PREFACE

In 1971 the Institution of Civil Engineers formed its Panel for Historical Engineering Works to record, advise on and promote knowledge of our engineering heritage. In Scotland measures to further these aims have included forming a Group of the Panel, arranging lectures and site visits and the publication of historical booklets of which this is the fifth! The previous booklets, all the work of enthusiastic civil engineers and written more with a general than a specialist engineering readership in mind, have sold several thousand copies, particularly through bookshops, and only a handful of copies of the second edition of 'Our Engineering Heritage' and 'A Heritage of Bridges between Edinburgh, Kelso and Berwick' now remain in stock.

In the present publication the tradition of engineer authors writing about historical engineering works is very ably continued by our Group member Jim Shipway of Robert H. Cuthbertson and Partners, Consulting Engineers, Edinburgh. His subject, the present Tay Railway Bridge, a vital link in the national railway network, is one of the world's longest bridges. It is less well-known by the public than it deserves to be, being eclipsed in print by its inadequate predecessor. The balance is now redressed, at least in part, one hundred years to the day that the bridge was opened to passenger traffic, by Jim Shipway's refreshingly readable narrative and authoritative comment on both old and present bridges. This long-awaited booklet is a most appropriate centenary tribute to the achievement of Barlow & Son and Arrol & Co. Incidentally, the recently published "National Trust Book of Bridges" credits Sir Benjamin Baker as the co-designer of the bridge, which is incorrect. In addition to serving as a convenient hand-book for the future it is hoped that, more immediately, the booklet will enhance the centenary celebrations to be held at the bridge on 20th June and 12th September 1987.

My editorial contribution to the booklet on this occasion has included content balance, compilation of the biographical notes and the selection and provision of illustrations. The centre page progress report is a special tribute to Crawford Barlow and the ingenious foundation pontoons of William Arrol. Of the other contributors, I should particularly like to record my thanks to Jim Shipway without whose valuable efforts the booklet would not have appeared; to the Director of Roads and Transport, Tayside Regional Council and Ian Weaver for the photograph of and information on Caputh Bridge; to ScotRail for support and access to the bridge; to Bill Morris, ICE Archivist for biographical information; to Don Munro, Chairman and the other members of the Edinburgh and East of Scotland Association Committee of the ICE for their enthusiastic support, including John Reid, Secretary of the Dundee Branch Committee who initiated the venture; to Graham and Alex Taylor of Edinburgh Impressions for printing the booklet on time against a tight time-table and an unplanned surge of work arising from the declaration of a General Election; and finally, to Gwilym Roberts, President of the I.C.E. for his most welcome contribution of the Foreword.

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BIOGRAPHICAL NOTES ON ENGINEERS *by the Editor*

Note: Except where otherwise indicated the following information has been largely compiled from ICE membership records.

BARLOW, William Henry (1812-1902) FRS (1850) MICE (1845) President ICE 1879-80

This eminent engineer was the son of Peter Barlow, FRS, Professor of Mathematics at the Royal Military Academy, Woolwich. His railway career commenced in 1838 when he was appointed Assistant Engineer to G. W. Buck on the Manchester and Birmingham Railway. In 1842 he became Resident Engineer to the Midland Counties Railway and in 1844 to the Midland Railway. About this time he developed the saddleback rail known as the 'Barlow Rail' which was extensively used in western England. From 1857 Barlow became the Consulting Engineer for the Midland Railway Company. Major iron structures that he designed included St Pancras Station roof of 240 ft span. His paramount role on the design and superintendence of the Tay Bridge from 1880-87 has already been discussed. On 1st January 1873 he entered into an engineering consultancy partnership with his son Crawford. In 1874 Charles B. Baker (1832-81), a former pupil and assistant on railway works, owned the partnership, and for seven years the firm was known as Barlow, Son & Baker. Baker died in May 1881 just before the Act was obtained for the present Tay Bridge and his contribution to its design was thus curtailed. He was also involved in the early designs for the Forth Bridge but by agreement its design was finally entrusted to Fowler and Baker.

Barlow was one of the earliest exponents of correct mathematical design in engineering structures and exercised a fundamental influence on professional practice. His exposition of the theory of the strength of materials and his application of it particularly in iron structures encouraged engineers to avail themselves more fully of the results of experimental research in relation to construction. He married Selina Crawford, daughter of W. Caffin.

Largely compiled from Min Proc. ICE CLI 1903 388-400).

BARLOW, Crawford Peter (d. 1920) MICE (1879)

Son of W. H. Barlow. Crawford Barlow graduated from Trinity College, Cambridge in March 1870. He then became a pupil to his father and from that time until 1874 he worked on various railway projects in England, gaining experience as an Assistant Engineer and Resident Engineer before joining his father in partnership. From 1880-87 Crawford Barlow exercised a principal role in the design and superintendence of the Tay Bridge project. In 1885 he presented a paper about the bridge to the British Association, 'The Engineer', reprint of which is included on the centre pages of this booklet. In 1888 he delivered another paper to the ICE and also a course of lectures to the Royal School of Military Engineering at Chatham. These lectures were published in 1889 under the title 'The New Tay Bridge' and constitute the definitive history of the design and construction of the structure.

BIDDER, William Henry (b. 1830) MICE (1876)
From 1854-60 Bidder worked in the office of Edwin Clark who had been the Resident Engineer for the construction of the Britannia Tubular Bridge over the Menai Straits. From 1860-76 he had the entire charge of the London office of Thos. E. Harrison, an eminent railway engineer and President of the ICE in 1873, on work including the iron bridges and roofs required for the North Eastern Railway Company. During the same period he assisted various other engineers in designing girder work and swing bridges. From 1876- 1882 he was in practice on his own account engaged in designing numerous iron bridges and other iron structures. His sponsors for ICE membership included Harrison, John Fowler, John Hawkshaw and Crawford Barlow. For the Tay Bridge, Bidder and a staff of assistants worked out details of the calculations of the strains in the ironwork and produced the ironwork drawings.

KELSEY, Fletcher Francis Sheridan (fl 1864-96) MICE (1877 resigned 1896)
Kelsey served his pupilage from 1864-69 in the office of Thos. E. Harrison (previously referred to) after which he was engaged on various works on the North Eastern Railway. By 1877 as a Resident Engineer he had charge of 25½ miles of construction for the Company. He was appointed Resident Engineer for the Tay Bridge c. 1881 and during the next six years in Crawford Barlow's words his "constant and strict supervision of the works produced very satisfactory results." Kelsey read a paper describing the bridge to the Institution of Mechanical Engineers in 1887.

CAFFIN, Francis Crawford (1857-1920) MICE (1906)
Caffin served his pupilage under W. H. Barlow from 1875 to 1878, followed by two years as an Assistant Resident Engineer constructing railways in the Midlands. From 1881-88 he was Assistant Resident Engineer on the Tay Bridge for Barlow & Son working under Kelsey. In 1888 he went to work for Thomas Oliver in charge of railway works in Derbyshire including the 3½ mile Totley Tunnel. From 1891-1900 he became a contractor on his own account constructing works for the Great Western Railway. By 1906 he was Managing Director of the Djebel Charra Lead & Zinc Mining Co., Tunis. Crawford Barlow in his 'New Tay Bridge' acknowledges his indebtedness to Caffin "for a very valuable series of photographs taken during the progress of the works—a selection of which appears in this book." (Also in this booklet—pages 2, 23, 24 and 25.)

ARROL, William (1839-1913) Knighted 4th March 1890, MIMechE (1887)
Arrol commenced his distinguished career as a blacksmith in Paisley. In 1858 he was earning 22 shillings a week. The beginnings of his bridge-building career can be said to have commenced in 1871 when he was entrusted with making the railway

bridges from Edinburgh to Balerno over the Water of Leith. In 1875 he obtained North British Railway contracts for the construction of the bridge over the Clyde at Bothwell with seven spans 120 feet above the water and the great bridge over the Clyde at the Broomielaw, Glasgow, completed in 1878. To execute the latter he invented a hydraulic rivetting machine. In 1882 he obtained the Tay Bridge contract and designed the plant and appliances used in the making and erection of the bridge. His innovations included four-legged pontoons through which the 170 pier cylinders were sunk; temporary caissons built on the cylinders to enable the masonry pier foundations to be built and placing the old and new horizontal girders by means of large pontoons the four columns of which were fitted with hydraulic rams. From 1883-90 the major part of the Forth Bridge was constructed by Arrol and can be considered his crowning achievement. Other major bridges constructed by Sir William Arrol and Co. were Tower Bridge (1886-94); North Bridge, Edinburgh (1894-97); Redheugh Bridge, Newcastle (1900); New Clyde Bridge, Glasgow (1905); Blackfriars Bridge (1907); and Middlesborough Transporter Bridge (1911). The firm continued in existence in Glasgow until its close in 1986.
(Largely compiled from Purvis, Sir Robert "Sir William Arrol—A Memoir", Edinburgh 1913)

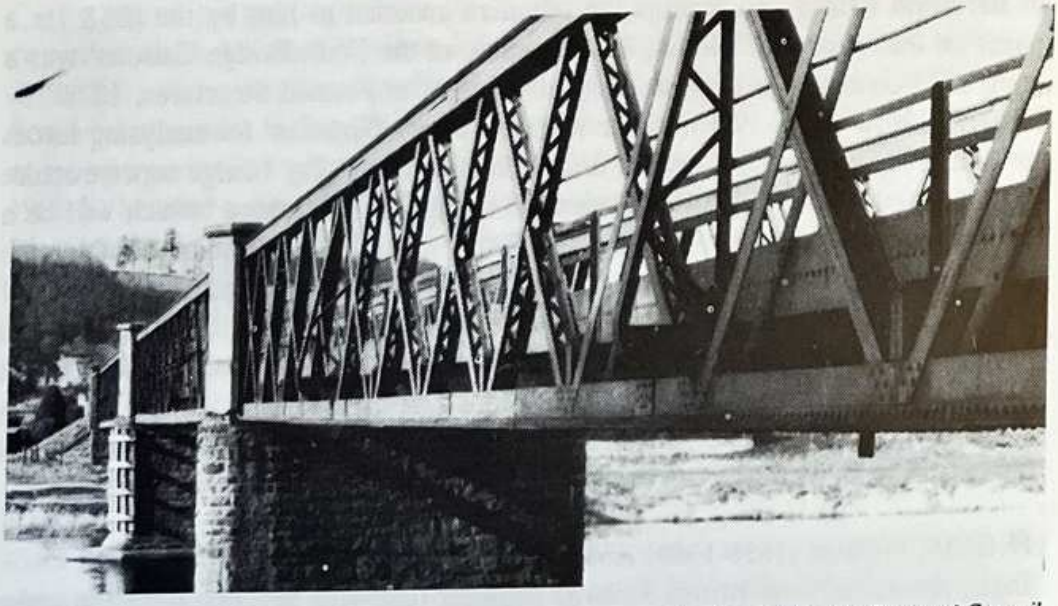
BIGGART, Andrew S (fl 1884-90)
Biggart was William Arrol's principal assistant on the preparation and erection of the ironwork and was involved in the construction of the pier foundations and superstructure of the Tay Bridge. He read papers on these subjects to the Institution of Engineers and Shipbuilders in Scotland (IESS) which were reprinted respectively in 'The Engineer' on 10th July 1885 and 'Engineering' on 31st December 1886. He also played a leading role for Arrol in the preparation and erection of the steelwork of the Forth Bridge. An appropriate premium awarded to him by the IESS for a paper on the 'structure, building and founding of the Forth Bridge Caisons' was a copy of "Economics of Construction in Relation to Framed Structures, 1873" by Robert H. Bow (1827-1909), the inventor of 'Bow's Notation' for analysing forces in frames. He concluded his paper on the erection of the Tay Bridge superstructure by referring to the "graceful and scientific design" of the bridge "which will be a lasting monument to Messrs Barlow and Son . . . and in the execution of which the genius of Mr William Arrol has shone with such lustre. As regard the quality of material and workmanship, nothing is left to be desired. Add to this the fact that a wind pressure of 56 lb per sq. ft. has been provided against and that each foundation has been satisfactorily tested to one-third more than the greatest possible load which could be put upon it, and we may with every confidence assert there is not the remotest possibility of the fate of the first Tay Bridge being that of the second."

INGLIS, William (1856-1908) AMICE (1881)
Inglis became a North British Railway engineer following his apprenticeship under agreement to the Company's Engineer-in-Chief, James Bell. In 1882 Inglis was

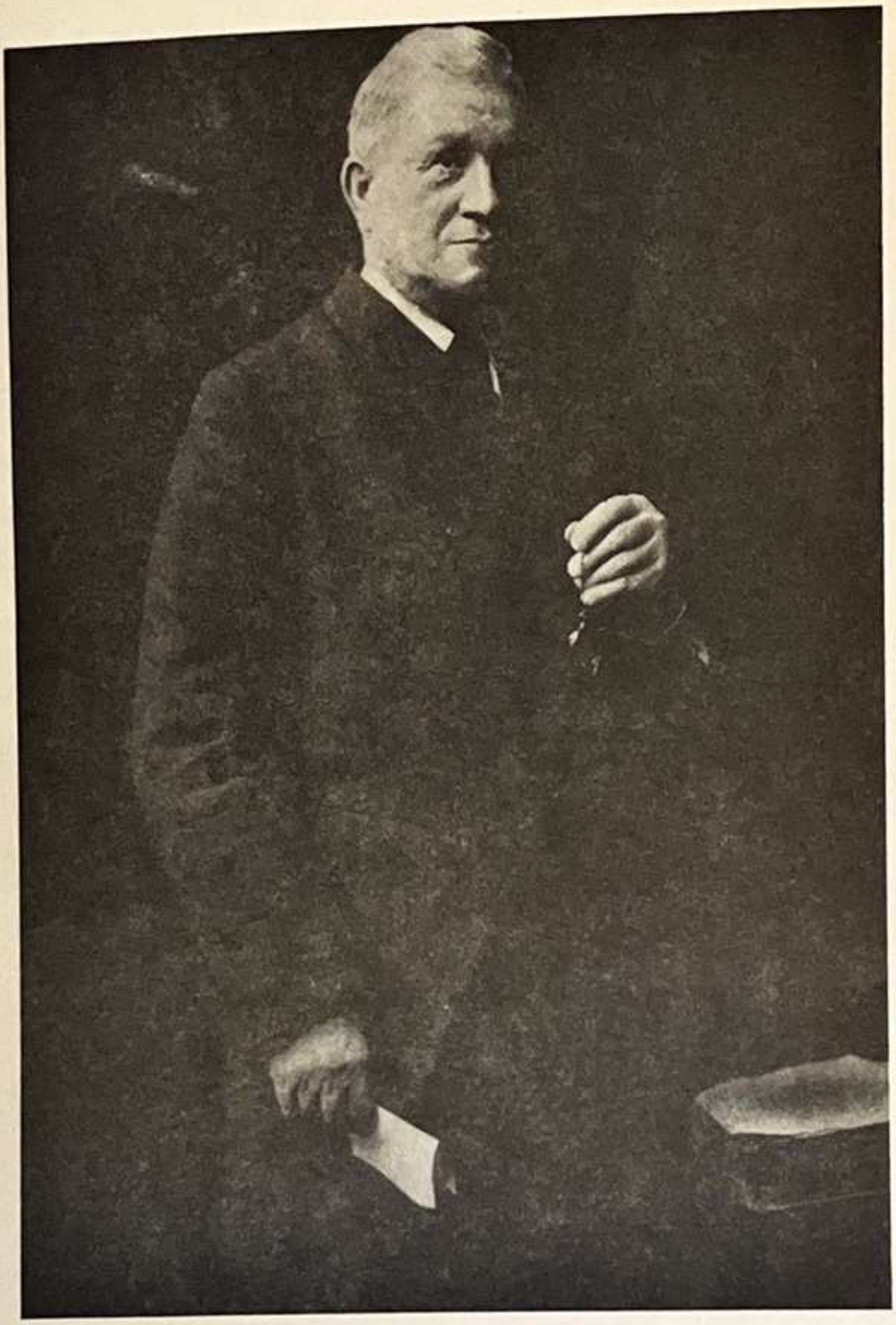
appointed maintenance engineer of their Northern Division. During completion of the Arbroath and Montrose Railway he came into close contact with William Arrol, then contractor for the South Esk Viaduct at Montrose, who recognised his talents and, when the opportunity arose, appointed him Resident Engineer for the construction of the Tay Bridge. Inglis served in this capacity for the next five years until its completion. He subsequently acted in a similar capacity for Arrol on the Forth Bridge connecting railways from Corstorphine in the east and Winchburgh in the west.
(Compiled from Min Proc ICE CLXXV 1909 332)

Postscript—A less well-known achievement of Inglis was his superintendence of the erection for Sir William Arrol of a substantial iron-girder road bridge of three spans over the Tay at Caputh (NGR NO 089395). The overall size of each girder or truss is 138ft 11½in x 11ft 3in and the clear space between pairs of trusses is 19ft 11in. Construction commenced in 1887 and the bridge was formally opened on 24th November 1888. Victoria Bridge as it is also known is believed from local repute, perpetuated by modern writers, to include iron from the first Tay Bridge. At the time of going to press it has not been possible, despite much searching and enquiry, to definitely confirm or refute this belief from contemporary written sources or to state with absolute certainty whether the iron of its girders is wrought iron or steel. Steel was hardly ever used in bridge girders before 1885, after which it was used increasingly, about 22 steel bridges being completed in Britain by the end of 1888.

If any readers can elucidate these matters relating to Caputh Bridge the editor will be delighted to hear from them. Although the bridge is programmed for replacement in the near future this seems unlikely to occur before it reaches its centenary next year. The bridge is worth seeing, but do not delay your visit too long!



Caputh Bridge *Courtesy of Tayside Regional Council*



William Arrol

***Illustrations**—Except for W. H. Barlow and Caputh Bridge the illustrations have been taken from material in the editor's possession from the following sources: 'The Engineer', 13 May 1887 & 25 Sept. 1885 (cover and pp. 16-17); G. W. W. c.1878 (p. 2); J. Valentine c.1878 (pp. 6 & 10); A. Grothe, Proc. Edin. & Leith Engineers' Soc. III 1878 (pp. 7-8); 'Dundee Advertiser' 18 Oct. 1879 (p. 13); C. Barlow, Min. Proc. ICE XCIV 1887-8 (pp. 19, 20, 22, 24 inset) and 'The New Tay Bridge' 1889 (pp. 2, 23-25); Sir William Arrol and Co. 'Bridges . . .' 1909 (above).*

ERRATA: p. 29: *l. 18, 'joined' for 'owned'; l. 20, 'Barlow' for 'Ile'; l. 22 end, add '(Benjamin)'.*