree of durability being 6000, 5000, and 5000 per minute respectively.

It would seem to be practically impossible to use belts at these speeds, except at certain distances between centres of over 20′. The author is of opinion that where many revolutions are required the tendency to reduce the size of the pulleys is the cause of much vibration and wear due to the shock, and consequent wave due to the joint crossing the pulley. Under such disadvantagous circumstances, the best belts may only last a few weeks. Pulleys not less than 12″ diameter for a double belt and 8″ for a single belt are desirable where reasonable wear is expected.

The keen competition among machine builders has resulted in reducing the diameter of the pulleys in slow moving machines, and cases are common where wide belts are used on pulleys of

small diameter, whereas the use of a pulley of large diameter would enable the belt tension to be proportionately less. The large amount of power absorbed in line shafting, may be traced in a great measure to a belt tension which may be modified by the general use of larger pulleys.

Jockey pulleys are found to work most satisfactorily on the loose side, which should always be uppermost. Such pulleys should preferably be hinged, rather than sliding in guides, and be set about one-third of the distance between centres near the smaller pulley.

In connection with high speed driving, the use of crowned pulleys with more than $\frac{1}{8}''$ crown for each 12″ of width is undesirable, any inequality of the belt resulting in chasing across the pulley. This chasing may be so serious as to affect the driven machine, and is due (1) to unequal local tension in the material composing the belt, (2) unequal density. In the first case the movement across the pulley face will be noticed at quite low speeds; in the second it will become evident as the speed rises towards maximum, being due to centrifugal effort of the denser part of the belt to reach the crown. In the case of $\frac{1}{2}$ crossed belts driving a vertical shaft the crown should be at least three times that stated.

The life of a main leather-belt, working under proper conditions of stress and cleanliness, has been variously estimated from twenty to thirty years. But a passage through the various factories of N.S.W. will show that belting generally does not receive the attention it deserves. Its very simplicity leads to neglect. Belts should be cleansed from adherent dust and grease at least twice yearly, and, if dirty, be scoured with soda and water. They should receive likewise every six months, or oftener, a dressing of boiled linseed oil or castor oil, or emollient preparations for the purpose. On no account should resin or such substances be applied. The pulleys should be kept clear of dust and grease. The author has seen many cases where the pulley face is no longer visible through such accumulations. When a new belt is put on, it should, before

use, be treated with oil as above stated, and be driven at its lowest tension. The journals and bearings of new machines are too often damaged at a time when they require the most kindly treatment, through using dry belts under great tension.

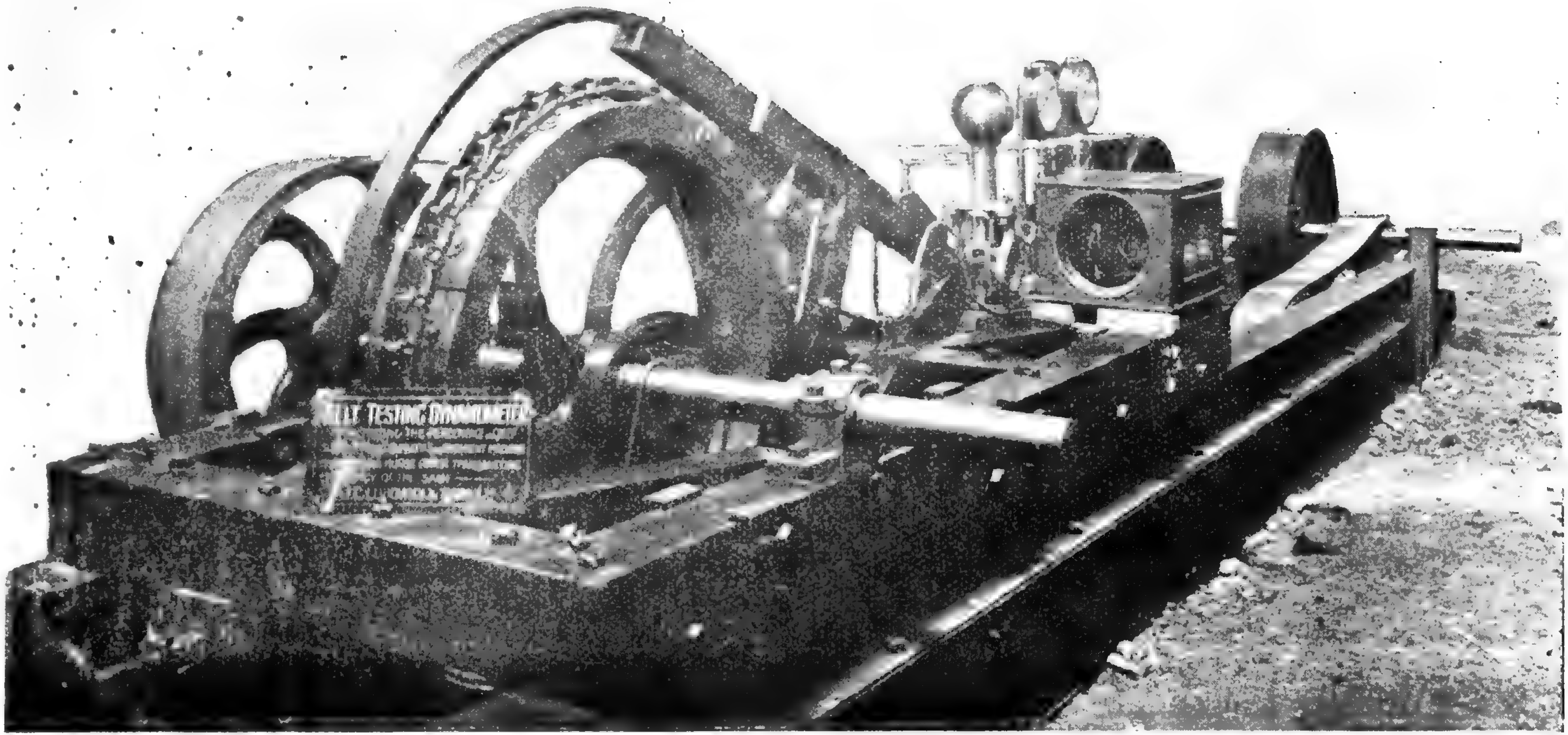
In conclusion, the author has found that some very peculiar ideas are prevalent among mechanics and millwrights in connection with this subject. A very general rule of thumb referring to the alignment of shafts, is that "the belt always moves to the high side," the fact, of course, that the opposite, is the effect makes the rule unconvincing. The origin of the fallacy may be traced to the known effect of crowning a pulley.

Again the general impression among mechanics that with any given belt-speed, and tension, there is greater grip on a wide pulley than on a narrow one, and on a greater diameter than a less, has resulted often in an unnecessary expenditure on belting and pulleys.

The dynamometer above described was built to the order and at the cost of Messrs. J. C. Ludowici & Son, Ltd., who, it will be seen, have been to some considerable expense in an endeavour to throw a little additional light on the subject of belt transmission. The author is indebted to them also for the samples of the various classes of belts dealt with in this paper.

Discussion.

Mr. Ludowici said that they found the dynamometer of very great use in their business as manufacturers. It enabled them to test belting before it left the factory, they can run the belting on that machine and satisfy themselves that it was perfect in every way before sending it out. Hitherto there had been no means of getting that information, and at times they were put to a good deal of trouble on account of complaints, as they had no means of proving whether the belts were perfect; but now they can give a guarantee with a belt, because if it runs right on that machine it will run straight in actual work. With regard to the question as to the sides for running belts on, it is a very open matter. The


T.T. TESTING DYNAMOMETER

hide of course had the two surfaces, the flesh and the grain side, the outer skin becomes worn in places and presents a somewhat unequal surface to the pulley. By running on the flesh side, that is the single belt, (you will bear in mind all double belts are made grain side to the pulley) the flesh side becomes smoother and smoother as it wears, and after a time it possesses an even better gripping face than the grain side, so you will see the difference in gain by running on the flesh side after it has been used for some time. It is a very open question now on which side the belt should run. We make them single to run on flesh side; we find our customers prefer that. With the patent edge they are made to run on the grain side.

Mr. H. B. Howe said that in reference to rope driving gear, comparison is made between this and other kinds of belting. Of course there is a lot to be said on both sides. Leather belting was in his opinion after several years' experience, decidedly the best for small machines, especially in comparison with rubber belting, but when you get to large gear, he questioned very much if rope driving would not be of considerable advantage. In some large electric plants, he had the pleasure of seeing in America, he saw some very heavy belting there running up to 4′ or 5′ wide stretched very tightly, and which must have thrown a very heavy strain on the shafting, whereas in rope driving there cannot be the same strain. He said that running belts on the grain side has been found advantageous. He then referred to the double edged belting and said it is one of the best improvements made yet, it gives flexibility to the centre and undoubtedly will keep belts running straight more so than if the belt had been single, and will do work equally as well as the more expensive double belt.

Mr. Grimshaw called attention to the fact that the tests had been made on new belts, and asked if in worn belts the coefficients varied as he thought that they did?

Mr. H. S. Barraclough called attention to the advantage to be derived from using a high speed for belts.

Mr. HOUGHTON stated that he had used many belts of leather and also woven belts, and after running under practically similar conditions, had not noticed any great difference in wear between the two of them, no doubt a great deal depended upon the way the belts were kept. He pointed out the desirability of always keeping the bottom instead of the top of the belt tight, especially in link belts.

Mr. Ross said in reply, that as regards Mr. Howe's experience of rope driving as against leather in the United States, no doubt a tight belt is bad at all times. No belt should be tight. If the belt is too tight then it must be either be driven at a speed which is too high or has passed the limit to which a leather belt can be used. Of course in such a case rope driving would no doubt be preferable, because it would depend for its transmission on the friction of the rope lying in the groove.

TRAMWAY RAIL JOINTS.

By G. R. Cowdery, Engineer for Tramways.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, November 17, 1897.*]

Although tramways (or as Americans would more properly say, street railways) have been in vogue for many years, it is only within the last three or four years that very considerable progress has been made in improving the rail joints. This was, no doubt, chiefly due to too close adherence to railway practice, insufficient allowance being made for the altered conditions under which rolling stock was required to move along street surfaces, and also from the fact that some conditions common to both were not properly understood, or, if understood, lightly ignored.

Two illustrations in passing will suffice. The author early noticed that the same expansion was allowed in street tracks as on the railway, although not necessary. Also that heavy expense was incurred when renewing joint sleepers owing to the necessity for first removing the concrete with which they were surrounded, although in the first instance no concrete was really required. This led to the experiment of laying the sleepers closer together on broken ballast without concrete, thus more closely conforming to railway conditions, preventing cold rolling to the rails similar to that which takes place in a rock cutting on railways where insufficiently ballasted. All tram lines whether relaid or constructed through macadamised streets, have been made for the last seven years without concrete, greatly reducing the cost of ordinary maintenance, and producing smoother running. Of course this cannot apply to woodpaved streets, where a rigid surface is indispensable. These two illustrations are sufficient to explain that in one case a departure from railway practice was necessary, in the other it was not.

Although endeavour will be made to adhere as closely as possible to the subject of this paper, it may not be inappropriate to briefly touch on the history of the present Sydney tramway permanent way. Passing by the Larson and Gjedsted rails first used, and which had a short existence, we come to the 42 lbs. T rail. This rail was first laid on sleepers 8′ x 8″ x 4″, 3′ apart, centre to centre, and concreted from rail level to 4″ below the sleeper, the concrete forming the street surface. The guard, 22lbs. per yard, was separate, and bolted to the rail with $\frac{5}{8}$″ bolts through cast-iron distance pieces 1′ 6″ apart to form the groove. Owing to the difficulty in repairing the joints, the practice of concreting to the surface was soon abandoned, and not allowed to come higher than half way up the sleeper, the surface then being formed with tarred metal and screenings. Concrete with this rail was finally abolished in 1890 as previously described.

The difficulty in obtaining a satisfactory joint led to an experiment of laying down 71½ lbs. T rails in Devonshire-street, the guard rail belonging to the 42 lbs. T rail being made adaptable for this purpose. The idea was that the stronger fishplate would give better results. These rails have been in their present position sixteen years, although the original guard rails have been removed, and guards formed from worn 42 lbs. rails substituted. The fishplates have also been repeatedly renewed.

The Devonshire-street experiment was considered so satisfactory that a further length of 71½ lbs. rail was laid in Phillip-street in 1886, special guard rails being provided. This guard rail also forms the fishplate on the inner side, and weighs 33 lbs. per yard. The 60 lbs. T rail was similarly treated for the outlying sections.

In 1891 the grooved girder rail, 86 lbs. per yard, was introduced in wood-paved streets, sleepers being dispensed with, the rail resting directly on the cement floating covering the concrete.

Now, in all these description of rails, from the Larson rail laid in 1879 to the more recent grooved girder rail, notwithstanding many improvements, there is still the same inherent weakness,

that is, the joint. Of course a great deal could be said in regard to the weaknesses and merits of the different descriptions of tramway rails, but that is somewhat outside the intention and scope of this paper, and could well form a separate subject.

Let us look into the history of the defects of a tramway joint, which, like the poor, whether in Europe, England, America, or Australia, are always with us. In the first place, what is a good joint? the absence of motion to both rails and cars. Take an ordinary rail and fish-plate, and presuming that the greatest care has been taken to see that head web and flange, the length and type of fishplate, and the number and size of bolts to be made have been well designed, we find on the arrival of the shipment that notwithstanding the rolls have been made with the greatest nicety, that the rolling and punching is done with the greatest care, there is, to begin with, an absence of fit, for by using the point of a penknife we find many places between the rolled surfaces of rail and fish-plate where the parts are not in contact. The fault of this cannot be fairly charged either to the designer or maker, but is the result of expecting too much from the bolting of two rolled surfaces together to resist a strain and stress that no other mechanical device would be expected to withstand.

Therefore we have to start with an inherent weakness which every blow of a motor and car wheel only accentuates. It is therefore clear, that we must have far better fittings than are to be obtained at the best rolling mills in the ordinary commercial way, in order to produce the desired results. But this is not in itself sufficient, as endeavour will be made to show.

Early in 1893 the author was greatly struck with a capable and thoughtful article by Mr. A. J. Moxham, which appeared in an American journal in November of the previous year, on "Expansion of Continuous Rails." This was not only interesting as showing what had been done in America, but because our own experience almost entirely coincided with it. He says—"If two rails be placed in perfect surface and alignment and closely butted

and so held, the problem is solved. Not only must they be true to surface and line, but they must be abutted. It will not do to leave the usual expansion. This can be quickly demonstrated by cutting a groove $\frac{1}{4}''$ wide in the head of the middle portion of a rail." The surface and alignment are here true, but not abutted. A slight jar can be felt from the first, and in a short time becomes worse, and after continued use bad and rapid wear, accompanied by a low spot, results. In this case there is no motion of the rails, the evil is resultant from the motion of the cars. This, however, goes without saying, as the cars are the destructive agency, and it is only emphasized because it is a very prevalent opinion that if the rails as laid to-day could only be held rigidly level the problem would be solved."

He then goes on to explain an experiment made with what was virtually a continuous track, 1160′ long, the joints being secured with bars 5′ 4″ long, and held with $1\frac{1}{4}''$ machine-turned bolts, filling at the same time the expansion by a carefully made dog or closer the same section as the rail. The results appeared so successful that the author obtained the Railway Commissioners' sanction, 20th April, 1893, to lay 510′ of somewhat similar track at Newtown. The place chosen was between Missenden Road and Egan-street on the down line. The rails were 60 lbs., with fishplates 5′ long and $1\frac{3}{8}''$ thick, and secured by twelve $1\frac{1}{8}''$ bolts. The fishplates were made from old steel tires, re-rolled at the Esbank Mills, and afterwards carefully planed at the interlocking shops, Redfern, care being taken to plane the plates to fit the rails, the ordinary contact between the two rolled surfaces being considered insufficient. The $1\frac{1}{8}''$ bolts were machine turned, and a driving fit.

The laying of the rails was begun on the first, and completed on the 16th November, the wood paving between and outside the rails being commenced on the 16th November and completed 1st December, 1893. At each end of the 510′ where the rails were secured, $\frac{1}{4}''$ and $\frac{3}{8}''$ were respectively allowed for expansion.

On 2nd December, 1893, the level of each rail at the joint and centres was carefully taken, and again on the 14th August, 1894. The greatest variation was ·02 of a foot, the difference being only such as would be expected by rails seeking their proper bed on the sleeper.

No alteration could be traced in the expansion allowance between the dates mentioned, and the rails have also remained in good line. It was thought that if there were a tendency for the rails to expand, their course would be directed to the point of least resistance, and it was believed that under the conditions it would be in an upward direction rather than laterally, hence the object of levelling. It is only necessary to add that after nearly four years' constant and fairly heavy traffic, some difficulty is experienced in finding where the joints butt. The author must admit, however, that several joints show some slight signs of weakness, and the cause of this is not far to seek. On exposing the joint it was found that while the fishplates perfectly fitted one rail, they did not, owing to a slight variation of section, fit the corresponding rail. How is this to be obviated? Only by milling both rail and fishplate, and it is only by this means that a perfectly mechanical fit can be obtained with fishplates.

The experiment at Newtown was considered so satisfactory that it was determined to extend the principle, with further improvements, and in March last the work of relaying from Bridge-street to Hunter-street, a length of 15 chains, was commenced. The track to be removed consisted of 71½ lbs T rails originally laid with 33 lbs. separate guard, the guard on one side forming the fishplate. These guards, owing to their worn state, were removed four years ago, and old 42 lbs. rails substituted. The sleepers were spaced 3′ apart, and bedded in concrete. The rails had been down 10 years and 10 months, and when taken up and weighed had lost an average weight of over 20 lbs. per yard.

The rails selected for relaying were 80 lbs. steel T, 30′ long laid on sleepers 2′ 4″ apart, or thirteen to a rail, with broken metal ballast. For guards 42 lbs. rails no longer suitable for

running purposes, were used. The fishplates were designed 4′ long, 1″ thick, and secured with ten $1\frac{1}{8}$″ bolts made a driving fit. To obtain a good mechanical fit both rails and fishplates were milled, and to ensure the rails abutting properly the ends were brought together and cut through with a cold saw.

The guards and rails break joint with one another, enabling the fishbolts of both to be tightened when necessary through the groove without in any way disturbing the street surface. The work of milling the fishplates and rails was carried out by the Interlocking Engineer, and it is due to that gentleman and his foreman that such excellent results were obtained, in the face of many difficulties chiefly due to the extreme hardness of the rails. A short description, therefore, of the machine and cutters, kindly supplied the author by Mr. Wilkin, may not be uninteresting to members.

"The machine was originally a planer of the ordinary type, and of the following dimensions—length of bed, 15′; table, 10′ 6″ x 3′ 1″, and would take in an object under cross slide 2′ 0″ high, and was fitted with two tool boxes. The machine has been in constant use for over eighteen years, planing points and crossings.

"The following alterations were effected to convert the planer into a milling machine. The two tool boxes were taken off, and in their place one double and one single bearing bracket were fitted. These carry a very strong steel horizontal shaft, on which is fitted four cutter heads. On the end of this shaft is a bevel wheel, which is driven by a corresponding wheel on a vertical shaft connected to the driving gear. The table is fitted with the old rack in which a pinion engages, but this is now driven by a worm and wheel so as to give the proper rate of travel to the table. The gear is arranged in such a way that the shaft carrying the cutter heads can be put out of gear while the table travels back with a quick return motion, thus preventing a back rubbing of the cutters. Altogether, the machine may be considered entirely suitable for the work it was designed to perform.

"Practically, there has been no difficulty with the machine itself, but owing to the extreme hardness of the rails to be milled, a considerable amount of trouble has been experienced with the cutters. At first the usual solid milling cutter was adopted, but owing to the high cost of this form of cutter, and to the fact that they would only mill a few rails before they required sharpening, and then it was found impossible to get them hard enough, and at the same time keep them true, it was decided to give them up. A cast iron cutter head was then tried, in which thirty steel cutters in a circle of 10″ diameter were securely fastened by keys. This was a distinct improvement on the previous method, but was far from satisfactory, for although the cutters were hardened as hard as possible, the very hard rails soon wore them out. The experience gained led to an entirely new form of cutter head being made. The heads are now in two halves, and the cutters are arranged to overlap each other ; there are now forty cutters in a circle of 10″ diameter, or eighty half cutters in a complete cutter head. The cutters are plain pieces of steel bevelled off to give the cutting edge. They are capable of being adjusted sideways, so that grinding does not spoil them. So far the result of the trial with this form of cutter is fairly satisfactory, and when some slight alterations are made, we may consider that the machine, and the method of doing this class of work, is all that could be desired.

"There are four rails or four fishplates put on the machine at one time ; the rate of travel is two feet per hour ; the rails are milled two feet up from end, and the fishplates from end to end (3′ 11″). The best result with the new cutters, without sharpening, was 50 rails, or 400 feet per cutter head, equalling 1600′ with the four sets of cutters."

It may be added that it is anticipated the extra cost of preparing the rails and fishplates will be more than recompensed in the ordinary maintenance of the track, to say nothing of the lessened wear and tear of the rolling stock. The additional comfort to the tram travelling public is another important matter.

With regard to the ordinary fishplates in use, it is found necessary under heavy traffic to renew them every three or four years, and the renewal has been found so unsatisfactory, owing to the wear on the under side of the head and flange of rail, that instead of using new fishplates, the old plates are taken to the shops, and there spread in a cast iron block under the weight of the steam hammer, the depth of the fishplates being increased by a quarter of an inch.

There are many other joint devices with more or less merit, but which fail to fulfil the conditions required of them, a description of which would only weary members. This paper would, however, be incomplete were two of the most recent methods of uniting tramway rails, which have largely come into use in the United States of America, omitted. These are the electric welding, and also its rival known as the "cast weld."

As far back as June, 1893, the West End Co., Boston, determined to try electrically welded joints. Four miles of track laid with the rail section known as the Providence girder rail, and three miles of $4\frac{1}{2}''$ girder were selected. The latter rail at this time was badly worn, and soon proved a failure.

The four miles of Providence rail remained in shape till the following winter, when it pulled apart in eighty places. The breaks were in most instances from 4″ to 8″ from the weld, though some were in the centre of the rail. Improvements having been made in the method of welding, the rail was repaired by being sawn at the breaks to make a clean edge, closers of the proper size being inserted, the rail afterwards being re-welded. The track is reported to have lasted satisfactorily through the summer of 1894, but in the following winter broke again in thirty places. The riding was stated to be very easy over this construction, and where not broken very satisfactory. Where the breaks occurred girder joints were employed. An interesting fact in connection with the breaks was that they did not occur at regular intervals, three or four occurring with 60′ or 90′, and then not again for half a mile.

It is reported that on the whole the Company were pleased with the experiment, it being believed that a large part of the trouble was due to the light and unsuitable section of the rail used, and in some instances defective welding. While about six per cent. of the joints parted at Boston, Captain Robert McCullock states that in St. Louis, of 2,203 electrically welded joints in three and a quarter miles of double track seventy-two joints, or 3·27 per cent. have broken. Thirty-seven broke during the cold weather of the first part of the winter of 1895, and each was repaired by casting a mass of iron round the broken part. During a second very cold period in the latter part of the same winter thirty-five more breaks occurred, which were not immediately repaired. Seven of the joints opened nearly two inches on breaking, while in others the crack was barely perceptible, the average amount of opening being $\frac{1}{4}''$. During the warm weather of the following summer it is stated these cracks closed a trifle, but the amount of the movement was unimportant.

After favourably noticing the driven bolt joint laid at Newtown, New South Wales, the *American Street Railway Review*, March 15, 1895, states that Mr. C. W. Wason, electrical engineer of the Cleveland Electric Railway, reports that out of 3,000 electrically welded joints they have only lost six during the past winter, two on 96lb. and four on 70lb. rails. The weather was extremely cold, the thermometer reaching ten degrees below zero for two or three days consecutively.

Notwithstanding the apparent success, as already indicated, of electrically welding rails, advice received from America as recently as March, this year, states that owing to a combination of circumstances nothing whatever was done last season with regard to the welding of tramway rails in that country. What the circumstances were is not explained, although it was expected that work would be again begun this year.

It is probable, however, that the successful results that have followed the introduction of the process of what is known as

"cast welding" has, owing to its easy adaptability, overshadowed for a time at least its more costly electric rival.

The process is under the control of the Faulk Manufacturing Co., Milwaukee, and was first applied to the National Railway Co.'s street lines, St. Louis, about three years ago. The apparatus for casting consists of a cupola furnace mounted on a heavy truck provided with a blower running 1,800 revolutions a minute, driven by an electric motor. In twenty minutes after the blast is turned on the iron is ready to pour. The cupola handles 8,000 to 9,000lbs. of metal in one heat, and thus makes approximately eighty joints.

The method of making the joint is as follows:—The rails at the joint are scraped and brightened, a cast iron mould, usually about sixteen inches long, is placed round the joint, making a tight fit; into this the molten iron—twenty-five per cent. scrap, twenty-five per cent. soft, and fifty per cent. hard silicon pig—is poured; the metal in contact with the moulds begins to cool, and forms a crust, while the interior remains molten. This crust continues to cool, and at the same time contracts, forcing the molten metal strongly towards the centre, and keying through the bolt holes makes a solid and rigid joint.

The application of this joint appears to be spreading, and is in use in St. Louis, Brooklyn, Chicago, St. Paul, Minneapolis, and other American cities. There is a great deal of difference of opinion as to the value of the joint as regards electrical conductivity. It is, however, the practice to copper bond over the cast welded joints on important roads. The necessity for this would appear apparent, as it is difficult to understand how any real amalgamation can take place between the cast iron and the steel.

It may be added that it is stated few cast welded joints have been found to break during cold weather. In Chicago, which is noted for its sudden changes, 17,000 joints were put up in 1895, and of these only 154 joints were reported lost. The Company now report they have twenty outfits at work throughout the States.

It should, however, be borne in mind that an ordinary fished joint gives little trouble for the first two years, therefore an extended trial is necessary before accepting the cast weld joint as possible perfection. Disadvantage may arise from the fact that cast iron and steel possess different co-efficients of expansion, and also whether the temper of the rail is not impaired by the heating, producing under heavy traffic a low place at the weld.

With regard to the effect of temperature on the 990 feet of non-expansion track in Phillip Street, it may be stated that with a variation of temperature of 121 degrees the rails, if not neutralized and restrained by the surrounding road bed, would expand 4·95″, and if held at the ends and permitted to bow in the centre would throw the rails 13′ 2½″ out of line. It is confidently anticipated no such variation of line or level will take place.

As to its practical application there are many precautions to be taken, such as not allowing the plate-laying to extend too great a distance beyond the paving or macadam filling, and also to allow for the removal of a defective rail, points, crossings, etc., which require constant attention. It is therefore not considered advisable at present to lay in a greater length than 1,000 feet without providing for expansion.

In conclusion, it may be stated that the climatic conditions of Sydney are very favourable for a continuous track. While there is a variation of temperature at Boston, U.S.A., of 106·5 degrees, New York 95 degrees, and Washington 99 degrees, the variation at Sydney is only 70·1 degrees Fahr.

The author is indebted to Mr. Russell, Government astronomer, for information with regard to temperatures, and to Mr. Elwell for the latest information regarding electric welding.

PLATE I.
STANDARD PROPORTIONS FOR TEST PIECES

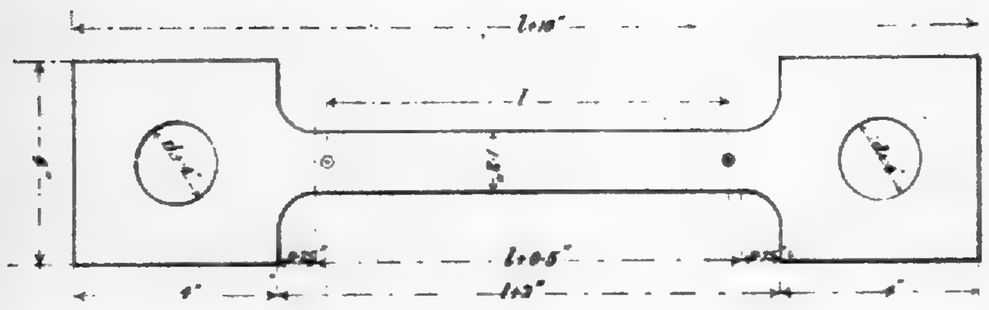


Fig. 1.

Rectangular and Square Sections

l = 8″ for 0·4 thickness
= 6″ = 0·6 ″
= 5″ = 0·8 ″
= 3″ = 1·0 ″

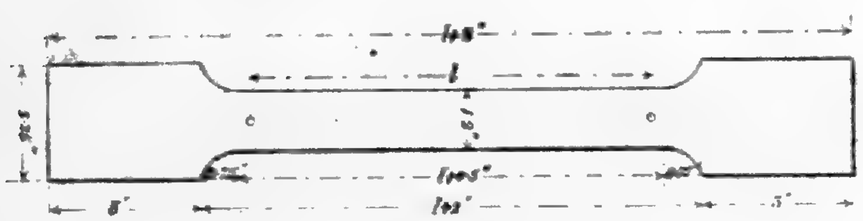


Fig. 2

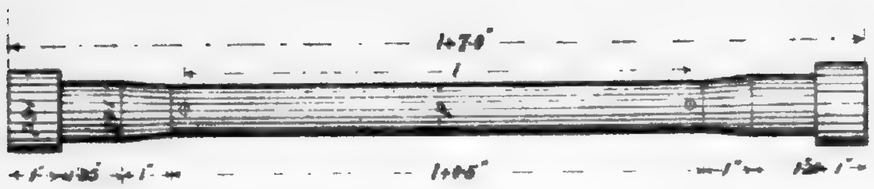


Fig. 5

Round Specimens : l = 10d

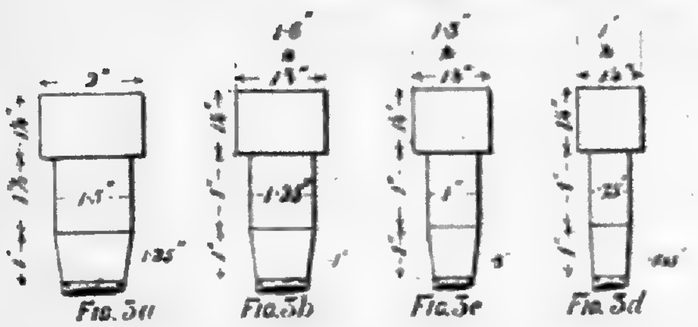


Fig. 3a *Fig. 3b* *Fig. 3c* *Fig. 3d*

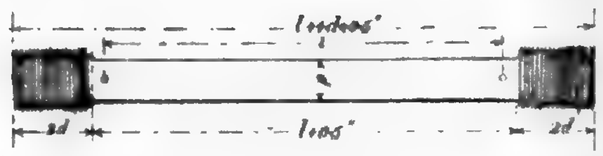


Fig. 4

Round Pieces, when length is limited, with screwed ends. l = 10 d.

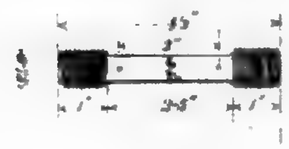


Fig. 3.

Standard form for Tyre Steel.

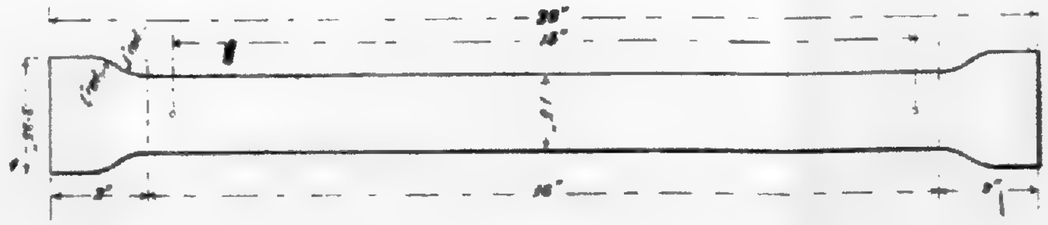


Fig. 6

Cast iron test pieces not turned.

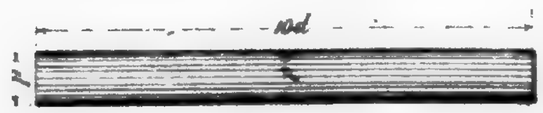


Fig. 7

Compression test pieces for Elastic Coefficients and Buckling.

Fig. 8.

Compression test pieces for Compressive Strength.

Fig. 4a

Fig. 4b.

Fig. 4c.

Fig. 4d

Fig. 4e

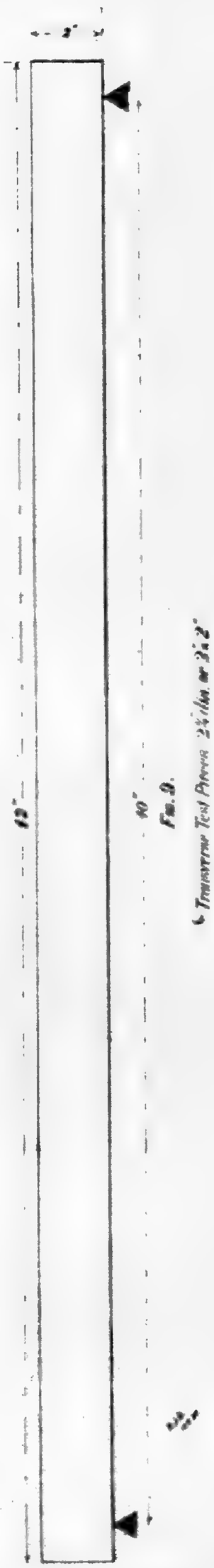
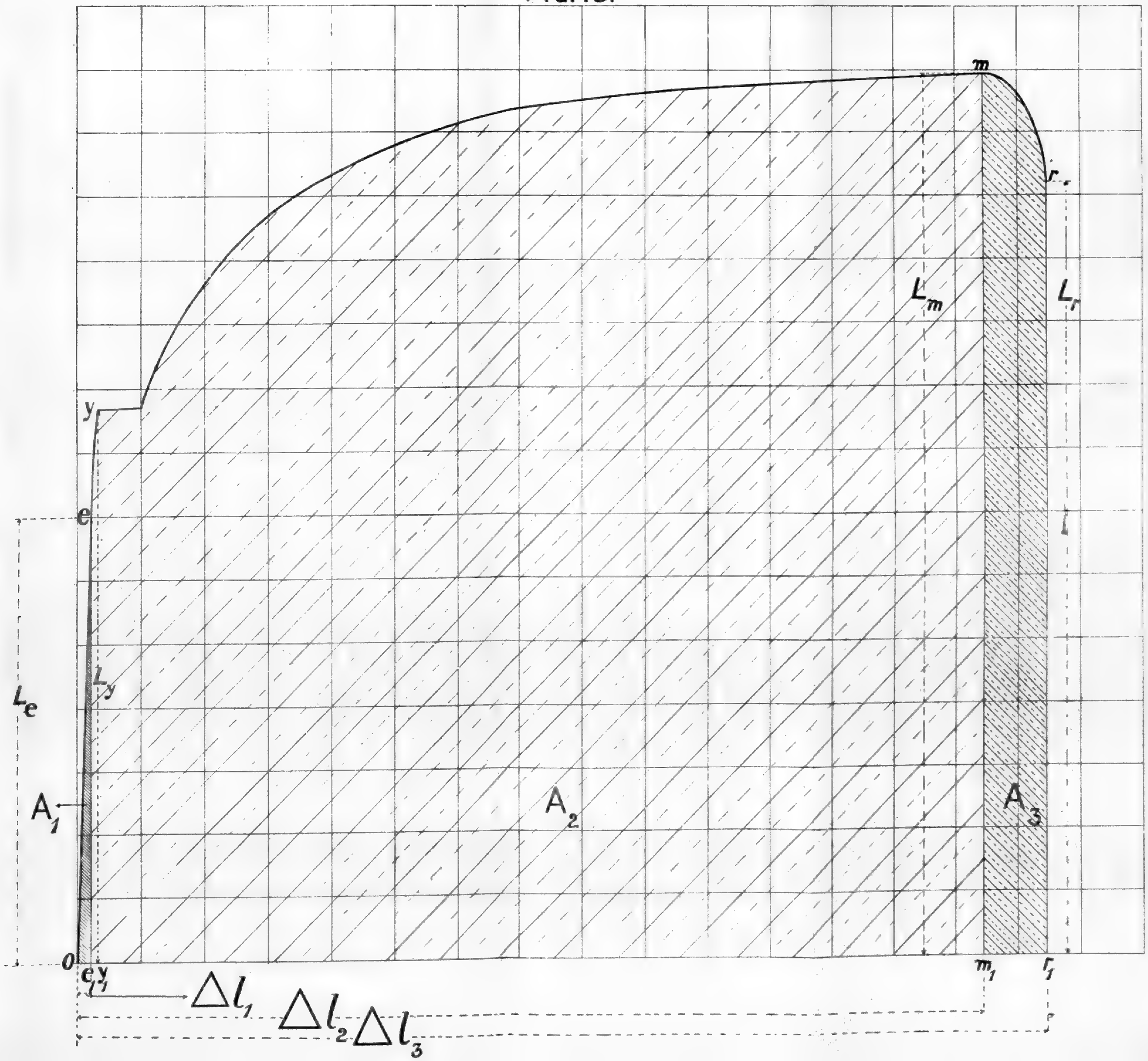


Fig. 9.

Transverse Test Piece 2½ in. or 2×2″

FIG. 10.



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