James Pugh Kirkwood, ASCE Second President, Water Filtration Pioneer, and His Scottish and U.S. Engineering Practice

Roland A. Paxton[1] and Jerry R. Rogers[2]

[1]MBE MSc PhD HonDEng CEng FICE FRSE, Institute for Infrastructure and Environment, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh EH14 4AS, Scotland UK R.A.Paxton@hw.ac.uk and
[2]Ph.D., P.E., D.WRE, D.WRE, Distinguished M. ASCE, 12127 Old Oaks Drive, Houston, TX 77024 rogers.jerry@att.net

ABSTRACT

James Pugh Kirkwood, after schooling, began employment with Thomas Grainger, Edinburgh civil engineer (Institution of Civil Engineers), from 1825-1832. Kirkwood worked on roads, stone bridges, canals, water tunnels, and Scotland's first 'inter-city' railway the *Edinburgh & Glasgow*. He and fellow Scot James Laurie, recruited by American railroader William Gibbs McNeill, began working on American railroads (Boston). Later, Kirkwood worked for the 1849 Erie Railroad (General Superintendent), Missouri Pacific Railroad (1850-52), Brooklyn water (1857-65), St. Louis Water Engineer (1865- 1867), designed the first U.S. water filtration system (Poughkeepsie, 1872), and engineered water systems in Pittsburgh, Salem, Portland, Fall River, Albany, Hempstead, Boston, Newark, and Lynn. Significant Kirkwood publications include:

1. Kirkwood, James Pugh 1869. *Report on the Filtration of River Waters, for the Supply of Cities, as Practised in Europe,*(City of St. Louis), D. Van Nostrand,
2. Kirkwood, James Pugh 1872. "Address of the President…….December 4, 1867," *Transactions of the American Society of Civil Engineers,* Vol. I, pp. 3-6 (first ASCE paper).
3. Kirkwood, J.P. 1876. *"A Special Report on the Pollution of River Waters,"* Massachusetts, 405 pp., Arno Press (reprinted in 1970).

Kirkwood was a co-founder of ASCE in 1852, serving as Director from 1853-1867. After ASCE President James Laurie, James Pugh Kirkwood became the second President. Kirkwood died in 1877.

In 1997, historical society delegations from: Kirkwood, MO and Kirkwood, NY placed a headstone at JPK's Greenwood-Brooklyn grave. James Pugh Kirkwood was a productive, scholarly, outstanding civil engineer who worked on roads, bridges, canals, tunnels, railways, buildings, harbors, water filtration, water supply and distribution, river pollution, and other projects in Scotland, the U.S., and Canada.

INTRODUCTION AND JAMES P. KIRKWOOD'S EARLY EDINBURGH ENGINEERING EXPERIENCE

James Pugh Kirkwood (JPK) was born in Edinburgh, Scotland March 27, 1807. He had four brothers and four sisters. JPK was the son of James Kirkwood (1772-1823) who was, according to family descendant David Kirkwood in 2014, a *wine and spirit merchant*. This is at variance with Cleary who states he was *a talented successful engraver* (Cleary 1986), possibly referring to his grandfather! His mother was Helen Pew from whom Kirkwood derived his middle name. Following his primary education at a private boarding school for boys at Galashiels (33 miles south of Edinburgh) from 1815, and further studies in Rotterdam in 1818-19 where he learned Dutch and improved his French, JPK returned to Edinburgh where he is believed to have worked for a time in his father's business before taking up surveying and civil engineering.

From 1821-32 (Cleary 1986), Kirkwood worked for Scotland's then leading land surveyor and engineer Thomas Grainger (1794-1852) to whom he was apprenticed, probably from 1821-25. In 1825 Grainger took into partnership his 20-year-old assistant John Miller, the firm then becoming Grainger & Miller, operating from new premises at 56 George Street, Edinburgh. For his engineering education, as well as learning from Grainger, Kirkwood may have followed his example and, as was then often the norm, attended appropriate classes at Edinburgh University without taking a degree.

From 1823-1826 Grainger was engaged by the Forth & Clyde Canal and other proprietors in setting out and constructing the canal-connecting *Monkland & Kirkintilloch* and *Ballochney* railways and surveying for others, including the *Garnkirk & Glasgow* and also, for leading Edinburgh civil engineer James Jardine, the western part of his *Edinburgh & Glasgow* proposal. At this time the firm practised as *Land and Road Surveyors* and, from 1828, as *Civil Engineers and Surveyors.*

In February 1829 Grainger became a Member of the Institution of Civil Engineers (Miller also in 1832) on the recommendation of its first president Thomas Telford. By then the firm's work had included railways in Dumbartonshire and Lanarkshire (Figure 1) and several main road improvements such as that from Glasgow to Ayrshire (Grainger and Miller 1829) which was partly eclipsed in 1831 by the firm's proposal for the *Glasgow, Paisley and Johnstone Railway*. From then on most of its work was on railways but by 1834 this also included harbour and water supply projects (Paxton 1982).

Jardine's 1825-26 scheme for the Edinburgh and Glasgow railway was not implemented and in 1830 Grainger & Miller, within a month of the opening of the world landmark inter-city passenger-carrying railway development the *Liverpool & Manchester*, put forward its own proposals for the *Edinburgh & Glasgow* in a report featuring one of the great images of the railway age - a 5ft long lithograph of George Stephenson's *'Rocket'* hauling a train of eleven coaches and wagons (Figure 2).

This inter-city proposal, upon which Kirkwood is understood to have worked, was developed in considerable detail and promoted in 1831 in two further tracts which included reports by the firm and leading railway engineer George Stephenson (Figure 3), with plans finely executed by leading Edinburgh engraver Robert Kirkwood Jr. (1798-1843), James Pugh Kirkwood's uncle, an association which must have given the Kirkwood family great satisfaction. Five miles of the Glasgow end of this proposal was to have utilized the newly-completed *Garnkirk & Glasgow Railway* (Figure 4).

Even though well-engineered and with Stephenson's support this Edinburgh and Glasgow railway proposal via Bathgate, contrary to Cleary, was not constructed, being strongly opposed by canal interests. It was not until 1838 that work eventually began on Miller's masterly 'cut and fill' high-speed northern line via Falkirk, with a maximum gradient between cities of 1 in 880, completed from its then Edinburgh terminus at Haymarket to Glasgow Queen Street in 1842. It is remarkable, as acknowledged by an ICE plaque at Haymarket Station, that the railway's basic line and many of its structures still serve on Network Rail's inter-city express route after 172 years (Paxton 2005).

The first railway in Scotland to be regularly operated by steam locomotion was the *Garnkirk & Glasgow* formally opened on 27 September 1831. There is little doubt that Kirkwood would have been in attendance at its spectacular opening when Grainger and Miller as the Company's engineers each directed one of the Stephenson *Planet* type locomotives hauling its invitees (Figure 5).

Kirkwood's invaluable experience with Grainger, and to some extent Miller (who went on to engineer most of Scotland's main line railways by 1850), enabled him to set up in business in Glasgow in 1832. But times were then unpropitious for railway development in Scotland and on being offered employment by a visiting American railroad promoter, William Gibbs McNeill, Kirkwood seized the opportunity. By mid-summer he had emigrated to the USA and embarked on outstanding and valuable contributions to its infrastructure and civil engineering profession. Sections of the following are from: Rogers, Jerry, "James Pugh Kirkwood: The Overlooked Environmental/Civil Engineer and ASCE President," ASCE Texas Section, Ft. Worth, Fall 2007.

KIRKWOOD'S U.S. RAILROAD ENGINEERING EXPERIENCE

Kirkwood traveled to Boston to start his new U.S. career and was assigned to locate the Norwich and Worcester Railroad (with fellow Scot James Laurie working under him). (Laurie helped found the Boston Society of Civil Engineers in 1848 and became the first President of ASCEA in 1852.) JPK worked on the Boston & Providence Railroad and Stonington & Providence Railroad as Resident Engineer, surveying the route for the Long Island Railroad. JPK worked with Julius Walker Adams and seven stone arch railroad bridges by Scot stone mason: Alexander Birnie in the Berkshire Mountains. James P. Kirkwood married the sister of Julius W. Adams. Adams was nephew of railroad engineer George Whistler. Kirkwood authored an 1838-39 survey for the Maryland Canal: *"Approximate Estimate of that Portion of the 'Brookeville Route' of the Maryland Canal."* JPK studied data (rainfall, streamflows) and proposed three routes. As engineer, Julius W. Adams moved to the Erie Railroad and JPK followed for employment with the Erie Railroad.

In 1848, Adams designed the Starrucca Viaduct near Lanesboro, PA (near the New York state border). Kirkwood was the construction engineer to supervise the 17 arches and viaduct 1040 feet long for 50-ton locomotives, now carrying 400-ton locomotives. Some of the first uses of concrete were for foundations of the main piers in 4 or 9 inch layers built upon other layers partially setting. JPK hired 800 men to complete the expensive viaduct so that the Erie Railroad could keep the contract for that railroad route in 1849. The nearby town of Kirkwood, NY was named after JPK. ASCE designated the Starrucca Viaduct as a National Historical Civil Engineering Landmark in 1973. With the success of the Starrucca Viaduct, JPK was made General Superintendent for the Erie Railroad in 1849. Based on his study of railroad accidents, JPK revised the Erie timetable and safety methods and other railroads copied Kirkwood's methods to minimize accidents. In 1850, James P. Kirkwood was selected as the Chief Engineer for the Pacific Railroad and surveyed three routes west from St. Louis. JPK's recommended rail width was 5 ft. 6 inches, for the rails west from the Mississippi River. Kirkwood ordered new locomotives and cars for the western rails. The route recommended went through an area later named after JPK as Kirkwood, MO, which was the first planned city west of the Mississippi River. The Barretts Station Tunnels designed by JPK are now part of the St. Louis Transportation Museum. After Kirkwood began having bronchitis health problems, he moved to Brooklyn, NY in 1852.

JAMES P. KIRKWOOD WAS A CO-FOUNDER OF ASCE IN 1852

James P. Kirkwood's name appears on the invitation letter from New York City October 23, 1852 requesting interested civil engineers and architects to attend the founding meeting of the American Society of Civil Engineers and Architects

(ASCEA) at 9pm November 5, 1852 in the office of Alfred W. Craven of the Croton Aqueduct at Rotunda Park. It is interesting to note that three (James P. Kirkwood, Julius W. Adams (Adams became the sixth ASCE President in 1874) and Alfred W. Craven (Craven became the fourth ASCE President in 1870) of the six invitation signers were or became municipal water engineers and the three served as ASCE Presidents. Not at the November 5 meeting, Kirkwood was elected as Director and served from 1853-1867 with fellow Scot: James Laurie as the first President of ASCEA. Laurie had experience with founding the Boston Society of Civil Engineers in 1848. Laurie's consulting work took him away from NYC, and ASCEA became inactive when the treasurer invested ASCEA monies in failed stocks.

NYC/BROOKLYN HYDRAULICS AND WATER WORKS

In 1855-56, for Alfred Craven, JPK supervised the lowering of the great water main in Eighth Avenue without service interruption. Kirkwood learned much about hydraulics and became interested in water-works. JPK served as chief engineer for the Brooklyn Board of Water Commissioners and authored publications in 1857, 1858, 1859, and 1862 with a Brooklyn waterworks summary printed in 1867. (Dr. Ron Cox's Civil Engineering Heritage Museum at Trinity College- Dublin has a copy of the 1867 Brooklyn Waterworks publication.) In 1856, JPK met and married a widow: Sarah E. Richards and moved into her house in Brooklyn Heights. The 1858 Brooklyn reports included the use of lead pipes or coated pipes for cities throughout the world. Also, in 1858, the Prospect Hill engine house and pumping experiments were redesigned with the steam engine pumps installed to deliver water throughout the Brooklyn system. In 1857-59, the Erie Railroad hired JPK to supervise excavation of a tunnel in Bergen Hill to a long dock at the river end of the tunnel with ferries to access freight to/from Manhattan. In 1860, JPK was commissioned to locate the terminal depot at Hunter's Point for the Long Island Railroad.

KIRKWOOD BECAME ST. LOUIS WATER ENGINEER IN 1865

Based on his famous Brooklyn/NYC water works, JPK was hired as St. Louis Water Engineer in March 1865 to design a new water plant. By May, Kirkwood submitted a plan for low service pumps at the Chain of Rocks site and water filters to clarify the Mississippi River water. The city council rejected this plan, discarded the filter beds, and recommended the water plant be located at Bissells Point. Later in 1865, Kirkwood submitted a settling basin design with pumps-storage- reservoir- standpipe for Bissells Point that was begun in 1867 (Schworm and Marshall, 1960s).

On December 11, 1865, JPK was sent to Europe to study water filtration practices for future St. Louis designs. JPK visited Scotland: Paisley and Forth, England: London and others, Ireland: Dublin, France: Lyons, Tours, Marseilles,…, Germany: Berlin,

Hamburg, Italy: Leghorn,….. (While on the European trip, Kirkwood visited the Thames Tunnel in London and submitted a report to investors which led to the first NYC subway.) These water plant visits and detailed notes led to JPK's historic environmental engineering water filtration book (Kirkwood 1869). After the ASCE book collection was moved from the NYC United Engineering Societies Library to Kansas City, a copy of his book with the initials JPK with personal margin notes was discovered in the Linda Hall Library by Dr. Glenn Brown, Oklahoma State University in 2004. Dr. Brown noted this book was the first American publication addressing water filtration in a systematic manner and suggested that 2007 be an anniversary of the 200th birth year for James Pugh Kirkwood. This JPK anniversary was celebrated by the EWRI History and Heritage Committee at the Tampa EWRI Congress in May. The Kirkwood water filtration book likely became a useful textbook in universities/colleges throughout the world. (Filters were not installed until 1915 at the Chain of Rocks plant.) Declining the St. Louis Chief Engineer position from a new board in 1867 but keeping a water office, JPK recommended Thomas J. Whitman, brother of the famous Walt Whitman, and returned to NYC/Brooklyn in 1867. (With Kirkwood's support and meetings in his St. Louis water office, the Engineers Club of St. Louis was planned in 1868, and the formation meeting was December 2, 1868 in St. Louis.)

JAMES PUGH KIRKWOOD WAS THE SECOND NATIONAL ASCE PRESIDENT IN 1867-68

When James Laurie returned to NYC in 1867, he asked for an officers meeting Nov. 6. When five shares of New York Central Railroad stock (which earned $555.25 in dividends) were found by ASCE (Rogers and Ports 2002), there were monies to re-start the society in a new office in the Chamber of Commerce Building. James Laurie then stepped down as ASCE president. James Pugh Kirkwood was selected as the second ASCE President. JPK called for the presentation, printing, and distribution of papers at ASCE meetings (Petroski 2002). He also noted that ASCE had needed a headquarters for years, and now had one. Kirkwood's Presidential Address on December 4, 1867, became the first paper published in the *Transactions of ASCE* (Kirkwood 1872). Perhaps due to bronchitis/health problems, Kirkwood resigned as ASCE President in 1868 and William McAlpine became the third ASCE President (Petroski 2002).

KIRKWOOD'S LATER WATER AND ENVIRONMENTAL ENGINEERING PRACTICE

In the late 1860s and early 1870s with many cities needing his expertise, JPK worked on municipal waterworks for Pittsburgh, Salem, Portland, Poughkeepsie (where slow sand filters were installed in 1872 in the first water filtration plant), Fall River,

Albany, Hempstead, Boston, Newark, and Lynn and designed pumps for Lawrence and Hoboken. Kirkwood designed infiltration galleries for Lowell and Lawrence, MA. In 1875 for the Massachusetts State Board of Health, JPK and four assistants gathered extensive data on major rivers of America and Europe including industrial polluters, and the means taken to alleviate them. JPK's staff sampled Massachusetts waters and made chemical tests before and after pollution. The classic 408 page report had many full maps and statistical tables: Kirkwood, J.P. 1876. *"A Special Report on the Pollution of River Waters,"* Arno Press (reprinted in 1970). Recommendations in the report included: "There should be absolute prohibition in all cases against casting sewage or filth of any kind into any stream or pond used as a water supply…….for, until our knowledge has so far advanced as to enable us to recognize "germs" of disease, and to destroy them by some simple and easy process,….that every town or city over four thousand inhabitants be required by law to appoint a board of health." It is a major tribute to Kirkwood that Massachusetts enacted all legislation in Kirkwood's significant report!

JPK's DEATH, BURIAL AND ASCE MEMOIRS (1807-1877)

At the age of 70 and in poor health from bronchitis, James Pugh Kirkwood died April 22, 1877 in Brooklyn and was buried in Greenwood Cemetery, lot 2018, sections 93, 94 in a plain grave. He had no children by either marriage. An ASCE Memoirs Committee of Alfred W. Craven, Julius W. Adams, William E. Worthen and James B. Francis wrote this important tribute: "….Mr. Kirkwood made thorough inspection of what had to be done, both here and abroad, and secured all books pertinent to the subject: he has left constructions which will long stand as precedents, and has enriched the literature by valuable memoirs and reports…..During the last 25 years of his life, Mr. Kirkwood was an invalid, but the works undertaken during this time show no feebleness in design nor execution, and in number and importance they exceed those of any other engineer in his line in the country."

The Town Historian for Kirkwood, NY compiled the significant biography of James Pugh Kirkwood (Cleary 1985). In 1997, a delegation from the historical societies of Kirkwood, NY and Kirkwood, MO paid for and placed a suitable headstone at Kirkwood's Brooklyn grave:

JAMES P. KIRKWOOD
CO-FOUNDER (1852) AND PRESIDENT (1867-1868) OF
THE AMERICAN SOCIETY OF CIVIL ENGINEERS
MARCH 17, 1807 – APRIL 22, 1877
THE WORLD WAS HIS WORKPLACE

CONCLUSIONS

Born in Edinburgh in 1807 and working for the Edinburgh firm of Grainger and Miller until 1832, James Pugh Kirkwood was a productive, scholarly, outstanding civil engineer who worked on roads, bridges, canals, tunnels, railways, hotels, harbors, lighthouses, water filtration, water supply and distribution, river pollution, and other projects in Scotland, the U.S., and Canada. Kirkwood wrote significant papers on the topics of Brooklyn water, European water filtration, and Massachusetts stream pollution, and served as the ASCE second President in 1867-68, writing the first paper printed in *ASCE Transactions.* In 1997, a delegation from the historical societies of Kirkwood, NY and Kirkwood, MO paid for and placed a suitable headstone at Kirkwood's Brooklyn grave.

REFERENCES AND NOTES:

[Figure 1] Grainger, T. & Miller, J. (1828): From, 'Sketch of Proposed Railway …' in *Report relative to the Proposed Railway to connect The Clydesdale or Upper Coal Field of Lanarkshire with the City of Glasgow …* Edinburgh. Plates engraved by Kirkwood & Son.- Edinburgh [Robert Sr. and Robert Jr.].

[Figure 2] Grainger, T. & Miller, J. (1830): *Observations on the formation of a railway communication between Edinburgh & Glasgow with branches to Leith and the River Clyde.* Edinburgh.

[Figures 3 & 4] Grainger & Miller and Stephenson, G. (January 1831): *Edinburgh, Glasgow & Leith Railway. Reports.* Edinburgh.

[Figure 5] Hill D.O. (1832): *Views of the Opening of the Glasgow and Garnkirk Railway.* Edinburgh – A late Victorian sepia reprint [Bartholomew, Edinburgh?]

Cleary, R. (1986). *James Pugh Kirkwood: Versatile Engineer of the Nineteenth Century*. Kirkwood, New York.

Grainger & Miller (1829). *Report of a Survey ... by which the best road from the City of Glasgow to Ayrshire is to be obtained.* Edinburgh. With a finely engraved plate by Kirkwood & Son, Edinburgh.

Kirkwood, James Pugh (1839). "*Approximate Estimate of that Portion of the 'Brookeville Route' of the Maryland Canal, Surveyed during the Summer of 1838."*

Kirkwood, James Pugh (1857). *Communication from the Water Commissioners of the City of Brooklyn to the Mayor and Common Council, 28th August, 1857*, Hosford & Co. - NY.

Kirkwood, James Pugh (1857). "*Communication from the Engineer to the Board of Water Commissioners on the Present Position of the Canal Grade, Accompanying Comparative Estimates of Canal and Conduit between Baisley's Pond and Hempstead Creek,*" Brooklyn, NY.

Kirkwood, James Pugh (1858). "*Report of the Chief Engineer on the Gaugings of the Several Sources of Water Supply for the Brooklyn Water Works,"* Brooklyn, NY.

Kirkwood, James Pugh (1858). "*Brooklyn Water Works Report in Relation to Proposals Made by Various Parties to Protect the Cast-Iron Pipes from Corrosion,*" Brooklyn, NY.

Kirkwood, James Pugh (1859). *Address of the Board of Water Commissioners to the Citizens of Brooklyn: with a Statement by the Chief Engineer*, Wm. C. Bryant & Co. - NY.

Kirkwood, James Pugh (1862). *Communication to the Board of Water Commissioners Relative to the Second Distributing Main from Ridgewood Reservoir*, L. Darbee & Son, Brooklyn, NY.

Kirkwood, James Pugh (1867). *Brooklyn Water Works and Sewers: A Descriptive Memoir*, D. Van Nostrand, NY.

Kirkwood, James Pugh (1869). *Report on the Filtration of River Waters, for the Supply of Cities, as Practised in Europe, Made to the Board of Water Commissioners of the City of St. Louis*, D. Van Nostrand (Linda Hall Library-Closed Stack Books- LHL TD441 .K6 1869 ESL).

Kirkwood, James Pugh (1872). "*Address of the President.....December 4, 1867,*" *Transactions of ASCE*, Vol. I, pp.3-6.

Kirkwood, James Pugh (1872). *Report of the Water Commissioners of the City of Albany: Transmitting the Reports of James P. Kirkwood,* Weed, Parsons and Co., NY.

Kirkwood, James Pugh (1876). *A Special Report on the Pollution of River Waters*, Massachusetts State Board of Health, Reprinted in 1970, Arno, 408 pp.

Paxton, Roland (1982). *Thomas Grainger C.E., F.R.S.E. 1794-1852 … EXHIBITION on the unveiling of his portrait* [at] *Heriot-Watt University by W.G.N. Geddes C.B.E … Past President of the Institution of Civil Engineers.* Edinburgh. Comprising 32 items from 1819-47 in the author's possession. Portraits of Grainger and Miller are on show at ICE Scotland Museum, Heriot-Watt University - Edinburgh.

Paxton, Roland (2005). *An appreciation of the professional work of John Miller CE FRSE (1805-83) Scottish Railway Engineer Extraordinaire.* Edinburgh. At an ICE plaque unveiling at Haymarket Station.

Petroski, Henry (2002). "The Origins, Founding, and Early Years of the American Society of Civil Engineers: A Case Study in Failure Analysis," pp. 57-66, American Civil Engineering History: The Pioneering Years, Dennis, Bernie et al, ASCE, Reston, VA.

Rogers, Jerry (2007). "Celebrating the 200th Anniversary of the Birth (1807-2007) of James Pugh Kirkwood: Environmental/Civil Engineer and ASCE Leader," *ENVIRONMENTAL AND WATER RESOURCES MILESTONES IN ENGINEERING HISTORY*, ASCE, Reston, VA.

Rogers, Jerry, Fall (2007). "James Pugh Kirkwood: The Overlooked Environmental/Civil Engineer and ASCE President," ASCE Texas Section, Ft. Worth.

Rogers, Jerry and Michael Ports (2002). "ASCE Is Born." *CIVIL ENGINEERING*, ASCE 150th Anniversary Issue, Nov. - Dec., pp. 188-191.

Schorm, William B. and Don Marshall (1960s). "History of Water Supply in the St.

Louis Area," for the St. Louis Water Works and St. Louis County Water Company (provided by Tom Ratzki, Black & Veatch Corporation, Chesterfield, MO.

Acknowledgements: Assistance and information was obtained from David Kirkwood, Dr. Michael Bailey, Kirkwood, MO, Kirkwood, NY and the detailed biography by Robert Cleary, Tom Ratzki of Black & Veatch Corporation, Jeffrey Fouse of Reitz- Jens, Gary Logsdon, Alistair MacKenzie- CSCE- Toronto,.....

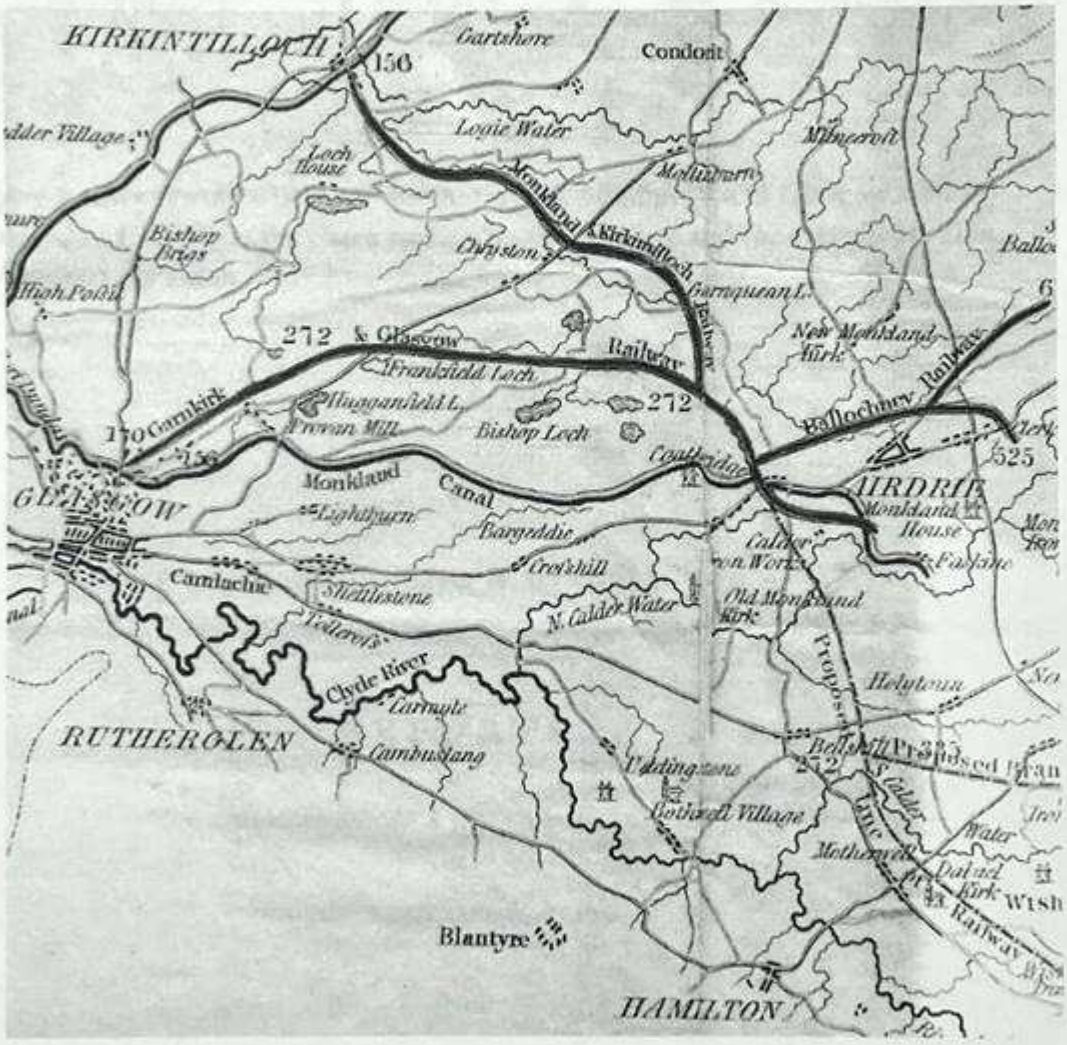


Figure 1. Railways near Glasgow in progress or proposed in 1828 familiar to J.P. Kirkwood. ©Paxton

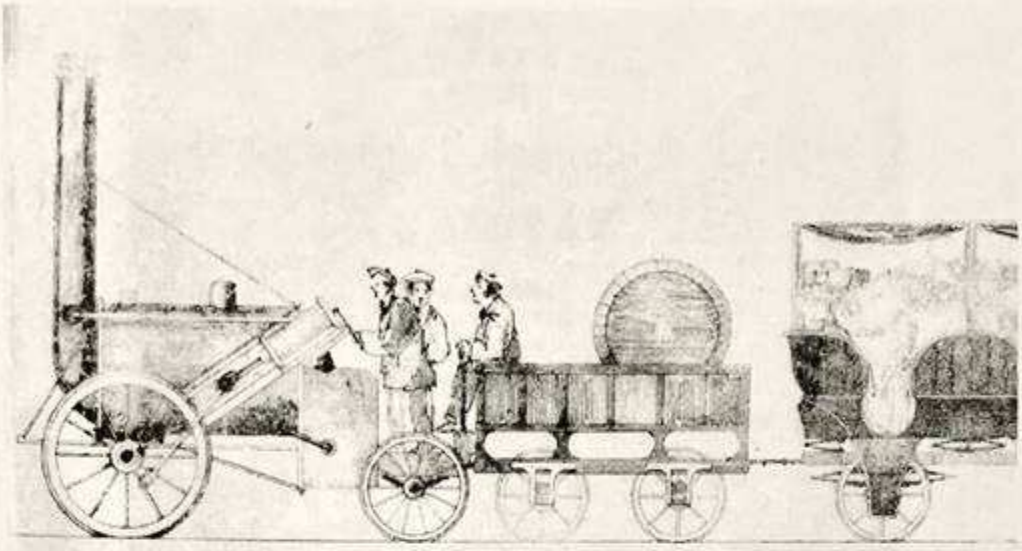
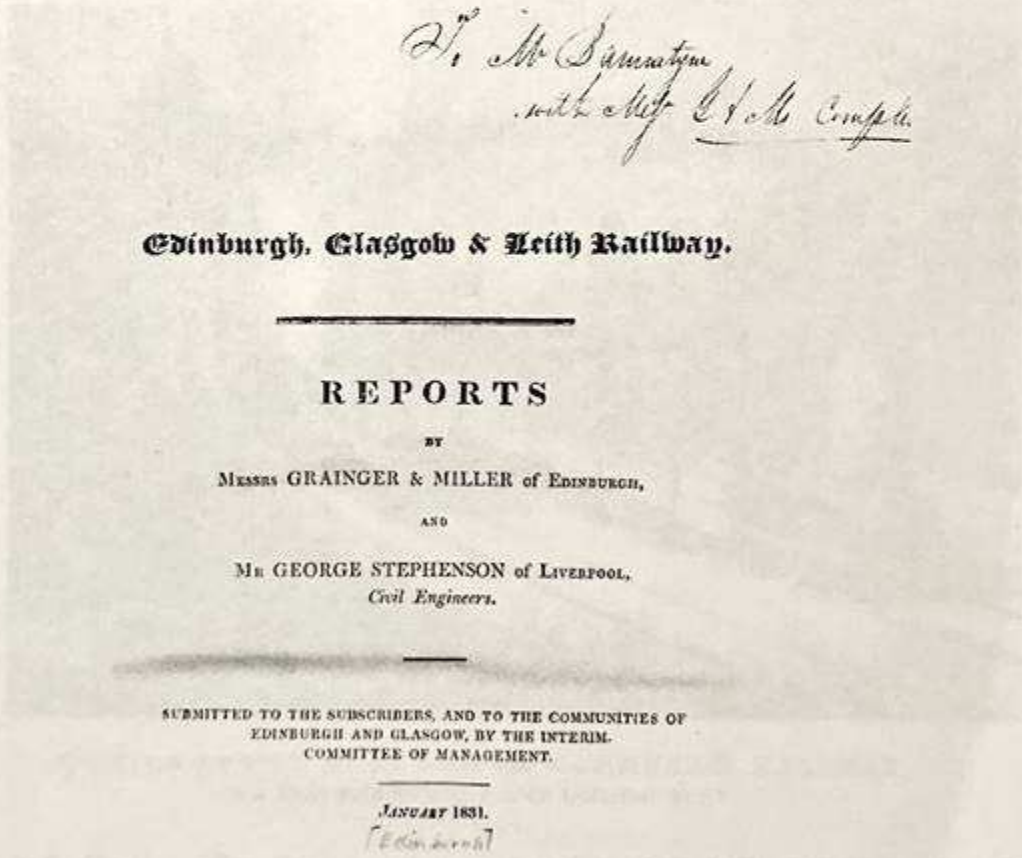


Figure 2. Stephenson's 'Rocket' promoting the Edinburgh and Glasgow Railway proposal in 1830. Note the coach springs on the carriage and the crewmens' *Tam o'Shanters*! ©Paxton



Edinburgh, Glasgow & Leith Railway.

REPORTS

BY

MESSRS GRAINGER & MILLER of EDINBURGH,

AND

MR GEORGE STEPHENSON of LIVERPOOL,
Civil Engineers.

SUBMITTED TO THE SUBSCRIBERS, AND TO THE COMMUNITIES OF EDINBURGH AND GLASGOW, BY THE INTERIM COMMITTEE OF MANAGEMENT.

JANUARY 1831.

Figure 3. First of two sets of 1831 reports by Grainger & Miller and Stephenson. ©Paxton

Figure 4. From Grainger & Miller's plan of 1830 'Engraved by Kirkwood & Son.' ©Paxton

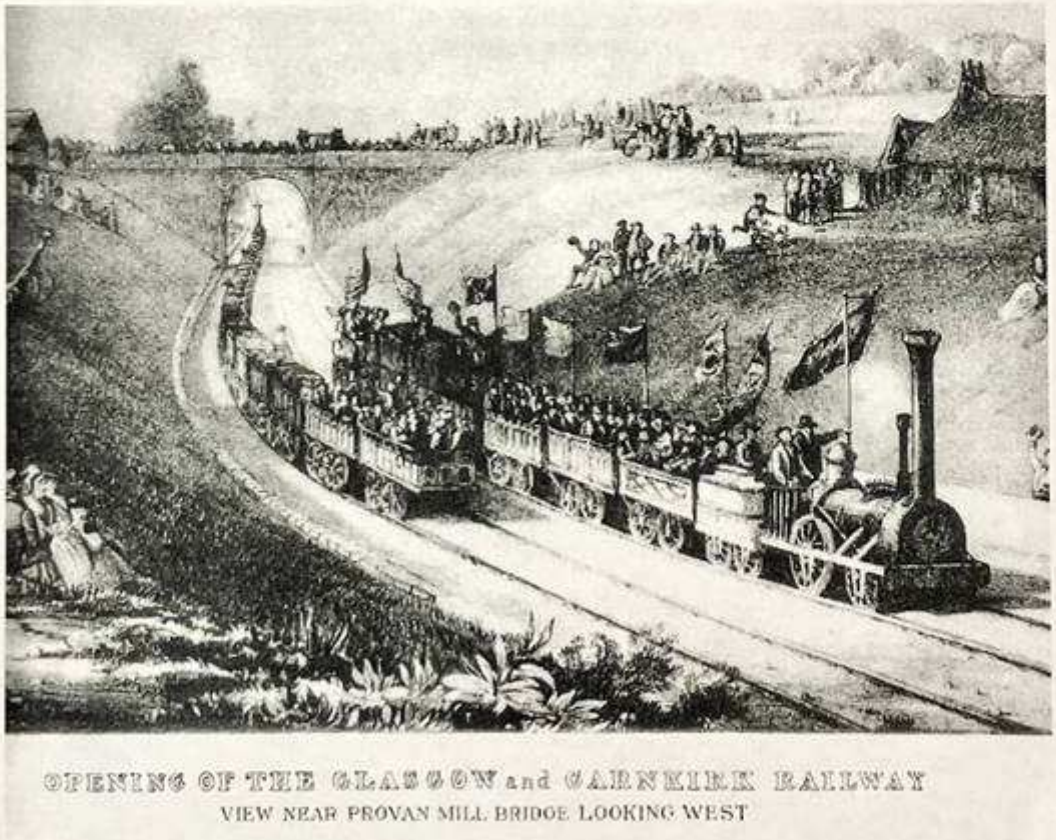


Figure 5. Grainger directing operations on footplate of 'St Rollox' on 27 September 1831. ©Paxton