THE SCOTTISH GAS INDUSTRY UP TO 1914

by

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SUMMARY

The gas industry which supplied illumination to commercial and domestic premises, played a significant but hitherto largely unstudied role in the economic development of Scotland. A wealth of detail is available on this multi-faceted industry, from gas company minute books to the voluminous Journal of Gas Lighting. Close connections existed with the engineering and coal-mining industries, which provided equipment and raw materials, and also with cotton and textile mills which consumed gas and frequently operated early private gasworks. Gas consumption reflected general economic prosperity or depression.

From alchemical origins, Lord Dundonald's tar process, and the private gasworks advocated by Boulton and Watt, and by Maiben of Perth, a detailed examination is made of the commercial development of the industry through its impact on tallow and whale oil producers, to collaboration with shale-oil manufacturers, competition with electricity, and the use of gas as fuel. Joint stock gas companies, operating mostly without Parliamentary sanction, obtained the financial benefits of large scale production and provided one of the earliest opportunities for Scottish entrepreneurs and small investors to co-operate in companies with a large membership. Before and during the age of railways, information from contracts of co-partnery, municipal records, and newspapers show the dates, locations, and mechanisms of company formation and regulation in this microcosm of entrepreneurship, as well as the occupations of partners. The exceptionally detailed financial statistics available in 1853, have been used in conjunction with minute books to analyse gross capital formation, the importance of loan capital and reinvestment of profits.

Technological change is examined chronologically with some recent illustrations of long established practices, but a comparable review of English technology is not available for detailed comparisons. Three concomitant factors were the development of special gases to enrich, or to compete with, coal gas; by-products and coal, the major price variables which imposed their own technological problems; and the skills of management and labour. The sources of management skills, the possibility of connections with other industries, innovation and technological expertise were reviewed, in addition to labourers' conditions, wages, and their effect upon mechanization policies. Problems of marketing gas, factors affecting its sale price, and the development of gas cooking, are examined from the viewpoints of both manufacturers and consumers. The hazards of competition between high capital companies in a fixed market, and difficulties which beset the Consumers' Movement are detailed, and an analysis made of the extent, regulation and success of Municipal "gas and water socialism".

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Beacons for navigation through the ocean of information available on the gas industry have been provided by my tutor, Dr John Butt, whose insights and constructive criticism were of invaluable assistance in placing the industry into a perspective framework within Scottish economic history. I must also express my grateful appreciation of his considerable patience in reading several manuscript drafts of the entire thesis. Considerable help, especially in the technological aspects of my thesis, has also been given by Mr John R. Hume. Without their enthusiasm the Scottish gas industry would have seemed a daunting subject.

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Finance for three years of research on this subject, approved by Professor S.G.E. Lythe, was provided by an Open Postgraduate Studentship from the University of Strathclyde. Generous sustenance in the final months came from my father, Mr T.J. Cotterill who financed most of the typing, and Mr G.R. McLellan who provided accommodation for my manuscripts and person. I also wish to thank Mr B.C. Careless, lecturer at Wulfrun College of Further Education, who first introduced me to the subject of industrial history and gave valuable encouragement to my career.

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Tables, Figures and Illustrations

APPENDICES - Index

Abbreviations

B.P.P. - British Parliamentary Papers

'Candles' - Candlepower (in context)

Ctd., contd. - continued

Desc. - description of

Diag. - diagram

D.N.B. - Dictionary of National Biography

Ed. - Editor

H. Lords, H. Commons - Manuscript Minutes of Committees of the House of Lords or House of Commons (House of Lords Record Office)

J.G.L. - Journal of Gas Lighting

Jl. - Journal

(N.A.) - Author unknown

Nat. Lib. Scot. - National Library of Scotland, Edinburgh

N.B.A.G.M. - North British Association of Gas Managers Transactions

(N.D.) - no known date of publication

Pat. - British Patent Number

Phil. Soc. - Philosophical Society

Phil. Trans. - Royal Society of London Philosophical Transactions

Proc. - Proceedings of

Ref. Lib. - Reference Library

Sperm Candles - Spermaceti Candles

S.R.O. - Scottish Record Office

Soho M.S.S. - Boulton and Watt Collection, Birmingham Reference Library

Trans. Transactions of

W.S.A.G.M. - West of Scotland Association of Gas Managers

Note - Some town names have changed since the nineteenth century, e.g. Dunse has become Duns; and Lesmahago is now Lesmahagow.

CHAPTER I

The Origins of the Scottish Gas Industry

Natural combustible gases issuing from the ground, near coalfields or oil and bituminous deposits, excited early philosophical speculation and craft technology in Europe and China respectively. China from the second century B.C. used natural gas from wells and boreholes to heat salt pans,[1] and by the early nineteenth century also had street lighting and cooking from gas without manufacturing it from raw materials. European alchemists and natural philosophers after the Dark Ages, catalogued many diverse "exhalations",[2] especially the "fire damp" of coal mines,[3] but these were not recognized as "gases" or substances which had specific unique properties, different to atmospheric air, until the term "gas" was used by J. Baptist von Helmont (1577 - 1644).[4] A distillation experiment made

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1. J. Needham, W. Ling, K.G. Robinson, Science and Civilization in China (1966, Cambridge), p. 66

2. J.F. Gmelin, "On the chemical knowledge which the Philosophers of the 16th and 17th Centuries had of the different Gases", The Philosophical Magazine 1801-2 Vol. XI, pp. 193-202. Vide infra Appendix I.1 p. 1504

3. Early Scottish examples of "fire damp" are described in:-

   J. Murray, "Observations on the Fire Damp of Coal Mines" Transactions of the Royal Society of Edinburgh Vol VIII 1815-18.

   B.F. Duckham, A History of the Scottish Coal Industry Vol I 1700-1815, (1970, Newton Abbot), pp. 88-92

   Explosion horrors were detailed by W.T. Brande, A Manual of Chemistry (1819), p. 158

4. J.B. von Helmont, Ortus Medicinae (Amsterdam, 1648), quoted in T. Thomson, The History of Chemistry (1830) Vol III of The National Library, Ed. G.R. Gleig, Ch. V "Von Helmont and the Iatro-Chemists". Von Helmont actually called the combustion products of burning coal "coal gas", quite different to the nineteenth century use of the term for distillation products. In his "Treatise de Flatibus", Helmont also observed that 62 lbs of "oaken coal" /charcoal?/ gave only 1 lb. ashes, the remainder being a "wild

made with coal in 1618 by J. Tardin[1] passed unnoticed by theorists.

In 1659 Thomas Shirley made detailed notes on a seepage of natural gas near Wigan, and published these in the Philosophical Transactions[2] of 1667. The subject remained of minor interest even in

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spirit" which could be captured by distillation in sealed vessels, and which he termed 'Gas'. C. Hunt, A History of the Introduction of Gas Lighting (1907), p. 5, quoting von Helmont's Works (1664, London, translation by J.C. of Oxford) pp. 69, 106.

D. Brownlie "The History of the Gas Process", Journal of the Society of Chemical Industry, 1924 Vol XLIII, p. 601.

C. Hunt's History, op cit., is the main reference work on the coal-industry up to 1810. Numerous other historical studies, of varying accuracy, have also been made: vide infra p. 1863 et seq

Detailed and largely accurate chronological tables of developments are given in:

S. Miall, A History of the Modern British Chemical Industry (1966) p. 208

D. Chandler and A.D. Lacy, The Rise of the Gas Industry in Britain (1949), Chapters 1 and 2

A.F. Armstrong "Chronology of the Development of Carbonizing Plant", Notebook for Gas Engineers and Students (1948) J. Terrance, Ed., pp. 43-7

F.S. Cripps, The Earliest Works on Gas Lighting (1907) pp. 16 - 17

King's Treatise on the Science and Practice of the Manufacture and Distribution of Coal Gas (1878) T. Newbiggings and W.T. Fewtrell Eds., Vol I, Ch. I

1. Jean Tardin of Tournon studied natural gas emitted from a "Burning Fountain" near Grenoble, and later successfully produced gas by coal distillation, as described in Histoire Naturelle de la fontaine qui brûle près de Grenoble, (1618), quoted by L. Pauwels and J. Bergier in The Morning of the Magicians (1971) 2nd Edn., p. 45; F.W. Robins, The Story of the Lamp (and the Candle) (1939, Oxford) p. 116

2. T. Shirley, "The Description of a Well, and Earth in Lancashire, taking fire by a Candle Approached to it", Philosophical Transactions 3/6/1667 Vol II No 26. Observation of 18 inch flame made in February 1659

1688 when John Clayton[1] (1657 - 1725) of Wakefield mentioned in those Transactions that he had produced "sulphurous spirits" from coal, which could not be condensed but could be stored "a considerable time in bladders", and remained inflammable even after bubbling through water. He wrote to Robert Boyle about that time, describing his experiments and mentioning a ditch near Wigan, probably the one Shirley had observed, where seeping gas was ignited to boil eggs. By excavation he had found that gas in the ditch occurred above outcropping coals, and hence his experiments with coal in a glass retort with a "turbinated receiver" to condense and remove oils which evolved. This correspondence was not published[2] until much later, in the Transactions of 1739.

Robert Boyle (1627-1691), the leading English experimental philosopher of the late seventeenth century, was also shown a process in

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1. John Clayton, Rector of Crofton, Wakefield - "A letter ... giving an Account of several Observations in Virginia, and in his Voyage thither, more particularly concerning Air".

   Philosophical Transactions 1693 Vol 17, p. 788. Letter dated 12/5/1688

   Glasgow Herald 9/10/1861 "The Discovery of Gas"

   Chambers Edinburgh Journal 1842 Vol XI, p. 392

   Clayton's coal gas research was probably in the years 1680-85

   W.T. Layton, The Discoverer of Gas Lighting - Notes on the Life and Work of the Rev. John Clayton, D.D., 1657 - 1725, (1926) p. 23

2. E.A. Parnell, Applied Chemistry in Manufactures, Arts, and Domestic Economy (1844) Vol I, p. 37

   Dr Robert Clayton, Bishop of Cork and Orrery, sent a copy of the letter to the Royal Society in 1739.

   Rev. J. Clayton "An Experiment Concerning the Spirit of Coals", Royal Society of London Philosophical Transactions (1739-40) Vol XLI, p. 59

1680-1 by Johann Joachim Becher[1] (1635-1682), whereby coal was distilled to produce gas such that "a foot of coal shall make a flame ten feet long". During 1681 Becher, in association with Henry Serle, took the first British patent (Pat. 214) to manufacture pitch and tar from coal. His work achieved much publicity. At Windsor he demonstrated to Charles II the potential use of tar for preserving rope and timber, and stated the value of coke and gas for smelting

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1. Son of a Lutheran pastor; born at Speyer. M.D. from Mainz University, where he lectured and became physician to the Archbishop Elector, and later to the Elector of Bavaria. Diplomat in Austria and Holland. Projected a World Language, and a canal to link Rhine-Danube. 1680 moved to England to experiment on coal; the results, and those on Dutch turf distillation, were published at Frankfort in 1683. Becher was the originator of the phlogiston theory - the 'terra pinguis' described in his Mineral Alphabet (1682) inspired Stahl (1660-1734) who renamed it 'phlogiston'. In continental Europe, Becher's coal-gas distillation experiments were not repeated until gas was used c. 1784 by Professors Minkelers of Louvain and Bickel of Warzburg to light lecture rooms, and in 1811 by Wilhelm August Lampadius (1772-1842) to light part of Freiberg town.

   G. Lockemann, The Story of Chemistry (1960) pp. 80-1
   J. White Ed. (c.1756) "William Cullen's History of Chemistry" published in An Eighteenth Century Lectureship (1950) A. Kent Ed. pp. 26, 67
   The History and Description of Fossil Fuel, the Collieries and Coal Trade of Great Britain (1835) pp. 404-10; (1841) p. 405
   G. Maltasa, Coal Tars and Their Derivatives (1921) p. 1
   R. Watson, Chemical Essays (1787) 4th Edn. Vol I, p. 33
   J. Butt, "James Young, Scottish Industrialist and Philanthropist" (1963, University of Glasgow, unpublished Ph.D thesis) p. 43

   Accum claims that Becher distilled coal-tar by 1665. vide F. Accum, Gasworks in London (1820) p. 298

metals. Subsequently, under the patronage of Boyle, he experimented with tin smelting in Cornwall, until his premature death.

It is highly probable that John Clayton was inspired by Becher's experiments, especially since he consulted with Boyle on his own work. Consequently, Becher deserves his recent appellation as "the real founder of the coal-tar and gas industries".[1] After Becher's death, although Boyle did experiment[2] in 1691 with the carbonization of various animal matter and coal to produce combustible gas, he subsequently concentrated his studies upon the physical and mechanical properties of air. Consequently most philosophers neglected the chemistry of air, and chemical differences between various gases were not accepted until Joseph Black's doctoral thesis[3] at the University of Edinburgh in 1754.

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1. G. Lockemann, The Story of Chemistry (1960) pp. 80-1
2. In 1680 Boyle made artificial 'air' by copying von Helmont's experiments.
   C. Hunt, Gas Lighting (1907) op cit., p. 9
3. Carbonic acid (Carbon Dioxide) gas was distinguished by Black (1728-1799) in 1754, and oxygen in 1774 by Priestley and Scheele. Black's research was based on magnesium, quicklime and alkalies,

Important empirical progress was made, however, by Stephen Hales[1] (1677-1761), the first European chemist known to have accurately measured the "air" and oily residues produced by the distillation of animal horns, wood, or "half a cubick inch" of Newcastle coal, in an iron retort in the 1720s. His musket-barrel retort, heated in a smith's forge, was similar to the private "gasworks" of enterprising Scotsmen from the early 1800s to the 1830s, while his conclusion that from "animal substances, a very considerable quantity of air was produced by distillation", later became the basis for a gas industry using whale and seal oils.

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and he was closely influenced by von Helmont's work.

C. Hunt, Gas Lighting (1907) op cit., p. 16

A. Schuster and A.E. Shipley, Britain's Heritage of Science (1917)

D. McKie "Some Early Work on Combustion, Respiration and Calcination", AMBIX - Journal of the Society for the Study of Alchemy and Early Chemistry 1937-8 Vol I, p. 164

1. J.E. Forbes, A short History of the Art of Distillation (1948) pp. 239-40

A.E. Clark-Kennedy, Stephen Hales D.D., F.R.S., - An Eighteenth Century Biography (1927, Cambridge) pp. 97-9

S. Hales, Rector of Farrington, Hampshire, Statical Essays : Containing Vegetable Statics or an Account of some Statistical Experiments on the Sap in Vegetables Vol I 4th Edn. 1769, Experiments LI, LV, LXVII

Hales' distillation work was based upon Query 31 in Isaac Newton's Opticks (1704) which stated that "true permanent air arises by fermentation or heat, from those bodies which chemists call mixed", by the separation of components. Hales tried a vast range of substances, from oyster shell to Indian Wheat. He regarded the gaseous fraction as homogenous, a common "cement" extracted from the substance distilled, and did not recognise their combustible nature.

E.L. Scott, "The 'Macbridean Doctrine' of Air : An Eighteenth Century Exploration of some biochemical processes including Photosynthesis"
AMBIX - Journal of the Society for the Study of Alchemy and Early Chemistry 1970 Vol XVII, pp. 44-6

M. Fichman, "French Stahilism and Chemical Studies of Air 1750-1770" AMBIX 1971 Vol XVIII, p. 98.

Hales influenced scientists like Watson vide R. Watson Chemical Essays (1796) 5th Edn. Vol II, p. 325

The increased pace of industrial activity in Britain during the eighteenth century,[1] enhanced by greater precision and understanding in the natural sciences, produced a growing awareness of the economic importance of chemical reactions. Sulphuric acid manufacture, and the dyeing of textiles,[2] the "fire damp" explosions in coal mines, and by-products from the coking of coal, became objects of increasing concern for enterprising Scottish entrepreneurs. Theoreticians like Richard Watson[3] (1737-1816) were fascinated by the idea of 'phlogiston'[4] and the causes of putrefaction and pollution,[5] while both the ideas and possible practical applications of their work provided intellectual stimulation for industrialists like James Watt.

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1. The 1740s - 80s have been stated as the period for "take off into self-sustained growth", as W.W. Rostow termed the growth of national product up to 2 per cent per annum.
   P. Mathias, The First Industrial Nation - An Economic History of Britain 1700-1914 (1969), p. 3

2. For example 1749 J. Roebuck began sulphuric acid production at Prestonpans. This type of acid was used in the early nineteenth century for ammonium sulphate production from gasworks residuals (vide infra, p. 530 et seq.; p. 88) ;
   1775 George MacIntosh's cudbear dye works near Dalmarnock, for cotton textiles ;
   1800 Charles Tennant's St Rollox chemical works making textile bleaches.
   H. Hamilton, The Industrial Revolution in Scotland (1932, Oxford), pp. 103, 145

3. R. Watson, Bishop of Landaff. 1762 M.A. Cambridge. 1764 Professor Chemistry, Cambridge. 1781 published Chemical Essays. 1782 Hon. member Manchester Literary and Philosophical Society. Dictionary of National Biography (1909) XX, p. 935

4. Phlogiston speculation in Edinburgh vide Wemyss Reid, Memoirs and Correspondence of Lyon Playfair (1899), pp. 180-1

5. Watson calculated in the 1760s that 25 per cent of air breathed by Londoners comprised the combustion gases from burning coal, and postulated that such gases contributed to making cities "the GRAVES of mankind."

   R. Watson, Chemical Essays (1796) 5th Edn. Vol II p. 367

In 1729 Carlisle Spedding was in charge of the excavation of a fifth coal pit for Sir James Lowther (1674-1755) near the sea at Whitehaven, when a pocket of natural gas was tapped at forty-two fathoms depth.[1] The enterprizing Spedding[2] collected gas in bladders for combustion elsewhere, and in 1765 lit the colliery offices with it. He offered to supply sufficient gas for public street lighting, and although it is not known whether this was achieved, gas was sent through a lead pipe to the nearby laboratory of Dr Brownrigg, a scientist. Samples were sent to the Royal Society in London for examination.

Brownrigg[3] published his notes on mine gases in 1767 and the "mineral elastic spirit" from Spa waters. In that year Richard

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1. The gas jet lasted two years, and produced a flare 18 inches wide and 6 feet high. "An Account of Damp Air in a Coal Pit of Sir James Lowther, Bart., sunk within twenty yards of the sea" 1/8/1733

   Royal Society of London Philosophical Transactions Vol 38, p. 109

   W.T. O'Dea, Lighting - Gas, Mineral Oil, Electricity (H.M.S.O., 1967)
   A. Tilloch, The Philosophical Magazine (1805) Vol XXI, pp. 275-7
   E. Hughes, North Country Life in the Eighteenth Century - Volume II Cumberland and Westmorland 1700-1830 (1965), p. 137

2. Carlisle Spedding had earlier worked for Lowther as an industrial spy in the Newcastle collieries. In 1730 he invented the Steel Mill, for cold illumination in mines, as well as better ventilation, and gunpowder blasting techniques. His father was Chief Steward on the estate.
   R.W. Moore, "Historical Sketch of the Whitehaven Collieries" Transactions of the Federated Institute of Mining Engineers 1893-4 Vol VII, pp. 613-38
   T.S. Ashton and J. Sykes, The Coal Industry of the Eighteenth Century (1929, Manchester) p. 51

3. William Brownrigg (1711-1800): 1737 M.D. Leyden. Friend of Dr Hales and Benjamin Franklin. Laboratories at Whitehaven. 1741 read paper on fire-damp to Royal Society.
   Dictionary of National Biography (1909) III p. 85
   Philosophical Transactions 1767 Vol 55, p. 218

Watson[1] also lectured in Cambridge University on the "permanent elasticity" of the'air' which he obtained by distilling any vegetable, animal or inflammable mineral like coal. It was also formed by putrefaction and had "a great resemblance to ... phlogiston, or food of fire". The problem which he posed for chemists was that, "as no particle of matter can be annihilated, what becomes of the inflammable air after it has been inflamed?" Was it reduced to "an unelastic earth", or "an uninflammable elastic fluid"? From a study of 'burning wells' of gas at Wigan, and near Broseley in Shropshire, and inflammable mine gases in Derbyshire shales, Watson inferred that inflammable air, and fractional distillation which in rock sections at Modena in Italy, placed light oils like naphtha and petroleum above heavy oils and asphaltum, were produced by strong heat and fires deep within the Earth. He also studied industrial distillation plants making coal-tar at Broseley, at Bristol, and at Liege in Belgium, and urged the development in Britain of large-scale alkali and coal-tar industry to reduce imports of wood tar from Scandinavia.

The coal-tar industry was the first to manufacture coal-gas as a by-product on a large scale, but made little use of it because the gas was mixed with atmospheric air and therefore highly explosive. During the 1760s George Dixon,[2] a colliery owner at Cockfield, County

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1. Richard Watson, Chemical Essays (1796) 5th Edn. Vol II, pp. 347-54, 329; Vol III, pp. 9, 10

2. A.T. de Mouilpied "Coal Gas as an Illuminant : A New Review" Discovery 1927 Vol 8, pp. 183-6

   A. Raistrick, Quakers in Science and Industry (1950, Newton Abbot) p. 242

   J. Macfarlan, "George Dixon - Discoverer of Gas Light from Coal", Transactions of the Newcomen Society 1924-5 Vol V, p. 53

Durham, used a tea kettle as retort and after luting a tobacco pipe-stem to the spout, placed the kettle on a domestic fire.[1] The gas which evolved was burned both at the extremity of the pipe-stem, and at pinholes made in the clay joints used to add extra pipe-stems. Dixon planned to manufacture tar, and gas to light his collieries and offices. He made a larger apparatus with a cast-metal boiler, with a wooden plug to remove tar, and the metal pipe through which gas travelled was submerged in water to condense volatile oils out of the gas. A serious explosion of this apparatus dissuaded Dixon from further research, in fear of his life.

Tar and other naval stores, which had to be purchased in the Baltic,[2] were in jeopardy during the Seven Years War (1756-63), The American War of Independence (1776-83) and the Napoleonic Wars (1793-1815). This stimulated demands for national self-sufficiency in strategic materials. The first commercial coke works in Europe, which supplied the Sultzbach[3] ironworks, by the late 1760s was making use of the tar

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1. When coal-gas is produced by the strong heating of coal in a retort sealed-off from the atmosphere, it expands with a strong positive pressure, as Clayton found earlier when his glass retorts were smashed. Apart from Becher and Serle in 1681 (Pat.214) other coal-tar patentees like Eele, Hancock and Porlock in 1694, T. Edwards in 1716 (Pat. 405) and Baron von Haake (Pat. 1015) in 1772, are not recorded to have made use of the incondensible gases which evolved.

   W. Richards, Practical Treatise on the Manufacture and Distribution of Coal Gas (1877) p. 55; J. Butt, "Technical Change and the Growth of the British Oil Shale Industry (1680-1870)", Economic History Review 1964-5 II Series Vol XVII

2. Payment in Dutch rix-dollars, which involved the export of bullion from Britain. P. Mathias, The First Industrial Nation (1969), pp. 87, 90, 43

3. Sultzbach ironworks, owned by the Prince of Nassau Saarbrucken, and described by De Genssane in 1770

   D. Brownlie, "Early History of the Coal Gas Process", Transactions Newcomen Society Vol III March 1923 produced but not the gases. This was left to Archibald Cochrane, the Ninth Earl of Dundonald,[1] a scientifically adventurous if financially weak coal-master who took residence at Culross Abbey house in 1781 or 1782, and introduced there the first use of coal-gas for illumination in Scotland[2] the same year. Archibald was visited by "some scientific friends"[3] who brought a book, possibly the 1781 edition

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1. A. and N.L. Clow, "Lord Dundonald", Economic History Review 1942 Vol XII, p. 47
   J. Butt and J.R. Hume, "Muirkirk 1786-1802 : The Creation of a Scottish Industrial Community", Scottish History Review 1966 Vol XLV
   A. Clow "Scotland's Contribution to Industrial Development Through the Application of Chemical Science since the Seventeenth Century" (1944, Aberdeen University, Blackwell Prize Essay) pp. 33-5, 64, 69
   J. Butt, Industrial Archaeology of Scotland (1967, Newton Abbot) p. 148
   A. and N.L. Clow, "The British Tar Company", The Chemical Revolution (1952)
   B. Trinder The Industrial Revolution in Shropshire (1973, Chichester) p. 227

   Dundonald is sometimes designated the "founder of gas lighting" e.g. Notes & Queries 1892 Second Series Vol II, p. 85

2. It remains possible that coal-miners used "blowers" or jets of fire damp to provide domestic illumination at an earlier date. This practice was recorded in the 1830s, and even in 1902, when R. Dron stated that "the colliers collected the gas in large bottles, which they closed with clay, carried them home, and there, making a small hole through the clay, have lit and used them as portable gas lamps."
   (N.A.) The History and Description of Fossil Fuel, the Collieries and Coal Trade of Great Britain (1835) p. 230; R.W. Dron, The Coalfields of Scotland (1902) p. 230

   In 1764 a Frenchman, M. Jars, tried to pump gas for illumination from a colliery in the Lyons district, but was prevented by an accidental explosion.
   F.W. Robins, The Story of the Lamp (and the Candle) (1939, Oxford) p. 116; D. Chandler and A.D. Lacy, The Rise of the Gas Industry in Britain (1949) Ch. I.

   Again in 1817 H. Wallace suggested that canvas tubes, like those for servicing ships at Port Glasgow, could be used to pump mine gases for illuminating the "dreary abodes" of miners, and with safety lamps over the burners, could also light the mines themselves.
   H. Wallace "Canvas tubes for Conveying Water" Annals of Philosophy 1817 Vol IX pp. 327-8

3. Dundonald was an acquaintance of Cavendish, Priestley and Black. Dictionary of National Biography (1908)

of Richard Watson's Chemical Essays,[1] describing the distillation of pit coal to produce coke and tar.[2] A small experimental "oven or kiln" was erected, and when Dundonald noticed the inflammable 'vapour' he "fitted a gun-barrel on the eduction pipe leading from the condenser".[3] When this was ignited, the flare was visible across on the south side of the Firth of Forth. A patent[4] for the distillation process was later obtained and shortly afterwards, "nine cylindrical ovens of brick were built in a row,"[5] each 'retort' 3 feet wide and 7 feet deep, with a moveable lid for charging the coal, and a lower door to admit some air and regulate combustion. While coke was being

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1. C. Hunt, Gas Lighting (1907) op. cit., pp. 15-16

2. Evidence of a blacksmith employed on the construction work by Dundonald, given to John Hart, a Glasgow scientist, in 1830. Culross Abbey was demolished in that year.
   Prof. T. Thompson, "On Coal Gas" Proceedings of the Philosophical Society of Glasgow 1843-4 Vol I p. 165

   Tar or 'rock oil' was of great importance for leather manufacture in the 1790s.
   (N.A.) History and Description of Fossil Fuel (1841) 2nd Edn. op. cit, p. 405, referring to Beckmann's History of Inventions (1798) Vol I p. 339

3. Described by Thomas, the Tenth Earl, who gives no precise date though it was certainly before 1793 when he sailed on the Hind.

   Thomas Cochrane, Tenth Earl of Dundonald, The Autobiography of a Seaman (1860) p. 40; (1861) pp. 24-5
   The Scotsman 2/3/1844 "The Earl of Dundonald's Improved Steam Engine"

4. Patent 1291 in 1781. The patent date indicates that Dundonald moved to Culross a year or so earlier than the normally accepted date of 1782

5. John Hart, Proc. Phil. Soc. Glasgow (1843-4) op. cit.

   Dundonald's Muirkirk kilns were described by J. Sinclair, Appendix to the General Report of the Agricultural State and Political Circumstances of Scotland (1814, Edinburgh) p. 312

   A diagram of tar kilns later built by Dundonald at Calcutts, Shropshire, is given by B. Trinder, The Industrial Revolution in Shropshire (1973, Chichester) p. 93

Fig. 1.1

Lord Dundonald's Tar Oven Design c.1784

Sketch by Mathew Boulton

Source - Birmingham Reference Library [Soho M.S.S.]

produced, a cast-iron pipe, seven inches in diameter, conveyed all gases which evolved to a lead box condenser like those used by brewers, with partial divisions inside to impede the rate of gas flow, and a pool of cold water on the roof. The condenser stood on an earthen bank behind the retorts, and on the opposite side of the bank pipes led the condensed tar and remaining gases down to be collected in brickwork cylinders. Each "had a small opening in the top for the escape of the incondensible part of the products", and at night the workmen used soft clay to attach cast-iron pipes to some of the openings, to provide a light while they worked.

Because some atmospheric air was allowed into the retorts for coking, the 'coal gas' varied in quality and contained much oxygen like the blast furnace gases of the 1880s, making it too dangerous for Dundonald to lay pipes for lighting his residence. But he did have "a vessel constructed resembling a large tea urn; this he frequently caused to be filled and carried up to the Abbey to light the hall with, especially when he had company with him".[1] The workmen apparently understood that atmospheric air caused explosions when mixed with the gas, because on one occasion "after a fresh charge"of coal a workman applied the light too soon and the explosion tore the top off the condenser and almost killed a bystander. "After this accident the men became very cautious in applying a light to the pipe until the whole of the atmospheric air was displaced,"[2] and unlike

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1. John Hart (1843-4) ibid. Hart, one of the pioneers of gas lighting in Glasgow, obtained this information in 1830 from Sir Robert Preston's gardener, who in turn had been informed by old local residents at Culross.

2. John Hart ibid. Dundonald's later tar retorts, in the early nineteenth century, were a more advanced design resembling gas-works retorts, quite sealed off, from the heating furnaces below them, though the gas was still used for lighting the works.
E. Rogers, "Manufacture of Charcoal and Coke" Proceedings of

George Dixon, they continued to use the light.

Dundonald's failure to develop gas lighting as a new industry has been ascribed by J. Hart[1] to the weakness of the gas when mixed with air, the cost of cast-iron pipes in Scotland which prohibited any large-scale distribution system, and the lack of necessary engineering skill. Thomas Cochrane believed that his father was preoccupied with producing tar, and coke for ironfounders, but it is perhaps significant that gas-light would have deprived him of one market for tar 'oil' which was used in lamps, and Dundonald was trying to sell 'oil' lamps on a large scale in London.[2]

Keen intellects elsewhere, however, continued research on the chemistry of gases. In 1783-4 Jean Pierre Minckelers[3] (b.1748)

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the Institute of Mechanical Engineers 1857 p. 30; plate 101

Rogers states that Dundonald's attention was not brought to the great wastage of small coals and gases from his old ovens until 1798

1. J. Hart. Proc. Phil. Soc. Glasgow 1843-4 op cit.
2. A. and N.L. Clow, The Chemical Revolution (1952) op cit. Quarterly Journal of Science, Literature and The Arts (1821) Vol XI p. 381
3. D. Brownlie, Trans. Newcomen Soc. 1923 op cit.
   Chandler and Lacy, Rise of the Gas Industry (1949) op cit., Ch. II
   M. Barash and W.J. Gooderham, Gas (1971)
   W.E. Wrigley "The Supply of Raw Materials to the Industrial Revolution" Economic History Review Vol XV (1962) p. 15

In 1784 Lapostolle published an idea for using gas from wood distillation, for balloons and lighting, but this was apparently never undertaken. J.P. Minkelers was also seeking a substitute for hot-air in balloons, and in 1784 published the idea of using gas from powdered coal distilled in a gun barrel. A. Elton suggests that from 1785 this gas was used for lighting, in laboratory experiments. A. Elton "The Rise of the Gas Industry in England and France" (No date. Typescript. Institute of Gas Engineers, London) p. 1

Minckelers was the first to use lime-water to purify coal gas aiming to reduce the specific gravity for balloons: 4 oz coal gave 1 cu ft gas, 4 times lighter than air.

J.P. Minckelers, Memoire sur l'air inflammable tiré de différentes substances, (1784, Louvain) quoted in C. Hunt, History of the Introduction of Gas Lighting (1907) p. 20

produced coal gas for inflating balloons, and for lighting the lecture theatre of the University of Louvaine. In 1788 J. Diller[1] (d. 1789), displayed a mystery gas as "Philosophical Fireworks" at the Lyceum Theatre, London. Philip Lebon[2] (1767-1804) in France began experiments in 1791 with gas from sawdust. He obtained a patent in 1799, and devized a 'Thermolampe' in 1801, as well as lighting the outside of his house and the Theâtre de Louvois with wood-gas. In Britain, members and correspondents of the Lunar

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1. In Parliament - Remarks Upon the Bill for Incorporating the Gas Light and Coke Company (1809, London) p.3 Birmingham Ref. Lib. B.P.P. 1839 (9) VIII 405 p. 55 (369) an unidentified gas. Murdoch believed this was not coal gas.
   W. Murdoch, A Letter to a Member of Parliament (1809) p. 6
   Chandler and Lacy, Rise of the Gas Industry in Britain (1949) p.38 op cit. claim this was coal gas, but without giving evidence.

   Diller's apparatus was described in 1787 to the French Acadamy of Science, and C. Hunt concludes the gas was hydrogen, made from zinc or tin, with colours added. Displays were held in Birmingham, advertised in Birmingham Gazette 25 May 1789
   C. Hunt, History of the Introduction of Gas Lighting (1907) p.19

2. C. Hunt, History of the Introduction of Gas Lighting (1907) op. cit., pp. 50-62

   Elton presents the strongest case for Lebon's work, and in 1801 he designed, in theory only, many of the uses for gas first made possible by Maiben in 1813
   A. Elton, "The Rise of the Gas Industry" op cit., pp. 2-3
   J.E. Forbes, Art of Distillation (1948) op cit., p. 281, description of apparatus
   T.I. Williams, ed., A Bibliographical Dictionary of Scientists (1969) p. 317
   A. and N.L. Clow, The Chemical Revolution (1952) op cit., p.281. State that the Hotel Seignelay was also lit by gas.
   D. Brownlie, Trans. Newcomen Soc. (1923) op cit. Lebon was an engineer employed by the French Government's Department of Roads and Bridges
   M. Biot "On Lighting with Gas" extract from Journal des Savans in The Analectic Magazine 1818 Vol xi p. 161
   A. Parnell, Applied Chemistry in Manufactures, Arts and Domestic Economy (1844) Vol I p. 40 claims Lebon used wood gas as early as 1785-6, and after 1801 built a pyroligneous acid factory near Versailles, where the gas was used to heat the retorts.
   Journal of Gas Lighting, 12/12/1865 p. 869

Society, based at Boulton and Watt's manufactory at Soho near Birmingham, were in the van of scientific research. Watt's interest in the phlogiston theory, and hydrogen which he termed "inflammable air", led him to correspond[1] on the subject with Black and Priestly as early as 1783. This was the intensive research-based milieu which William Murdoch[2] (1754-1839) entered in 1777 when he obtained employment at Soho.

Murdoch was born at Billou Miln,[3] above the coalfield of Auchinleck parish in Ayrshire. Educated at the nearby village school of

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1. E. Robinson, "James Watt, Engineer and Man of Science", Notes and Records of the Royal Society 1969-70 Vol 24 p. 227

   Phlogiston theory was strongly supported by James Keir, Edinburgh-born chemist and later founder of Tipton Chemical Works, near Soho, in his 1777 "Treatise on the Various Kinds of Permanently Elastic Fluids or Gases"
   B.M.D. Smith and J.L. Moillet "James Kier of the Lunar Society" Notes and Records of the Royal Society 1967 Vol 22 pp. 144-54
   J.G. Crowther, Scientists of the Industrial Revolution (1962) pp. 149-55

2. Murdoch did not publish the results of his research, and despite many Biographies, little is known in detail about the enigmatic engineer. A paper published in 1808 by the Royal Society under his name, was apparently written by the James Watts, senior and junior, with data supplied by Wm. Creighton.
   Vide A. and N.L. Clow, The Chemical Revolution (1952) op cit., p. 430
   The Dictionary of National Biography
   Journal of Gas Lighting 11/9/1883 pp. 490-1 "William Murdoch - The Founder of Gas Lighting"
   J. Butt, The Industrial Archaeology of Scotland (1967, Newton Abbot) p. 218
   A. Clow, "Scotland's Contribution to Industrial Development" (1944) op cit., pp. 40-2
   A.G. Clement and R.H.S. Robertson, Scotland's Scientific Heritage (1961, Edinburgh) pp. 57-8
   A. Wolf, A History of Science, Technology and Philosophy in the Eighteenth Century (1962) 2nd Edn., p. 665

3. Later renamed Bello Mill.
   Vide J.A. McCash, "William Murdoch - 'Man of Little Showing' " The College Courant, being The Journal of the Glasgow University Graduates' Association (1966, Glasgow) Vol 18 Ed. J. MacRitchie

Old Cumnock, he was the son of a skilled corn miller, John Murdoch (d.1806) who undertook his own millwright work and stone-dressing, and devised the first cast-iron, toothed, bevelled mill-gearing which was cast in 1766 at Carron Ironworks. William learned many of these skills, and before leaving home was experimenting with a prototype tricycle.[1] He had probably observed and pondered the local practice of adding a small quantity of expensive parrot coal[2] to the common coal used in domestic hearths, to increase the fire-light illumination. Lesmahagow cannel gave a flame "approaching near to a jet [which] is used by the poorer sort of people in place of a candle."[3] Lord Douglas had a colliery at Blair which produced a similar cannel, "here called candle coal, or light coal, much valued for the strong bright flame which it emits in burning."[4]. Blair coal was so popular that it was transported over a fifty mile radius.

When he travelled to Soho in 1777, Murdoch may have had a letter of introduction to Boulton from Dr Roebuck or from James Boswell of

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1. Ibid., pp. 120-21. This may have been known by P. Macmillan of Courthill, Dumfriesshire, who invented the bicycle in 1839.

   It is not possible to substantiate the tradition that Murdoch distilled coal in an iron pot during his youth, at Lugar, Ayrshire, though Brownlie accepts the statement. D. Brownlie, "Early History of the Coal Gas Process", Trans. Newcomen Soc. 1923, op. cit.

2. A. Murdoch, Light Without a Wick (1892, Glasgow) pp. 27-8. Cannel was termed "parrot coal" because it crackled while burning.

   J.L. Carvel and J.C. George, The New Cumnock Coal-Field - A Record of its Development and Activities (1946, Edinburgh) p.15

3. (Old) Statistical Account (1791) Vol. 15, pp. 4-5.

4. (Old) Statistical Account, Vol. 7, p. 424. The practice was later noted by J. Naismith General View of the Agriculture of Clydesdale (1806) p. 38.

   The opposite type of coal, poor in bitumen, was termed "Blind Coal". By 1811 cannel coal was being mined in Ayrshire at Bedlaw Hill, Kilbirnie, and Adamel Hill near Tarbolton. W. Aiton, General View of the Agriculture of Ayr (1811, Glasgow) pp. 48-9.

Auchinleck, and he was given employment despite Watt's dislike of Scots mechanics.[1] Murdoch only remained at Soho until 1779 before being sent to Cornwall, where he resided at Redruth and supervised[2] the company's pumping engines at the surrounding copper mines. Little is known of the background to his interest in coal gas,[3] especially in view of that remote location away from the coalfields. The interest shown by Boulton and Watt in 'gases' may explain this, and also their pique in refusing to allow him to develop gas lighting.

Tar ovens were erected in the late 1780s at several locations in the English Midlands, for examply by Wilkinson[4] at Bradley, and by Lord Dundonald at Tipton and at Dudley Wood. These last two were near Soho, but observers[5] did not record the gas being used for arti-

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1. J.R. McCash, College Courant (1966) op. cit., pp. 124, 126. Despite Watt's attitude, by the 1780s most of his recruits came from Glasgow.

   Murdoch's success is traditionally attributed to the lathe with which he fashioned a wooden hat to attend his interview with Boulton. But Dr Roebuck, Watt's steam engine partner, had used John Murdoch's mill gearing at Carron ironworks. James Boswell, the biographer, visited Soho in March 1777, and Auchinleck near Murdoch's home, the following month. He may have been acquainted with Murdoch.

   C. Hunt, History of the Introduction of Gas Lighting (1907) op. cit., p. 27.

2. "Senior Engine Erector". J.R. McCash, op. cit.

3. He was not aware of Lebon's work in France, contrary to a recent statement in T.I. Williams, Ed. A Bibliographical Dictionary of Scientists (1969) pp. 382-3.

4. Chaloner has recently suggested that Isaac Wilkinson (1704? - 1784) produced coal-tar in the late 1770s, thus preceding Dundonald's process. W.H. Chaloner "Isaac Wilkinson, Potfounder" L.S. Pressnell, Ed., Studies in the Industrial Revolution (1960) pp. 23-51.

5. W. Pitt "On Converting the Smoke arising from Steam Engines &c into Tar" Trans. Soc. Encouragement of Arts and Manufactures, 1791 Vol IX, pp. 131-40. S.H. Blackwell "A New Process of Open Coking" Proc. Inst. Mechanical Engineers 1857, p. 188. Comments by J. Clift.

ficial lighting. Before 1793, Thomas Cochrane was preeent when his father Archibald visited James Watt at Handsworth, Birmingham, and discussed "the various products of coal, including the gas light phenomena at the Culross Abbey tar-kiln".[1] In 1783 Boulton actually visited and sketched another tar works owned by Dundonald in Ayrshire.[2] In 1790 John Champion of Bristol wrote to Boulton: "I have from some inflammable matter in Pitt Coal made a light for Light Houses".[3] He offered Boulton a half share in the project, for £300, but this was declined. Boulton apparently believed coal-gas illumination had been used at an earlier date and could not be patented. It is probable that Murdoch was not informed of Dundonald's experiments.[4]

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1. No precise date is available. T. Cochrane, Autobiography (1860) op. cit., p. 40.

   R.E. Schofield, The Lunar Society of Birmingham : A Social History of Provincial Science and Industry in Eighteenth Century England (1963, Oxford), p. 344. Schofield dates the visit c.1782, but gives no evidence.

2. A. and N.L. Clow, The Chemical Revolution (1952) op. cit., p. 413
   A. Clow, "Scotland's Contribution To Industrial Development" (1944) op cit., p. 34.
   S. Smiles, Lives of the Engineers - Vol. IV Boulton and Watt (1878), p. 329.

3. R.E. Schofield, The Lunar Society (1963) op cit., p. 345, pp. 347-8. The apparent reason for Boulton's refusal was his patent, with Argand, of the Argand lamp in 1784. The patent was revoked in 1786, because Glasgow University used a similar lamp in 1766. Boulton apparently believed coal-gas light had been used earlier, and the process could not be patented.

   Champion's Bristol works c.1776 made zinc spelter for Birmingham in short vertical 'retorts' holding calamine (zinc silicate) and charcoal, from which vapour evolved to be condensed. This could easily have been adapted for coal-gas experiments.

   R. Watson, Chemical Essays (1796) 5th Edn., Vol. IV, p. 39.
   N. Cossons, Industrial Archaeology (1975, Newton Abbot) p. 200. J.Day Bristol Brass (1973, Newton Abbot) p.120

4. R.E. Schofield, The Lunar Society (1963), op. cit., p. 416.

He was, however, probably informed by Boulton about Dr Priestley's experiments in 1780 which involved carbonic acid gas in a crude apparatus including tobacco pipes, kitchen utensils, and a gun barrel retort. In September 1780 Boulton took his phlogiston experiments with him on a visit to the Cornish operations. Soon he had "annihilated Wm. Murdock's bedchamber, having taken away the floor," and filled the enlarged room with chemical apparatus including "a Priestleyan water-tub, and likewise a mercurial tub for experiments on gases, vapours &c, and next year I shall annex to these a laboratory with furnaces of all sorts, and all other utensils for dry chemistry."[1]

Murdoch probably utilized some of the equipment later, for he patented a green vitriol[2] from pyrites in 1791. The recollection of "parrot coal" used in Scotland probably inspired him to try coal distillation. In 1792 he designed a retort and conveyed coal gas indoors to light his rooms and office in a house at Cross Street, Redruth.[3] He experimented with a wide variety of coals from Swansea,

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1. S. Smiles, Lives of the Engineers, Vol. IV, Boulton and Watt, (1878), pp. 297-8. Quoting correspondence 6/9/1781 from Boulton to Henderson.

2. A. Murdoch, Light without A Wick (1892), p. 27. Green vitriol for ships' bottoms by distilling pyrites and condensing the vapour (1791 patent no. 1802) C. Hunt History of Gas Lighting (1907) op. cit., p. 40.

3. A. Murdoch, Light Without A Wick (1892), op. cit., p. 29. Murdoch's equipment was very similar to that used earlier by Priestley.

   In 1818 Mr Saddler, a balloon "aeronaut", claimed that coal-gas illumination was first demonstrated in about 1788 at an exhibition in Oxford Town Hall, and that he had discussed the gas-light with William Murdoch "while on a professional visit to Sir Francis Bassett, in Cornwall, about the year 1792 or 1793".

   The Montrose, Arbroath and Brechin Review (Forfar & Kincardineshire Advertizer), 31/7/1818, p. 253.

   James Saddler's evidence is, however, suspect in view of his conflict with J.Watt over steam-engine patent infringements for a locomotive in 1786. W.Fletcher Steam on Common Roads (1891; reprinted 1972 Newton Abbot) p. 42

Haverford West, Newcastle, Shropshire, Staffordshire, and several Scottish coals.[1] Two years later, in 1794, he travelled to Soho but failed to persuade James Watt into sponsoring a patent for the process, possibly because Watt was preoccupied with persons evading his existing steam-engine patents, and knew of Dundonald's earlier work which could have nullified the patent.[2]

During 1794 Murdoch also demonstrated his apparatus to Mr Phillips[3] and others at Polgooth Mine, and then to Tregelles and others at Neath Abbey Ironworks in Glamorganshire. He was already disappointed by Watt's refusal to patent the steam locomotive which he had earlier devised, and by the "multifarious and odious duties"[4] imposed by Watt to frustrate his experiments. When the firm refused to develop either

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1. T.S. Peckston, The Theory and Practice of Gas Lighting (1819) p.95.
2. S. Smiles, Men of Industry and Invention (1905) 8th Edn., p. 139.

   Watt was aware of the earlier work of both Dundonald and Watson, and apparently gave so little attention to the matter that in 1809 he could not recall if Murdoch had seen him in 1795 or 1798. B.P.P. 1809 (220) III p. 51 (365); 61 (375); 60 (374).

   Watt was unwilling, in fact, to interrupt his own research programme with Thomas Beddoes at the Pneumatic Institute, Clifton, Bristol. There he was designing miniature gasworks, with a furnace, retorts, condensers, and counter-balanced gasholders, which were to produce medicinal gases to be carried in oiled-silk breathing bags. Boulton and Watt hoped to manufacture the entire miniature gasworks for mass sales to private persons. The technology was later adapted very successfully for coal-gas equipment, in which Murdoch had outmanoeuvred them in observing the practical and financial advantages. Cf. Dr. T. Beddoes and J. Watt, Considerations on the Medical Use and the Production of Factitious Airs (1795, Bristol).
   F.F. Cartwright "The Association of Thomas Beddoes M.D., with James Watt, F.R.S."
   Notes and Records of the Royal Society 1967 Vol. 22, p. 135.
   Humphrey Davy, who later bitterly opposed the introduction of gas lighting, worked for Dr. Beddoes from 1799

3. Phillips verified this in 1808. Soho MSS Letterbook, T. Wilson 29/1/1808 (Birmingham Ref. Library).

4. W. Jacks, James Watt (1901, Glasgow) p. 149.
   In 1786 Boulton reached Cornwall just in time to prevent Murdoch travelling to London in search of sponsors for his locomotive.
   Dictionary of National Biography. Letter from Boulton at Truro 2/9/1786.
   A. Murdoch, Light Without A Wick, op cit., p. 33
   D. Brownlie, Trans. Newcomen Society (1923) op. cit.

scheme,he resigned in 1797 and returned to "his old home at Cumnock."[1] There he set up a foundry, and a gas-works which he spent some time improving. This was probably the first gas-works in Scotland. It has recently been suggested, however, that Murdoch could have used the iron foundry at the nearby large Muirkirk Iron Works,[2] founded in 1787, for his experiments.

This would account for the very early references to gas-light apparatus at Muirkirk[3] in the 1790s, and at Govan Colliery[4] offices in 1802. It was the basis for a considerable early interest in gas

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1. Murdoch refused an offer of £500 a year to act as consulting engineer to Cornish mines in order to pursue his invention.

   A. Murdoch, Light Without a Wick (1892) op. cit., pp. 32-3.
   W. Mathews, Historical Sketch of Gas Lighting, (1832) p. 22.
   T.S. Peckston, Theory and Practise (1819) op. cit., p. 96, misstates 1796 A.D.

   The dispute according to A. Murdoch (1892) was due to Boulton and Watt's failure to enter a co-partnership with him to patent the locomotive as suggested in 1784, their lack of interest in gas-light, and the imminent expiry of Watt's steam patent in 1800 which would reduce the work available. Unsubstantiated reports have been made that Murdoch tried gas street-lights at Eaglesham, and marsh-gas lighting at Grangemouth, at about this time.

   Third Statistical Account - Renfrew and Bute (1962, Glasgow) p. 397. Third Statistical Account - Stirling and Clackmannan (1966, Glasgow), p. 369.

2. J.A. McCash, College Courant, 1966, op. cit., p. 140.
   The original information on Murdoch's actions came probably from Henry Creighton of Soho, and was published by Dr W. Henry in Nicholson's Journal in 1805. Since Murdoch was then again employed by Boulton and Watt, it would have been impolitic for him to have admitted associations with the Muirkirk company. C. Hunt is therefore probably incorrect in dismissing the Cumnock project as a myth, despite the lack of extant records. C. Hunt, History of the Introduction of Gas Lighting (1907) op. cit., pp. 44-5.

3. J. Butt, Industrial Archaeology of Scotland (1967, Newton Abbot) p. 148.

4. Govan was then probably the largest colliery in the 'Glasgow Coal Fields', and gas experiments would have appealed to the progressive manager, William Dixon, who in 1801 with David Mushet founded the Calder Iron and Coal Works, and later purchased Govan colliery. P.L. Payne "The Govan Collieries 1804-5", Business

lighting in the West of Scotland. Murdoch[1] won his case for recognition, and returned to the permanent staff at Soho in 1798 as manager of the engineering works where he was allowed to continue gas experiments with the assistance of Henry Creighton and Samuel Clegg (1781-1861).[2] The work was apparently suspended from 1799 to 1801, but recommenced after a letter was received from Gregory Watt describing Lebon's success in Paris.[3] Success was achieved, with two 'Bengal' gas-lights among the public illuminations at Soho for the 1802 Peace of Amiens. Soho foundry was regularly lit by gas from 1803, and after 1805 gas-apparatus was manufactured to supply many textile mills and similar factories.[4]

From 1805 to 1816 when Glasgow Gaslight Company was mooted, interest in coal-gas in Scotland was fostered and disseminated by three types of sponsors. Intense activity by scientists, later orchestrated by the Glasgow Philosophical Society, was matched by the enthusiasm

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History 1960 Vol III, pp. 75-96.

No details of the Govan gas-lights are extant, yet the 1802 public display, which was observed by J.B. Neilson whose father was engine-wright at the colliery, was in the same year as the first public display of gas at Soho, where S. Clegg claimed the apparatus was more advanced and guarded as a close secret by Murdoch.
T.B. Mackenzie, Life of James Beaumont Neilson (N.D.) p. 7
Mechanics Magazine 1834-5 Vol 22.p.470

1. J.A. McCash, "William Murdoch - Faithful Servant", Jl. Institution of Mechanical Engineers 1966

2. Clegg was a pupil of Dr. Dalton before joining Boulton and Watt. Dictionary of National Biography (1909) Vol. IV.

3. B.P.P. 1809 (220) III p. 51 (365)

4. Not before 1805 as stated by F.S. Taylor, The Century of Science (1941) p. 245.

of amateur mechanics and corroborated by a number of advance designs installed by Boulton and Watt. Interest in coal gas experiments was closely connected with J. Dalton's atomic theory of 1804, which developed from his analysis[1] of 'olefiant gas' and carburetted hydrogen in 1802-3. Practical scientific research in Scotland was in its infancy[2]

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1. By combustion Dalton (1766-1844) calculated that "one volume of olefiant gas is composed of $H^2 + C^2$ condensed in one volume", while carburetted hydrogen (CH_4) was $H^2 + C$ condensed in one volume. Because of these fixed ratios, the 'atoms' or 'smallest quantities possible' would, he predicted, always react in these ratios.

   T. Thomson "Bibliographical Account of the late John Dalton" <u>Proc. Royal Philosophical Society Glasgow</u> Vol II 1844-8, pp. 79-88.

   In 1805 Dalton was making "oil gas" by heating olive oil and hydrate of lime ($CaCO_3$ 6 H_2O) in a gun-barrel 'retort' to produce carburetted hydrogen (CH_4), olefiant gas (ethylene C_2H_4) and hydrogen. Later he was also involved in analysing oil gas made by T. Hoyle for illumination.

   <u>Memoirs of the Literary and Philosophical Society of Manchester</u>, (1824) Second Series Vol 4, pp. 69, 78.

2. William Cullen (1710-1790), lecturer in chemistry at Glasgow University (1747) and later Edinburgh (1755) organised chemical lectures and experiments relevant to industrial problems from 1748, but much of his work on improved linen bleaches, and agriculture, was done outside the laboratory. Most research in the eighteenth century was within industrial premises rather than in universities. There is no detailed history of British science around 1830 though by then the Scottish Universities and Thomson's pioneering work at Glasgow in 1810, and the Andersonian University appear to be important elements.

   J.B. Morrell, "Thomas Thomson : Professor of Chemistry and University Reformer", <u>The British Journal for the History of Science</u> 1968-9 Vol IV, p. 264.

   A. Fleck, "The Industrial Development of Scotland in the Cullen-Black Period", <u>An Eighteenth Century Lectureship in Chemistry - Essays and Bicentenary Addresses relating to the Chemistry Department (1747) of Glasgow University (1451)</u> A. Kent, Ed. (1950, Glasgow) pp. 112-4.

but Dalton's close associate, Thomas Thomson[1] (1773 - 1852) set up one of the first science laboratories[2] there while giving extra-mural tuition in Edinburgh from 1800-1811. In these laboratories, Dr Henry of Manchester "made his first experiments on the constituents of coal gas."[3]

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1. T. Thomson 1789-90 student at St. Andrews University.
   1795-6 studied chemistry under Dr Black
   1799 M.D. Edinburgh.
   1800-1811 gave private extra-mural lessons to about 100 pupils a year
   1818 Prof. Chemistry, Glasgow.
   1796-1800 Ed. Supplement to Encyclopaedia Britannica.
   Pub. 1812 History of the Royal Society
   1815-21 Ed. Annals of Philosophy
   1830-1 History of Chemistry

   (Partington is incorrect in dating Thomson's private lectures as commencing 1807).

   A. Kent "Thomas Thomson (1773-1852) Historian of Chemistry" The British Journal for the History of Science 1964-5 Vol II, pp. 59-63
   J.R. Partington "Thomas Thomson" Eighteenth Century Lectureship (1950) op. cit.

   The laboratory Thomson set up at Glasgow in 1818 inspired Andrew Fyfe in 1820 to open a laboratory in Edinburgh for practical science and pharmacy. By 1822 Fyfe ran five practical courses, and became an important chemist in the Scottish gas industry, and later Professor of Chemistry at King's College, Aberdeen.

   Vide infra 'Technology' p. 416

   J.B. Morrell "Practical Chemistry at the University of Edinburgh 1799-1843", AMBIX - Journal of the Society for the Study of Alchemy and Early Chemistry, 1969 Vol XVI, p. 69.

2. Details of the laboratories are not extant.

3. W. Crum "Sketch of the Life and Labours of Dr Thomas Thomson, F.R.S." Proceedings of the Royal Philosophical Society of Glasgow 1848-55 Vol III pp. 250-64. Crum claims this was the first science laboratory in Britain to be used for teaching.

   Dr William Henry, (b.1774) son of Thomas Henry F.R.S. 1795 entered Edinburgh University, studied under Dr Black, Dr Gregory, and in 1805 L. Playfair. From 1797 Henry was experimenting to prove that Carbon was an element. In 1821, during his work on gases, he proved that carburetted hydrogen (methane, CH_4) was a chemical compound, and not a mixture as the Royal Society believed.

   W.C. Henry "A Memoir of the Life and Writings of the Late Dr Henry" Memoirs of the Lit. and Phil. Soc. of Manchester (Second Series) 1842 Vol 6.

   A.E. Musson and E. Robinson, Science and Technology in the

The precise chemical reactions which occurred during distillation were of great interest, but Dr Henry maintained close connections with the gas industry and made practical suggestions for coal's giving higher gas output, and improved purifiers to remove the noxious constituents of raw gas.[1] During 1804 Henry demonstrated

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Industrial Revolution (1969, Manchester) p. 100

Quarterly Journal of Science, Arts and Literature 1821 Vol XII p. 133

Buckley and McCulloch "A record of some Early Experiments on Carbonization of Oil and Coke by Dr W. Henry", Manchester Literary & Philosophical Society (1929-30) Vol LXXIV p. 69.

R.D. Thomson, Records of General Science 1836 Vol VI pp. 395-8

The modern terminology for nineteenth century gases and chemical names is taken from King's Treatise on ... Coal Gas (1879) Vol II, Ed. Newbigging and Feutrell op. cit., pp. 200-4.

Henry's early analyses of coal are described in W. Henry An Epitome of Chemistry (1806, Edinburgh) p. 352, Birmingham Ref. Library.

1. In 1808 Dr Henry presented to the Royal Society, shortly after Murdoch's first paper, a "Description of an Apparatus for the Analysis of the Compound Inflammable Gases by slow Combustion; with Experiments on the Gas from Coal". The chemical conundrum was shown to be similar to that described by Dalton, and the apparatus used was designed by Henry Creighton of Soho, one of Murdoch's assistants. Dr Henry proposed "agitation with quicklime and water", in place of the water-wash purifiers earlier used. He made the first empirical analysis of the weight, specific gravity, oxygen consumption during combustion, and per centage of sulphuretted hydrogen (H_2S), Carbonic acid (CO_2) and olefiant gas (C_2H_4 ethylene) in gas from a wide range of coals including Wigan, Wednesbury, Newcastle, Leeds and Merthyr, and from "native coal tar". Also the amount of flame produced. Thus Scottish science enhanced early understanding of coal-gas combustion, and techniques of coal-gas manufacture.

Subsequently Henry advised local manufacturers like Phillips and Lee, how to improve their private gasworks, which coals to use and how to analyse the gases accurately. Wedgwood 'pyrometers' to measure retort temperature, red-hot tubes as purifiers, and aqueous solutions of white carbonate of lead ($PbCO_3$) instead of chlorine absorption to measure the proportion of sulphuretted hydrogen, and potash solution to absorb carbonic acid, followed by an electric spark over mercury /'Bomb Calorimeter'/ to determine the amount of combustible matter which remained, were all applied to the gas industry initially by Dr Henry.

W Henry "Experiments on the Gas from Coal, chiefly with a

'Argand gas lamps in Manchester, similar to those at Soho[1], and in the same year Dr Stancliffe demonstrated gas-light during chemistry lectures in Birmingham. Andrew Ure, (1778-1857)[1], who was appointed in 1804 to the Chair of Natural Philosophy in Anderson's Institution, Glasgow, travelled extensively to visit factories and institutes throughout Britain early in 1805, before advancing gas-light technology in Glasgow later that year. He used it to illuminate the large lecture room "every evening through that and the succeeding winter",[3] though the equipment was far from perfect and frequently the light "danced in tremulous movements or altogether disappeared".[4] Ure's private apparatus continued to be used until 1818 when the Glasgow Gas Company voted to provide free gas to his "Lecture Room,

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View to its Practical Application" Memoirs of the Lit. and Phil. Soc. of Manchester (Second Series) 1819 Vol.III pp. 391-429
Annals of Philosophy 1820 Vol. XV pp. 32-9
W.Henry was not involved directly with Murdoch's experiments until c. 1807; vide :
N. Cossons Industrial Archaeology (1975, Newton Abbot) p.299

1. W.Mathews Historical Sketch (1832) op. cit. p.37

2. A. and N.L. Clow Chemical Revolution (1952) op. cit., p.431
W.V. Farrar, "Andrew Ure, F.R.S., and the Philosophy of Manufactures" Notes and Records of the Royal Society (1973) Vol. 27 p.300

A.Ure, M.D.(1801,Glasgow), succeeded Dr.George Birkbeck(1776-1841) in 1804 as Prof. Chemistry and Natural Philosophy at the Andersonian. This chair carried no salary and Ure was strongly motivated to promote new ideas in order to attract fee-paying pupils, to pay for his lecture hall, assistants and apparatus. He helped the foundation of Glasgow Observatory (1809), and made electrical experiments on a cadaver to restore animation (1818).In 1830 he became a consulting chemist in London. Publications : Dictionary of Chemistry (1821), New System of Geology (1829), Philosophy of Manufactures (1835), The Cotton Manufactures of G.B.(1836); The Revenue in Jeopardy from Spurious Chemistry (1834) attacked the proceedures of W.T.Brande and Thomas Graham. Vide :
J.Muir John Anderson, Pioneer of Technical Education, and the College he Founded (1950, Glasgow) Glasgow Mitchell Lib.
Dictionary of National Biography 1899 Vol. LVIII p. 41

3. A. Ure A Dictionary of Chemistry (1823) pp. 340, 341

4. H. Barclay ('Nestor') Rambling Recollections of Old Glasgow (1890, Glasgow) pp. 62-5
Ancillary oil lamps remained in use until 1818. Vide University of Strathclyde Library 'Andersonian Institution Minute Book' 4/3/1819 p. 157

as a small tribute from the Company, to the Institution."[1]

Glasgow was a Mecca for inventors at that time. "Chemistry and other branches of experimental philosophy have been studied with great assiduity and applied with much success to the advancement of different manufactures",[2] stated Naismith in 1806. The Philosophical Society of Glasgow had a considerable influence upon the early development of gas technology in Scotland. With sixty members, it began in 1802 with the "purpose of reading essays and conversing on scientific subjects, for the exhibition of machinery and for the formation of a scientific library."[3] Lectures on the phlogiston theory were followed

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1. 'Andersonian Institution Minute Book' Vol III:
   22/9/1818 p. 133 Letter dated 10/9/1818 from J. Robison, Chairman of the Gas Company Committee.
   18/11/1818 p.135, the Andersonian 'Managers' agreed to purchase the redundant gas plant from Dr Ure, at a valuation made by Hutton and Creighton, engineers of the Gas Company. Ure himself gained infamy among socialists for insisting that gas-light in factories was as healthy as sunlight. L. Mumford Technics and Civilization (1946) p. 169.

2. J. Naismith, General View of the Agriculture of Clydesdale (1806) p. 195. Forsyth concurred: "it is in the West of Scotland that every useful art meets with the readiest encouragement, and every improvement, from the formation of iron to the combustion of inflammable air as the means of illumination, has been most readily brought to perfection." R. Forsyth, The Beauties of Scotland (1806, Edinburgh) Vol III p. 326.

3. W. Keddie "Early History and Proceedings of the Society", Proceedings of the Royal Philosophical Society of Glasgow (1857) Vol IV.
   A. Fergus "Opening Address - Sketch of the Early Years of the Society" Proc. Royal Phil. Soc. Glasgow (1880-2) Vol XII pp. 8-9.
   A.A. Bowman "The Royal Philosophical Society of Glasgow", Proc. Royal Phil. Soc. Glasgow (1932-4) Vol LXI, p. 108.

   This formal organization was in the tradition of scientific fraternities like the Lunar Society (1768), the Taylors and Martineaus of Norwich, Roscoe and Currie of Liverpool, and Aikin, Enfield and Priestley of Warrington.

   S. Smiles Lives of the Engineers Vol IV Boulton and Watt (1878) op. cit., p. 292. Many prominent Glasgow citizens later joined, including Dr A. Ure, George and Charles MacIntosh, Dr G Birbeck, H. Houldsworth a cotton spinner who supported the 1817 Glasgow Gaslight on 15 February 1805 by a demonstration of the cast iron retort, water purifier, "receiver", pipe and gas-burner devised by George Lumsden.[1] This was the first gas apparatus used in the city and when the retort, holding "an English pint" of coal, was placed on a fire the vivid gas-flame was maintained for almost three quarters of an hour.

Dr Nimmo in Glasgow was abreast, if not ahead, of Dr Henry in early research on coal gas. In September 1805 he demonstrated to the Society a new type of gasometer, and in October described the comparative quality of gas from different kinds of coal, particularly those of Lesmahagow, Banton, and Newcastle.[2] Public demonstrations

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Company (vide infra pp. 138,156,1155), Charles Tennant of St. Rollox chemical works (infra pp.565,1155), J.Spreull the Glasgow City Chamberlain, Dr.James Monteith, James Cook engineer (possibly related to Archibald Cook, gas engineer of Paisley—infra p.p.139, 438,958); J.Laird of Dalmuir Ironworks and J.Buttery of Monkland Iron and Steel Company (infra p.209); and Robertson Buchanan (infra pp.41,66), civil engineer and exponent of steam heating for factories (a piped utility with similar problems as gas distribution). James Lumsden (infra p.1130), and Andrew Liddell the gas apparatus manufacturer (infra pp.139,1131) became members in 1818; John and Robert Hart (infra pp.66,1248) joined in 1819; and J.B. Neilson (infra p.596) in 1820. C.Macintosh vide infra pp.543,560.

In 1821 the Society discussed problems of water condensation inside gas street lamps, and Andrew Liddell demonstrated Messrs Hart's apparatus for lighting the Tron; in 1822 J.B. Neilson lectured on Sulphate of Iron to purify gas. In 1823 the Society considered the use of gas to singe muslin during manufacture; in 1825 they reviewed gas-engines, and observed a balloon ascent at Glasgow Gasworks; and in 1827 discussed the use of gas 'governors' for steady pressure.

1. A. Fergus "Opening Address" (1880) op. cit.; A. Murdoch, Light Without a Wick, op. cit., pp. 45-6.

Lumsden's work may have inspired Dr Ure, though H. Barclay later claimed that it was Andrew Ure who first introduced gas at James Lumsden's stationery shop in Argyle St. where a subsequent fire "had the effect of greatly retarding the introduction of gas into dwellings and shops". H. Barclay Rambling Recollections (1890) op. cit., pp. 62-5.

Keddie (1857, op. cit.) based his account on the Society's First Minute Book and the reminiscences of Robert Hart. He claimed that G. Lumsden's shop was not gas-lit until about 1810.

2. A. Fergus "Opening Address" (1880-2) op. cit.

of the brilliant 'new light' were arranged, and the front of the Exchange building[1] was illuminated on the 8 and 10 October 1805. The Glasgow Courier[2] that month reported that "several shops in this city, and manufactories in the neighbourhood" had used gas light for some months past,and described the principles in detail. The distillation of coal was preferred to wood because it gave a whiter and denser flame that could be used instead of lamps or candles for lighting streets, factories, or theatres. Gas gave "immense saving in point of expense", less fire hazard, and coke which was more valuable than the original coal. 3lb to 4lb coal could illuminate a large appartment for several hours, while 7lb coal costing ½d was sufficient to light a shop and workroom employing six men, for four hours.

The Courier described irnn retorts, probably vertical, filled three-quarters full of small coals, with an air-tight cover fitted with an iron or copper tube running directly to the gas burners. Gasometers were sometimes used, but set in a rigid position above a water reservoir so that gas pressure could be increased by adding water to the reservoir. A tar-tank could be fitted on the pipe between the retort and gasometer, with a tap below it to remove tar, and a stop-cock on the service pipe leaving the gasometer was used

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1. R. Chapman The Picture of Glasgow (1812, Glasgow)

   The Exchange was then part of the Tontine Buildings, one of the principal business centres in the City, on the High Street. The building is described in R. Forsyth, The Beauties of Scotland (1806, Edinburgh) pp. 272-4.

   C.P. Donald "The Tontine Building" The Regality Club (1893, Glasgow) p. 65.

2. Glasgow Courier, 17/10/1805. Ure, Nimmo, and Lumsden all had sufficient knowledge to write in that depth.

to regulate the supply to the burners. No purifiers were used, other than the water of the reservoir, but the burner was praised because it eliminated the problem of wicks, and the flow of gas was very easily controlled. Full combustion was achieved by a small aperture, "the size of a small sewing needle", or "by making the gas issue through a fine slit."

The "manufactories" mentioned may have included the Pollokshaws mill, making it the second earliest industrial premises in Britain and certainly the earliest textile mill to install gas-lighting for regular use. Available evidence is circumstantial. After the Courier article, Gregory Watt wrote from Glasgow in 1805 that the new lights:

> are much in vogue here; many have attempted them, and some of them have succeeded tolerably in lighting their shops with them. I also hear that a cotton mill in the neighbourhood is lighted up with gas.... I think there is full room for the Soho improvements, when once they see one properly executed, it will have numerous imitations. 1

This was presumptuous. Soho manufactory[2] itself was not regularly lit by gas until 1803, and the Pollokshaws installation was probably much larger than Murdoch's first commission, in Manchester, where by 1805 he had fitted gas light for Mr Lee's dwelling house, but only

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1. S. Smiles, Lives of the Engineers (1870) Vol IV p. 348. Smiles believed that by 1805 £5,000 had been spent at Soho on equipment for producing gas apparatus, but the real total was only £2-3,000.
   B.P.P. 1809 (220) III p. 55 (369).
   Proceedings of Glasgow Architectural Society (1865-7) Vol VI p. 95.

2. Dictionary of National Biography (1908) - W. Murdoch. Smiles gives the date 1802, but that was only when experiments recommenced. S. Smiles, Men of Invention and Industry (1905) 8th Edn. p. 140.

two rooms of Phillip and Lee's mill and their counting houses.[1]

Lee's mill, one of the largest textile factories in England ultimately had 940 gaslights producing 2,500 candlepower,[2] yet Pollokshaws[3] had up to 420 lights producing 1,260 candlepower from an apparatus not built at Soho. The scale is especially significant because even the Manchester area up to 1809 had no large

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1. Soho MSS Letterbook 20/12/1805. Murdoch wrote from Manchester in December 1805 that the second retort had not yet arrived, and he postponed the lighting of the Mill until the new year 1806.

2. W. Murdoch "An Account of the Application of the Gas from Coal to Economical purposes" 25/2/1808, Royal Society of London Philosophical Transactions 1808 p. 124. Murdoch gives detailed operating statistics.

   W. Buckie (Soho) "On the Inventions and the Life of William Murdoch" Proc. Institution of Mechanical Engineers 23/10/1850 p. 16.

   Confusion over installation dates occurs in some printed sources e.g. Dictionary of National Biography (1908) states 50 gas lamps at the mill by 1805; George Lee, however, stated that in 1804 there was only an experimental apparatus for his dwelling house. Lee's mill gas-apparatus was ordered in 1805, but erected mainly in 1806, and completed in 1807.

   B.P.P. 1809 (220) VIII PP. 38(352); 39(353)
   Watt stated it was erected in the winter of 1806 and the winter of 1807.
   B.P.P. 1809 (220) VIII p. 51 (360)

   Soho was slow in making the installation because experiments were in progress for more efficient apparatus, which was technologically quite superior to that at Pollokshaws.

3. W. Johnstone Proceedings of Glasgow Architectural Society 1865-7 Vol VI p. 95.

   A and N.L. Clow, Chemical Revolution (1952) op. cit., pp. 231, 432. Clow states the mill was gaslit before 1805, but later contradicts this.

   Pollokshaws Printfield Company was sold in 1789 to John Monteith of Anderston, and Robert Dunmore of Kelvinside, who constructed there a large steam-powered cotton spinning and loom works, later known as the Auldfield Weaving Factory, A. McCallum, Pollokshaws Village and Burgh 1600-1912 (1925, Paisley).

gas apparatus other than that from Soho.[1] J. Wilson in 1812 recorded that only one mill in Renfrewshire was lit by gas,[2] thereby confirming Pollokshaws to be the mill referred to by Watt and the Courier in 1805. Mr Miller,[3] brother of a manager at Pollokshaws, recalled later that the retort he observed there in 1807 was "the old cylinder of a steam engine, 6ft by 20 inches in diameter, which towards lighting time was heated to a bright red, the coals pitched in and the old cylinder lid bolted on." The gas passed through a condenser in a large cask of water, and then to the loom shops where "the flares, 6 to 9 inches long, entirely eclipsed the light of the oil lamps". To remove tar deposits, steam was periodically blown through the pipes. By 1812 "all the buildings for cotton spinning and weaving at that extensive establishment" were lit by 420 gas-lights, each giving illumination equivalent to three candles normally used in mills.[4]

The advantages of gas-light were immediately obvious. Eighteenth century lighting was very expensive and a fire hazard. Many experi-

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1. Evidence of G. Lee. B.P.P. 1809 (220) VIII p. 48 (362).
2. J. Wilson, General View of the Agriculture of Renfrewshire (1812, Paisley).

   A. McCallum, Pollokshaws (1925) op. cit., states this was the first Scottish mill to be lit by gas.
3. In 1807, Miller was aged 12. His evidence was given in an interview by W. Johnstone, recorded in Proceedings of Glasgow Architectural Society 1865-7 Vol VI, p. 95.

   The Supply of Gas to Glasgow (1935, Glasgow)
4. J. Wilson, Renfrewshire (1812) op. cit.

   There was still occasionally a problem with an "offensive smell" caused by unconsumed gas.

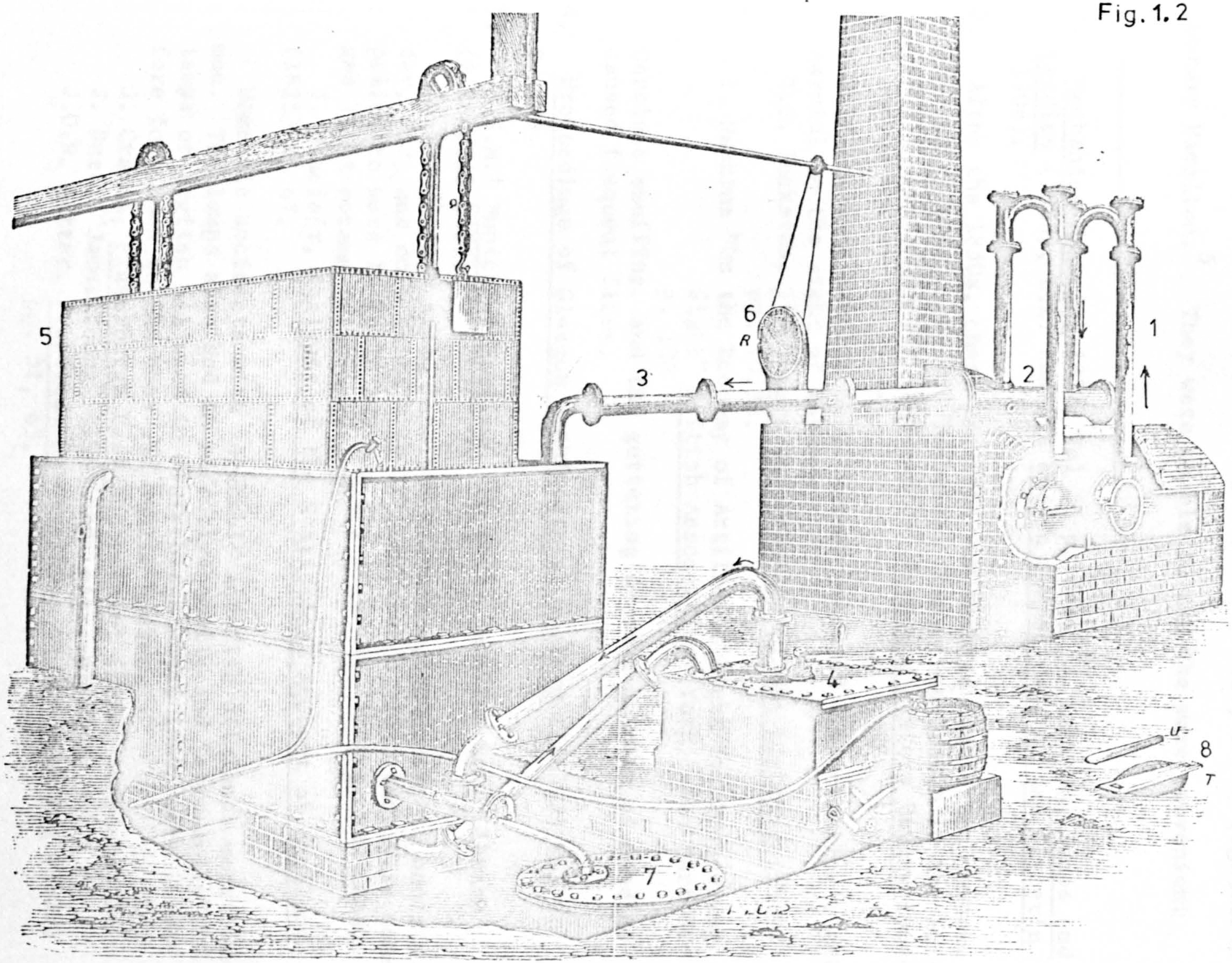

Fig. 1.2

Private Gasworks, 1812

Samuel Clegg's design for Mr. Ackermann's works.

1 - ascension pipe with lid at summit to permit cleaning
2 - hydraulic main
3 - condensor, partly submerged in gasholder-tank
4 - purifier
5 - gasholder
6 - meter showing contents of holder
7 - tar sump from condensor
8 - detatched retort-lid

Source - King's Treatise on Coal Gas (1878) Vol I p. 25

menters tried to improve candles,[1] like the machine by W. Cooper in 1787 for twisting wicks, and the costing process introduced in 1801 by T. Binns.[2] When wicks became too long, candle illumination was reduced six to eight times, so that much labour was used for the snuffing of candles, a process with great fire danger. Oil lamps were used domestically, but often stained furniture and clothes.[4] Domestic handloom weavers, a major occupational group, could only afford poor bawbee candles hanging over their web, as in eighteenth century Hamilton.[5] They were unable to use the more convenient

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1. Mechanics Magazine 1852, Vol 56 p. 243; J. Cameron, Soaps and Candles (1888), L.L. Lamborn Modern Soaps, Candles and Glycerin (1906).

2. After the 1850s, cheap paraffin wax enabled candles to compete with gas-light, J. Butt, "Technical Change and Growth in the British Oil Shale Industry (1680-1870)" Economic History Review 1964-5 Second Series Vol XVII.

3. Self-snuffing candles by E. Walker produced a fluctuating light, harmful to the sight of workers.
   T.S. Peckston, The Theory and Practice of Gas Lighting (1819) pp. 10,33.
   I. Hawkins "On the Economy of Artificial Light for Preserving Sight" British Association (York) 1844 Part II p. 100
   Careless snuffing, and the guttering or burning down of candles caused frequent fires.

4. Proceedings of Glasgow Architectural Society (1865-7) Vol VI p. 104.

5. 'A.G.M.' Municipal Hamilton (No date) Hamilton Ref. Library (21164/155 L352).
   In the Glasgow area, handloom weavers c.1800 worked 9 hours a day, and only up to 9 or 10 p.m., but by 1825 they were compelled to work 14 to 16 hours a day to earn a living, and cheap gas light became very important.
   J. Sinclair, Analysis of the Statistical Account of Scotland (1825) p. 47.

   Domestic accidents with vegetable and fish oil lamps were common. The lamps also had an offensive smell, and "eely-dolly" lamps of dogfish oil used in Fraserburgh until 1840, were therefore forbidden in churches and public houses.
   J. Cranna, Fraserburgh Past and Present (1914, Aberdeen)
   J. Butt, "James Young" (1963) op. cit., p. 47.
   J.O.N. Rutter, Practical Observations on Gas Lighting (1833) pp. 51, 45.

cruisy or lamp, with oil and a wick, because grease splashed onto the cloth.

Renfrewshire mills experimented with Argand oil lamps from 1800, in a search for cheap light, but Wilson[1] in 1812 observed that four of the largest mills in the county had been gutted by fire in twelve years, and advised the use of gas-light. Gas burners could not be knocked over, and did not emit sparks or embers.[2] Insurance companies, like the Phoenix,[3] reduced the premium charged for cotton and other factories which used gas. Inadequate safe illumination could have radically[4] retarded the later stages of the industrial revolution.

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1. J. Wilson, General View of the Agriculture of Renfrewshire (1812) pp. 253, 272.

2. F. Accum, "On the Method of Illuminating the Streets with Coal Gas" Annals of Philosophy Vol VI 1815 pp. 16-19.

3. F. Accum, A Practical Treatise on Gas Light (1815) p. 161
J. Maiben, A statement on the Advantages to be Derived from the Introduction of Coal Gas ... (1813, Perth) op. cit.
The Royal Exchange company raised the premiums of cotton mills in 1791, and faced record fire-loss claims in 1796, but reduced rates after 1809 as construction methods, steam heating instead of coal fires, and gaslight reduced hazards. The Sun Insurance Company was also forced by competition to reduce premiums in 1811 and 1815, and in the 1840s for specially fire-proofed mills.
B. Supple, The Royal Exchange Assurance. A History of British Insurance 1720-1970 (1970, Cambridge) pp. 90-1, 158.
P.G.M. Dickson, The Sun Insurance Office 1710-1960 (1960, London) pp. 75, 92-4, 144, 159.

4. W.T. O'Dea, A Short History of Lighting (1958) p.1
Cheap Gas light made possible the provision of public halls, Mechanics Institutes, Mutual Improvement Societies, concerts and public meetings. As domestic light it encouraged an "extraordinarily rapid increase in the rate of intellectual development" and study in the mid-nineteenth century (J.G.L. 6/1/1891). This has received insufficient attention vide
E.L. Woodward, The Age of Reform (1961, Oxford) 2nd Edn., p. 49.
A. Briggs, Victorian Cities (1963) p. 16.
W.H.B. Court, A Concise Economic History of Britain (1954) p. 262.
S. Pollard, The Genesis of Modern Management (1965) p. 110.
J.L. and B. Hammond, The Rise of Modern Industry (1967) 9th Edn. p. 220.
T.K. Derry and T.I. Williams, A Short History of Technology (1960) pp. 506-18.

Factory overheads could be significantly reduced[1] by a multiple-shift system for operating machinery by day and night, thereby reducing the time for turnover profits to repay the capital cost of a machine before new inventions made it outdated and uncompetitive.

Engineers[2] employed by Boulton and Watt in Scotland received numerous queries about gas light apparatus after 1805. In December 1805, E.S. Hutton[3] delivered a reply concerning gas-light from Soho to Mr Dunlop's mill in Glasgow, and also received the first Scottish order for a gas-plant from Soho, for the new saw-mill owned by Mr Grieve of Inveresk. Grieve requested only three lights, each of six candlepower, and was advised to place the retort in the boiler-flues of his steam engine. Hutton examined the Inveresk saw-mill, and requested details from Soho on the size and operation of gasworks used by Mr Lees in Manchester, and also on the saving "between using this light & Candles including the first cost of an apps."[4] In March

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1. P. Deane, The First Industrial Revolution (1969, Cambridge) pp. 98,138.

2. Unfortunately there has been inadequate research on the activities of these itinerant engineers. Letters to Soho from William Creighton, an engineer on Murdoch's team whose brother joined Glasgow Gaslight Company, indicate that after work in the Manchester area he served in Scotland until about November 1802, though there is no record of him pursuing gas experiments there. E.S. Hutton, also from the Manchester area, travelled to Edinburgh in 1803, and by about 1805 was granted the position of Engineer for the Scottish area of operations. Murdoch himself was frequently employed in Scotland, and could have encouraged interest in gas-light (e.g. in 1802 at Fulton's Engine in Glasgow. Soho Letterbook 3/9/1802).

3. Birmingham Ref. Library. Soho MSS Loose Letters - Hutton 15/12/1805. Hutton may have been the son of Wm. Hutton, wealthy Birmingham bookseller and member of the Lunar Society. S. Smiles, Lives of the Engineers Vol IV (1878) pp. 115, 334.

4. Soho MSS ibid. Hutton 11/2/1806.

1806 Grieve finalised the order, including a Gasometer from Soho because he was "apprehensive his wooden butt might not keep out the smell"; but the order was refused by Soho[1] later that month.

Also in March, James Finlay & Co.[2] ordered a gas lighting apparatus from Soho, to beinstalled at their Catrine mills by the following winter. Hutton travelled to Catrine, where he sketched the mill Finlay wished to try first, before a short trip to Manchester to observe gaslight at Lee's mill. In July 1806, after his return, Hutton[3] was disappointed to find that the Gourock Rope Work Company[4] was unwilling to experiment with gas-light throughout their works, and wished to try first with a plant no larger than Mr Grieve had requested. Soho had informed Mr Bain that the five-storey mill under construction, 65 feet long by 32 feet wide, would require a gasworks

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1. Ibid., Hutton 15/3/1806.

   The full extant list of Soho gas apparatus is given as an Appendix (vide infra). Very small installations were apparently always refused. Grieve was "satisfied the apps. will be charged him as to others", at a fair price set by Soho - he made no specific price demands. Vide infra p. 1341

2. The order was placed by Kirkman Finlay, the manager, who had "acquired control of a major part" of the Scottish cotton industry, with mills at Deanston, Catrine, and Ballindalloch.
   R.H. Campbell, Scotland Since 1707 (1971) p. 104
   Soho MSS Loose Letters - Hutton 15/3/1806.
   Vide infra, Chapter II p. 155

3. Soho MSS, Loose Letters - Hutton 26/7/1806.

4. Trade connections with England stimulated the demand for gas light. C.H. Turner, a director of Phoenix Fire Office and member of Pelican Life Office, after observing the Soho gas apparatus at Messrs Burleigh in Manchester, about 1809, "recommended it to a mill in which I am concerned in Scotland, to write to Messrs Boulton and Watt for the purpose of supplying the gas light in Scotland." The firm apparently sold canvas and rope, and may have been Gourock ropeworks, but they did not purchase the equipment from Soho.

   B.P.P. 1809 (220) III PP. 46(360), 51(366).

costing £800 to £1,000. Hutton warned Soho that such a price would lead the company to abandon its plan, since "the intst /interest/ of the money would be more than what will be expended in Candles & Oil". He suggested 150 lights, of three candlepower each, two retorts, and one 10-foot cube gasometer would be far more suitable, at a lower price.

Soho was unable to meet the Scottish demand for gas apparatus. Deadlines could not be met, and the itinerant engineers lacked sufficient skill to design a gas installation. Designs, apparently at excessive estimated cost, were made at Soho on the basis of very rough sketches and diagrams of the buildings and clients' requirements, sent in by the itinerant engineers. Finlay's apparatus was not completed by the winter of 1806-7, despite reassurances from James Watt; and when Hutton[1] wished to take sketches of Mr Dunlop's mill and the Lanark Mills for the "New Light" in March 1807, he reported that the owners were pressing for installation before the next winter. In no case[2] was this achieved and in December 1807 Kirkman Finlay decided to send Mr Buchanan from Catrine, the following spring, to examine Mr Lee's mill. Meanwhile he cancelled their order with Soho. During 1807 Robert Stevenson[3] (1772-1850) inquired at Soho about the cost of providing gas-light (instead of 300 guineas a year oil-lamps) for a three mile tunnel proposed under the Firth of Forth. The tunnel never materialised, and neither did the gas apparatus for Lanark Mills or Mr Dunlop.

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1. *Ibid.*, Hutton 9/3/1807, 20/5/1807.
2. *Ibid.*, Hutton 8/10/1807, 10/12/1807.
3. Soho MSS Letterbook 20/4/1807, 6/5/1807.
   A. and N.L. Clow, *The Chemical Revolution* (1952) *op. cit.*, p. 431
   Stevenson was a pioneer of lighthouse construction in Scotland.

Hutton reported no further progress until the spring of 1809 when Soho prepared drawings of "Photogenous Apparatus" requested by Messrs Richard Gillespie & Co.[1] of Glasgow, and Messrs Neilson & Co. of Kirkland in Wemyss parish. In January 1809 Hutton sent diagrams and details of Gillespie's requirements to Soho, which indicate that he had developed a greater technical knowledge of the equipment involved. Gillespie required light equivalent to 100 candles for his Dye House, and was prepared to install a very expensive gas apparatus because of the difficulty in keeping candles alight in that steam-filled building. The Dye House therefore was only in use during daylight hours, and Gillespie wished it to operate the same long hours as the rest of his factory. He was only prepared to extend the gaslight to other departments after proving its value on a small scale.

Installation problems were outlined by Hutton.[2] The gasometer had to be placed high, because the water outlet could not be sunk

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1. Soho MSS. Loose Letters - Hutton 5/5/1809, 18/5/1809.
   E. Gauldie, Dundee Textile Industry 1790-1885 (1969, Scottish Historical Society), p. 10.

   This order was possibly associated with Mr Miller of Craigend. At a time when fire safety was of great concern to industrialists, and iron pillars and floors were devised to build fire-proof compartments (A. Ure, The Cotton Manufacture of Great Britain 1861 p. 32; R.L. Hills Power in the Industrial Revolution (1970, Manchester) p. 231), Gillespie and other gas-light enthusiasts were also in the forefront of those introducing steam-heating into factories instead of coal fires. James Watt used steam heaters in 1784-5, and in 1799 Soho persuaded both Mr Lee of Manchester and Wormalld & Gott of Leeds to use steam, while Richard Gillespie of Anderston was the first to use steam-heat in a calico works, and by 1808 also used it for his block-printing shops and copper-plate house.

   R. Buchanan, An Essay on the Warming of Mills and Other Buildings by Steam (1807, Glasgow)

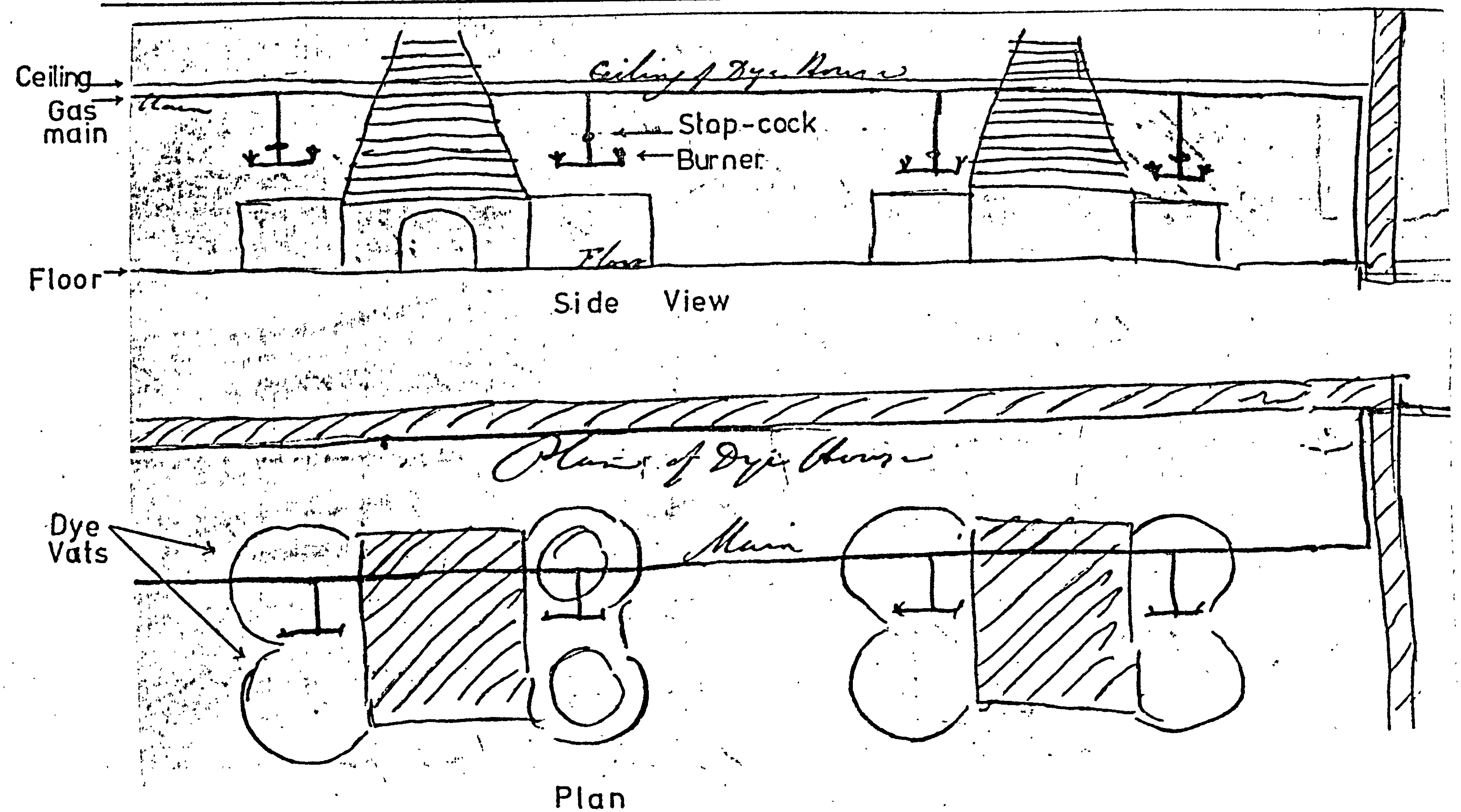
   R. Buchanan, Practical and Descriptive Essays on the Economy of Fuel and Management of Heat (1810, Glasgow).

2. Soho MSS Letterbook 3/1/1809.

more than sixteen inches below the ground level. The ash pit of the retort could be excavated only four feet below the ground, so the top of the retort had to stand six feet above the dye-house floor. This suggests that vertical retorts were involved, though details are not available. An existing chimney was to serve the retort-furnace. If " a pergatory [purifier ?] is absolutely necessary " a suitable position was marked by Hutton before he sent his sketch to Soho with a remark that "Murdoch I presume could specify the apps. " Detailed knowledge was apparently still confined to Murdoch and his closest associates. Hutton's sketch of the lights[1] required appears in Figure 1.3

1. Richard Gillespie, the entrepreneur, may have been related to William Gillespie (d.1807), linen and calico and cotton-yarn merchant at Anderston, who built the first spinning factory at Glasgow (Woodside c.1796) in partnership with Henry Houldsworth. William was grandfather of William Honeyman Gillespie who owned the Torbanehill gas mineral. Vide infra p. 492
G.Stewart Curiosities of Glasgow Citizenship as Exhibited chiefly in the Business Career of its Old Commercial Aristocracy (1881, Glasgow) pp. 80, 214.

Fig.1.3 Private Gasworks at Mr Gillespie's Dyehouse, Glasgow - Drawn by E.S.Hutton 6/9/1809



Source - Birmingham Reference Library [SohoM.S.S.]

A firm order was placed[1] in February 1809. The dye-house[2] contained four chimneys, with two dye-boilers each side of them, and two gas lights were placed above each boiler. Before the precise site for the plant was chosen, Hutton urged Soho to get started on "those parts that are not influenced by the local g.g. [geography ?]". Construction began in April, and was fully documented since Boulton and Watt apparently wished it to be a showpiece which would attract other consumers. This was Hutton's first experience in erecting such equipment, and several problems arose. He raised the "gasometer pit"[3] or tank by six feet compared to the first diagrams, making the base only 3½ feet below the Dye-House floor. He could not see the need for "the condenser emptying itself of water as well as tar", and omitted any drain from it. For cleansing, he relied upon the manual use of buckets, though a drain was built from the main tar sump. A constant influx of water was planned by Murdoch for the gasholder tank, but instead of placing the necessary drain at the base of that tank where detritus would be flushed out, Hutton placed it at the side only 15 inches below ground level. Because the Dye-House was only 20 feet high and the gasometer was designed to hang from a pulley in the roof, Hutton requested Soho to provide a "Gazometer" 7 feet deep, 9½ feet wide and 14 feet long, instead of the standard 10 foot cube. Also a "house [tank ?]" 13½ feet wide instead of the normal 14 feet. Murdoch[4] arrived personally to examine the problems in August 1809.

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1. Soho MSS Letterbook 25/2/1809 (Birmingham Ref. Library).
2. The building measured "92/8" (92 feet by 8 feet?), and the entire gas apparatus was built inside the existing building. Soho MSS Letterbook 3/1/1809.
3. Soho MSS Letterbook 12/4/1804.
4. Soho MSS Letterbook 6/8/1809, 19/8/1809.

Fig.1.4 Private Gasworks of Mr Gillespie - Longitudinal section of Gasholder Tank

24/4/1809 Scale - 1/4 inch to 1 foot

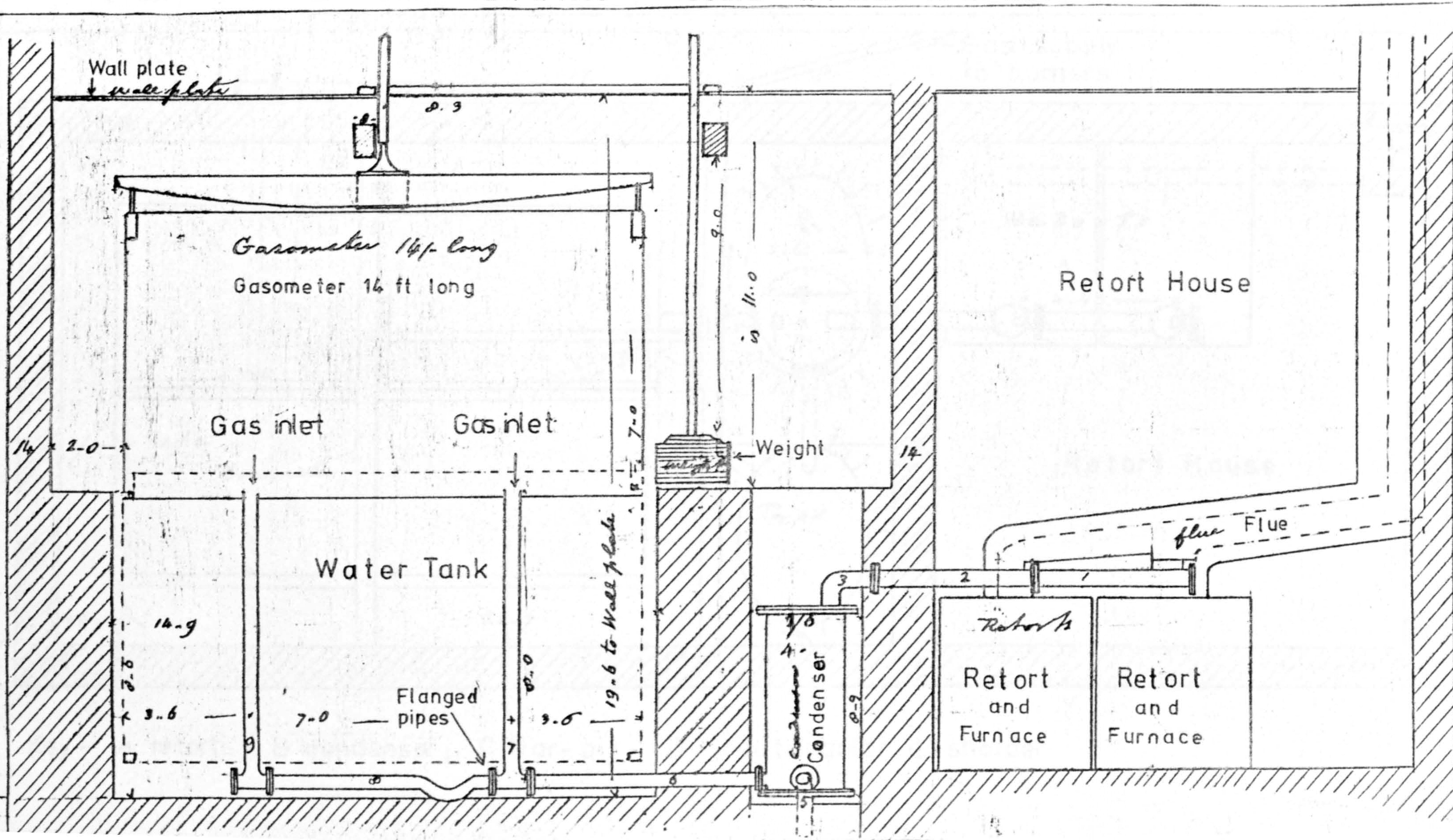
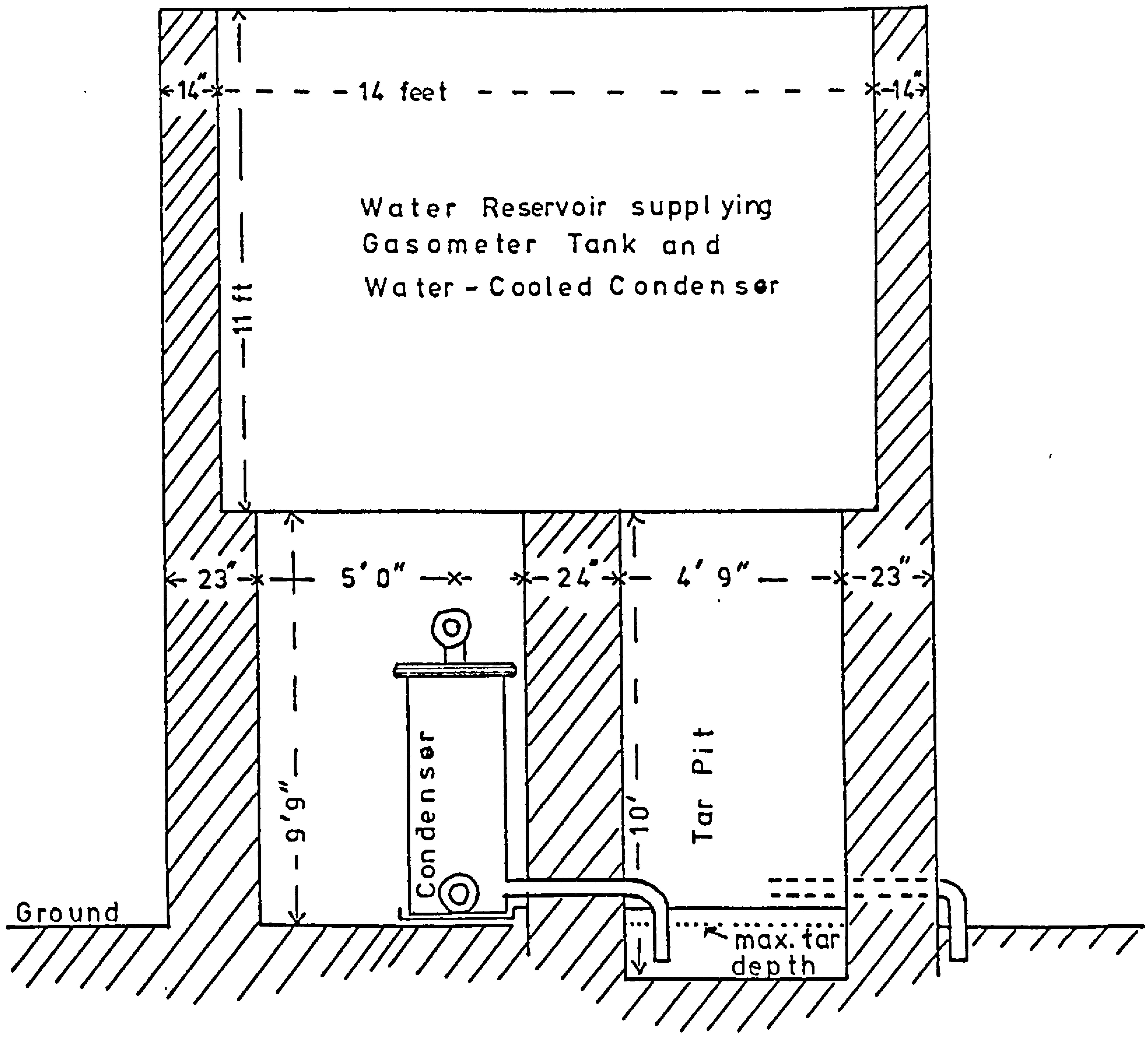


Fig. 1.5

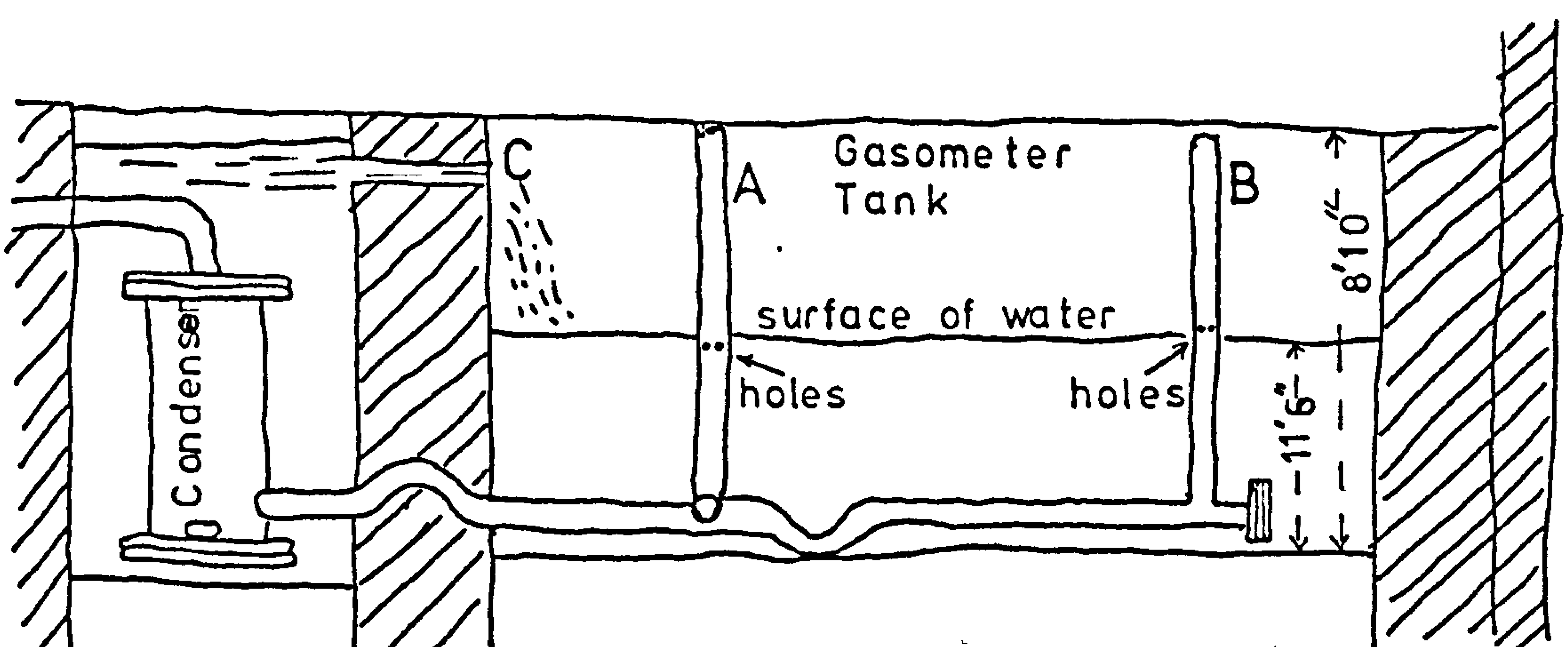
Plan of Private Gasworks at Mr Gillespie's Dyehouse, Glasgow 1809

Key - A retorts; B condenser; C tar-pit; D - rectangular gasholder

Fig. 1.6



Gillespie's Gasworks, Glasgow 1809



Note - holes for gas 6 inches lower in inlet pipe A than B

C - water inlet to gasometer tank from condenser pit

Source - Birmingham Ref. Lib. Soho M.S.S.

Most of the ironwork was transported[1] from Birmingham, including a pipe sent urgently "by Coach" in September.[2] In November the gasholder tank began to leak water, but Gillespie by that stage was keen to try the equipment and financed a temporary lead lining for it, and for the "condenser pit".[3] The first trial was held that month, but the gas produced from Monday morning to Wednesday afternoon only raised the gasometer two feet, and the leaking gasometer had to be covered by a mixture of tar and hard rosin applied with a hot iron. During December, Hutton[4] was unable to produce the high temperatures and "that rapid distillation" advised by Soho, but gas was produced successfully which was "tolerably pure and furnishes a very good light." To prevent steam extinguishing the cockspur burners, the tops had to be cut off and large gas-flares used instead.

Gillespie extended the use of gas-burners throughout his Warehouses and Counting Houses, and ordered extra pipe from Soho for the Print Shops. Nevertheless the Soho apparatus had many faults, especially low productivity. Hutton reported:[5]

> the average production of the two retorts working together is abt. 100c. [cubic] feet pr. hour - the retorts are charged in the morning before breakfast. They are generally ready for work at about 9 O'clock, but tho' the fires are put on while the Retorts are preparing & soon made and kept up pretty strong yet the gas does not begin to come over until noon, & the retorts are not distilled until between 7 & 8 in the evening.

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1. In February 1809 Hutton requested the equipment to be "delivered at Soho in time to be at Glasgow about the beginning of July". Soho MSS Letterbook 25/2/1809.

2. Soho MSS Letterbook 6/9/1809. 3. Soho MSS Letterbook 11/11/1809

4. Soho MSS Letterbook 21/12/1809. Murdoch personally visited both Messrs Gillespie & Co and Neilson & Co in December 1809 but, like Varley and McMurdo the other Soho engineers in Scotland, he was working hard on steam-engine contracts and could spare little time. Soho MSS Loose Letters - Hutton 19/12/1809.

5. Soho MSS Letterbook 29/12/1809.

Hutton tried three varieties of local coal, in a dry condition and free from gypsum and other impurities, but the experiments were seriously interrupted by Gillespie's eagerness to use the gas. Gillespie complained to Soho that the gasometer had never risen above eighteen inches, but Hutton[1] replied that despite heavy leakage from tin pipes between the retort and gasometer, it had risen four or five feet, and when no gas was being consumed it rose eight inches an hour, equivalent to 100 cu ft. The retorts each held about 1½ cwt of coal, and produced 350 cu ft each per day, with one charge per day.

Within the factory, the Dye House and parts of the Warehouse began to use gas at 6 to 7 am, and by 3 to 4 pm it was used in the other departments and remained in use six or seven hours a day. In the dyehouse, one gaslight instead of two was found sufficient to light each boiler, but Hutton was unable to estimate the consumption of each light. He complained that "sometimes Mr. R.G. lights up a grand crown he has stuck at the front of his Counting House, in which there are ab't 80 lights - most of the gas is indeed consumed at this quarter."[2] The difficulties faced by Hutton enhance the earlier achievement at Pollokshaws. At Kirkland Mill,[3] meanwhile, Messrs

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1. Soho MSS Letterbook 31/12/1809.
2. Soho MSS Letterbook 31/12/1809.
3. Kirkland Mill built in 1794 by A. Neilson for cotton spinning, converted to flax in 1794, and rebuilt as an advanced "palace" works in 1800 after a fire.
   By 1838 the mill employed 681 people, consumed 1,000 tons flax and hemp per year, with 280,000 spindles making yarn, canvas, sacking etc. At nearby Wemyss Coal Pit, 20 men mined parrot or gas coal which was probably used at the Mill.

   New Statistical Account Vol IX p. 397.
   Dundee Textile Industry 1790 - 1885 E. Gaudie, Ed. (Scottish Historical Society, 1969) p. 10.

Neilson originally hoped to fit the entire gas apparatus during 1809, while the mill was stopped for several weeks to fit a new water wheel. The pipes were fitted then, but gas lighting was delayed until 25 January 1810. Recurrent problems, however, led to a visit by Murdoch in April 1811 when he promised to use "every exertion in my power to complete Messrs. Neilson & Co. apparatus to their satisfaction."[1] By 1812, "besides the Mill, Heckling Shop, Counting House, Mechanics' Shops, Workhouse, &c, the gas is extended below ground to the Partners' Dwelling houses"[2] 300 and 700 feet distant. Coal costing 6s gave light for three hours, equivalent to five stones of candles worth £4 3s 4d. The fire hazard of lighting the mill was greatly reduced. Each flame was twice as bright as an oil or candle flame, and produced so much heat that it was no longer necessary to pay for steam-heating the mill.

During August 1809, Hutton[3] was informed that Messrs Monteith and Bogle planned to light their Blantyre factory[4] with gas, but

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1. Soho MSS Letterbook 26/4/1811.

2. 'D.D.' of Kirkland The Gas Lights - A Poem (1812, Leith) (Nat. Lib. Scot. 3/717; Boulton & Watt Coll., Birmingham Ref. Lib.). 'D.D.' described the apparatus as an appendix, but in the poem rebuffed the cost of installation.

   "Gude e'enin Gas, we've heard your praises wide,
   Your high flown puffs o' insolence an' pride"
   "Mind what was paid to Bolton [sic], Watt, & Co.,
   For you unfinished, as ye left Soho
   An' what's been gi'en to fit ye up sinsyne,
   Wad maist had toomed a hale Potosian mine"

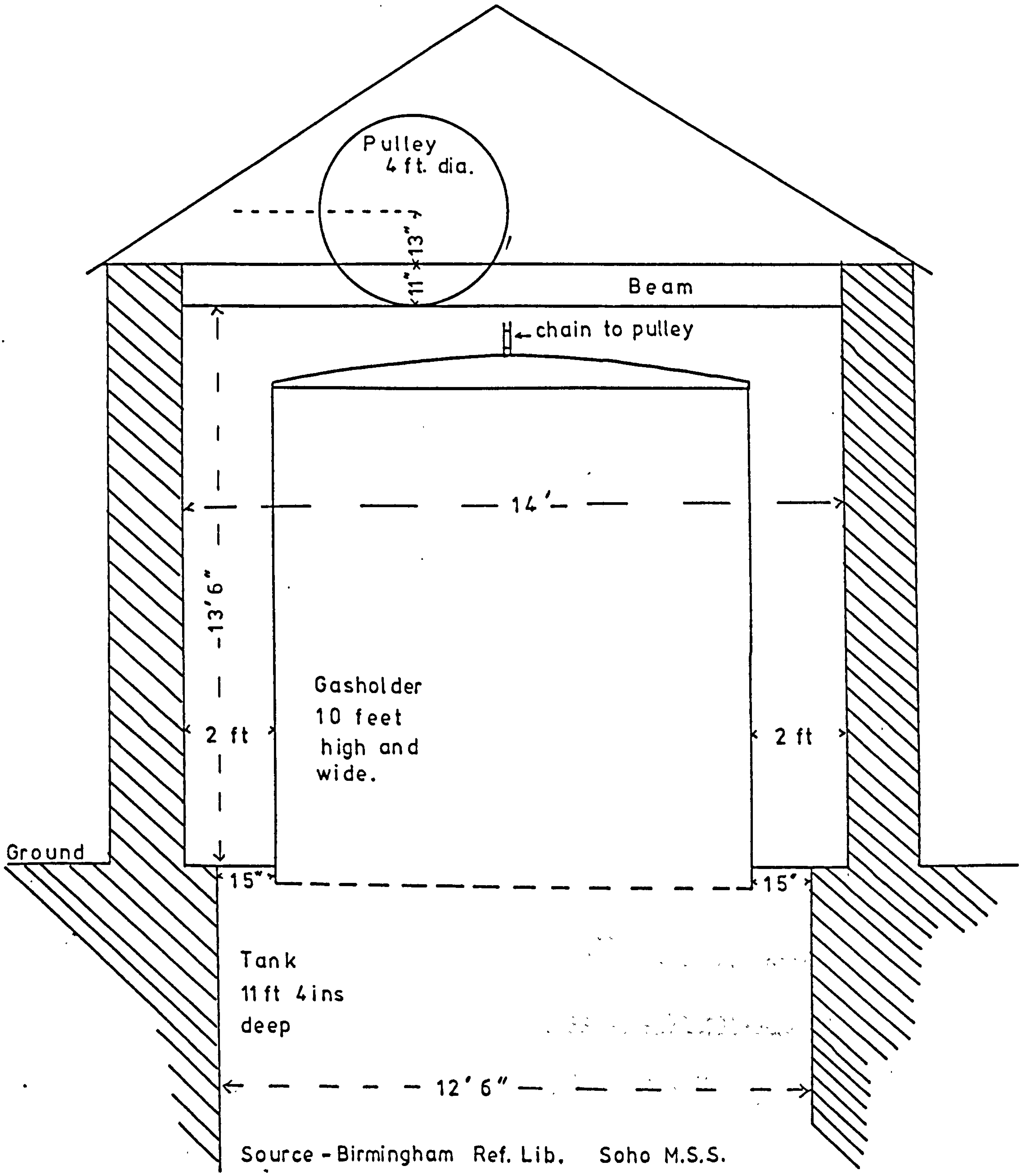
3. Soho Mss Letterbook 18/8/1809.

4. Blantyre Mills, built in 1785 by David Dale and James Monteith, powered by R. Clyde for spinning water-twist cotton yarn. 1791 a second mill for spinning mule-twist. Also in 1813 a weaving factory with 463 looms on steam and water power. By 1830s, 458 spinners and 915 weavers, working 6 am to 7.45 pm. New Statistical Account - Lanark Vol VI pp. 322-5.

   In Yorkshire also, Boulton and Watt found mill owners employing

Fig.1.7

Cross Section of Gasometer House for Messrs Neilson & Company 1809



Source - Birmingham Ref. Lib. Soho M.S.S.

Table 1.8 Boulton and Watt Accounts - Gas Apparatus to Scotland

Date	Customers	Foundry Charge	Soho Charge
1808 - 9	Neilson & Co	£420 14s 7d	£503
1808 - 9	R. Gillespie & Co	£307	£378
1809 - 10	Gillespie & Co (additions)	£2 12s 11d	£2 19s 4d
1809 - 10	Neilson & Co	£24 10s 11d	£28 10s 0d
1810 - 11	Neilson & Co	£207 2s 10½d	£249
1810 - 11	Gillespie & Co	£32 7s 0d	£37 10s 0d

Source: Soho MSS Box 30

since the work could not be completed by the following winter, they did not place a definite order for equipment. They did enquire at Soho how large the apparatus would be to supply 1,000 candlepower for six hours a day, but later had it built privately and not by Boulton and Watt. The third and final Soho gas installation in Scotland, was made in John Maberley's Broadford Mill,[1] Aberdeen, in 1814. It was,

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local craftsmen, like Messrs. Glover, Whitesmiths, to build cheaper private gasworks.

W.B. Crump Leeds Woollen Industry 1780-1820 (1931) p.156.
W.O. Henderson Industrial Britain Under the Regency (1968) p. 162.

1. Broadford Mill and a mill near Montrose were purchased in the 1800s by J. Maberley, a former London draper, and MP for Abrington. He was a prominent reformer, and helped the 1818 formation of Aberdeen Exchange and Deposit Bank. After the Bank failure in 1832, the business was acquired by Richards & Co who became one of the main linen companies.

Power-loom weaving was not introduced at the Mill until 1824, by John Maiben & Co. Details of the gas installation are not extant.

W.H. Marwick, Economic Developments in Victorian Scotland (1936) p. 63.

Aberdeen Philosophical Society 1903 Vol. IV

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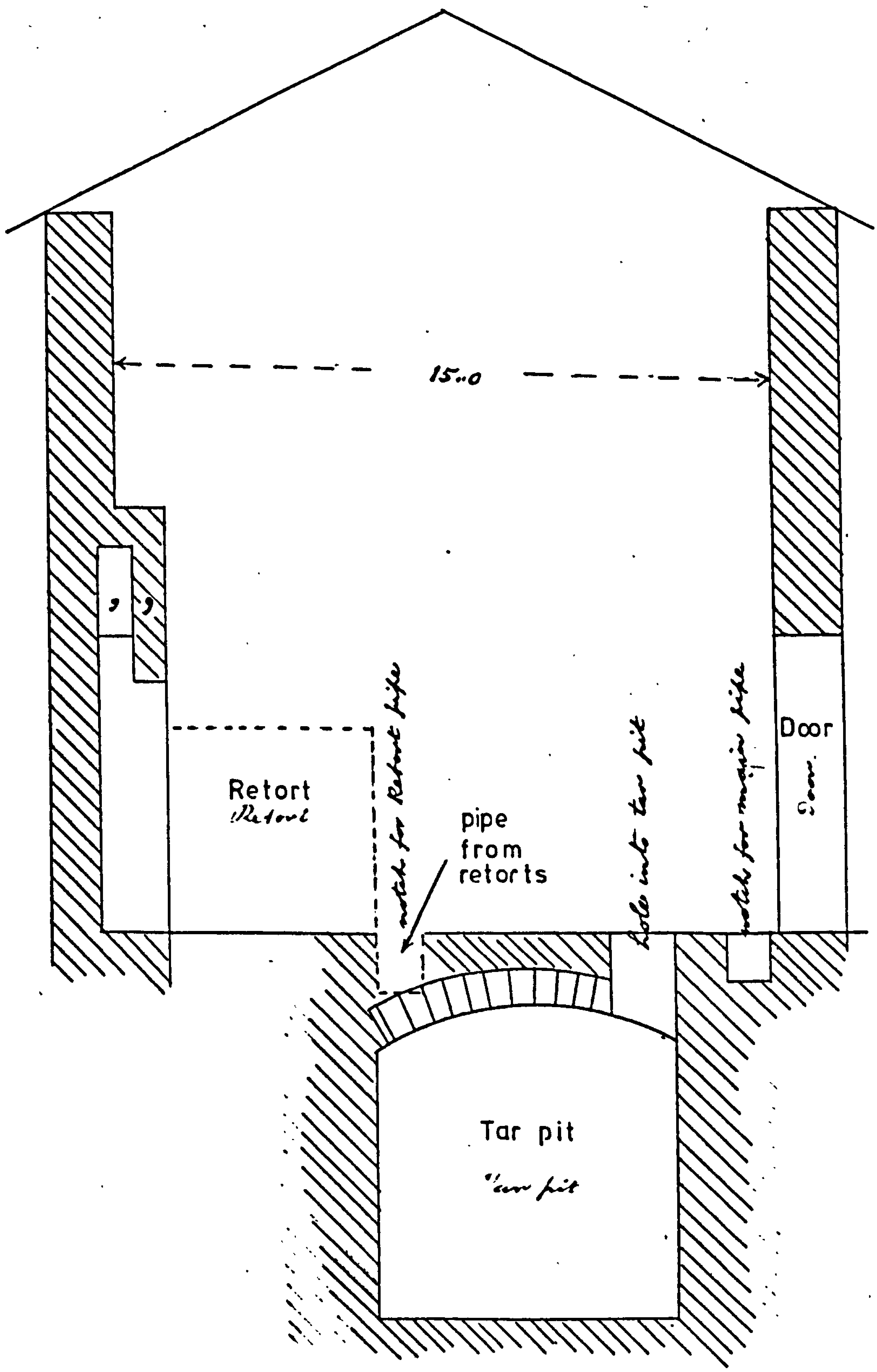
Fig. 1.9 Plan of John Maberley's Gasworks 1814

Source - Birmingham Ref. Lib.

Fig. 1.10

John Maberley's Retort House 13/3/1815



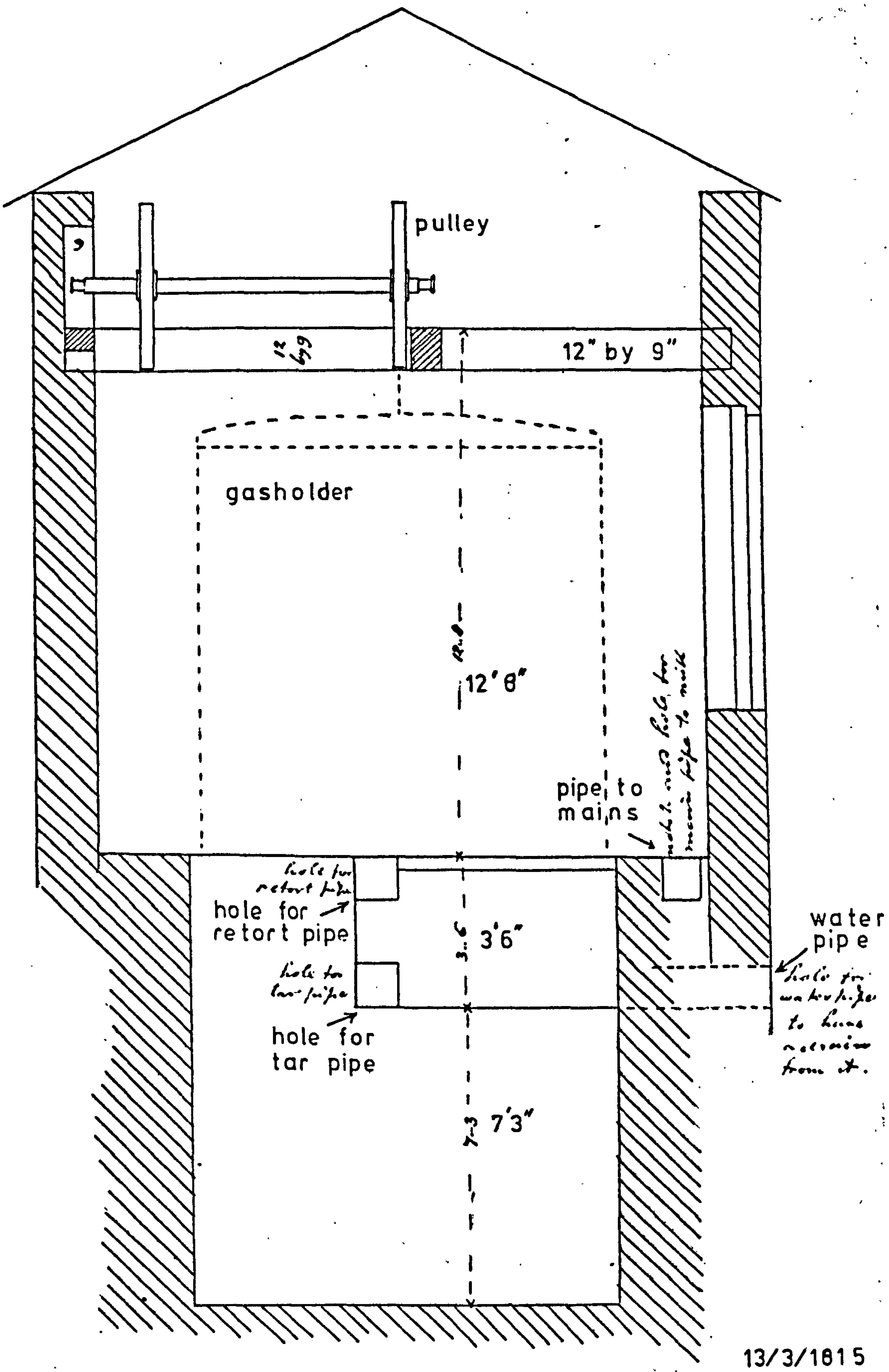
Source - Birmingham Ref. Lib.

Fig. 1.11

Longitudinal Section of Maberley's Gasworks 1815

Fig. 1.12

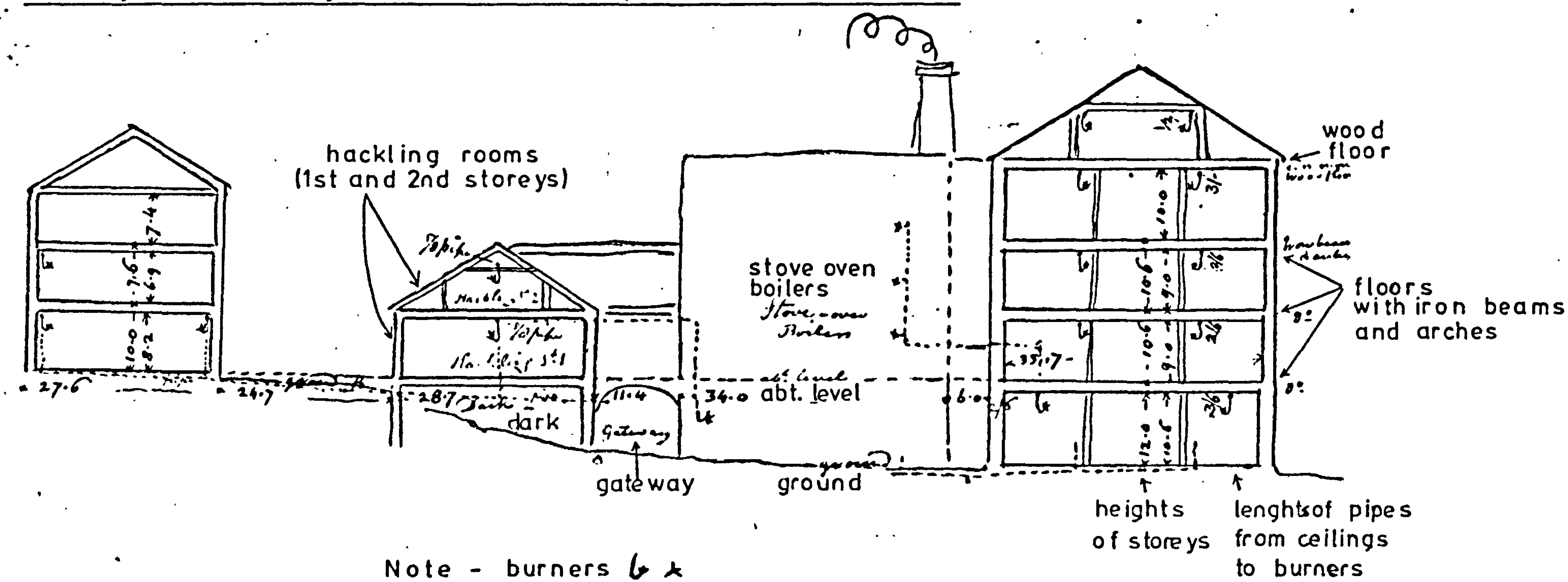
Soho Gasometer House for John Maberley 1815



Source - Birmingham Ref. Lib.

Fig. 1.13

Maberley's Mill - Longitudinal Sketch of Pipes and Burners 1815

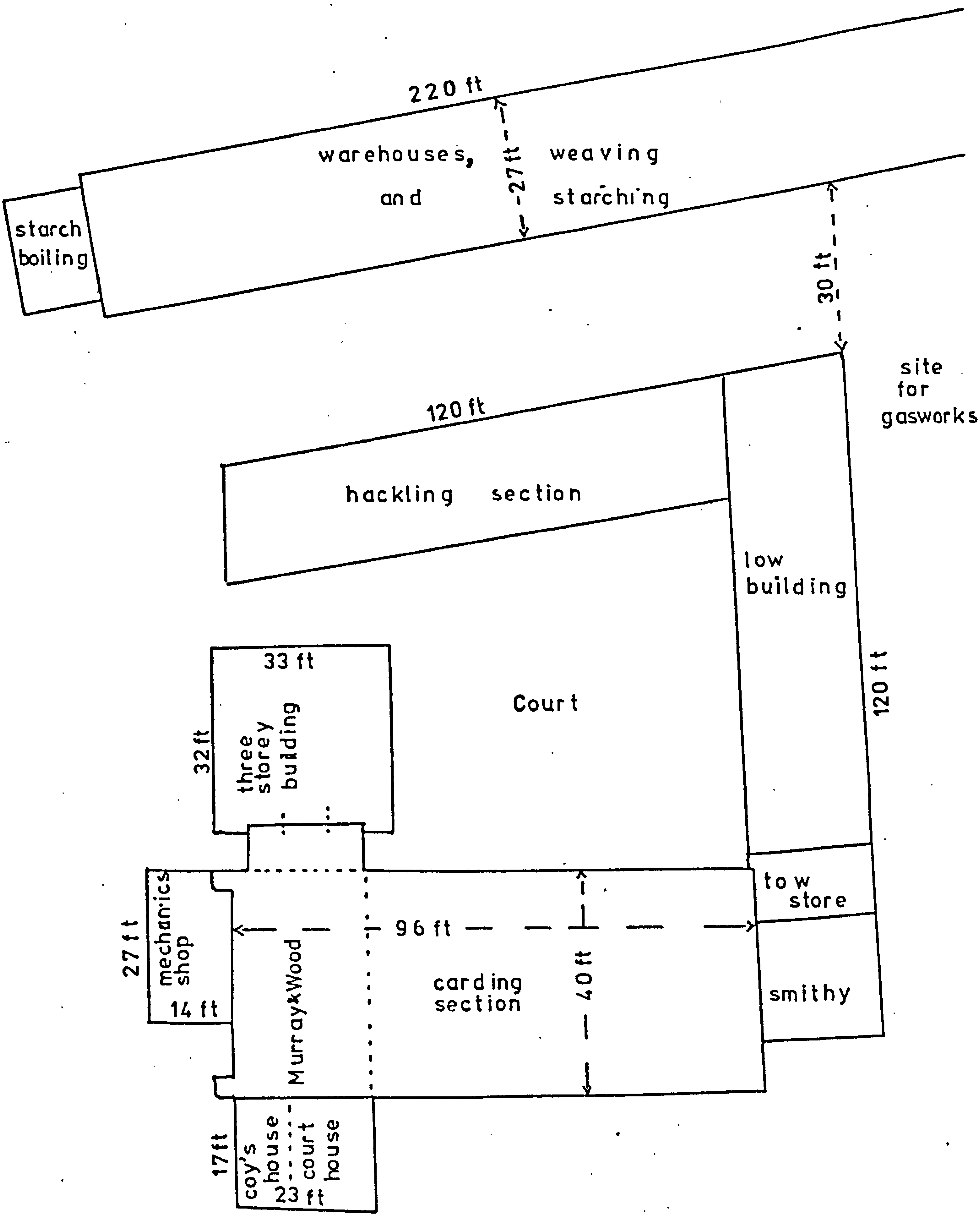


Note - burners

pipes ----

Source - Birmingham Ref. Lib.

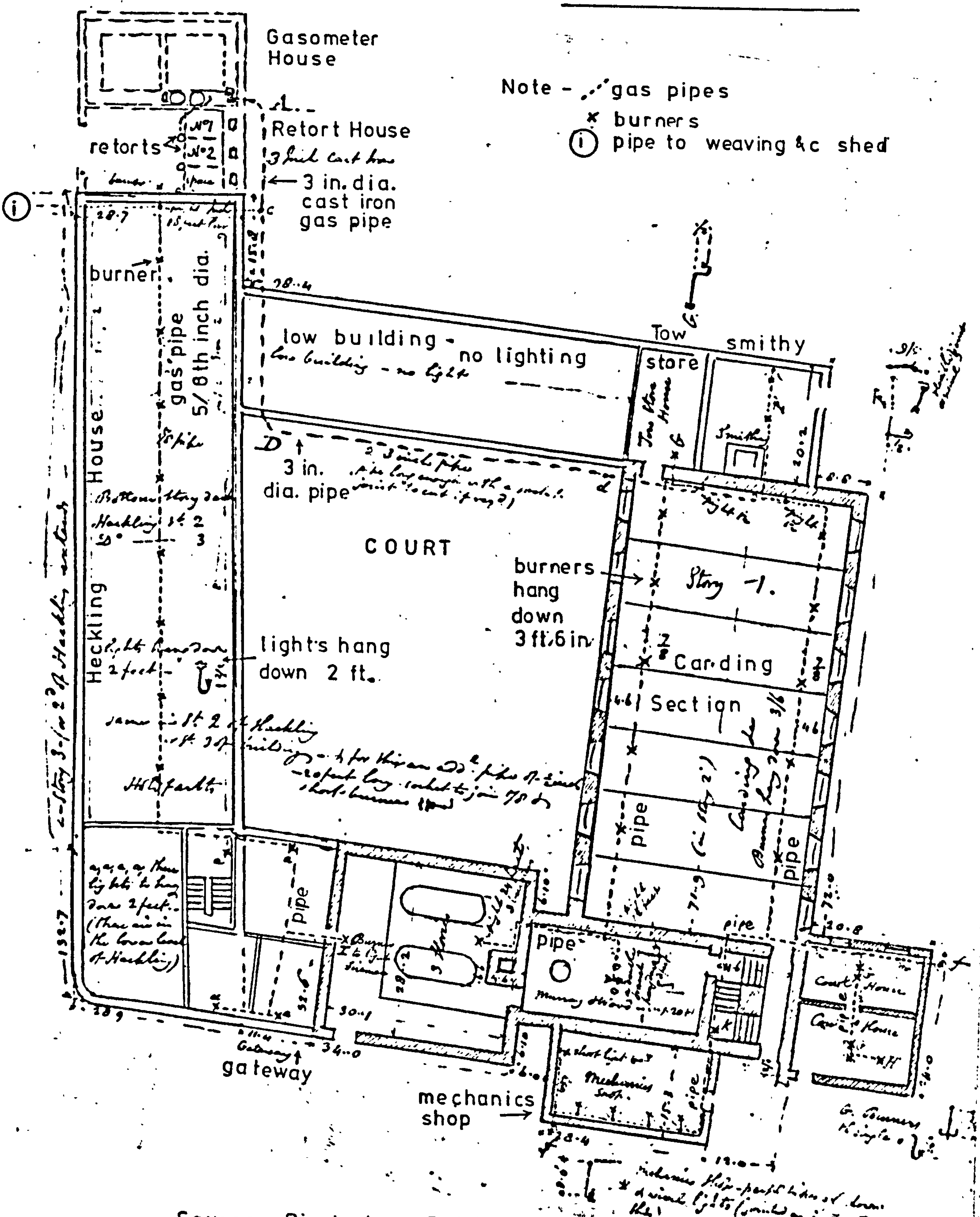
Fig. 1.14 Plan of Broadford Mill, Aberdeen 12/5/1814



Source - Birmingham Ref. Lib.

Fig. 1.15
Broadford Mill - Plan of Gaslight Arrangements 1815

(I) Part of Ground Floor

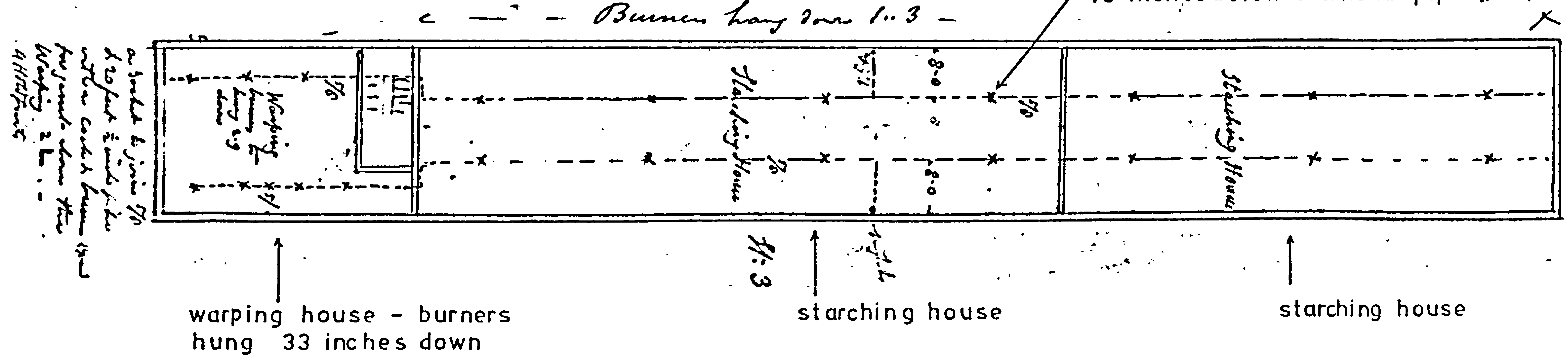


Source - Birmingham Ref. Lib.

Fig. 1.16
Broadford Mill - Plan of Gaslight Arrangements 1815
(II) Weaving &c building

Fig.1.17 Gas Installation at Maberley's Mill, Aberdeen 1815

Weaving &c Building PLAN : 3rd storey



Murdoch's Gas Burners

Examples from Strutt's Milford Mill, Derbyshire 1806

Source - Birmingham Ref. Lib. Soho M.S.S. Box 30

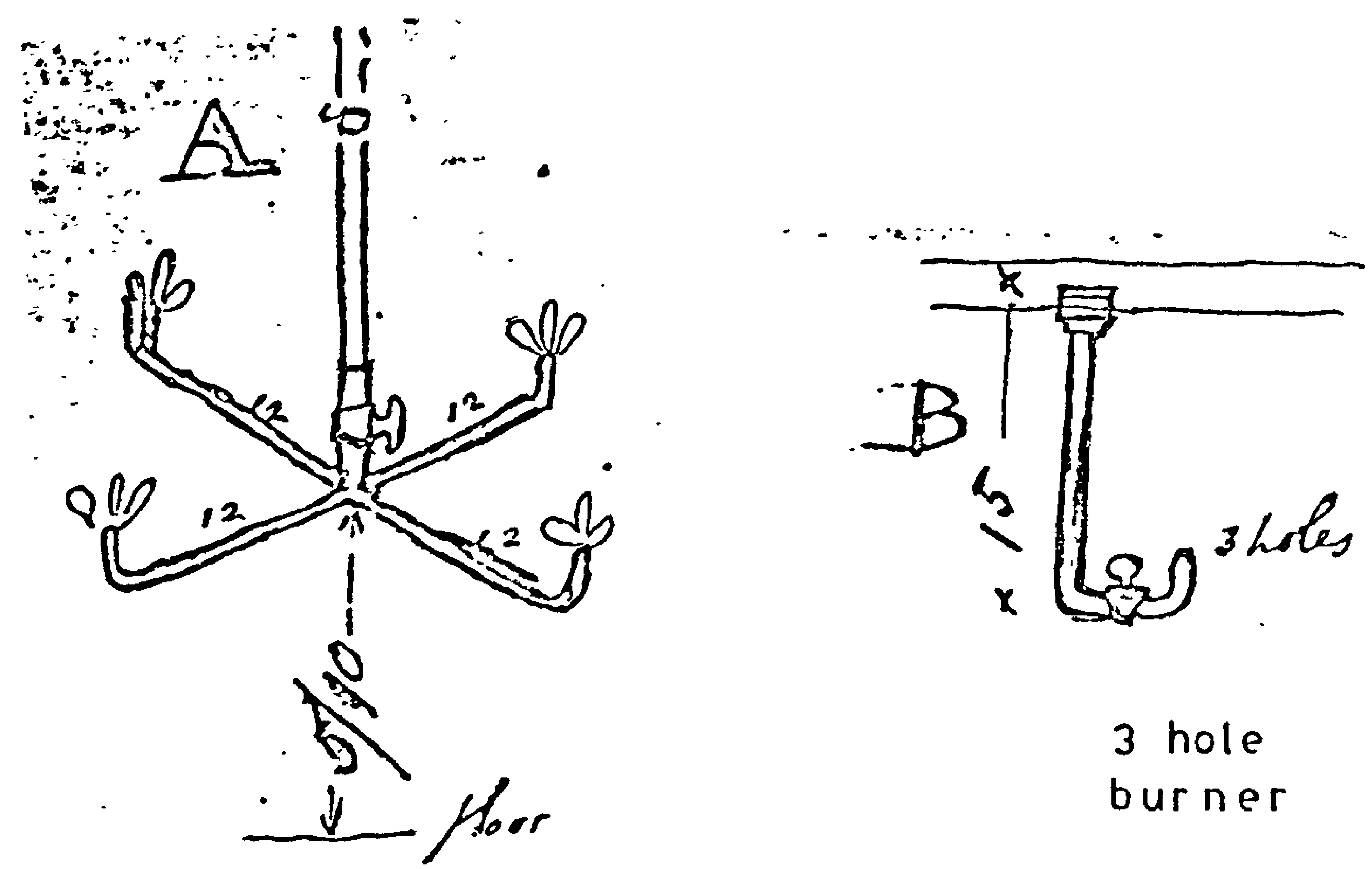
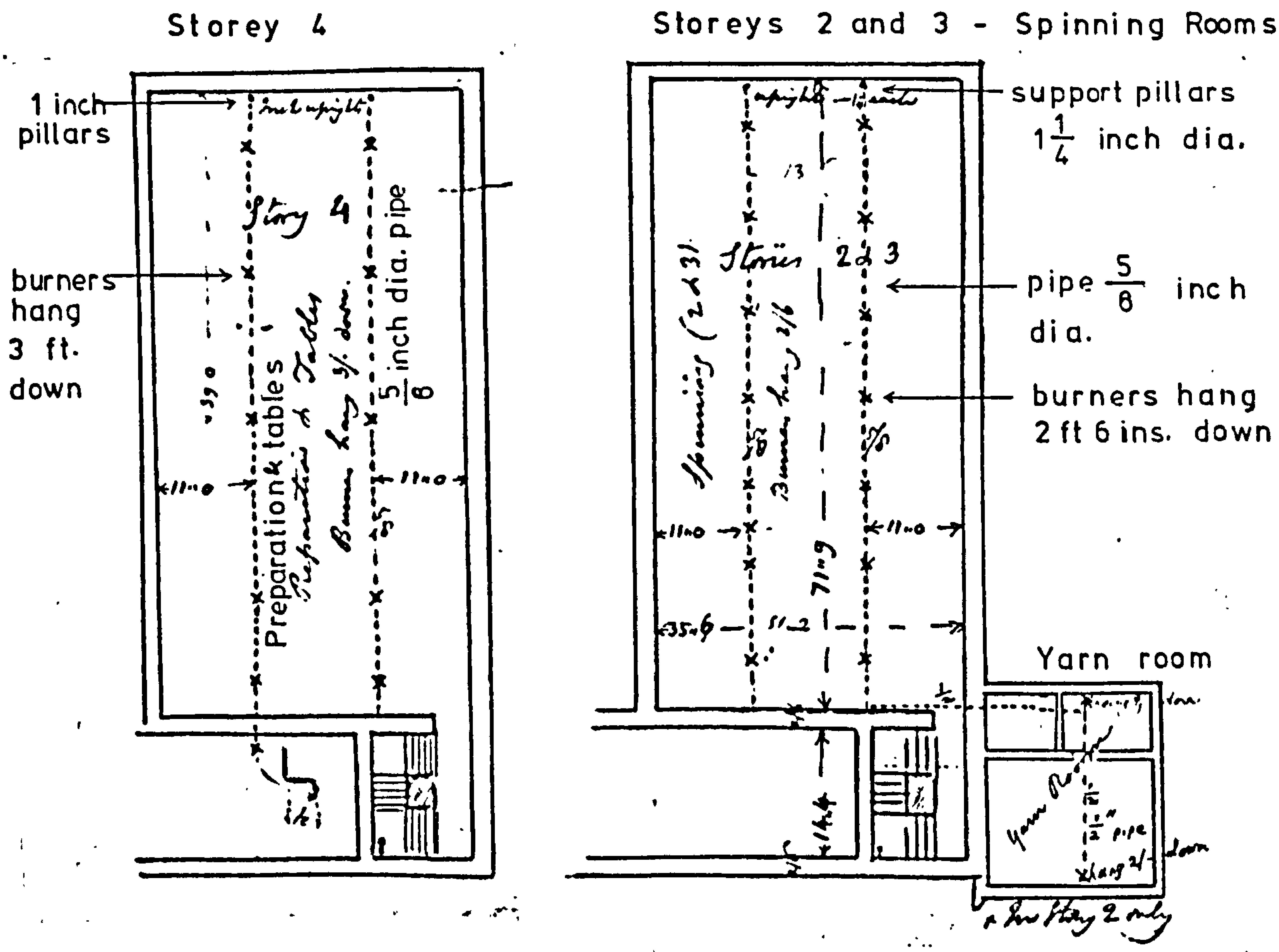


Fig. 1.18

Broadford Mill, Aberdeen - Plan of Lighting Arrangement in Carding &c building



Total Lighting Estimate for Broadford Mill 12/11/1814

Boiler house	1
Drying stove over boiler	3
Engine	2
Street outside Mechanics shop	1
Mechanics shop	5
Street outside Count house	1
Count house	5
Mill (carding&c):	
staircase	5
storey I	11
" II	16
" III	14
" IV	11
garret	12
Smithy	2
Gasworks house	2
Hackling rooms (2 storeys)	21
Weaving&c building:	
Blacksmith	3
Shipping store	4
Engine	1
Yarn store	3
Cutting room	3
Starch boiler	1
storey II:	
Starch house	6
Picking room	2
Cloth received	3
storey III	
Starch house	6
" "	8
Warping room	7
Garret light	1
Staircase	2
Outside lights	3
Total number of gas burners	164

Equipment installed adequate for 200 lights each of 2½ candlepower, requiring 250 cu ft gas per hour. Used 6 hours per day (night only) = 1500 cu ft, supplied by "one oven retort" and stored in two gasholders (1000 cu ft each).

Retort house built at end of new Hackling house " with water from the small engine."

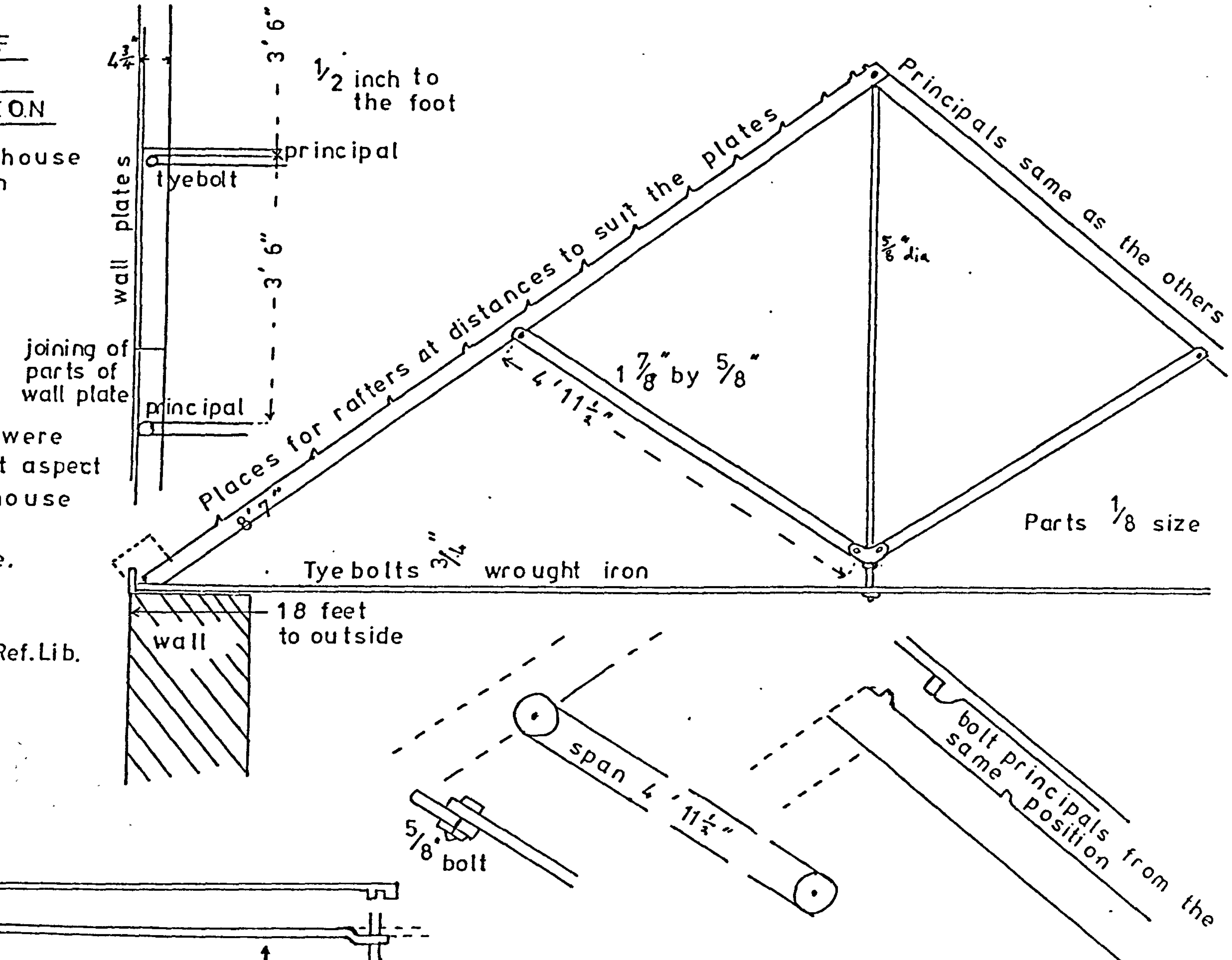
Source - Birmingham Ref. Lib.

Fig. 1.19
FIREPROOF
IRON ROOF
CONSTRUCTION

Soho retort-house roof for John Maberley, Aberdeen 18/3/1815.

Iron roofs were an important aspect of retort-house design and expenditure.

Source - Birmingham Ref. Lib. Soho M.S.S.



The principals as above, a tyebolt to every third one. The rafters, each iron 5/8" deep and 3/16" thick, with notched ends to go on the principal.

in fact, one of the last ever installed by Boulton and Watt who had spent £2 - 3,000 on tooling-up for production and "instructed a number of workmen, at great expense",[1] but failed to maintain an overwhelming technological lead, or to prevent F.A. Winsor[2] from obtaining Parliamentary sanction for his Gas Light and Coke Company[3] in London in 1810.

In the Glasgow area private experiments[4] on gaslight made little progress between 1805 and 1810, though in January 1810 Gillespie[5] gave a detailed account of the Soho plant installed at his Anderston works. About the same time, two city bakers, John and Robert Hart,[6]

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1. Schofield gives the last date incorrectly as 1812, and his theory of antiquated technology appears unlikely.
R.E. Schofield The Lunar Society (1963) op. cit., p. 417
B.P.P. 1809 (220) III Select Committee on the Gas Light and Coal Company Bill pp. 56(370), 59(373).

2. Hofrath Friedrich Albert Winzler (1763-1830), anglicized Winsor.
G.E. Davis "Distillation of Coal", Journal of the Society of Chemical Industry Vol II p. 516.
S. Everard, History of the Gas, Light and Coke Company 1812-1949 (1949), pp. 17-18; biography p. 55.
Winsor's son later ran Brick Lane gasworks, London. Ibid. pp. 87-8.

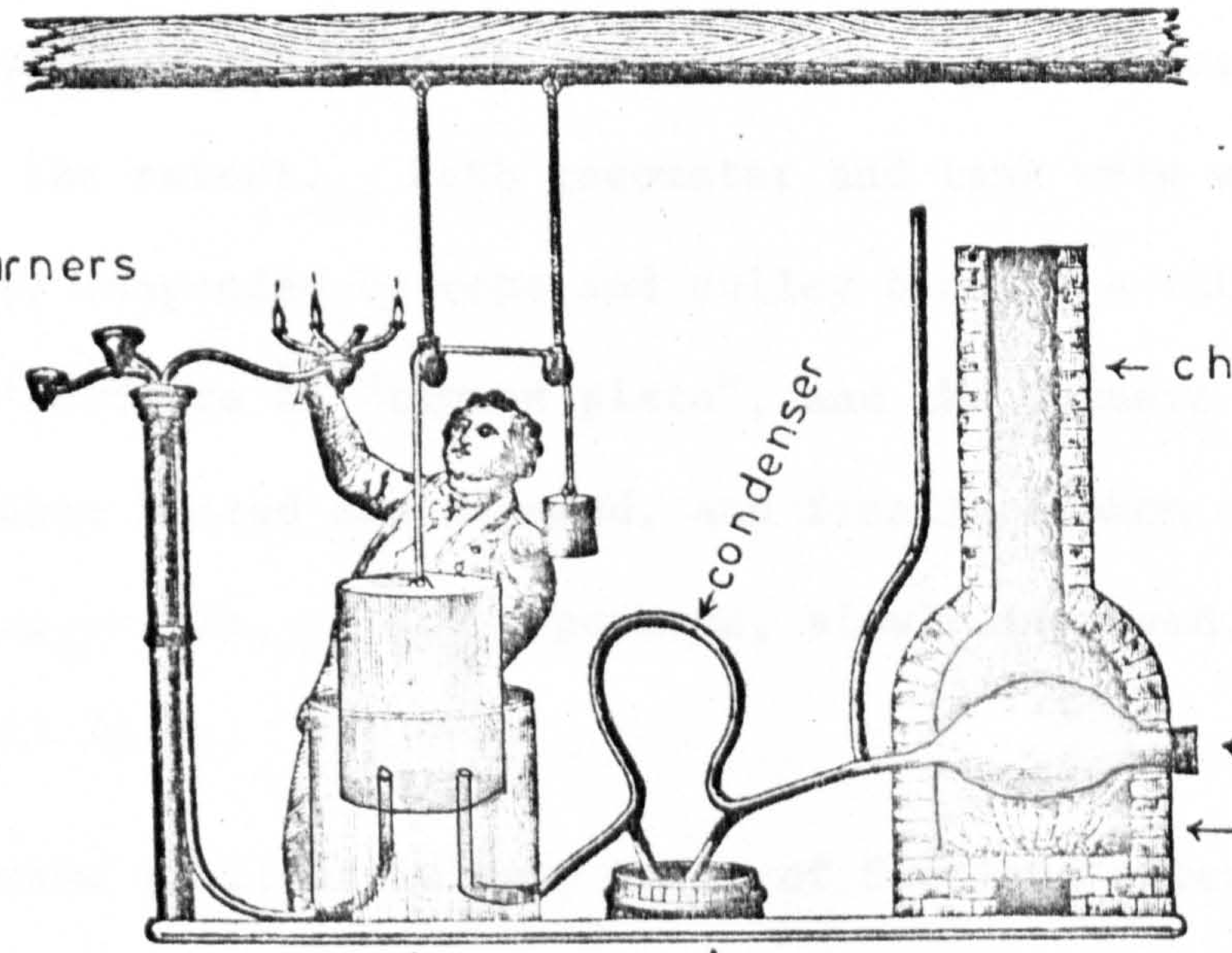
3. Boulton and Watt successfully opposed Winsor in 1809 on the grounds that they, by not patenting Murdoch's apparatus, had encouraged free competition whereas the Company would be a monopoly; and a Chartered Company with limited liability for shareholders would have great advantages under the Bankruptcy Laws compared to the partnership at Soho. Sir Robert Peel believed the Company would injure the public interest by reducing competition, and Watt stated it would sabotage his work by bribing his skilled gas engineers into leaving Soho. If the Company began, Watt stated he would "get out of the business as soon as I could."
B.P.P. 1809 (220)III Select Committee on the Gas Light and Coke Company pp. 59(373), 60(374), 53(367), 45(359).

4. Several attempts were also made to light separate shops with gas in Dundee about 1805, but on a small scale they were not economical and were abandoned. New Statistical Account Vol XI p. 9.

5. A. Fergus "Opening Address" (1880-2) op. cit.

6. T. Thomson "On Coal Gas" Proceedings of the Philosophical Soc. of Glasgow 1843-4 Vol. I.
Mechanics Magazine 1844 Vol. 40 pp. 410-12.
A. Murdoch Light Without a Wick (1892) op cit., pp. 45-6.
Messrs Hart claimed inspiration from R. Buchanan's book of 1810,

Fig.1.20 Experimental Coal Gas Apparatus c.1810



Design probably similar to apparatus by F. A. Winsor

Sources - T. Newbigging Ed. King's Treatise (1878) Vol. I p. 21

S. Parkes The Chemical Catechism 1816 7th Edn. p. 457

were experimenting with a quite primitive gas apparatus. Cannel coal could not be obtained in Glasgow, and the common coal they used gave a poor grey flame. This may have been the main discouragement for other amateurs, but J. and R. Hart tried to enrich the gas by passing it over hot charcoal in a 1½ inch cast-iron pipe placed in the furnace below the retort. Both gasometer and tank were wooden barrels, the former suspended by rope and pulley beneath a table in the shop. Gas pipes were of "tinned plate", and the burners were made from glass tubes heated and tapered, and finally broken off to give the correct aperture. This apparatus, slowly improved, remained in use until 1818.

Gas-light became familiar in many parts of Scotland after 1810 on a miniature scale. Coal-dust was placed in the bowl of a clay tobacco-pipe, and the top of the bowl sealed with clay, or "a cement made of beer and sand".[1] The bowl was then heated on a domestic fire, with the stem protruding through the grate, and as gas was

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but this contains little practical detail on gas-light, and describes mainly steam-heating; they must have learned more by verbal communication with Buchanan, who himself may have been the investigator employed by J. Finlay & Co in 1807, (vide infra p. 155)

Cf. R. Buchanan, Practical Treatise and Descriptive Essays on the Economy of Fuel and Management of Heat (1810, Glasgow) pp. 70-77, 251.

1. The Mechanic and Chemist - A magazine of the Arts and Sciences 1840 Vol VI Part II p. 80 (Scot. Nat. Lib.).
R.H. Patterson, "Gas and Gas Lighting" British Manufacturing Industries (1877) 2nd Edn. G.P. Bevan, Ed. p. 154
R. Routledge, Discoveries and Inventions of the Nineteenth Century (1876) p. 550.
The English Mechanic 1865 Vol. I, p. 129.

It is probable that F.A. Winsor introduced the tobacco pipe experiment in 1804. Vide

Cow Pox and Gas Lights, Contra Malice and Ignorance (c.1805, London, pub. D.N. Shury) Birmingham Ref. Lib., p. 10.

forced out through the stem it was lit at the mouthpiece. Thomas Graham[1] (1805 - 1869) was amused by such experiments as a child, in 1811-12.

John Maiben was the first resident Scottish engineer to challenge Boulton and Watt's technology in coal-gas equipment. With workshops in Perth, he designed a gas apparatus substantially smaller than the Soho installations, and suitable for any tradesmen or others who spent above £20 a year on illumination.[2] The brilliant light, easy to use, was "equally fit for great public works, or the private houses of men of fortune ... susceptible of being made the subject of splendid and beautiful ornament" by concealing the burners on statues. It was "the safest of all lights", and could be used in public rooms, lobbies and passages, Assembly Rooms and Theatres.[3]

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1. R.A. Smith "The Life and Works of Thomas Graham", Proc. Royal Philosophical Society of Glasgow 1883-4 Vol. XV p. 261.
   The method was used for many subsequent decades, as at Kilsyth in 1830.
   Rev. A. Anderson, A History of Kilsyth (1901, Edinburgh) p.129.
   The English Mechanic 1865 Vol. I p. 129.
   The Penny Magazine of the Society for the Diffusion of Useful Knowledge (1834) p. 427.

   The tobacco-pipe method was used for testing coals while sinking a new coal pit and the "black fluid" paraffin in Boghead or "Scaly Bleas" was first noticed by Mr Douglas in such a test. I.I. Redwood, Mineral Oils and Their By-Products (1897) pp. 3-4, quoted from Glasgow Weekly Herald 18/11/1865.

2. John Maiben and Co.
   A Statement of the Advantages to be Derived from the Introduction of Coal Gas into Factories and Dwelling Houses as a Substitute for the Lights Now in Use (1813, Perth) p. 40. (Perth Ref. lib. 'Perth Pamphlets' Vol I Pamphlet 3 ref. L.040; Institute of Gas Engineers, London 'Chandler Collection' Vol. 8).

3. Ibid., p. 10.
   It is uncertain whether it was the same "John Maiben & Co." who built one of the first powerloom linen factories at Broadford, Aberdeen, in 1824.
   W. Watt, "Fifty Years Progress in Aberdeen", Aberdeen Philosophical Society 1910 Vol. IV.

Maiben's horizontal retorts,[1] which he patented in 1810, were quite unlike Murdoch's and were designed for the rapid carbonization of thin-layers of coal placed on two metal pans[2] which could easily be inserted and later withdrawn to remove the coke. They were the prototype[3] for horizontal flat retorts designed by a famous English gas engineer, Samuel Clegg, six years later. By experiment Maiben found that in normal, strongly heated retorts, the first gas produced was unsuitable for combustion, the middle period of distillation gave the best illuminating gas, and the final period produced a sulphurous gas which gave little light and emitted sparks.[4] His new retorts, resembling "a folio volume"[5] minimised the first period by

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1. 2/5/1810 (Pat. 3333) Abridgements of the Specifications Relating to the Production and Application of Gas (Excepting Gas Engines) 1860 (Comm. of Patents) "Improvements in the Construction of Apparatus for making Carbonate Hydrogen gas from pit coal, and using the same in lighting mills, factories, houses, shops, lamps &c herewith."

2. J. Maiben, A Statement (1813) op. cit., p. 27. Reserve pans filled with coal made re-charging far quicker than with conventional retorts.

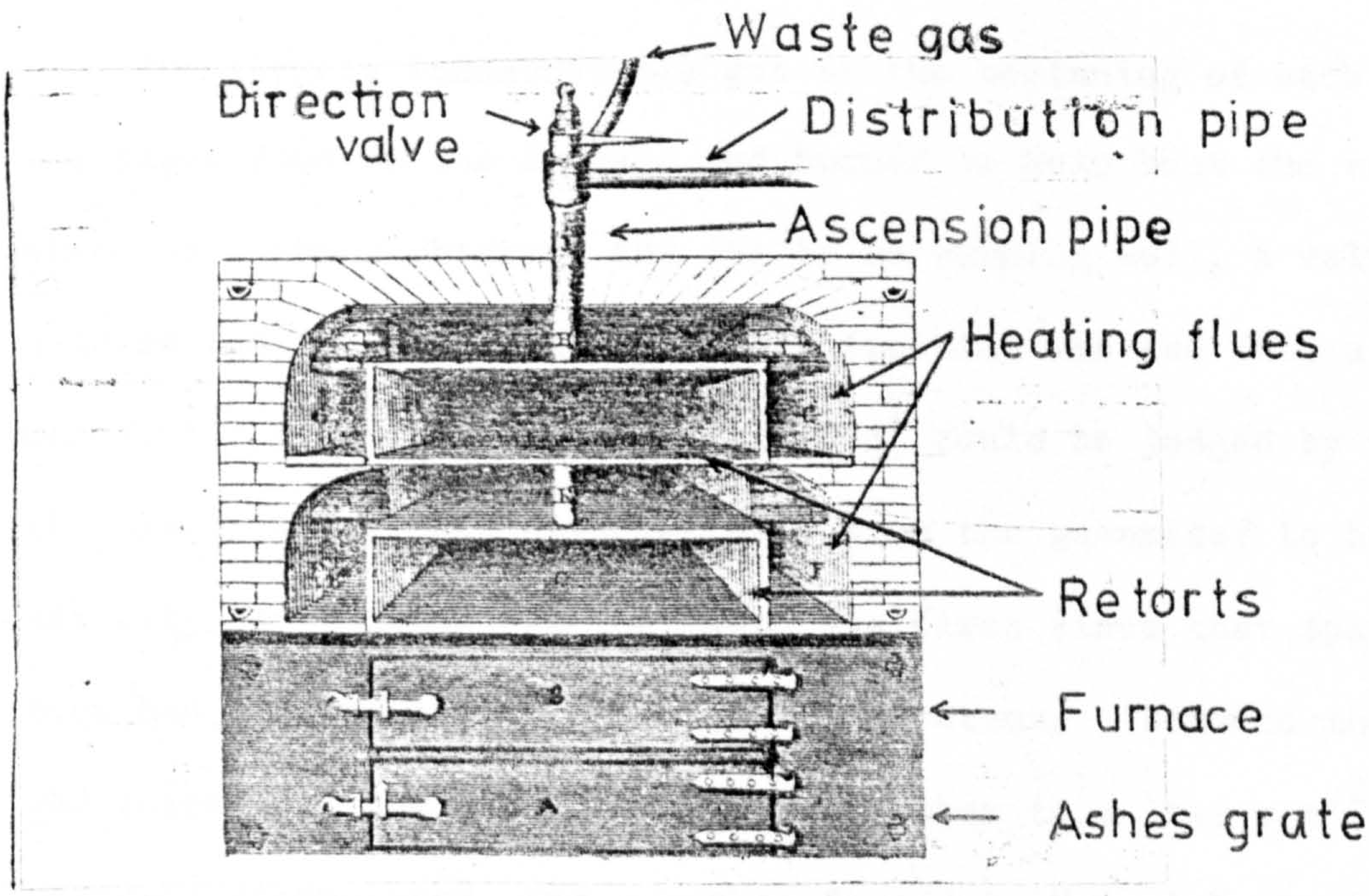
3. "Further Accounts of Mr Samuel Clegg's Improvements in Gas Illumination", Journal of Science and the Arts 1817 Vol. III p. 132; J.G.L., 14/7/74, p. 44
   F. Accum, Gas Works in London (1820) op. cit., pp. 14-15
   W. Richards, A Practical Treatise on the Manufacture and Distribution of Coal Gas (1877), pp. 82-3.
   "Mr. Clegg's retort is made upon the same principle as the new Scotch stills", a statement which gives clear indication that Maiben's retorts were widely used, vide The Analectic Magazine 1817 Vol IX pp. 197-8.
   T.S. Peckston, The Theory and Practice of Gas Lighting (1819) pp. 120-3.

4. J. Maiben, A Statement (1813) op. cit., pp. 24-5.

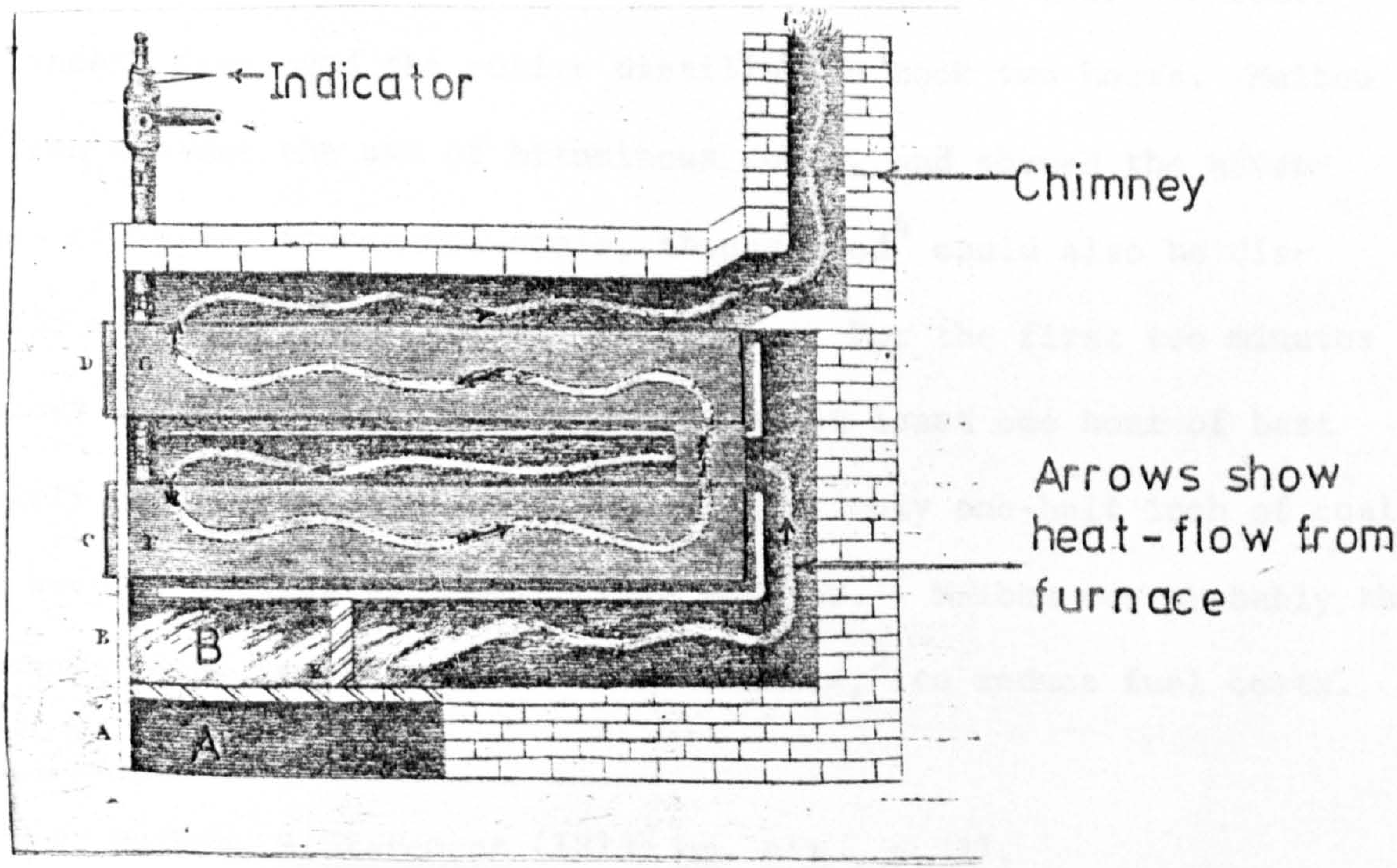
5. The retort-mouth was sealed by a metal plate, with a groove containing a wet sand 'lute' which fitted against the retort, where it was held in place by tightening a screw. The arrangement was as advanced as any used in large city gasworks in the 1820s.

Fig. 1.21

John Maiben's Gas Retort 1813



Front View



Side View

Source - Perth Reference Library

rapid heating, and by equalizing the rate of distillation throughout the coal being processed, enabled the different fractions of gas to be controlled manually.

The largely incombustible gas at the beginning of each charge, was piped down to the furnace and burned to help heat the retorts. When the workmen observed the gas to be burning well, a valve was altered and the high quality middle fraction was fed into a gasometer. If required, the last fraction[1] could be judged by timing the distillation, and diverted away from the gasometer to be used directly for heating premises with gas fires since that sparky fraction had low luminosity but high heat content. Between the retort and gasometer, the gas passed through tubes to a 'tar pot'[2] where residues accumulated, and was then forced to "wimple" through partitions in a water purifier box. Each retort[3] held 25lb of coal, two inches deep, and the entire distillation took two hours. Maiben advised against the use of bituminous coals, and showed the advantages of splint and cannel coals, though wood[4] could also be distilled and gave a high quality charcoal. For the first ten minutes useless vapour was produced, followed by at least one hour of best quality gas. For an ultra brilliant gas, only one-half inch of coal was used in charges lasting fifteen minutes. Maiben was probably the first to place two retorts over one furnace,[5] to reduce fuel costs.

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1. J. Maiben, A Statement (1813) op. cit., p. 37.
2. Wrought-iron retorts were preferred to cast-iron.
3. Abridgements (1860) op. cit., p. 14.
4. J. Maiben, A Statement (1813) op. cit., pp. 27, 37.
5. Later 'ovens' contained up to 12 retorts, and in a large gasworks the 'ovens' were placed side by side in retort 'benches'.

In 1813 Maiben advertised his equipment for sale throughout Scotland:

> In some of the earlier attempts on this subject, egregious failures took place, which had the effect of creating no small degree of incredulity and misapprehension in the public mind.... Better contrivances have been found out, and that one in particular constructed by Messrs BOULTON & WATTS [sic] is now in frequent use. [But] Having discovered an apparatus for which we have received a Royal Patent, and which we think is more free from important defects to which the other is still liable, we presume, in this manner [of pamphlet advertizing], to recommend it to the notice of the public. 1

The market which they hoped to develop was that of small industrialists and merchants, and the advantages of the apparatus included many features which reduced the initial cost.

The gas-holder was stationary, making it more durable and removing the need for an expensive "large room and building to protect it."[2] It cost one-twentieth of the amount required for Murdoch's holders which were raised by gas pressure and forced gas out by the weight of the gas-holder. The water-tank and gas-holder worked best when placed below-ground level. Gas entered at the base of the holder, through a perforated plate which increased the area of contact for washing impurities away, while water displaced from the holder escaped through a siphon tube. A constant but regulated flow of water into the gas-holder was then used to force the gas out into the

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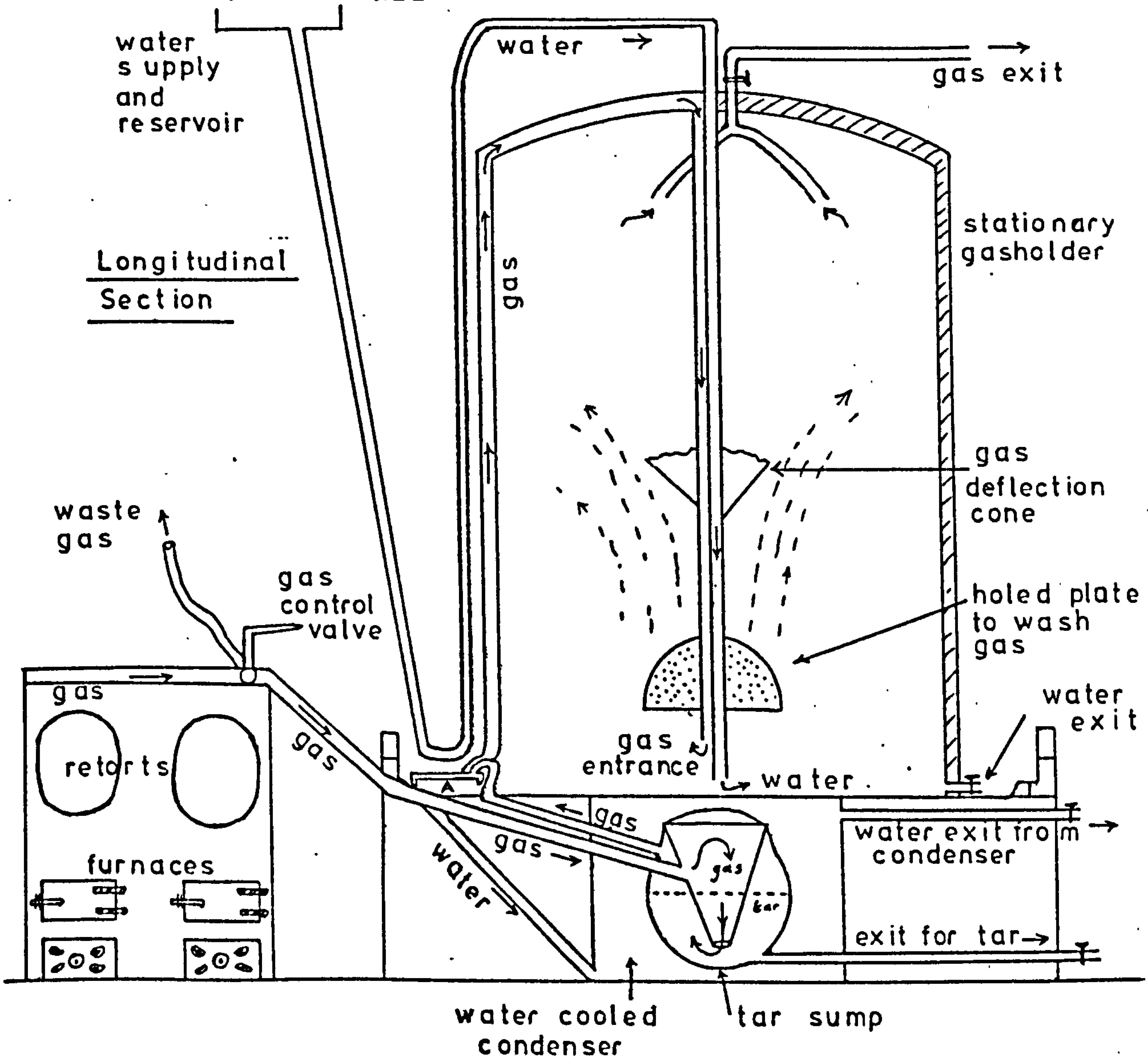
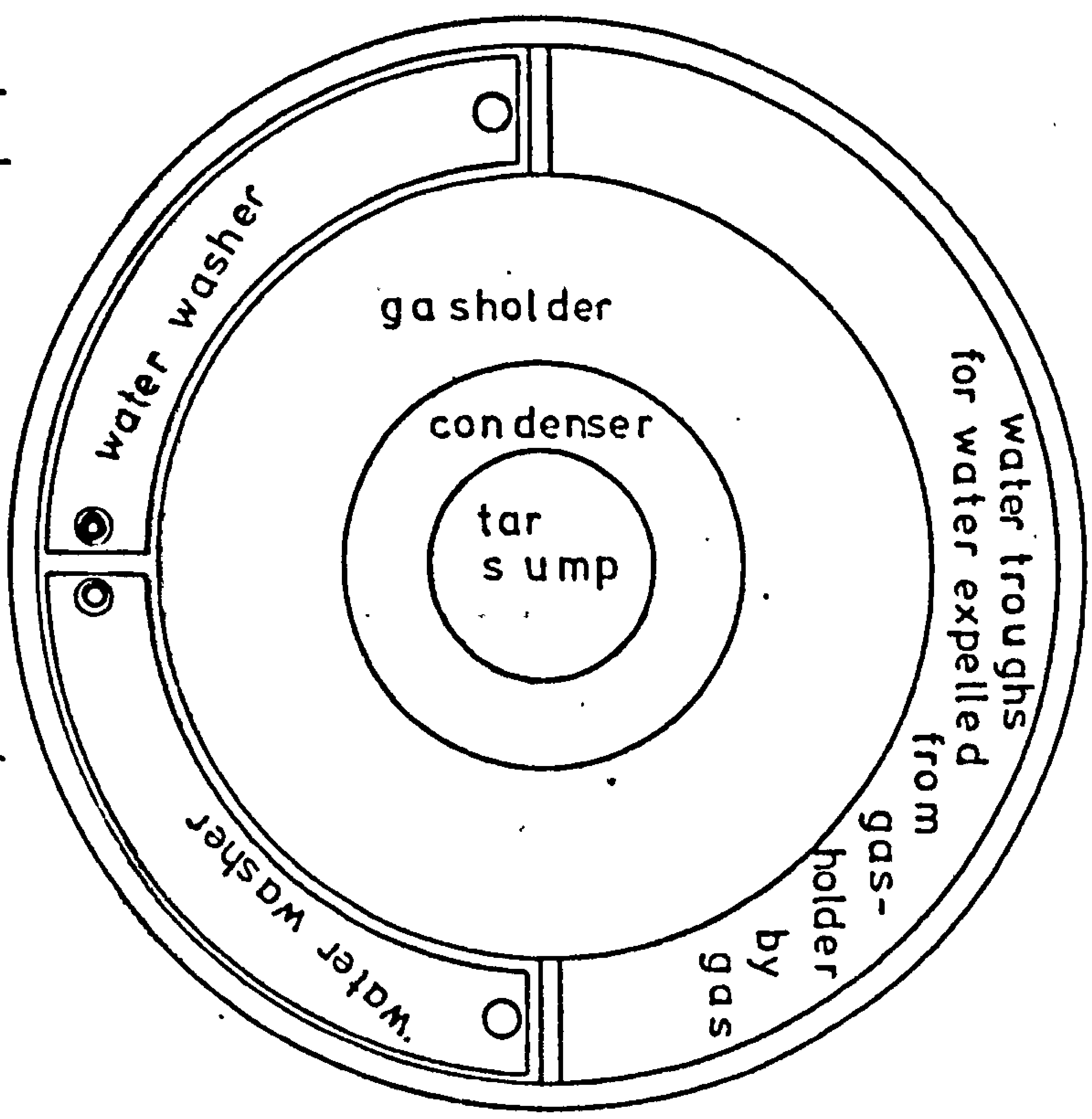
1. J. Maiben, A Statement (1813) op. cit., p. 11.
   "Many" accidents at factory gasworks in the 1810s in England led to public opposition to gas companies.
   G. Atkins "Origins and Progress of Gas Lighting", Repertory of Patent Inventions Vol. III 1827 pp. 88-9.
2. J. Maiben, A Statement (1813) op. cit., pp. 12, 16.

Fig. 1.22 MAIBEN'S PATENT GAS APPARATUS 1810

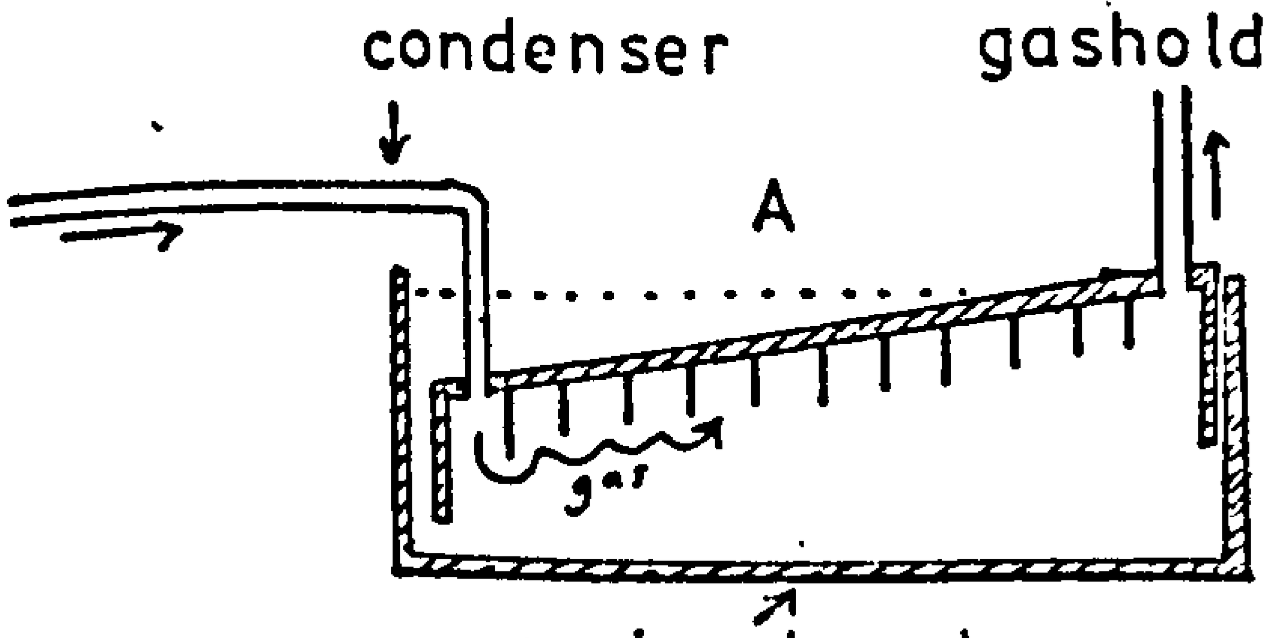
Longitudinal Section



Plan of Gasholder base



Water Washer (A)



Source - S.R.O. (C 20/10/25)

service pipes, and then to the gas-burners.[1] This produced a more steady and reliable flow of gas than from a conventional gasholder. Maiben realized that potential customers in Scotland were already aware that:

> the original expense of fitting up a proper apparatus, even on the most economical plan, exceeds the expense of the present lights for a considerable time: its ultimate cheapness must therefore depend upon its durability, more especially of the reservoir, which is by much the most expensive part.

Consequently he offered robust reservoirs made of freestone and Roman Cement.[2]

With Maiben's apparatus, "management requires nothing but what the most ignorant person, with a common degree of attention, is competent to perform,"[3] with no "violent effort" or "risque of injury", in less time than would be taken to snuff candles giving equivalent light. The retort house was built like a Chinese temple for efficient ventilation[4] which would remove all danger of explosions. One

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1. Ibid., pp. 17, 15 Abridgements (1860) op. cit., p. 14 Maiben claimed that sea-water was adequate, and tried to sell gas apparatus to Trinity House for lighthouses. Because the changing height of the "gasometer" could not be used to "meter" the contents, Maiben devized "an appendage in the form of a clock dial" to show the water level inside the gas-holder; this was the first "station meter" invented to indicate gas consumption.

2. J. Maiben, A Statement (1813) p. 39. Wood or brick could be used, but was less durable.

3. Ibid., pp. 18, 19

4. A recent explosion at Peter Street Gasworks in London had resulted in criticism of gaslighting. Maiben's solution for ventilation was a very advanced idea, and he clearly had a close understanding of developments elsewhere.

   Ibid., p. 40.

great difficulty was the absence of reasonably inexpensive metal service pipes in Scotland, a fact which may have been of considerable importance in deterring other mechanics. Several bizarre substitutes were proposed in Maiben's patent of 1810, including glass pipes, "charred wood or other materials ... covered with the gut of animals" and varnished. Inside dwelling houses he hoped to use baked wooden pipes, covered with three layers of cow gut, or six of sheep gut, painted, covered with thin rolled lead and finally varnished. Outdoors a final covering of thin rolled iron and then pitch encased the pipe. Thus stood the frontier between eotechnic and palaeotechnic[1] industry.

To attract customers, Maiben explored the potential uses of gas in a depth of vision well in advance of his contemporaries. He tried to explain the illuminating power and precise financial savings of gas lights, and he invented gas fires, gas cookers, and 'ventilated' gas lights.[2] Gentlemen who wished to examine his apparatus could "have a model of our apparatus of any size they please at a moderate charge, together with pipes fit for making experiments",[3] either from the Company's agents,[4] or by sending a post-paid request to Perth. They could also obtain pipes, "retorts, gas cocks, lanterns and lustres of every description, warranted air tight, and proved with gas before being sent from our manufactory." Through high quality workmanship, Maiben became probably the most important

1. A. and N.L. Clow, The Chemical Revolution (1952) p. 390, i.e. between traditional crafts and 'modern' industry.
2. An invention normally ascribed to W.T.Brande (1816) Vide infra p.1214
3. J. Maiben, A Statement (1813) op. cit., p. 40.
4. Unfortunately the Agents are not recorded.

gas-apparatus manufacturer in Scotland[1] by 1815.

Maiben calculated that 50lbs cannel coal costing 5½d, distilled in his 'oven' for 1½ hours, would produce sufficient light for six gas-lamps burning 12 hours, each lamp giving the light of six mould candles.[2] He found, however, that the size of the gaslight greatly affected the illumination received.[3] Four separate lamps, each using 1 cu ft gas per hour, gave as little illumination as four rush lights, but one lamp using 4 cu ft per hour gave a light equal to six mould candles, a vast difference. Maiben in fact advised consumers to use lamps requiring 2½ cu ft per hour, to give light equal to three mould candles. This was a practical approach to the problem of "efficiency" in gas-burners which puzzled scientists until the 1840s.

For private mansions, Maiben placed the retort-house[4] at least 500 feet away, and service pipes to ceiling lights were fitted from the room above. Around each light was placed an ornamented "crystal globe", open at the base to admit air, but joined above by a brass

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1. This opinion has been reached by Chandler and Lacy (op. cit., p. 59), but there is no precise information on the Company's activities. Apart from Boulton and Watt, no rival firm is known to have emerged, and certainly none with improvement patents in Scotland. In 1851 A. Macfarlane & Co of Perth Foundry were still manufacturing and erecting "Gas Apparatus for Private Mansions, Villas, or Public Works" on the most modern lines.

   Perthshire Courier 27/2/1851, p. 1

2. J. Maiben, A Statement (1813) op. cit., p. 3. Vide infra 'Markets' pp. 1208 - 9

   Each mould candle weighed one-sixth of a pound, and represented the 'Standard Candle' first used in Murdoch's paper to the Royal Society in 1808.

3. The illumination 'efficiency' of different types of burners was a perennial problem, vide infra pp. 413, 1254

4. J. Maiben, A Statement (1813) op. cit., p. 20.

tube surrounding the service pipe, which carried all odious combustion products upwards and away to the outside of the building.[1] Mantlepiece lights could be ventilated into the chimney, and the method was useful for providing ventilation in large factories or crowded rooms. Airing-rooms could use gas-lamps with less hazard than the normal open fires. Maiben believed that the combustion of coal gas gave one-third of the heat obtained from burning gas-coal directly, but the heat was more easily controlled and removed the problems of ashes, chimney sweeping, kindling, and disturbances by servants.[2] Consequently he designed a burner to fit into a coal fire, where "the flame issues from a number of small perforations in a tube, which is passed along the grate, in the place of the lower bars".[3] Fancy figures in cast metal could be placed in the flames as ornamentation.

In the centre of large rooms, a gas stove could be "enclosed in a foot stool, or put under a table", and Maiben had built one in which a large argand lamp supplied hot air to a convoluted tube, like a radiator, before piping the waste gas away into a chimney. With 10 cu ft gas per hour, it could heat a room 12 feet square, and was well adapted "for airing rooms containing fine furniture or valuable paintings". Gas stoves could be used "in kitchens for keeping meat warm or for boiling water, and ... for keeping greenhouses at an equable temperature." In England such devices were a rarity until after the 1850s, but Maiben inspired many similar schemes in Scotland,[4] as well as confidence in private gasworks.

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1. Ibid., pp. 21, 23
2. Ibid., p. 34
3. Ibid., pp. 32, 33.
4. Vide infra 'Markets' p. 1273

Gillespie's gasworks[1] was still considered one of the most impressive in the Glasgow area in 1812, and although John Sinclair[2] recorded in 1814 that "several cotton and one printworks" had been built in that region since 1809, he indicated why progress was so slow:

> Several shops - first in Glasgow, then in Edinburgh, and other towns - were lighted up with gas; but it required so much management and work, - produced so much heat and smell, when the tubes leaked, and all not in proper order, - that few have persisted in using it. Indeed it is only on a large scale that it, as yet, can be employed with advantage. 3

This "large scale" meant the factories where cast-iron retorts were charged with 2 cwt to 3 cwt coal, and the "brown bituminous vapour" was purified only by water in the gasometer tank.[4] Gasometers were about sixteen feet long, ten feet broad and nine feet deep, of "thinly rolled sheets of iron rivetted together", or a wooden framework covered with tarpaulin , and painted inside and out with tar. They were suspended by a chain and pulley from the ceiling of the gasometer house, over water pits built of stone, brick or wood.

Theoretically gas was twenty-four times cheaper than candles. 1 lb tallow candles, costing 1s., when burned consecutively lasted for

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1. R. Chapman, The Picture of Glasgow (1812, Glasgow)
2. J. Sinclair, Appendix to the General Report of the Agricultural State and Political Circumstances of Scotland (1814, Edinburgh) Ch. XVI Appendix 2 pp. 302-4.
3. Ibid.
4. Ibid. Sinclair's account was based on "Gillespie's Essay", probably his lecture to the Philosophical Society of Glasgow.

forty hours. 20 cu ft of gas would give equal light[1] for the same time from 7 lb of best coal costing ½d. Sinclair warned, however, that "the interest of the outlayed money, tear and wear, &c is very great", and gave the first detailed statistics from a Glasgow factory using gas-light to illustrate his argument. He concluded that 1,000 candles burning ten hours each would use 250 lbs tallow, worth £12 10s., while gas-light would cost £1 2s 4d. after allowing for the sale of by-products. Gas was eleven times cheaper than tallow, but in small factories the possibility of explosions and the amount of labour involved with the apparatus greatly reduced the advantages.

Nevertheless, with a northerly latitude of 55 to 60 degrees, Scotland had daylight only from 9 am to 3 pm during parts of the winter and the potential advantage of gaslight was enormous. Sinclair calculated that if each inhabitant used only one-half ounce of oil or tallow for one hour of artificial light per day, the 9165 tons consumed per year, at £55 per ton, represented over £500,000 per year spent on illumination. While Maiben undermined the opposition to small private gasworks in Scotland, well publicised attempts were also in progress in England towards small scale units. Samuel Clegg[2] took the lead in those, at factories in Lancashire and Yorkshire, but his installation at the printing works of R. Ackermann[3]

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1. i.e. one gas-light, with 1/32 inch orifice, consumed ½ cu ft gas per hour at "moderate pressure" to give light equal in intensity, "by comparison of shadows" to one tallow candle (of 6 in 1 lb). Coal cost 8d per cwt, and 1 lb coal gave 3 cu ft of gas.

2. Vide infra, Appendix I.2 (E) p. 1349

3. E.G. Stewart, Historical Index of Gasworks Past and Present in the Area now Served by the North Thames Gas Board (1806-1957) (1957) p. 123 (Institute of Gas Engineers).
Vide infra pp. 35, 1351

Table 1.23 Private Scottish Gasworks Expenditure and Revenue in 1814

GAS LIGHT DR			
To 1000 lights, each equal in intensity to a candle six in the pound, and burning ten hours each, will consume 5,000 cubic feet of gas; this will require 1666 lb, or 15 cwt of good coal, at 8d p. cwt	L 0	10	0
To the same quantity of common coal for outside of retort at 6d - (N.B. Dross is sometimes used for this purpose, but, requiring a great current of air, it is more dangerous for the retorts.)	0	7	6
To attendance, 2 men keeping the retorts going night and day, as, when allowed to cool overnight, they are long before they become effective in the morning - (N.B. The Watchman of the work sometimes officiates during the night; but where retorts are numerous, continual going is not absolutely necessary)	0	5	0
One day's interest of sum sunk in buildings, retorts, gasometer, pipes, cocks, incidents, and layings, say 30s each light, 1500L - (N.B. In some cases the outlay exceeds, in others it is less than this, a good deal depending on local circumstances and economical arrangements.)	0	4	2
To one day's tear and wear, including new retorts, fire bricks, building, incidents, repairs &c 10 per cent on outlay	0	8	4
	L 1	15	0

CONTRA CR			
By 10 cwt of coke, being part of the residuum of 15 cwt coals enclosed in the retorts, or 2/3 ds of the weight, say at 8d per cwt	L 0	6	8
By 75 lib coal tar, additional residua, or 5 per cent of the weight of the coals, say only	0	6	0
Net cost	L 1	2	4
N.B. This is about 10 lights per hour for 1 farthing, or one fortieth of a penny for each light.			
	L 1	15	0

Source - J.Sinclair Appendix to the General Report of the Agricultural State and Political Circumstances of Scotland (1814, Edinburgh) in London, in 1811, was the first to be widely acclaimed. Messrs Lloyd in London, and Cook[1] in Birmingham, also published details of gas apparatus at this time.

Popular scientific authors in the mid 1810s had a considerable influence in encouraging Scottish mechanics to build the improved apparatus. F. Accum[2] in 1815 published a detailed but simple "Description of a Portable Apparatus for exhibiting, in a small way, the general nature of this species of Light". Samuel Parkes[3] also instructed amateurs to build an apparatus, of the "greatest simplicity ... perfectly safe in its application". T.S. Peckston in 1819 aimed "to describe every part of the gas light apparatus, so as to enable any one who is at all acquainted with mechanics, to erect such, either for supplying his own premises with gas, or for lighting up large manufactories, streets, or even towns."

Describing gas apparatus in 1819, A. Rees noted that "the method has been adopted in many places by different individuals, who, proceeding from their own ideas, naturally introduced various forms of the apparatus, the most perfect of which we propose to describe with drawings, in such a manner as to enable mechanics to construct

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1. T.S. Peckston, The Theory and Practise of Gas Lighting (1819) p. xiii

2. F. Accum, A Practical Treatise on Gas Light (1815) pp. 77 - 99.

   S. Miall, A History of the British Chemical Industry (1931) p. 189 gives a biography of Accum.

3. S. Parkes, The Chemical Catechism (1816) 7th Edn. pp. 457-9.

   Parkes stated the coke was worth as much as the original coal; and the tar was a very good cement eg for water cisterns, and was much in demand by Birmingham manufacturers.

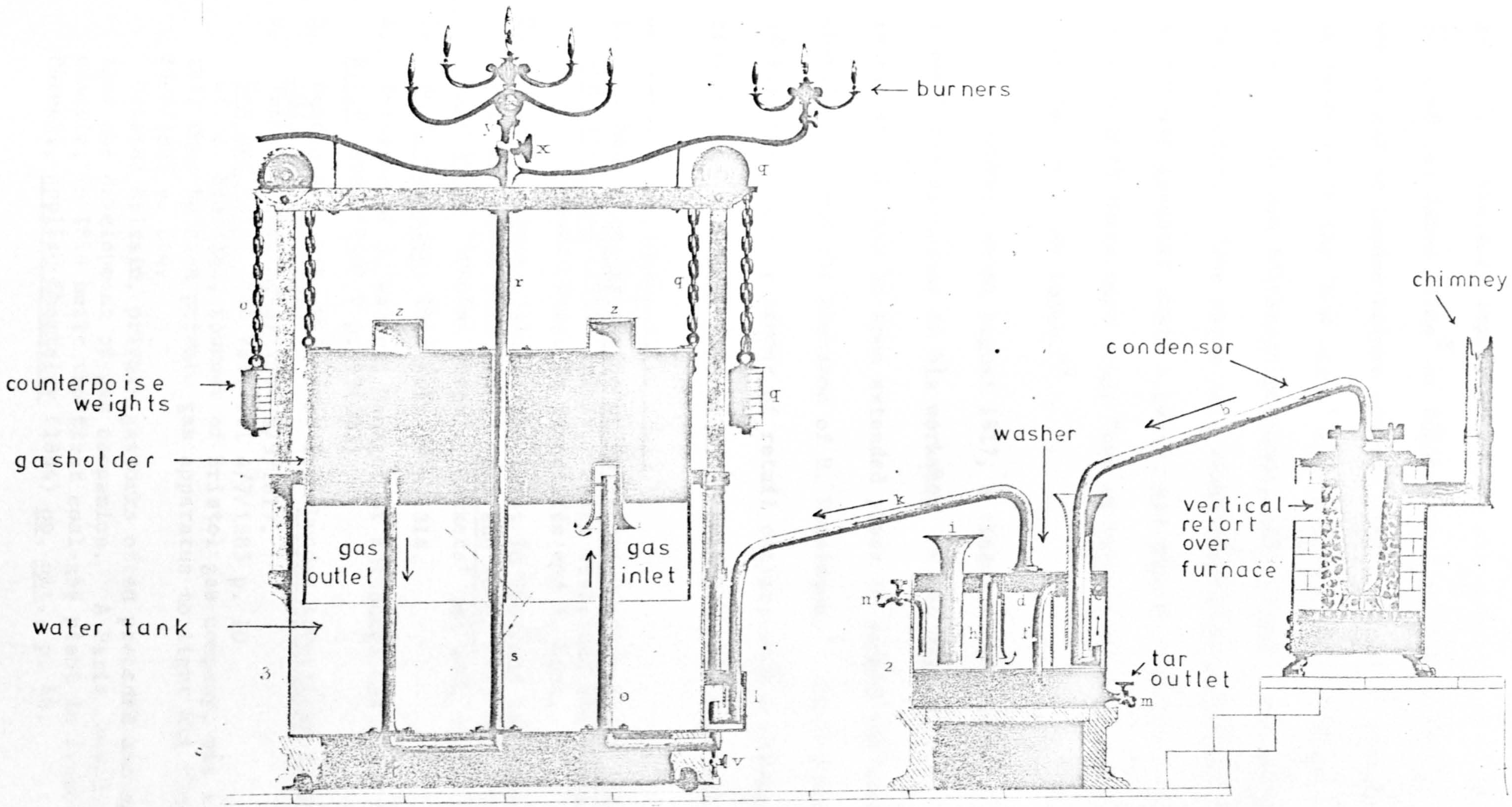

Fig.1.24
<u>Private Gasworks For Amateurs</u>, advocated by F. Accum <u>Practical Treatise</u> (1815) op cit pp. 77-99

them, this being the most probable means of their being farther improved".[1] The most important of the new experimental mechanics in Scotland was James Milne[2] of Edinburgh, a journeyman brassfounder who worked in London before gas was used there, but soon developed an interest in the 'New Light' and in about 1816 built gas apparatus both for his own Edinburgh premises, and to light the three main shops in that city. "The shops of several merchants in the city"[3] retained private gasworks until a public gas supply began in 1818, and even in 1823 there were still "one or two private apparatus ... [for] lighting their own homes."[4]

In Dundee, about August 1817, a tinsmith, Andrew Small, set up a small gas apparatus in his workshop on the High Street. It was so successful that he soon extended pipes to supply the nearby Merchant's Inn, and the bookshop of R. Donaldson.[5] This proved a good advertisement and "a number of retail dealers felt a strong inclination to have a similar apparatus."[6] Realizing the high cost of

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1. A. Rees, The Cyclopedia or Universal Dictionary of Arts, Sciences and Literature (1819) Vol XV. Rees described the equipment designed by Samuel Clegg, Dr Stancliffe and B. Cook.

2. Milne has been claimed "the first in Scotland to essay a practical experiment with gas". Gas and Water 1885 Vol. II, p. 11. Vide infra 'Special Gases', 'Markets' pp. 410, 1244, 1250, 1256

3. Scots Magazine, 1817 Vol. 79 p. 314.

4. Evidence of J. Watson, Manager of Edinburgh Gas Light Co. B.P.P. 1823 (193) V p. 93(303)

5. Dundee Ref. Lib. MSS notes from Dundee Advertizer 22/8/1817; J.G.L. 1/2/1876 p.164

6. Ibid., Dundee Advertizer 5/9/1817.
Gas and Water 1885 Vol. III 4/7/1885 p. 10
Cf. J. Braillat, founder of Bristol gas company, was a dyer in 1811 when he used private gas apparatus to light his shop. J.G.L. 29/4/1856 p. 244.
Outside Britain, private gasworks often preceded and encouraged the development of gas companies. A Paris hospital, for example, in 1818 built the first coal-gas plant in France. E.A. Parnell, Applied Chemistry (1844) op. cit., p. 46.

separate plants, they met at the Merchant's Inn and appointed a committee to negotiate with the Magistrates for laying pipes, a move which led ultimately to the formation of Dundee gas company in 1823. In January 1818 Mr Muir, a copper-smith in Bridge Street, Kelso,[1] developed his own gas apparatus sufficient to supply ten burners which illuminated his shop, workshop and dwelling house for only 3d per night. During 1819 James Williamson,[2] a china merchant in the High Street, Paisley, distilled coal gas and even obtained permission from the town council to lay pipes across a public street to supply premises on the opposite side. His success encouraged the formation of Paisley Gas Company in 1823. Private gasworks in Aberdeen[3] were regarded only as "a curious philosophical toy" before the formation of a company there in 1824. William Young[4], later an eminent gas engineer, first made gas in an old tea kettle at Clippens, where J. Hall observed gaslight for the first time, though he too subsequently became a gas engineer. James Rennie[5] the inventive

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1. Blackwood's Edinburgh Magazine 1818 Vol. III p. 724. The Montrose, Arbroath and Brechin Review 2/1/1818 p. 5. F. Groome incorrectly states this to be the first gas apparatus in Scotland. F.H. Groome, Ordnance Gazetteer of Scotland - A Survey of Scottish Topography (1882, Edinburgh) Vol. IV, p. 343. Muir sometimes used cloth bags to carry the gas like candles.

2. R. Brown, The History of Paisley from the Roman Period down to 1884, (1886, Paisley) Vol. II p. 288., quoting the Council Record 24/11/1819.

3. New Statistical Account (1839) XII p. 78

4. J.G.L., 30/7/1878 vide infra 'Management' p. 638 J. Hall was manager at St Andrews in 1878.

5. His father, Bailie James Rennie, built the first flax spinning mill in Arbroath. James jun. succeeded him as owner of the local candleworks and candle-shop in Market-gate. As a child, Rennie studied the generation of 'natural gas' in the mud of R. Barothock, and designed a miniature steam-engine. He superintended gaswork construction at Forfar and Kirkcaldy. J. M. McBain, Arbroath: Past and Present (1899, Arbroath) pp. 215-9. Vide infra Chapter 2. p. 145

son of a candle-maker in Arbroath, built a gas apparatus which enabled the candle-shop to give the first demonstration of gas-light in that town. Through the experience he gained, Rennie became the first manager of Arbroath Gas Company in 1825, and besides supervising that installation he later engineered other Scottish gasworks.

The Orbiston Community[1] in Lanarkshire in 1825-26 built a private gasworks; and even in the 1830s the only coal-gas in Motherwell was used by a resident who regularly filled an old gun barrel with coal, plugged the end, and after heating it lit gas escaping at the firing nipple. Later, Robert Barron[2] operated a small gasworks in his garden in Motherwell. Many Scottish gas companies were inspired by similar amateur experiments. Robert Barr,[3] for example, promoted the Bridge of Weir company in 1847 after examining the back-garden gasworks of a Kilbirnie shoemaker who used a beer-barrel gasholder and leather pipes to convey the gas.

Private gasworks continued to be operated by industrial companies, especially in the textile industry, and by private individuals, throughout the nineteenth century. In 1814 McIntosh and Inglis's flax spinning mill,[4] using pierced thimbles as burners, gave the first demonstration of gas-lighting in Dunfermline where it drew crowds of spectators. Dunfermline did not acquire a central gas company until 1829, but Midmill, three miles to the south-west,

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1. T. Orr, Historic and Descriptive Sketches of the Joint Burgh of Motherwell and Wishaw (1925, Motherwell.) (Motherwell Ref. Lib. R.5934).

2. Ibid., owner of the Railway Tavern, and later a Director of Motherwell Gas Company.

3. Third Statistical Account - Renfrew and Bute (1962, Glasgow) p. 246

4. E. Henderson, The Annals of Dunfermline 1069-1878 (1879, Glasgow).

acquired gas lighting in January 1817. At Balfron[1] in Stirlingshire, shops obtained gas-light in 1819 from the large Ballindalloch cotton works which had recently been enlarged by James Finlay and Company of Glasgow. In Brechin,[2] the first display of gas was the lighting of Messrs. McKenzie and Watson's spinning mill in 1820. Lennoxmill[3] near Campsie built a private gasworks in 1828, and in the same year Messrs. E. Birrell & Son's Spinning Mill in Kirkcaldy was sold "with an excellent Gas Apparatus almost new."[4] In 1820 a paper mill at Culter,[5] in Aberdeenshire, possessed a large gas apparatus worth £145 in a separate 'Gas House' measuring 32 feet by 30½ feet, compared to the total value of the mill at £5,169. Rothesay[6] cotton mills, the first in Scotland, operated a private gasworks during the 1830s since the town had no gas company until 1840.

Scottish rural factories,often at water power sites,[7] were

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1. New Statistical Account Vol. VIII pp. 292, 293, 297. 1789 Ballindalloch was built by Mr Dunmore of Ballindalloch and the Buchanans of Carston, and acquired in 1793 by J. Finlay & Co. By 1841, water mules had reduced labour force from 400 to 258. Vide infra p. 155

2. D.H. Edwards, Pocket Guide and History to Brechin (1884, Edinburgh) p. 137

3. T. Cameron The Parish of Campsie (1892, Kirkintilloch) p. 142

4. Dundee, Perth and Cupar Advertizer 10/4/1828 p. 4
The mill was in Coal Wynd, Kirkcaldy.

5. Glasgow Chronicle 18/3/1820, 25/4/1820.

6. Provost Sharp, "The Cotton Industry in Rothesay", Transactions of Bute Natural History Society 1908-9 Vol II (Mitchell Library, Glasgow), p. 18.

7. Vide infra, Chapter 2 p. 103
Many obtained technological data by close commercial ties with urban cities; Glasgow 'houses' owned 52 cotton mills in 1816.
J. Cleland, Annals of Glasgow (1816, Glasgow) Vol. II p. 373
Scottish mines and quarries did not use gas lighting, and elsewhere examples were most unusual, like the Cornish Tresevan and Balleswidden mines, Festiniog slate quarry in N. Wales, Cinderhill Colliery, Nottingham in 1858, Mr Ackroyd's Yorkshire pits,

unable to take advantage of centralized gas supply from urban companies, but by the 1840s most large factories had private gasworks.[1] Thus while no Dundee factories made gas, the nearby weaving village of Lochee was not supplied by Dundee Gas Company until 1844, and so several mills, like Messrs. Hindman and Hall and James McDonald and Son, produced their own coal gas.[2] Elderslie cotton mill built a gasworks in 1836 when the local Paisley Gas Company refused a supply, and then itself refused to sell gas to local residents. Several villages[3] around Paisley in the 1840s were more fortunate, and obtained a partial gas supply from local factories. A few houses at Thornhill and Quarrelton,[4] for example, were supplied by a cotton mill. Nevertheless, on the entire Fernege[5] estate near Paisley, which included the villages of Grahamston, Gateshead and Chappleford, only Fernege Spinning Mill had any gas, from a private apparatus.

Several mills in Neilston parish,[6] Renfrewshire, had gasworks

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and Elsecar Colliery, Barnsley in 1858.
The Builder 21/11/1857, 16/10/1858 p. 700
The Engineer 25/4/1856
Notes and Queries 26/3/1859 p. 256
North of England Inst. Mining Engineers 1861 Vol X pp.150-9.
J.G.L. 24/11/57, 12/5/57, 13/4/58, 22/6/58.

1. Evidence of George Miller, House of Commons MSS 1846 Vol.102 Committee on Hamilton New Gas Company 11/5/1846 p. 163.

2. H. Commons MSS 1846 Vol 98 23/3/46 p. 99; 24/3/1846 pp. 81, 92. Private individuals in Dundee suburbs also had to rely upon their own gasworks in 1843 when the old company refused supplies. Dundee, Perth and Cupar Advertizer 10/11/1843

3. Evidence of J. Stranant, House of Lords MSS 1844 Vol. 8 The Paisley Gas Bill 30/7/1844 p. 28 (New Statistical Account Vol VII p. 282)

4. House of Lords ibid., 30/7/1844 pp. 133, 135.

5. Evidence of J. Graham, owner of Fernege Estate, ibid., 30/7/1844 p. 114.

6. New Statistical Account Vol VII, p. 349.

in 1837 and planned to obtain coal from Hurlet and Muirkirk, as well as supporting a railway to the east near Barrhead because of "the immense quantity of coal" they consumed. In Denny parish, Stirlingshire, many mills along the River Carron in 1841 used their own gas equipment. A coarse-paper mill owned by R.B. Lusk was "lighted by gas, and dried by steam and heated air".[1] Herbertson Mill[2] nearby operated twenty-four hours a day to produce writing paper, and the gaslight consumed four tons of coal each day. Three water-powered textile mills[3] in the parish were lit by gas and heated by steam, and the water-powered Gryfe Mill[4] in Houston Parish was also gas lit in the 1840s. Shaw's extensive Water Cotton Works,[5] completed near Greenock about 1840 and employing about 400 people, was noted for the extensive fire-proofing and fire-precaution devices including steam heating, and built nearby "a gaswork and comfortable houses for the workers." In 1845 the woollen spinning mill owned by

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1. New Statistical Account Vol VIII p. 127.
   Lusk employed 25 people making millboard and coarse paper from old rope for sheathing ships and packing steam-joints.

2. New Statistical Account Vol VIII op cit. Mill owned by W. Forbes and Messrs Alexander Duncan and Sons. The mill used expensive new machinery to process rags, and continuous working was necessary to repay the expenditure.

3. Two at Stoney Wood and one at Randolph Hill, all owned by Messrs Wingate, Son & Company of Glasgow. Employed 200 to make tartan and fancy shawls, and undertook all processing from spinning and weaving to dyeing and finishing.

4. Built in 1793, owned by Messrs. John Freel & Co, employed 260 New Statistical Account Vol VII p. 51.

   Engineers even at the small mills tried to improve gas apparatus. In 1843 J. Lothian at Esk Mill, Edinburgh, introduced better flues which halved the cost of "metal, fuel and fire". One small retort gave 846 cu ft gas in 4½ hours distillation.
   "Improvements in the Manufacture of Gas" The Civil Engineer and Architects Journal, February 1843 p. 51.

5. New Statistical Account, Vol VII pp. 442-3.

D. Moir & Co. at Devonside[1] incorporated a dye-work and a gas-work, while a steam powered paper mill at Colinton[2] also had its own gas-works. Mr Cadell of Grange operated a private gaswork to supply his works, and the houses of his employees at Bridgeness until 1878 when 280 yards of mains were laid to obtain a supply from the pipes of Boness Gas Company.[3]

Many small towns and villages were supplied with gas from private gasworks and until at least 1835 or possibly far later in the nineteenth century outside the principal cities, private installations were in toto probably more important to the Scottish economy in terms of financial savings and total output, than urban Gas Companies. Alva[4] was supplied from a private gasworks from 1832 to 1844 when a company was formed to purchase the equipment for £528. In the early 1830s George Walker built Tillicoultry Gasworks[5] in a community where about 1,000 were employed making woollen shawls and blankets. Most of Duntocher village in Dunbartonshire at that time

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1. Stirling Journal and Advertizer 31/1/1845
2. The Scotsman 26/2/1845 p.3
3. S.R.O. Boness Gas Company Minute Book (GB 1/11/1) 28/2/1878, 5/3/1878, 8/3/1878.
   The Cadell dynasty commenced with William (1708-77) from Cockenzie, a partner with S.Garbett and J.Roebuck in sulphuric acid works (1749). With William junior (1737-1819), the family operated salt works, a timber trade, and purchased Crammond malleable ironworks in 1771. William purchased one third share in Clyde Iron Works c.1790 (founded 1786). Grange colliery, which became important for gas coals, was operated in the 1770s by William jn. and his brother John, with some English partners like John Beaumont (Though not the namesake of James Beaumont Neilson, who was named after colliery engineer Mr Beaumont of Lainshaw, Irvine. S.Smiles Industrial Biography 1863 p.150) Grange colliery in the nineteenth century was managed by H.M. Cadell.
   J.Butt Industrial Archeology of Scotland (1967) op.cit. p.23.
   W.H.Marwick Economic Developments in Victorial Scotland (1963)p.165.
   H.Hamilton The Industrial Revolution in Scotland (1966) p.165
   B.F.Duckham Scottish Coal Industry (1970) pp.64,174,177-8
4. Journal of Gas Lighting 4/4/1882. The date 1844 was significantly during a period of consumer agitation in the gas industry.
5. Pigot and Co's National Commercial Directory for the Whole of Scotland (1837) p.328

was owned by William Dunn[1] who built a gasworks to light it. The model village of Froickham in Forfar was designed in the 1830s "to encourage the settlement of weavers", most of whom were employed by the owner, Mr Anderson,[2] in spinning and weaving flax. Anderson built a gasworks to light his mill, and the buildings connected with it. At Kilbarchan[3] the streets were lit with gas for the first time in twenty years when the Road Trustees negotiated a supply from a local factory. In Stirlingshire, Milton[4] village still obtained gas in the early twentieth century from nearby Lillyburn Print Works.

Although gas supplied by Gas Companies was adopted extensively by urban factories, from silk mills in Edinburgh[5] to the highly integrated Woodside Cotton Mills of Aberdeen,[6] not everyone was satisfied with such a remote source. The supply was not reliable. At 6 pm on 18 November 1829, for the second time that winter, all of the mills in the west end of Dundee were plunged into darkness, leaving hundreds of people, including many young children, "in the midst of complicated and dangerous machinery".[7] The spinners turned off their frames as quickly as possible, causing the steam engines to accelerate so rapidly that they could have caused fires, or fallen apart.

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1. Ibid., p. 338
2. Ibid, p. 456.
3. J[ournal] of G[as] L[ighting] 13/12/1881.
4. Third Statistical Account - Stirling (1962) op. cit., p. 260
5. The Scotsman 14/5/1845 p. 3
6. Owned by Messrs Gordon, Barron & Co.
   A. and N.L. Clow, The Chemical Revolution (1952) op. cit., p.432.
   W. Watt "Fifty Years Progress in Aberdeen" Aberdeen Philosophical Society 1/4/1903 (Glasgow Mitchell Library).
7. Dundee Perth and Cupar Advertiser 19/11/1829 p. 2.

Newspaper advertisements indicate private gasworks in several towns where Gas Companies also operated. John Clark & Co's cotton spinning mill[1] in Abercrombie Street, Glasgow, had its own gasworks in 1820, as did Robert Humphreys & Co.[2] five-storey cotton mill at Hutchesontown in that city the following year. Similarly William Ford's Flint Glass Work[3] at South Back of Canongate, Edinburgh, was "all lighted by a gas-work belonging to the property" in 1819. Messrs John Barclay & Co's Abbey Mill[4] loom factory in Paisley still had a gasworks in 1836, whereas the local gas company began in 1823. In some cases this was simply equipment installed before a central gas supply was available, as in 1836 when Messrs. James and John Kibble & Co.[5] sold their extensive Print Works at Dalmonach, Bonhill, with "extensive Gas Works ... nearly new". Sometimes the apparatus was made portable and offered "To Let", like that from the Anderston Printfield[6] in 1817, when Glasgow gas became available.

Elsewhere, however, it was retained on purpose. S. Hughes in 1853 believed that this was caused by the gas companies' failure to install a 'governor' at their gasometer, rather than high gas prices. Without the 'governor' to give steady pressure in the mains, large factories had inadequate light for several hours in the early mornings. Consequently -

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1. Glasgow Chronicle 17/2/1820
2. Glasgow Chronicle, 3/2/1821, p.1
3. Glasgow Chronicle, 14/9/1819, p. 3
4. Glasgow Herald, 18/7/1836 p. 1.
5. Glasgow Herald, 4/4/1836, p. 3
6. Glasgow Chronicle, 10/5/1817

> in most large towns ... many private establishments for the manufacture of gas ... /had been established and reflected/ a great scandal on the Gas Company, which with all its appliances, its large joint stock capital, and the presumed skill of its management, cannot control the custom of individual manufacturers ... /despite the/ undeniable disadvantages of making it on a small scale. 1

Industrialists also used the threat of a private gasworks in an attempt to force gas companies to charge reasonable prices for gas.

At Annan,[2] the Glasgow, Dumfries and Carlisle Railway Company in 1848 requested a gas supply for thirty lights. When the gas company tried to impose a ten-year contract as compensation for the £39 cost of pipes, the railway considered building a private gasworks like those built "at several stations on the Ayrshire Railway". The gas company capitulated. Several railway stations maintained independent gasworks even where a local supply was available, as at Oban on the Callender and Oban Railway[3] in 1880. When gas became expensive at Perth[4] in 1875 the General Railway Station Committee threatened to open their own gasworks.

In the 1810s London manufacturers and engineers like F. Accum,[5] S. Clegg, Farley and Manby,[6] advertized private gasworks for sale.

1. S. Hughes, A Treatise on Gas Works and the Practice of Manufacturing and Distributing Coal Gas (1853) p. 198.
2. S.R.O. Annan Gas Company minute book (GB1/1/1) 8/9/48
3. J.G.L., 16/8/1880
4. J.G.L., 16/3/1875
5. F. Accum, Gasworks in London (1820) p. XVI
6. The Civil Engineer and Architects Journal, March 1847, p. 79

In the mid-nineteenth century, G. Bower of St Neots,[1] Messrs. J.J.B. Porter & Co. of Lincoln[2] Messrs. Milne in Edinburgh, and Glasgow companies like Messrs Laidlaws and Henry Field & Son,[3] were important suppliers of private gasworks. W. Richards,[4] in 1877 provided detailed observations on private works in his textbook on the industry.

George Mushet in 1833 threatened to cease using the gas supplied to his house and iron-foundry by the Dalkeith Gas Company,[5] and to erect a rival gasworks, unless the company purchased all their cast-iron goods from him. This ploy failed, as did complaints by manufacturers against the Selkirk gas company, which from 1836 sold gas at 15s per 1,000 cu ft. In 1840 a discount of five per cent was offered on gas costing above £10 per year, but Mr Brown[6] manufacturer of Dunsdalehaugh, demanded gas at 12s 6d with a discount of five per cent on the second thousand cu ft, ten per cent on the third, and fifteen per cent on further quantities. He threatened to start his own gasworks, and repeated the threat in 1846, disrupting the Company's expansion plans, but in 1851 was still using the Company's gas.[7] Again in 1867 a meeting of the local millowners approved proposals by George Roberts and William Brown to set up a private gasworks for their own use in Selkirk.[8]

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1. Engineering and Mechanics Magazine 1856-7 p.252; 1858 p.254
S. Clegg, Treatise on Gasworks (1866). 4th Edn. op. cit.
2. J.G.L., 27/9/1859
3. W. Halliburton, The County Directory of Scotland (1862) p. xxxviii
4. W. Richards, Practical Treatise (1877) op. cit., p. 329
5. SRO. Dalkeith Gas Company Minute Book (GB1/24/1) 12/1/1833
6. S.R.O. Selkirk Minute Book (GB1/72/1) 23/1/1836, 27/5/1840
7. Ibid., 10/3/1846, 18/12/1851
8. Ibid., 11/2/67. This action followed a failure by the Comsumers Movement in 1861 to enforce price reductions. It is not known whether the private works was finally constructed.

Leven Gas Company in Dunbartonshire faced more determined threats in 1854. Messrs. Black & Co requested gas for their Print Works at Ferryfield at a rate of 5s per 1,000 cu ft, or they would supply gas themselves from their existing private apparatus at Dalmonach.[1] Ferryfield was expected to consume 500,000 cu ft a year, but the Gas Company was not able to meet the large order, because its prime manufacturing cost was 4s 8½d per 1,000 cu ft. The following year Messrs. A. Orr-Ewing[2] of Levenbank Works contemplated erecting a private gasworks, or contracting for a gas supply from either Messrs. Black or the Leven Gas Company. The Gas Company obtained the contract, which involved them in laying £340 mains pipes under the River Leven, but only when Messrs Orr-Ewing[3] agreed to the onerous condition of using their gas only, for ten years. Messrs Black, however, retained a large independent gasworks.

Natural gas deposits[4] were not widely utilized in Scotland, or elsewhere in Britain,[5] for gas-lighting. Fredonia near Buffalo in

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1. S.R.O.
   Vale of Leven Minute Book (GB1/82/1) 4/5/1854, 14/6/1854
2. Vale of Leven Minute Book, op. cit., 30/7/1855. Vide infra p.172
3. Ibid. 26/6/46, 14/12/55, 27/12/55, 20/2/56, 13/6/56
   In 1845 the Leven Gas Company tried to sell gas to the factories of Messrs Stirling of Cordale, and Messrs Orr Ewing, but demanded contracts of 5 years, which Messrs Stirling refused and the plan was abandoned when the distance to Bonhill was found so great that a sufficiently large pipe would have damaged the bridge, and an auxilliary gas-holder was necessary.
4. Viz all naturally occurring combustible gases.
5. B. Redwood, A Treatise on Petroleum (1922) 4th Edn. Vol. I, pp. 1, 160, 175.
   In 1937 a natural gas pocket was tapped at Cousland, Midlothian The Search for Crude Oil and Natural Gas in the Area of the O.E.C.D. (1962, O.E.C.D.) p. 67.
   W. Topley "The Sources of Petroleum and Natural Gas" Gas World 9/5/1891.
   H.M. Cadell "Oil Possibilities in Scotland" Transactions of

the United States of America,[1] was the first Western community to use natural gas in 1830, and was followed in about 1837 by Coatbridge[2] in Lanarkshire. Seepages of gas were observed elsewhere, as at Cadder[3] in Lanarkshire where gas on the surface of a pond could be ignited by a match in 1829, or at Hawkhurst in Sussex where two workmen were burned to death by gas escaping into a water-well in 1838. But Coatbridge was the first British town to use natural gas and, apart from two houses at Wigmore[4] in Hertfordshire during 1847, it was perhaps the only town to do so until 1899 when a railway station near Heathfield, Sussex,[5] initiated a new phase of exploita-

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the Institute of Mining Engineers 1919-20 Vol. LVIII pp. 47-70
G. Wherle, American Gas Works Practice (1919, New York) pp. 26-32 "History of Natural Gas"
C. Hunt Gas Lighting (1907) pp. 3-4.
No detailed history of British natural gas utilization has been published.

1. Edinburgh New Philosophical Journal 1830 Vol. 9, p. 185.
In the Orient natural gas was used far earlier, vide infra Appendix I.1 pp. 1339 - 40
Even in America, natural gas was rarely used until 1885, when Andrew Carnegie used it in his steelworks; 1872 first used domestically at Titusville, Pa.
Chambers Edinburgh Journal 1847 Vol. 8 p. 260

2. A. Miller, The Rise and Progress of Coatbridge (1864, Glasgow)

3. New Statistical Account - Lanarkshire (1841) p. 951.
As early as 1824, coal engineers like J. Buddle, understood that a process of natural distillation occurred in underground coalfields which produced pockets of 'natural gas' under high pressure that could ultimately escape to the surface. Evidence of J. Buddle B.P.P. 1830 (9) VIII Lords Select Committee on Coal Trade, p. 436.

4. Chambers Edinburgh Journal 1847 Vol. 8 p. 80

5. R. Pearson, "The Discoveryof Natural Gas in Sussex, Heathfield District" Trans. Institute of Mining Engineers 1903-4 Vol XXVI.
H.B. Woodward "Occurrence of Natural Gas at Heathfield, Sussex" Trans. Inst. Mining Engineers 1902-3 Vol XXV.
Digest of Evidence Given Before the Royal Commission on Coal Supplies 1901-5 (1905) Vol. I p. 259.

Gas was struck at Heathfield in 1895, tapped in 1899 by the London and Brighton Railway to light a station, and in 1904 by tion. A mineral bore, sunk and abandoned by Messrs. Baird of Gartsherrie behind the Main Street inn owned by James Tennant in Coatbridge, produced ghostly noises which prompted an investigation at night by Tennant's son. The gas took fire, but was extinguished by a wet sack, and Tennant purchased a purifier and gasometer into which the supply was later piped. For three years the gas supplied twenty six burners, and became an important tourist attraction. In 1887 a pocket of natural gas was struck at Fairburn Castle, Strathpeffer, yet although Hugh Miller in 1890 urged the Physical Society of Scotland[1] to finance a national exploration for gas, no progress was achieved.

Most rural mansion houses, hospitals and estates were unable to obtain supplies from a Gas Company because of the cost of pipes, a

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"The Natural Gas Fields of England, Limited" to light 80 houses, and later 3 villages.

In 1840 an attempt was made to convey gas from a colliery at Wallsend to light Newcastle-on-Tyne, but the candlepower proved too low. J.G. Bromilow "Drainage and Utilization of Fire Damp" Coke Oven Manager's Year Book 1956 pp. 310-334
E. Ronalds and T. Richardson, Chemical Technology, or Chemistry in its Applications to the Arts and Manufactures (1855) 2nd Edn. Vol I Part II p. 516
Chambers Edinburgh Journal 1840 Vol X p. 304, quoting Gateshead Observer, October 1840.
The Burning Well of Broseley, Shropshire, and similar phenomena in the Staffordshire coalfield were well known, but never utilized for gas-lighting.
A History and Description of Fossil Fuel, the Collieries and Coal Trade of Great Britain (1841) 2nd Edn., op. cit.
British Association Handbook (1849) S. Howard "Spontaneous evolution of gas at the village of Charlemont, Staffordshire".

A large seepage of natural gas occurred in 1890-7 at Hepburn Colliery, Newcastle, and in 1887 the Salt Union made several borings for gas in S. Yorkshire.
A. Allan, Modern Power Gas Producers (1908)

1. J.G.L., 21/1/1890

factor overlooked by Dr Thomas Chalmers[1] who had service pipes fitted in Kilmeny Manse in 1810 after being persuaded by F.A. Winsor's London lectures in 1807 that gas supplies would soon be universally available. In 1849 Dr Carstairs of Ferry Bank wished to replace his private gas-works with a piped supply from Cupar Gas Company,[2] but the Company only paid £10 towards the £60 cost of 1,050 yards of pipe required. Near Cupar, Russell Mill produced gas until 1853, and supplied some to Edenwood and Springfield villages as well as 2,500 cu ft a year to the local railway station. When that plant closed, Sir G. Campbell requested the Cupar Gas Company to supply the villages, but they refused to spend £300 on the necessary pipes.[3] The Mill apparently resumed gas production, and in 1864 a new Asylum was built nearby to hold 200 patients. Comparisons with Melrose Asylum's gas consumption persuaded Cupar Gas Company that the new Asylum would use about 202,000 cu ft a year in 276 lights. Consumption in the villages[4] had risen considerably in the meantime, but the cost of mains pipes had also risen, to £681. The Asylum was 1,000 yards from Springfield, and required a further £103 in pipes. Consequently the Cupar Gas Company offered to supply gas at 7s 6d instead of 5s 5d in

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1. W. Hanna, Memoirs of the Life and Writings of Thomas Chalmers (1849, Edinburgh) Vol. I pp. 115, 190.
2. S.R.O. Cupar Minute Book (GB1/23/1) 9/1/1849.
3. Cupar Minute Book op. cit., 21/5/53, 14/7/53, 9/6/53
4. viz., 150,000 cu ft per year in Springfield village;
   16,000 cu ft Springfield Railway Station;
   120,000 Russell Mill plus 16,000 nearby dwellings and outhouses;
   14,000 Edenwood;
   50,000 Brighton village.

Cupar, and required both Messrs Smith and Laing of Russell Mill, and the Lunatic Asylum, to guarantee an annual consumption of 200,000 cu ft and 120,000 cu ft respectively.[1]

Messrs. Smith and Laing refused outright, and no pipes were laid towards Springfield. The Asylum alone required 3,000 yards of pipe costing £478, and the Cupar Company offered to supply gas at 8s provided a consumption of 200,000 cu ft a year was guaranteed. The Asylum Directors then made preparations to erect their own gasworks, but finally accepted the Company price, though gas was reduced to the Cupar level of 5s after the guaranteed minimum had been used. Russell Mill was still making gas in 1874, when about 450,000 cu ft at the very high price of 10s was consumed by their own works and at "Eden Wood, Edenfield (Mr Moors), Springfield Railway Station, and their new cottages."[2]

In 1835 the Reverend P. Bell[3] (1799-1869) described to the Highland and Agricultural Society an efficient small-scale gasworks which could be built for only £2 7s, excluding the gas-holder and outer building. A cast-iron retort, 15 inches long and 5 inches in diameter held 8 lbs of coal, and the gas passed through a simplified

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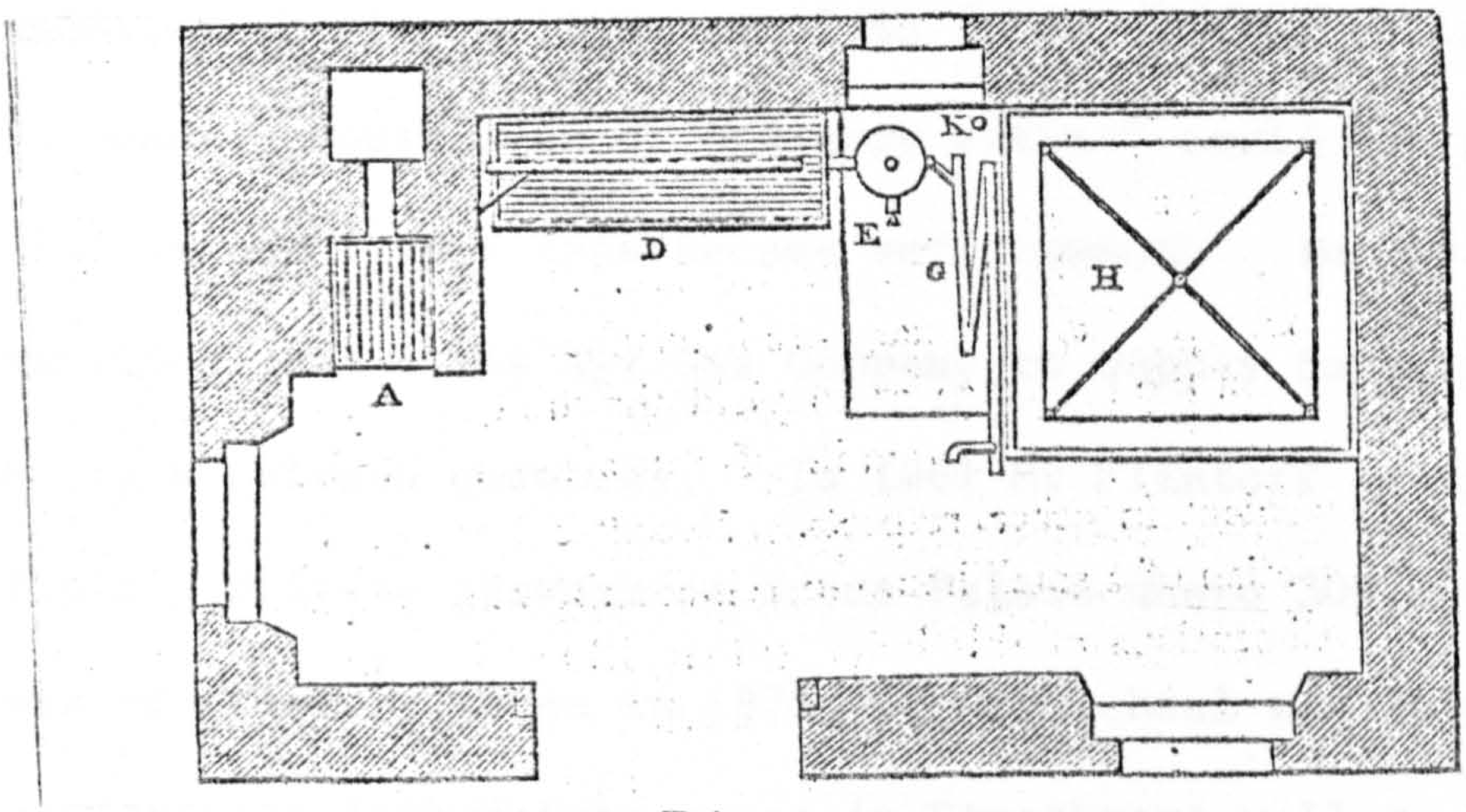
1. Ibid., 12/5/1864, 12/7/1864, 28/9/1864.

2. Ibid., 10/11/1864, 7/12/1864, 11/1/1865, 15/2/1865, 25/2/1865, 15/6/1865, 9/4/1874, 17/4/1874.

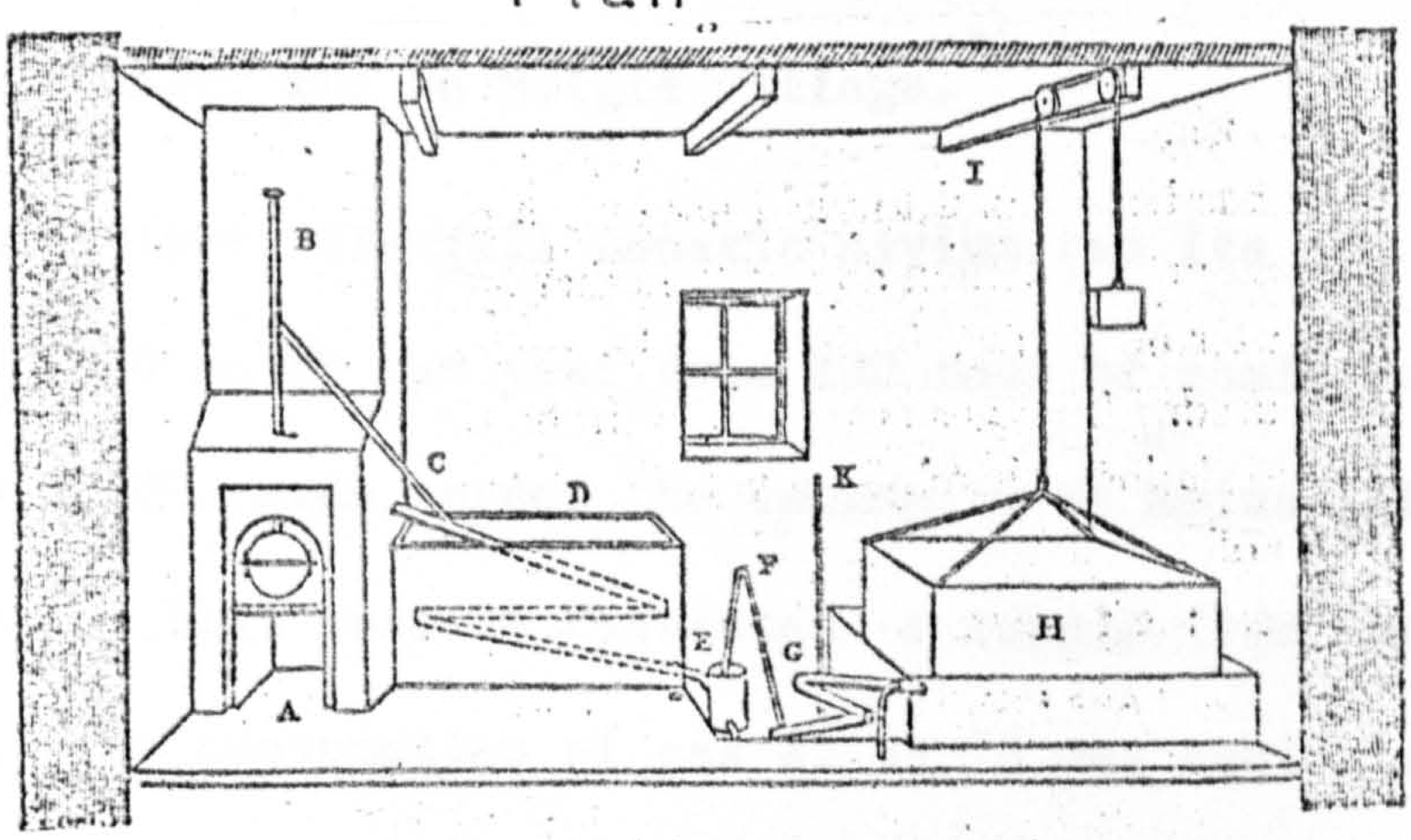
3. P. Bell "Essay on Economising Fuel and Lighting in Private Dwellings" Prize Essays and Transactions of the Highland and Agricultural Society of Scotland 1835 Vol X pp. 155-9. Dictionary of National Biography (1908) Vol II p. 171 In 1827 Bell invented, but did not patent, a reaping machine for farmers. In 1830, R. Phillips had suggested a gas apparatus costing only £80 to light factories, churches, workhouses or small villages. One retort gave 50 cu ft every 8 hours, for 12 lights, at a daily cost of 4s, less 1s 6d revenue for by-products R. Phillips, A Familiar Cyclopaedia or Dictionary of the Arts of Life and Civilization (c.1830, London), p. 755.

Fig.1. 25

Private Gasworks by P. Bell 1835



Plan



Side View

A - Direct-fire furnace with one cast-iron retort (5"dia. x 15")

B - Ascension pipe, - iron; top lid for cleaning
D - Condenser within water-filled tub
E - Tar - sump
G - Tube - purifiers filled with slaked lime
H - Gasometer

Source - Prize Essays and Transactions of the Highland and Agricultural Society of Scotland 1835 condenser and lime purifier into a gasholder only 3 feet cube. Coal for the retort, and another 8 lbs for the furnace cost 1½d, but the 27 cu ft gas produced could maintain three jet burners for three hours, each with a light equal to three or four tallow candles. Thus "a country house even of ordinary extent" could use gas-light. Installations of this type became very common. In 1853 Lady Jane Hamilton[1] asked the Ayr Gas Company to supply Lorzell, or she would build a private gasworks. In 1861 Mr Flintoff examined Lord Mansfield's private gaswork at Scone Palace where 300,000 cu ft a year was produced.[2] Even in 1878, P. Carmichael was obliged to build a gasworks at Arthurstone house in Strathmore valley, because the nearest gas company was in Meigle village.[3]

Until 1888, Glengall Lunatic Asylum ran its own gasworks, to make 700,000 cu ft per year from 100 tons of coal, because it was located 3,000 yards beyond the extremity of mains laid by Ayr Gas Company.[4] That year it requested a supply from the Company, and although the consumption of gas at 4s 7d was equivalent to £160 a year, the Company refused to spend £800 on mains pipes. By 1893 the consumption had risen to 1.04 million cu ft, and the Company agreed to spend £1,096 on pipes when the Lunacy Board guaranteed to use over £200 gas per year. When Glasgow Corporation, under the

1. S.R.O. Ayr Minute Book (GB1/4/1) 4/7/1853
2. Perthshire Courier 10/9/1861 p. 3. Flintoff was a prominent gas engineer and reformer, vide infra p.1157. c.f. 60 million cu ft.year at Perth.
3. E. Gauldie, Dundee Textile Industry (1969) op. cit., p. 203.
4. S.R.O. Ayr Minute Book (GB1/4/1) 30/4/1888, 25/6/1888, 18/9/1893.

1898 Inebriates Act, purchased a mansion at Girgenti near Irvine, as a reformatory, a private gasworks was operated for the building.[1] Several companies specialized in gas apparatus for large farms and private estates.[2]

Few indications remain of the importance of private gasworks in Scotland during the late nineteenth century, but the original matrix of the Scottish gas industry was still present, though intermeshed with the later joint-stock gas companies. Lausdale Bleachfield[3] near Paisley had a gasworks in 1880, as did Glengowan Print Works[4] near Airdrie. Messrs. Stuart's of Musselburgh[5] had a private gasworks in 1861 producing gas at the very low price of 1s 9d per 1,000cu ft, and in the same town Messrs. G. Mackay[6] in 1882 operated an independent gas-plant. Eglinton Iron Company works and associated houses near Muirkirk were supplied after 1876 by the Iron Company's own gasworks, and pipes from Muirkirk Gas Company were disconnected.[7] Similarly at Kilbirnie[8] industrial village in 1890, 700 consumers were supplied by Messrs. W. & J. Knox, thelocal branch of Englinton Iron Company.

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1. Municipal Enterprises - Glasgow (1904, Glasgow) (22nd Congress of the Sanitary Institute) p. 141.
2. e.g. T.B. Porter of Lincoln; H. Stephens and R.S. Burn, The Book of Farm Buildings, their Arrangement and Construction (1861) pp. 410-1, 485-7.
3. An accident in the gasworks caused a £20,000 fire in 1880 Third Statistical Account - Stirling and Clackmannan (1966) op. cit., p. 260
4. Journal of Artificial Light 6/3/1880 p. 456.
5. Edinburgh Evening Courant 20/5/1861
6. J.G.L., 12/12/1882
7. Muirkirk Minute Book (GB1/62/1) S.R.O. 1/12/1876
8. J.G.L. 30/9/1890.
A survey of private gasworks in Britain, published by the Journal of Gas Lighting in 1871, mentions only Burntisland in Scotland, and is not comprehensive. JGL 3/1/1871, p. 23.

In 1880 a gasworks was designed for Messrs John Elder and Company's Fairfield Works,[1] the largest shipyard in Britain, by Mr Miller[2] of Thomson Street, Govan, who had installed similar equipment for Messrs Crum's cotton printing works at Thornliebank. Two benches of five retorts each were designed to use coal dross or 'triping' to produce 7,000 cu ft of 28 candlepower gas per ton. In part payment, Miller was given the by-products by a preferential contract. By 1882 Fairfield's new gas cost only 11½d per 1,000 cu ft, compared to 3s 8d charged by Glasgow Corporation gasworks, and the shipyard lighting cost had fallen from £1,400 to £300 a year.

The Clydebank shipyards of James and George Thomson[3] used a private gasworks up to 1882 when they introduced electricity. To provide gas for the houses of their workmen, they were then obliged to enter a three year contract with Glasgow Corporation for gas mains from Yoker to Clydebank. The Corporation gas department was confident of obtaining a contract to supply the large factory under construction there for the Singer Sewing Machine Company, but in 1885 that Company built a private gasworks using the new Siemens regenerative system[4]. By 1887 the factory gas also supplied the street lamps in north Clydebank.[5]

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1. J.G.L., 14/12/1880

2. Miller was probably a member of the family of that name who operated by-product works in Glasgow. Vide infra pp. 547, 964
   In 1883 Messrs. A. & A. Miller of Govan unsuccessfully tried to persuade Johnstone Corporation to use their equipment to produce 25 candlepower at 1s 6d per 1,000 cu ft instead of the 4s 6d they normally charged.
   J.G.L., 18/9/1883

3. J.G.L. 19/12/1882

4. Vide infra 'Technological Evolution' p. 357

5. J.G.L. 6/1/1885, 17/5/1887. W.H. Marwick, Economic Developments in Victorian Scotland (1936) pp 80-1.
   Stratten's Glasgow and its Environs (1891, Glasgow) p. 43.
   Stratten's diagram of Messrs Crawford Bros., flax spinners of

At Bonnyrigg in the 1880s Messrs Smith and Wellswood operated a gas plant for their Columbia Gas-Stove Works and also supplied part of the village.[1] In Fife, Lochgelly gasworks was owned privately from 1856 by Mr Leich[2], while Messrs. Douglas, Fraser and Sons in 1885 operated the Froickham Gasworks, Arbroath. In the late nineteenth and early twentieth centuries quite a number of industrial companies supported the original pattern of private gasworks.[3] In 1903 the Lothian Coal Company operated gasworks at Newton Grange and Rosewell, J.F. Blakey and Company at Kincardine on Forth, J. Finlay and Company at Deanston, W. Dixon and Company Ltd. at Carfin, and in 1904 S. Blaikie and Company at Stromness. Individual owners in 1903 included Robertson and Young at Bankfoot, A.Cameron at Cove and Kilcreggan, Thomas Gass at Ecclefechan, B. Howat and Son at Sanquhar, Forbes Waddel at South Queensferry, and the Duke of Sutherland at Golspie. From the 1820s, however, the gas supply in Scotland was increasingly provided by joint-stock companies formed for that purpose.

Beith, also appears to illustrate a gasometer and hence private gaswork (p. 232).

1. J.G.L. 16/8/1887
2. J.G.L. 5/12/1856
3. C.W. Hastings, The Gas and Water Companies Directory (London, annually)

   In Campsie parish the use of oil-gas in "some of the mansion houses and larger villas" from private sets of apparatus was popular in the 1890s.
   J. Cameron, The Parish of Campsie (1892, Kirkintilloch) p. 142
   For 'Oil Gas' plant, vide infra p. 410

CHAPTER II

Company Development, Location and Ownership

The supply of water by joint-stock companies was developed in Scotland during the eighteenth century, and in the early nineteenth century even water-power was distributed in this way, for example by Shaw's[1] Water Company of Greenock in the 1820s. Steam-power, however, did not develop into a centralized service industry, and until 1810 gas-lighting was subjected to the same restriction of small units located in the separate factories which they served. Boulton and Watt of Birmingham, who hoped to corner the market for supplying such gas apparatus, maintained that this was the only feasible system.

They were successfully challenged by F.A. Winsor,[2] an amateur chemist but skilled publicist, who copied the wood-gas apparatus of Lebon in France. In 1810 Parliament sanctioned Winsor's proposal for a chartered gas company to distribute gas over a wide area of London, through a network of pipes joining a series of "sub-stations" which would manufacture gas from coal. The first attempts were primitive and not commercially viable, until the Chartered Company was joined by Samuel Clegg, a skilful engineer who had trained under Murdoch. With better apparatus, the economies of large-scale production ensured the success of centralized gasworks and several

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1. D. Campbell, Historical Sketches of Greenock (1881, Greenock). Greenock Advertizer, 9/12/1828, p. 3

2. Vide infra, p. 1355 Appendix II.1 ; see also pp. 64, 530
In 1807 F.A. Winsor tried to form a National Deposit Bank in London vide B.C. Hunt, Business Corporation in England 1800-1867 (1936,Cambridge,Mass.) p.14

competing companies were established in London during the 1810s, making that city the new focus of gasworks technology. Both sources of skill were soon imported into Scotland. Edinburgh Company in 1817 employed John Grafton,[1] a London gas engineer, to design their first works, while Glasgow employed H. Creighton, a gas engineer from Murdoch's team in Birmingham.

Only 18 Scottish joint-stock companies obtained Parliamentary charters.[2] The remainder relied upon the adjudication of Scots Common Law which, unlike that of England, recognised a company as a separate persona,[3] independent of its constituent members and trading upon the credit of its resources. The investors had freely transferable shares, not subject to the consent of all other partners, unlike English partnerships.[4] Transfers, subject to company regulations, did not invalidate the company's existence, management was remitted to 'directors' who alone could incur obligations on behalf of the company, and the Scottish gas companies fulfilled other criteria for joint-stock companies as defined by Lord President Inglis[5] in 1868.

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1. Engineer to the Chartered Company; 1815 planned and superintended construction of Preston gasworks, using skilled London workers; 1820 built Wolverhampton gasworks. Vide M.E. Falkus, Economic History Review, 1967, op. cit.
   Vide infra, 'Technology' p. 280
   Consultant engineer assisting Stamford Gas Company in 1824, Mechanics Magazine 1824 Vol. 3, p. 265.
2. Vide infra 'Chartered Companies' p.946
3. W.H. Marwick, Economic Developments in Victorian Scotland (1936) op. cit., p. 52
   The 1856 Scottish Bankruptcy Act included "any ordinary common law partnership" under the definition of 'Company'.
   R. Brown, "Early English Joint Stock Companies", Trans. Royal Philosophical Society of Glasgow 1902-3 Vol XXIV
4. R. Brown ibid. quoting Lord Lindley (1891), and the English Joint Stock Companies Act (1841).
5. R. Brown ibid. quoting Dove v. Young (1868)

Influenced by French law and Roman views on partnership, the "societas" or company in Scotland was granted rights, privileges and duties apart from those of its members. English law, in contrast, regarded ordinary partnerships as an aggregation of individuals and allowed no such distinction. From the eighteenth century, the right to sue and to transfer stock was considered at least as important as 'limited liability' by Scottish companies. Some confusion existed within Scottish legal circles over the precise privileges and duties of companies. In 1757 liability in Arran Fishing Company was deemed to be restricted to the value of shares,[1] but this privilege was not allowed to D. Heron and Co., Bankers, in 1773. Nevertheless, gas companies were well accommodated by Scots Law, thriving even in small communities, which in England had no supply because of the cost of an Act.[2] The early spread of small Scottish companies was quite different from the English pattern described by M.E. Falkus[3] in which companies were formed in large towns, and later at distinct intervals of time, in progressively smaller towns. English joint stock gas companies first obtained legal status under the 1844 Companies Act, which many adopted,[4] though limited liability was denied until the 1855 and 1856 Companies Acts. The latter was the first to which some Scottish

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1. R. Brown ibid. quoting Douglas Heron & Co. v. Hair (1778)
R.H. Campbell, "The Law and the Joint Stock Company in Scotland" Studies in Scottish Business History (1967) P.L. Payne, Ed.

2. In 1847 an English company with £20,500 capital equipment, had to spend about £800 for an Act. B.P.P. 1847 XXII, p. 95 et seq.

3. M.E. Falkus, "The British Gas Industry before 1850", Economic History Review, 1967 Second Series, Vol. XX

4. B.P.P. 1847 LIX p. 231; B.P.P. 1852 LI p. 531, Reports of Registrar of Joint Stock Companies.
F.R.J. Jervis, The Evolution of Modern Industry (1960) pp. 165-7.

gas companies subscribed, and marked an influx of English commercial law which slowly produced a less liberal attitude in Scottish Law[1] towards unincorporated companies.

Until the 1840s, gas companies were one of the few manufacturing industries with joint-stock organization in Scotland. City newspapers confirm the opinion of J. Watson[2] that during the 1830s shares were also sold only by water-supply companies, the Forth and Clyde and Monkland Canal, the Garnkirk and one or two mineral railways, five Edinburgh banks, and a few other companies.

Railways have been considered "the first real scope for modern financial devices"[3] and by implication the first method of mobilising the savings of the general population for use as capital in industry where it could perform work and increase the wealth of the nation and of the shareholders. Because this coincided with the establishment of Stock Exchanges[4] in Glasgow (1844), Edinburgh (1844) and Aberdeen (1844), Marwick stressed that joint-stock enterprise was largely absent in Scotland until the mid-nineteenth century. Private partnerships, as at Falkirk Ironworks founded in 1819 by a thirty-years co-partnership between former employees of Carron works, were

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1. R.H. Campbell, op. cit.
   Vide infra p. 895

2. J. Watson's speech to Glasgow Stock Exchange in 1881, Memoirs and Portraits of a Hundred Glasgow Men (1886, Glasgow) Vol II p. 187; J.S. Jeans, Western Worthies (1872, Glasgow) p. 153

3. W.H. Marwick, Economic Developments in Victorian Scotland (1936) pp. 52-3
   Marwick restated the theory in 1964, but his ideas are more clearly formulated in the 1936 volume. W.H. Marwick, Scotland in Modern Times (1964) op. cit., p. 51

4. Cf. London (1773), Dublin (1793), Manchester (1836), Liverpool (1836)
   The Edinburgh Stock Exchange 1844-1944 (1945, Edinburgh) Edinburgh Public Library.

the most typical industrial organizations. "Such private partnerships from an early date occasionally took the style of a company, but there were few genuine specimens of joint stock enterprise until" the Companies Act of 1862, when began "the modern era of investment" in Scotland. He quoted Christie's[1] view that "economic backwardness" negated the legal benefits of Scots law until after 1856.

Marwick stated that most companies formed in the "mania" of 1825 soon collapsed in Scotland, and partly in consequence throughout the 1820s to 1840s joint-stock enterprise in Scotland was largely confined to banks, insurance companies and railways. Evidence from the 1839 London Stock Exchange, John Read's Manual of Scottish Shares (1842) and Fenn's Compendium (1869) indicated a slow increase in variety, with chartered gas and water companies plus miscellaneous specimens like Shotts Iron Company in the 1830s, growing to twenty-six others in the 1840s especially canal, shipping and investment, supplemented in the 1860s by tea, waggon, steamship, jute and cemet ry companies.

If Marwick's original hypothesis is correct, and true "companies" were rare before the 1850s-60s, not having taken earlier advantage of Scots Law, then a valid picture may be constructed from printed material on shares and companies. There is, however, strong evidence regarding the gas industry to challenge this analysis. In 1842

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1. W.H. Marwick, op. cit., quoting J.R. Christie Judicial Review XXI 1909-10.

Even in 1864 the number of Scottish gas companies registered for Limited Liability was minute compared to those elsewhere in Britain.

Vide B.P.P. 1864 (452) LVIII 291 Report on Joint Stock Companies - detailed data on all types of registered companies.

Reid's Manual took notice of only eighteen gas companies in Scotland when above 113 were operating. Such sources severely underestimate the number of unincorporated, unregistered joint stock companies.

Capital availability in early nineteenth century Scotland remains an important open question. W. Vamplew[1] believed the slow development of railways in Scotland, with only 137 route miles in 1840, was due to a lack of capital despite adequate technical skills. Thus capital was first concentrated upon short mineral lines, like the Kilmarnock and Troon line by the Duke of Portland, and the Pollok and Govan line by William Dixon. Moreover, English investors especially from Lancashire took a major role in financing the Glasgow, Dumfries and Carlisle line, the Edinburgh and Glasgow line, and the 1844 Edinburgh and Hawick lines. It is therefore difficult to view railways as catalysing a widespread desire throughout Scotland to invest and participate in the profits of industrialization.

Marwick's analysis has recently been restated by P. Deane[2] who claims that the massive social overhead capital for canals, railways, street lighting and water supply "was possible because the promoters were able to draw on the mass of often quite small personal and institutional savings which were becoming available in an economy that had

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1. W. Vamplew, "Sources of Scottish Railway Share Capital before 1860", Scottish Journal of Political Economy 1970 Vol. 17

   Even on the Glasgow, Paisley and Greenock Railway, where the Provosts of Greenock and Port Glasgow were directors, Lancashire and English investment predominated; M.C. Reed, "A Note on Subscriptions to the G.P. and G. Railway", Journal of Transport History 1973 Vol. 6
   Vide infra, 'Finance' Fig. 4.5

2. P. Deane, The First Industrial Nation (1969, Cambridge) pp. 166-67.

already begun to industrialize and grow." But they were exceptional organizations, because the characteristic unit of production was the family firm or partnership, self-financed or aided by personal friends, and the promoters even of large-scale canals tried to restrict shares to those with a direct interest in the success of the canal. Hence it was not until later that "the education of the non-participant saver took an immense stride forward in the railway age", and these savers subsequently transferred their attention to the genuine Limited Liability Companies after the Act of 1856.

Analysis of the coal gas industry now suggests that during the crucial period 1830 to 1856, this was the first large-scale industry to mobilize the personal savings of a wide cross-section of the population, and to foster that confidence in industry which stimulated later investment in other companies. It brought the knowledge and skills of industrial partnership and organization to the smallest villages, led to a pooling of local skills in finance, management, book-keeping and law,[1] and introduced local investors to the mechanism of corporate control. Investment was exceptionally free from risk,[2] and in the absence of very poor management, gave dividends in excess of ten per cent. Although ownership was often restricted initially to local inhabitants, especially consumers, the premium

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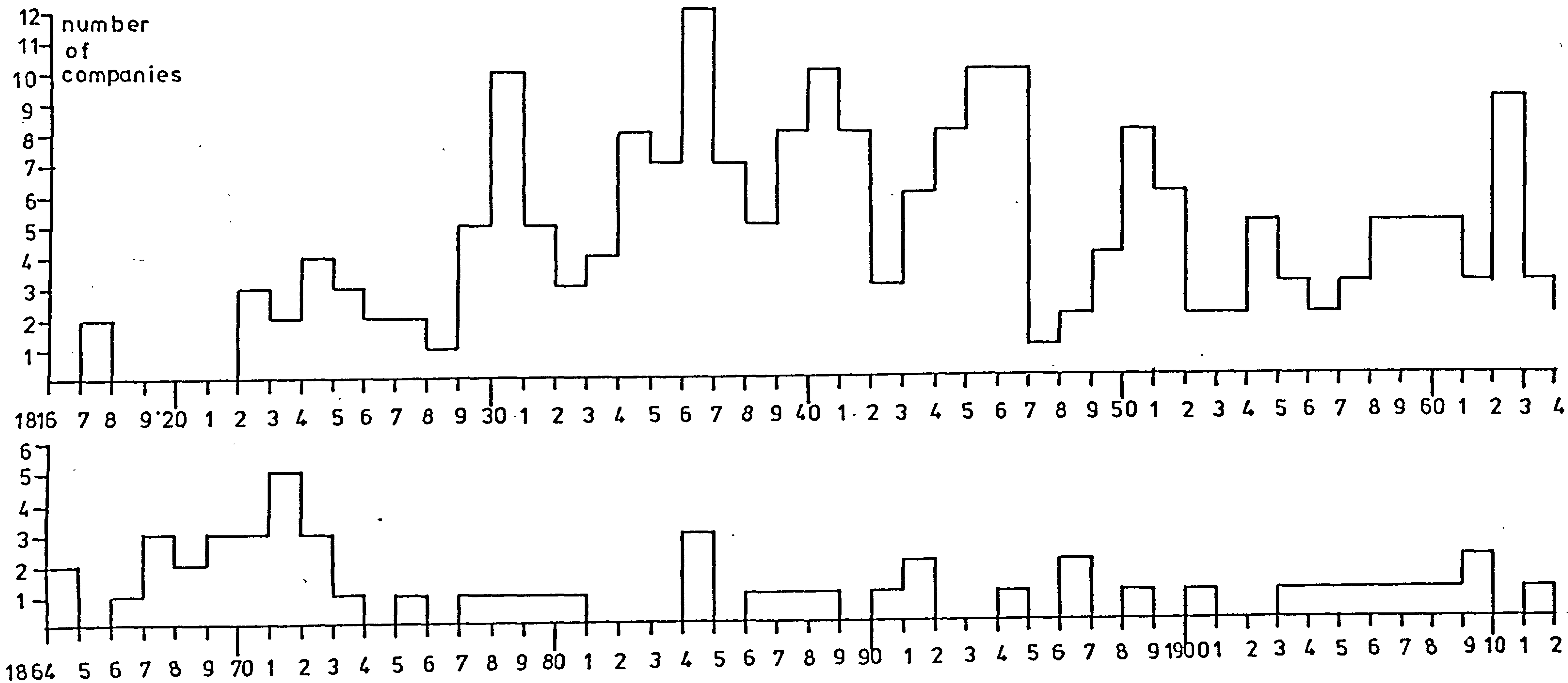
1. e.g. Stirling gas company always had "several of the best business 'heads' in the Community on its directorate"; Stirling Ref. Library Industries of Stirling and District (1909, Stirling) pp. 111-2.

2. The public was, however, slow to appreciate the lack of risk. Gas companies survived even the 1825-6 'mania' better than most companies. Twenty-nine companies worth £12.077 million were promoted then, out of a total 624 companies worth £372 million, but by 1827 twenty gas companies worth £9.061 million survived out of a total 127 companies worth £102.7 million. B.C. Hunt, The Development of the Business Corporation in England 1800-1867 (1936, Cambridge, Mass.) p. 46

Fig. 2.1

Annual Number of New Gas Company Formations in Scotland 1816-1914

Note - Because the interval between company formation and practical operations varied from months to years, the extant dates of origin are sometimes only approximate. Inoporative "consumers' companies" excluded from histogram.



which grew on shares in the larger companies, like Dundee, soon produced an influx of distant or "blind" investors and speculators, although the vast majority of these were Scottish residents.

During the 1820s gas lighting was confined to the larger commercial towns in Scotland, but by the 1830s it was being promoted in many small towns and villages which were still ignored as "villages" by the Census.[1] In the North, Ellon[2] village was the first such village to make gas, in 1827, in parochial simulation of the nearby Aberdeen city gasworks of 1824. Some villages like Balfron from 1819 were partially supplied from the private gasworks of a local factory, and in other cases like the Vale of Leven in Dunbartonshire, local industrialists were the principal promoters of companies and the main consumers of gas.[3] But gas promotions were not confined to the machinations of industrialists. Local landlords, gentry, philanthropists, magistrates and town councillors were all active in promoting these genuine joint-stock ventures. Companies were a means not only of encouraging thrift, and an expression of communal self-help, but also a way of effectively tapping for the first time the accumulated savings of the middle and lower classes. P. Deane[4] has emphasised the lack of State encouragement to industry in the early nineteenth century, when railways, canals, gas and water companies

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1. The Census ignored these 'villages' entirely, and since gas can only be distributed in a compact 'village' the Census is an unreliable guide to the extent of 'villages' in Scotland at that time.

2. J. Godsman, A History of the Burgh and Parish of Ellon (c.1950, Aberdeen). Ellon company took limited liability in 1874, and was purchased by the Town Council in 1904.

3. Also Johnstone, Renfrewshire. Vide infra, 'Municipal Gasworks' - Paisley p. 955

4. P. Deane, The First Industrial Nation (1969, Cambridge) p. 162

relied entirely on private rather than public enterprise. However, the gas companies were often supported and controlled by a far larger and more representative selection of local inhabitants than those with Parliamentary franchise, and were actively encouraged by many organs of local government. Shareholders were applauded as public benefactors, and because candles were expensive compared to gas, initial mistakes in technology or management could be offset by high charges for gas.

In many cases investors did not expect immediate financial returns. Their motives included the practical advantage of being able to use cheap light themselves, and parochial pride in displaying the "new light". These social benefits were enhanced by dividends, though many gas companies paid no dividends during the first two to five years of operation. During the 1820s the greatest risks from imperfect technology, and problems in adapting the managerial and organization methods of large Chartered companies in the shipping and colonial trades to the more sedate requirements of the gas industry, were faced and surmounted by large city companies. Few became incorporated, despite the heavy capital investment demanded for their large prosperous markets, but the very size of the companies and their markets provided flexibility and enabled them to overcome costly mistakes, poor quality gas, or low gas output per ton of coal.

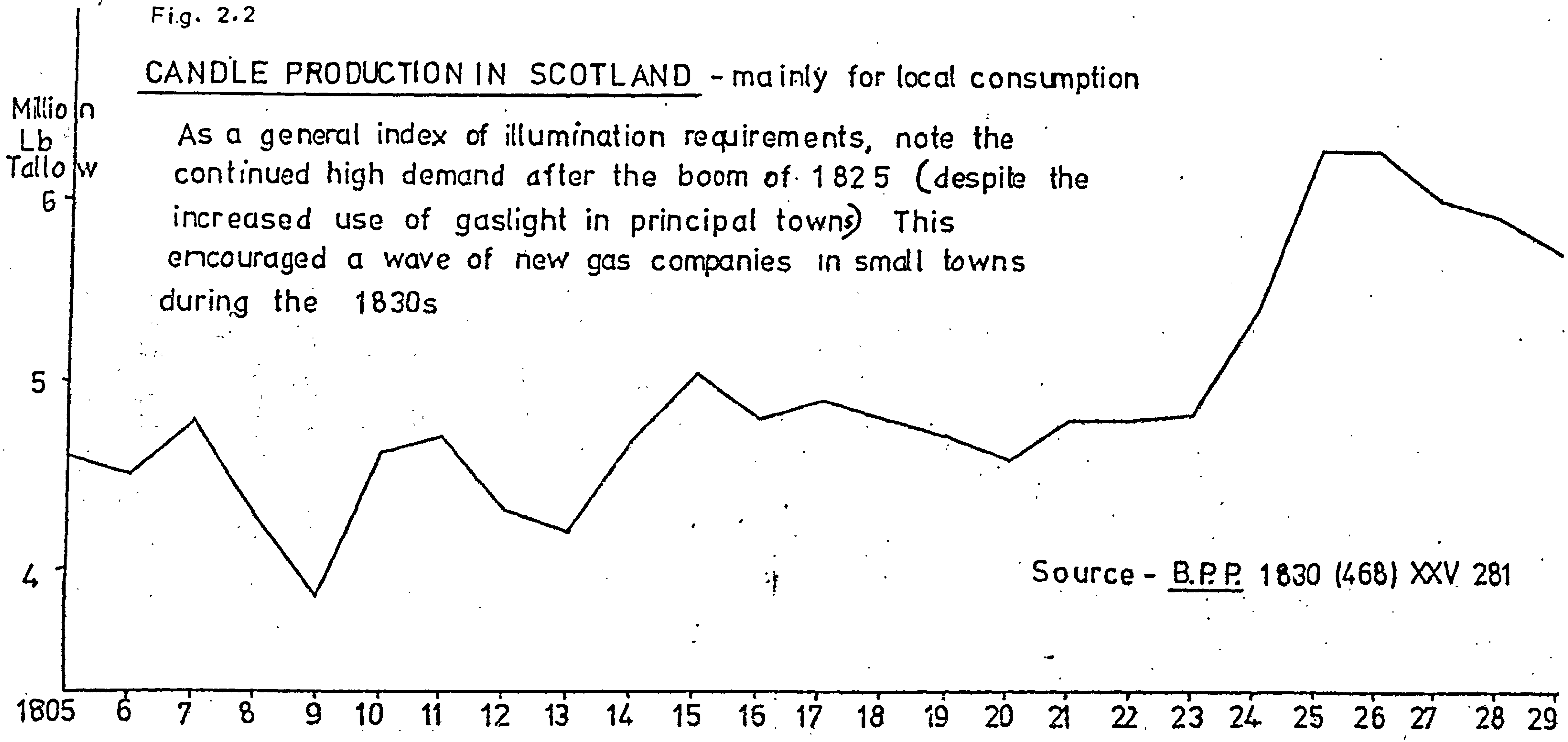
The stability of these companies,[1] and their profits, released

1. Marwick saw stability, in comparison to frequent withdrawals of capital which were normal in short-term co-partneries, as vital to the increase of fixed capital throughout the Scottish economy, but believed that it only came later, with Limited Liability. W.H. Marwick, Economic Developments in Victorian Scotland (1936) p. 121.

Fig. 2.2

CANDLE PRODUCTION IN SCOTLAND - mainly for local consumption

As a general index of illumination requirements, note the continued high demand after the boom of 1825 (despite the increased use of gaslight in principal towns) This encouraged a wave of new gas companies in small towns during the 1830s



Source - B.P.P. 1830 (468) XXV 281

"a tidal wave of formations in the United Kingdom in the 1830-40 decade",[1] the social benefits of which in Scotland were eulogized in the New Statistical Account. The pace of change was fragmentary, and some large towns were slower than small villages. Local initiative was the keynote.

Several important pre-conditions can be distinguished for rapid expansion in the industry. Cheap illumination always had a ready market in workrooms and dwellings,[2] but this demand was increasing during the industrial revolution, for example in loom 'shops', and also as a result of increasing urbanization. An external stimulus was therefore required to initiate the expansion. Adequate sources of capital and willing sponsors were necessary, as was the effective marketing of shares, and sufficient, competent engineers to increase the confidence of investors and to construct an efficient gasworks which would not dampen the enthusiasm of later sponsors in neighbouring towns and villages. Preferably, the profits would inspire them to greater exertions. A successful wave of gas companies on these lines swept through Scotland in the 1830s and 1840s.

The external stimulus took two forms. A change in the pig-iron market was fundamental in view of the very large quantities of iron used in the structure, apparatus and underground distribution pipes. Because the prosperity of consumers, whether private individuals or manufacturing companies, was directly reflected in their potential demand for gas, the prosperity of gas companies was also intimately bound by the trade cycle in Scotland and reflected general

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1. F.W. Robins, The Story of the Lamp(and the Candle)(1939, Oxford) p. 118.

2. High candle prices in 1830 stimulated investment in gasworks. Vide infra p.1215

Fig. 2.3

The Intensity of Railway Communications as an Index of Regional Commercial Prosperity and Population Density

The Intensity of Railway Communications as an Index of Regional Commercial Prosperity and Population Density

Abbreviations - A - Annan

B - Beith

Bg - Bathgate

D - Dalkeith

Df - Dunfermline

E - Edinburgh

G - Glasgow

Gr - Grangemouth

H - Hamilton

Km - Kilmarnock

Ky - Kirkcaldy

L - Lanark

M - Motherwell

Mu - Muirkirk

Source - W.M. Ackworth

<u>The Railways of Scotland</u> (1890)

Fig.2.3


Railway
Communications
Thurso
Wick
Golspie
Tain
Lossiemouth
Cullen
Fraserburgh
Elgin
Banff
Forres
Peterhead
Dingwall
Inverness
Huntly
Lochalsh
Aberdeen
Banchory
Blair Atholl
Montrose
Forfar
Arbroath
Dundee
Killin
Perth
Crieff
Oban
Cupar
N.Berwick
Df
Ky
Stl
Dunbar
Gr
Dumbn
Bg
D
Eye-
mouth
Gr
Pa
Dunse
B
M
H
L
Peebles
Galashiels
Kelso
Km
Irvine
Biggar
Selkirk
Mu
Ayr
Cumnock
Hawick
Girvan
Langholm
Dumfries
Lockerbie
A
Carlisle
Stranrae
Port Patrick
Kirkcudbright
Whithorn

trends within the country as a whole.[1]

Improved transportation infrastructure in Scotland, especially lower coal freight charges, an overall growth of population and urbanization which increased the market for gas-light, and a growing choice of competing gas-apparatus manufacturers, were also important factors in stimulating the growth of the gas industry.

Determining the importance of improved transport systems is difficult because the embryo company rarely acknowledged preceding social developments. However at Banchory[2] where a gas company was formed in November 1845, the impetus was "the belief that the projected railway from Aberdeen to Banchory would be completed in a very short time afterwards." Aberdeen citizens may indeed have encouraged the company, because although the transfer of shares for two years was restricted to persons living within five miles of the gasworks, Messrs P. and A. Davidson, Advocates of Aberdeen, were appointed the Company's agents in 1845. Construction of the railway was delayed, and so the gas company suspended its activities until July 1853.

Railways themselves raised the demand for gas, possibly to a level where a gas company became economically feasible. At Banchory, the Deeside Railway Company terminus, station, engine sheds and workshops were the main consumers of gas in the town, and gas companies at Stonehaven, Laurencekirk, and Drumlithie also relied

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1. Vide infra, 'Finance' p. 728
2. S.R.O. Banchory Minute Book (GB1/5/1), 10/8/1854.

heavily upon consumption by that Railway Company. Where necessary, railway companies built their own gasworks, as at Burntisland,[1] at Oban[2] in 1880, and at the Kyle of Lochalsh[3] where the Highland Railway Terminus used acetylene gas in 1898.

In a recent survey of "The British Gas Industry before 1850",[4] M.E. Falkus used two sources of data to plot the formation of gas companies, and stated that companies began at dates closely related to the trade cycle. He detected a boom from 1818 to 1825, despite a recession in 1819, another boom in 1831 to 1837, and a third from 1842 to 1846. The dates of Acts of Parliament were used to determine when companies commenced, a procedure which is invalid for Scottish towns like Hamilton and Dundee.[5] Data from Newton Chambers and Company, a Sheffield firm which supplied iron apparatus to gasworks throughout Britain, was used to determine when a large number of unincorporated companies, and "small undertakings operating under deeds of trust or owned by private individuals" were formed. It is difficult to judge how far these commercial data indicated an absolute increase in the number of unincorporated companies, or was distorted by the growing volume of total business handled by the Company. The use of industrial and bank credit to finance embryo gas companies, which Falkus saw as increasing the influence of the trade cycle, is less immediately evident in Scotland.[6]

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1. Vide infra, 'Municipal gasworks' p. 1044
2. J.G.L. 16/3/1880.
3. Gas World, 25/6/1898 p. 1038
4. Economic History Review, 1967, Second Series Vol. XX
5. Vide infra, 'Chartered companies' pp. 954, 960
6. Vide infra, 'Finance'. p. 769
   Heavy loans used by Scottish companies almost invariably post-dated initial construction contracts, and were frequently unanticipated by company promoters at the outset.

Falkus found gas-lighting widely established in all but the smallest towns by 1850. He believed that areas where coal was very expensive were not slow to build gasworks and sold gas at prices little above those in towns of equal size elsewhere, because of the additional revenue from coke. He found "little evidence of any regional variation in the rates" of gas. However, the situation in Scotland was complicated by a number of factors. Local coal gave very poor coke, while gas was used domestically as well as for factories and street lighting, unlike England until the late 1840s. Falkus also observed the prevalence of small market towns in Scotland where the 1851 Census showed an average-sized town to be 5,134 if those above 50,000 inhabitants were excluded, whereas in England that average was 7,551 residents. Outside the main towns, Scottish gas promoters were therefore faced with the demands of a great number of small urban centres, rather than a few small towns. The practice in some parts of England during the 1820s and 1830s, where a gas engineer financed the gasworks himself and then sold them to a company which he promoted, is not evident in Scotland.

"The uniform spread of gas lighting as between particular-sized towns" was claimed by Falkus who thought it was due to changing costs of apparatus, and technological change which resulted in cheap apparatus suitable for supplying smaller markets. This was brought into relief by the "equalization of the costs of transporting coal as a result of railway expansion." These hypotheses invite a critical examination in the light of data on Scottish companies, and especially the early prevalence of numerous small companies and private gasworks.

Fig. 2.4

Locations of Gas Companies Formed Up To 1830

Locations of Gas Companies Formed Up To 1830

KEY -

Land above 500 feet stippled.

Number	Town	Date	Number	Town	Date
1	Glasgow	1817	18	Dunfermline	1828
2	Edinburgh	1817	19	Kirkcaldy	1829
3	Leith	1822	20	Alloa	1829
4	Kilmarnock	1822	21	Falkirk	1829
5	Perth	1822	22	Peebles	1829
6	Paisley	1823	23	Greenock	1829
7	Johnstone	1823	24	Campbeltown	1830
8	Dundee	1824	25	Hamilton	1830
9	Aberdeen	1824	26	Port Glasgow	1830
10	Dumfries	1824	27	Elgin	1830
11	Arbroath	1825	28	Banff	1830
12	Ayr	1825	29	Airdrie	1830
13	Stirling	1825	30	Cupar	1830
14	Inverness	1826	31	Kelso	1830
15	Dalkeith	1826	32	Hawick	1830
16	Montrose	1827	33	Penicuik	1830
17	Ellon	1827			

Fig. 2.4

COMPANIES

UP TO 1830

Fig. 2.5

Map of Gas Companies Formed Outside the Central Lowlands Region

1831 - 1850

Map of Gas Companies Formed Outside the Central Lowlands Region

1831-50 KEY

Number	Company	Date	Number	Company	Date
(i) 1831-34			(iii) 1840-44		
1	Forfar	1832	25	Coldstream	1840
2	Sanquhar	1832	26	Keith	1840
3	Macduff	1833	27	Wick	1840
4	Peterhead	1833	28	Fraserburgh	1840
5	Fruickham	1834	29	Girvan	1840
6	Jedburgh	1834	30	Cullen	1841
7	Brechin	1834	31	Thurso	1842
8	Galashiels	1834	32	Castle Douglas	1843
(ii) 1835-39			33	Aberdeen New	1844
9	Duns(e)	1835	34	Lochgilphead	1844
10	Selkirk	1835	35	New Pitsligo	1844
11	Melrose	1836	(iv) 1845-49		
12	Stranraer	1836	36	Maxwelltown }	1845
13	Forres	1837		Dumfries }	
14	Huntly	1837	37	Banchory	1845
15	Stonehaven	1837	38	Eyemouth	1845
16	Annan	1838	39	Gatehouse	1846
17	Kirkwall	1838	40	Wigtown	1846
18	Turriff	1838	41	Innerleithen	1846
19	Moffat	1839	Companies pre 1849		
20	Nairn	1839	42	Oban	
21	Inverary	1839	43	Stornoway	
22	Kirkcudbright	1839	44	Dingwall	
23	Inverurie	1839	45	Fort William	
24	Portsoy	1839	46	Newton Stewart	

Fig. 2.5
Companies up to 1850

Fig 2.6

Map of Gas Companies Formed in the Central Lowlands up to 1840

Map of Gas Companies Formed in the Central Lowlands up to 1840

KEY

Number	Company	Date	Number	Company	Date
(i) 1817-24			30	Dumbarton	1831
1	Edinburgh	1817	31	Stewarton	1832
2	Glasgow	1817	32	Lanark	1833
3	Leith	1822	33	Barrhead	1834
4	Kilmarnock	1822	34	Grangemouth	1834
5	Perth	1822	35	Bathgate	1834
6	Paisley	1823	36	Dalry	1834
7	Johnstone	1823	37	Maybole	1834
8	Dundee	1824	(iv) 1835-9		
9	Edinburgh Oil	1824	38	Blairgowie	1835
(ii) 1825-29			39	Haddington	1835
10	Arbroath	1825	40	Kilsyth	1835
11	Ayr	1825	41	Kinross	1835
12	Stirling	1825	42	Kirriemuir	1835
13	Dalkeith	1826	43	St. Andrews	1835
14	Dunfermline	1828	44	Carluke	1836
15	Kirkcaldy	1829	45	Coupar Angus	1836
16	Alloa	1829	46	Dunbar	1836
17	Falkirk	1829	47	Kilwinning	1836
18	Peebles	1829	48	Lochwinnoch	1836
19	Greenock	1829	49	Newburgh	1836
(iii) 1830-4			50	Pollokshaws	1836
20	Port Glasgow	1830	51	Saltcoats	1836
21	Hamilton	1830	52	Leven Fife	1837
22	Airdrie	1830	53	Old Cumnock	1837
23	Cupar	1830	54	Catrine	1838
24	Penicuik	1830	55	Largs	1838
25	Strathavon	1831	56	Auchtermuchty	1838
26	Musselburgh	1831	57	Biggar	1839
27	Beith	1831	58	Kirkintilloch	1839
28	Linlithgow	1831	59	Alexandria	1839
29	Pittenweem	1831			

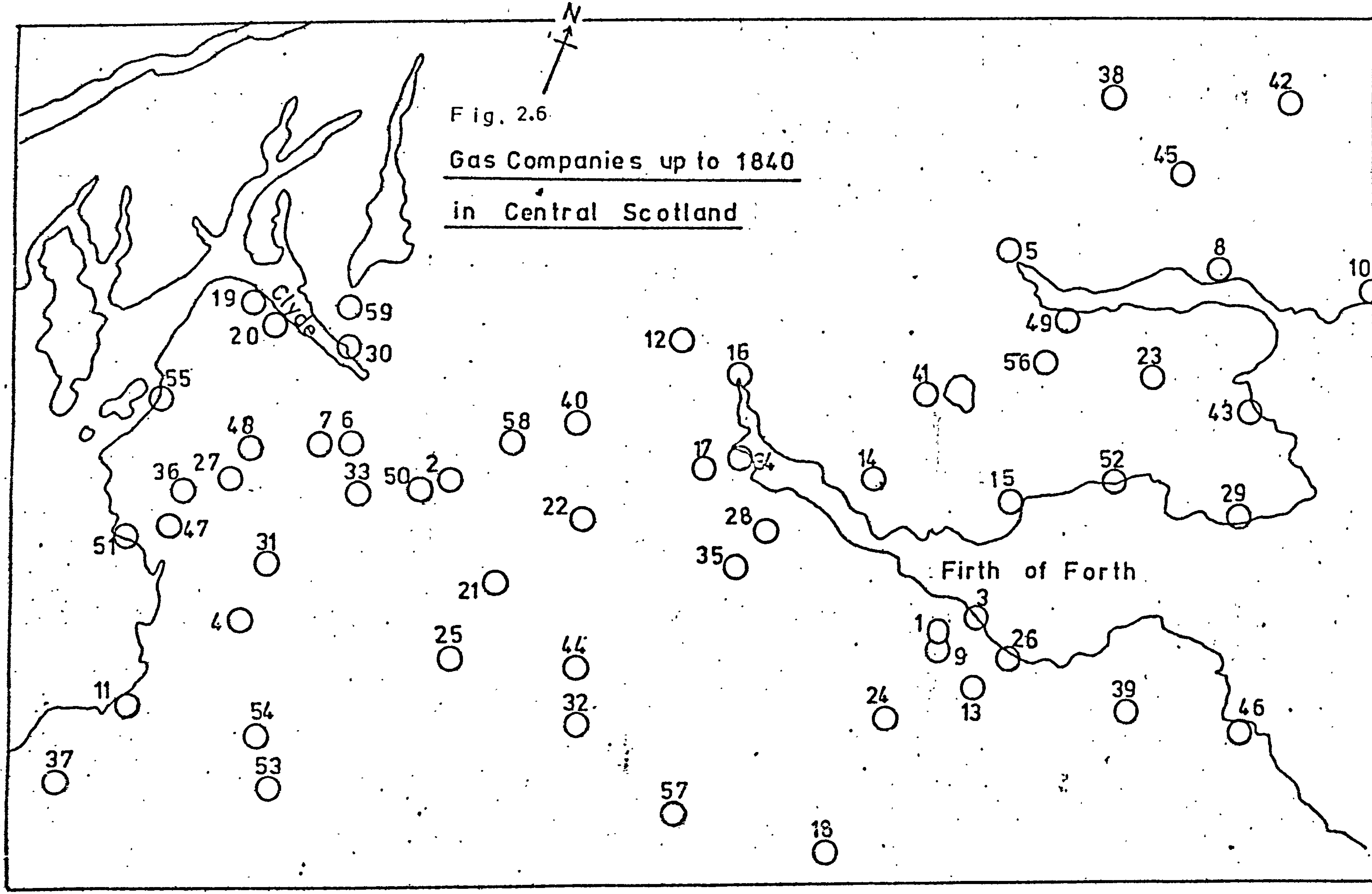


Fig. 2.6

Gas Companies up to 1840 in Central Scotland

Fig. 2.7

Map of Gas Companies Formed in the Central Lowlands

1840 - 1850

Map of Gas Companies Formed in the Central Lowlands 1840-50

KEY

Number	Company	Date	Number	Company	Date
(i) 1840-44			34	Innerleithen	1846
1	Broughty Ferry	1840	35	Buckhaven/E.Wemyss	1846
2	Strathmiglo	1840	36	Bridge of Weir	1846
3	Rothesay	1840	37	Alyth	1847
4	Anstruther	1841	38	Kettle/Freuchie	1849
5	Auchterarder	1841	39	Motherwell	1849
6	Bridge of Allan	1841	40	New Cumnock	1849
7	Collinsburgh	1841	41	Stonehouse	1849
8	Crieff	1841	42	Kingskettle	1849
9	Dunblane	1841	Companies pre 1849		
10	Leslie	1841	43	Burntisland	
11	Lauder	1842	44	Clackmannan	
12	Wishaw	1843	45	Crail	
13	Coatbridge	1843	46	Cumbernauld	
14	Dysart	1843	47	Dunkeld	
15	Elie/Earlsferry	1843	48	Falkland	
16	Galston	1843	49	Inverkeithing	
17	Glasgow C. & W.	1843	50	Kincardine	
18	Boness	1843	51	Kinghorn	
19	Larkhall	1844	52	Largo	
20	Thornhill	1844	53	Lasswade	
21	Tranent	1844	54	W. Linton	
22	Helensburgh	1844	55	Markinch	
23	Alva	1844	56	Mauchline	
(ii) 1845-49			57	Mid & E. Calder	
24	Ayr Newton	1845	58	Muirkirk	
25	Falkirk J.S.	1845	59	Neilston	
26	Portobello	1845	60	N. Berwick	
27	Prestonpans	1845	61	N. Queensferry	
28	Gourock	1845	62	S. Queensferry	
29	Dundee New	1846	63	Renfrew	
30	Hamilton New	1846	64	Troon	
31	Kilbarchan	1846	65	Tillicoulty	
32	Perth New	1846	66	Torryburn	
33	Lesmahagow	1846			

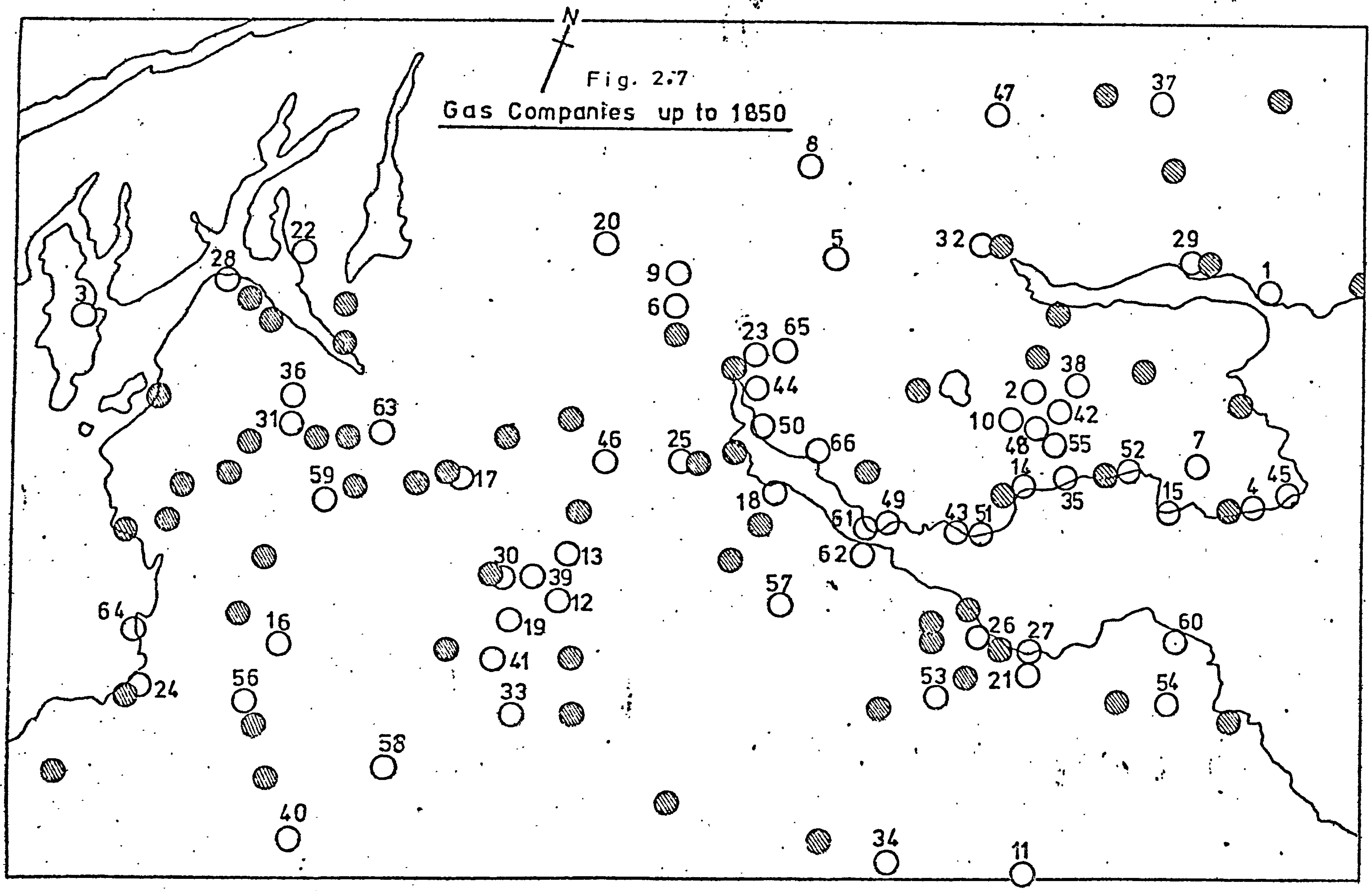


Fig. 2:7
Gas Companies up to 1850

Fig. 2.8 **Map of**

Gas Companies Formed Outside the Central Lowlands

1850 - 1870

Gas Companies Formed Outside the Central Lowlands 1850-70

KEY -

Number	Company	Date	Number	Company	Date
1	Rothes	1850	13	Lochmaben	1858
2	Bervie	1850	14	Aberlour	1859
3	Dornoch	1850	15	Beauly	1860
4	Fochabers	1850	16	Ecclefechin	1860
5	Dufftown	1854	17	Golspie	1862
6	Old Meldrum	1854	18	Stonehaven Consumers	1862
7	Latham	1854	19	Whitehorn	1862
8	Lerwick	1854	20	Ballator	1863
9	Insch New	1855	21	Grantown	1864
10	Lockerbie	1855	22	Fortrose	1869
11	Garmouth/ Kingston	1857	23	Easter Buckie	1869
12	Dalbeattie	1858			

Fig 2.8 Companies up to 1870

Fig. 2.9

Map of Gas Companies Formed in the Central Lowlands

1850 - 1870

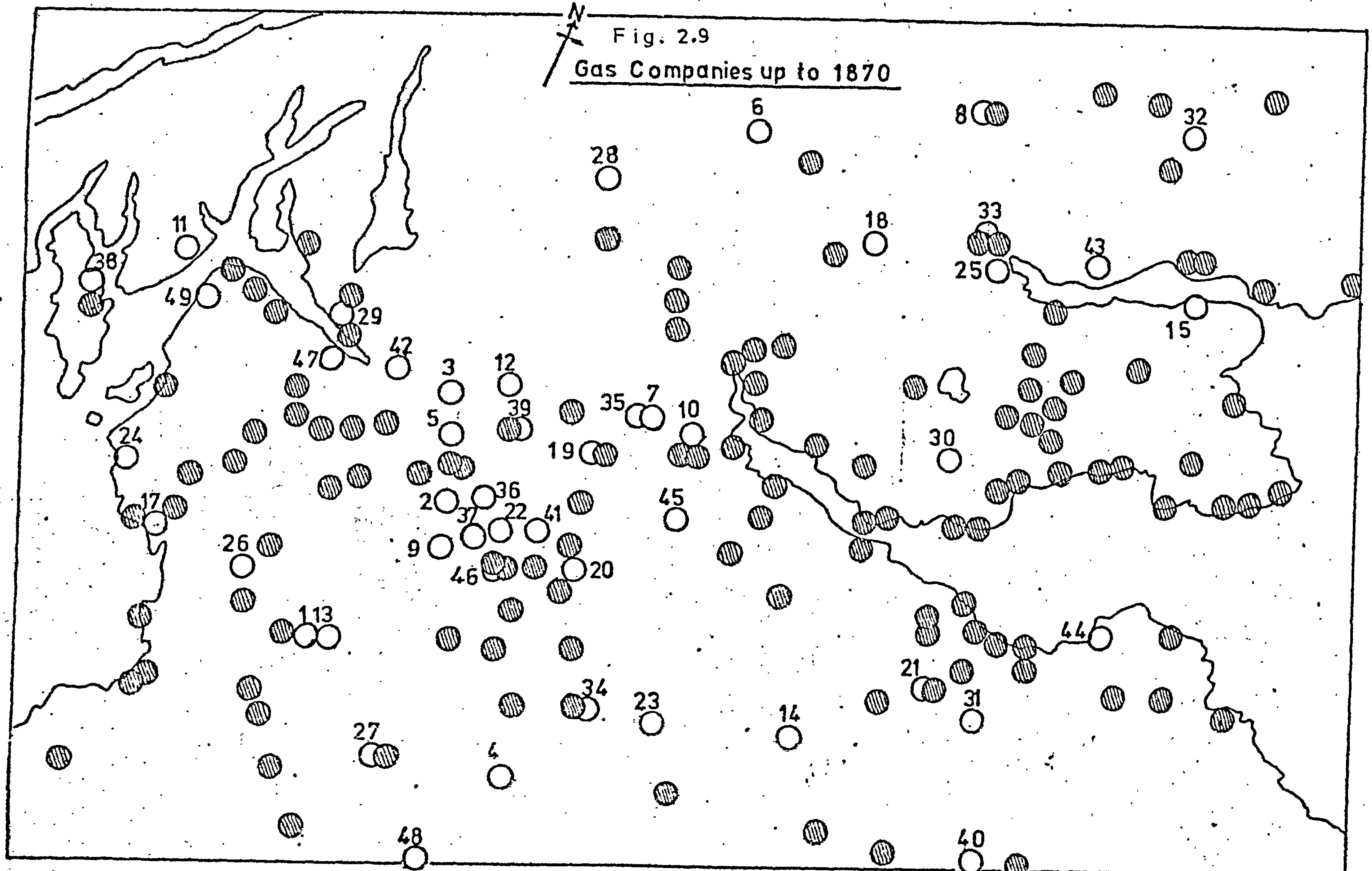
Map of Gas Companies Formed in the Central Lowlands 1850-70

KEY

Number	Company	Date	Number	Company	Date
(i) 1850-54			26	Kilmaurs	1859
1	Newmills	1850	27	Muirkirk New	1859
2	Rutherglen	1850	28	Callander	1859
3	Milngavie	1850	(iii) 1860-64		
4	Douglas	1850	29	Renton	1860
5	Maryhill	1850	30	Lochgelly	1860
6	Comrie	1851	31	Gorebridge	1861
7	Denny	1851	32	Meigle	1861
8	Dunkeld New	1851	33	Perth Consumers	1861
9	E. Kilbride	1851	34	Lanark Consumers	1861
10	Grahamston	1851	35	Denny Consumers	1861
11	Dunoon	1852	36	Baillieston	1862
12	Lennoxtown	1852	37	Blantyre	1862
13	Darvel	1853	38	Kamesburgh (Port Bannatyne)	1862
(ii) 1855-59			39	Kirkintilloch Consumers	1862
14	W. Linton New	1855	40	Stow	1862
15	Carnoustie	1855	41	Bellshill	1863
16	Newport (Dundee)	1856	(iv) 1865-69		
17	Stevenston	1856	42	W. Kilpatrick	1865
18	Aberuthven	1857	43	Errol	1866
19	Cumbernauld New	1857	44	Aberlady	1867
20	Holytown	1857	45	Slamannam	1867
21	Lasswade New	1857	46	Hamilton Consumers	1868
22	Bothwell/Uddingston	1858	47	Langbank	1868
23	Carnwath	1858	48	Sanquhar New	1868
24	W. Kilbride	1858	49	Inverkip	1869
25	Bridge of Earn	1859			

Fig. 2.9

Gas Companies up to 1870



Incompetent engineers were an important factor in hindering the expansion of the Scottish gas industry in the 1820s, and although few data remain about their origins, their actions were manifest. At Kilmarnock[1] the new company in 1822 built on a high-level site, disregarding the expanding properties of rising gas which required forceful pumping to reach the lower level supply zone. Consequently in September 1823, with pipes laid to only a few of the main streets, the capital of the company had to be raised from £4,000 to £5,000. The mistake of several companies in choosing oil-gas apparatus was directly due to the inability of scientists to measure light,[2] and not the fault of engineers. However, Ayr gasworks were built in 1825 by a London engineer who was accused in the Mechanics Magazine[3] (1829) of "unblushing quackery", and of installing at Ayr and later at Dalkeith in 1828, condensers as primitive as those first used by Winsor in 1807. Even the retort bench at Ayr had to be rebuilt shortly after being installed.

The shortage of engineers led the Perth company in 1822 to enlist a local academic, Adam Anderson,[4] to advise them. He was financed

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1. J.G.L., 24/3/1884

2. Vide infra, 'Oil Gas' p. 421

3. Mechanics Magazine 1829 Vol II pp. 7-9. The Ayr engineer had apparently trained originally in 1823 with the Bow Oil-Gas company in London.

4. Vide infra 'Technology' pp. 413, 247
9/8/1809 Anderson, a resident of Edinburgh, elected Rector and science teacher at Perth Academy. Popular lecturer, eulogised in Perthshire Advertizer 12/7/1810.
1810 granted £240 for scientific apparatus, for some of earliest practical classes in Britain.
1812 granted £15 for chemicals, and introduced Chemistry on curriculum.
1827 received honorary LL.D from St Andrews University.
29/8/1837 became Prof. Natural Philosophy at University of St. Andrews.
'Superintendent' of Natural History in Perth Antiquarian

to visit several of the main Scottish gasworks, including Edinburgh, Glasgow and Berwick, where the gas managers were quite willing to explain their apparatus, and without secrecy gave him the full benefits of their experience. Preparations for Perth gasworks, of a novel design, began in 1823, but it was not completed until 1824. It became a model works, visited by many aspiring Scottish gas engineers, and Anderson himself subsequently designed several other Scottish gasworks, including those of Stirling and Inverness.[1]

The employment of outside engineers, who were associated with the construction of a gasworks but did not subsequently manage the daily running of the works, is the basis of the 'contractor system' outlined by Falkus.[2] He claims that they -

> were often responsible for the entire establishment, from the selection of a site to the completion of the works. They decided on the equipment to use, and ordered it from the manufacturers of their choice. To the contractors can be traced many of the important technological innovations in the various stages of gas manufacture, and advances in the design of apparatus.

Scottish evidence supports the importance of their technological contribution, but does not indicate any 'closed shop' for the purchase of equipment. Frequently, the company made its main choice between several rival engineers on the strength of their reputation,

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Society.
Died 4/11/1846
Vide E. Smart, History of Perth Academy (1932) pp. 110, 116, 118, 121
History of the Literary and Antiquarian Society of Perth 1784-1881 (N.D. National Library of Scotland, ref. 3/2830).
New Statistical Account Vol X p. 86

1. J. Ker, Considerations relative to nuisance in Coal Gas Works (1828, Edinburgh) p. 6

2. Economic History Review XX 1967 op cit.

and the expenses they estimated, and after making a cross check, the "method of comparisons", with the management of the gasworks of similar size. Once the engineering specifications were provided, it was standard practice even in the 1820s to advertise in the press or by circulars sent to a number of rival manufacturers, for a sealed tender to provide equipment to those specifications. This method was used even for minor contracts like carpenter and slater work, and was applied even when the engineering data was supplied by the engineer from a company which supplied gas-apparatus. That company had to rely upon its own skills to under-price its rivals, and not upon a pre-arranged agreement.[1] In no known case did a 'contractor' in Scotland build the gasworks before inviting a company to purchase it, and there is considerable evidence that company committees were very careful to minimise the cost of the original gasworks, especially in view of the large capital sums involved.

"Gas manufacture I believe is still very imperfectly known", Ritchie told the Stranraer[2] company in 1836. Instead of relying upon textbooks, he found it necessary to make practical observations at "all the Gas Works in the neighbourhood" to note improvements which he could use in designing new gasworks.[3] He had "seen many works both in Scotland and England which are erected on such bad principles that it would have been bad economy ... to have executed such plans altho got for nothing". The engineers patronized by

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1. Vide infra 'Finance' on tenders taken, and rivalry between suppliers; also infra p. 1616

2. S.R.O., Stranraer Minute Book (GB1/78/1) 4/3/1836. Vide infra p. 632

3. For technological improvements in the 1820s-40s vide infra 'Technology'.

iron-foundries charged less for their plans than did independent gas-engineers who worked full-time as gas managers, but Ritchie believed they were more interested in canvassing for contracts than in adopting improvements which made gas cheaper. Yet while independent gas-engineers improved the standards of production, the iron industry was active in promoting the physical growth of the gas industry.

The iron industry was subject to an inelastic and "derived rather than a direct demand."[1] Normally it relied upon the demand especially from railroads, machinery, and the gas industry, before expanding, rather than expanding in order to generate a market. Nevertheless, the economies which resulted from J.B. Neilson's "Hot Blast" process of 1828, and the use of Blackband ores,[2] stimulated Scottish iron output out of all proportion to the growth of demand within Scotland where railways were slow to expand. Although a considerable amount was exported to England, the growth of the Scottish gas industry during the 1830s gave an important fillip to the iron industry when even the rapidly deteriorating 'retorts' were made of cast iron.

Cast iron goods in 1801 were worth twice as much as pig iron in the Clyde area,[3] and Scottish iron products were sold in the

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1. P. Deane, <u>The First Industrial Revolution</u> (1969, Cambridge)

2. R.H. Campbell, "Statistics of the Scottish Pig Iron Trade, 1830 to 1865" <u>Journal of the West of Scotland Iron and Steel Institute</u> 1956-7 Vol. 64. Lanarkshire and Ayrshire benefited most, and iron output rose from 40,000 in 1830 to 500,000 by 1840s, and 1 million tons by 1860s. Scottish iron was 5 per cent British total output in 1830, but above 25 per cent in mid-1840s.

3. J. Butt, "The Scottish Iron and Steel Industry before the Hot Blast", <u>Journal of the West of Scotland Iron and Steel Institute</u> 1965-6 Vol. 73.
Extensive bibliography.

Americas and Ireland from the boom of 1783. Over fifty small foundries were producing cast iron goods by 1813, but largely for export, and a lack of demand within Scotland, and hence a lack of competition, kept the prices high there until the late 1820s. The question of whether this inhibited gas company formation until the late 1820s, or was partly a consequence of the absence of such companies, must remain open. Dr J. Butt has shown that cast iron prices at Shotts fell from 22s 6¾d per cwt in 1826 to 15s 8d in 1828, and attributes the delay in price reduction to the slow rate in adopting cast iron in place of wood and stone in structural work in Scotland. Industrial growth was slower than in England and "the pace of acquiring social overhead capital such as gas and water companies was less rapid." This may be related to the size of Scottish towns, and the consequence of this upon the rate of technological diffusion, but certainly the rate of forming new gas companies rose very rapidly in the late 1820s, 1830s and 1840s, stimulated by lower costs for cast-iron goods.

From 1825, gas pipes were greatly improved in quality, and leakage reduced, by a process of 'butt-welding' patented by C. Whitehouse and subsequently adapted and automated by J. and J. Russell of Wednesbury.[1] This replaced the expensive 'skelp' welding of overlapping

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1. R.T. Crane, "Early History of Wrought Iron Gas Pipes", Gas World 28/10/1893.
English service-pipes were in fact imported into Scotland in the 1820s, e.g. 1829 Dunfermline gas company ordered £163 pipes from J. Russell of Wednesbury (Dunfermline Minute Book 10/6/1829, 30/6/1829) A. Liddell of Glasgow made butt-welded tubes from 1835, A. and N.L. Clow The Chemical Revolution (1952) op. cit.
James Russell previously worked for Aaron Manby of Horsley Iron Works. S. Clegg, Practical Treatise on the Manufacture and Distribution of Coal Gas (1853) 2nd Edn., p. 20.

tapered edges which was used in gun-barrels and early gas pipes.[1] Several Scottish tube manufacturers purchased licences under the patent.

During the 1830s and 1840s virtually the entire structural engineering required by Scottish gasworks was supplied by Scottish manufacturers, indicating that a pool of skilled engineers had developed during the relatively slow expansion of the gas industry during the 1820s. Shotts Iron Company was the most important general engineering company to take advantage, like some English companies,[2] of existing commercial contacts to promote a market for gas apparatus. From about 1825 until 1833 when he was demoted, Mr Blaikie senior as manager of the Carlton Foundry,[3] was assisted by his son, Joseph G. Blaikie in designing gasworks at Grangemouth, Haddington and Carluke for which Shotts provided ironwork, and the iron roof of Edinburgh retort house.[4] Blaikie was later reinstated, and promoted gasworks

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1. Gas pipes stimulated iron production, according to H. Scrivener, History of the Iron Trade (1854), p. 313
   J.O.N. Rutter, Practical Observations on Gas Lighting (1833) pp. 1-2.

2. e.g. Manby of Horseley Iron Works in 1816 while making an offer to supply iron for Dublin harbour, also tried to sell a gas-apparatus to the City, B.P.P. 1817(102) VIII 325.
   Reduced demand for iron, especially armaments, after the Napoleonic Wars led Messrs Newton Chambers and Co of Yorkshire to cultivate the gas-industry market, as did Robert Ransome of Ipswich who employed W. Cubitt to diversify their output from agricultural implements.
   T.S. Ashton, Iron and Steel in the Industrial Revolution (Manchester, 1963) pp. 157, 181.
   A. Raistrick, Quakers in Science and Industry (1950, Newton Abbot) p. 212.

3. A.M.C. MacEwan, "The Shotts Iron Company 1800-50" (1972, unpublished M.Litt. thesis, University of Strathclyde) p.51

4. Shotts Iron Company Sederunt Book (GD1/3/5) S.R.O. Vol. II 24/10/1828 p. 169.
   J. Miller, The Lamp of Midlothian, or The History of Haddington

energetically because on some occasions he retained the commission for designs without entering it in the company books. In 1834 he employed Mr Sinclair, the company's Collector, to design Galashiels gasworks, and later gave £18 of the commission to Sinclair[1] without making a written record. Hence Blaikie's personal interest in the gas industry was very considerable, but in 1837 he was again demoted from managing Leith Walk foundry shortly after designing Dunbar gasworks, for "want of energy, management and economy" in attending to the general business of Springfield Foundry.[2]

Directors like Mr Houldsworth[3] complained from 1836 of the waste of time and wages in sending employees to erect gasworks, mills and steam engines, and desired the Shotts company to manufacture only pig-iron and castings. Nevertheless, late in 1837 the company continued to build gasworks at Cupar and Stonehaven. Blaikie was dismissed that December, and his salary withheld until he produced a list of gas companies which had purchased his designs. He admitted to having received £30 from Galashiels, £8 from Dunse, and £5 from Selkrig [?] company,[4] and his departure resulted in the withdrawal of Shotts from promoting new gasworks. Thereafter they only sold standardised ironwork like gas pipes[5] and retorts to the industry.

Elsewhere brassfounders and general engineers in a few centres,

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1. S.R.O., Shotts Sederunt Book (GD1/3/4) Vol. II 1/11/1837, p. 87
2. Ibid., (GD1/3/6) 6/9/1837 p. 47; 4/9/1837 p. 72
3. Ibid., (GD1/3/5) Vol. II 6/1/1836 p. 379
4. Ibid., (GD1/3/4) 16/11/1837 p. 91; 6/12/1837 p. 95; 3/1/1838 p. 108.
5. A. Muir, The Story of Shotts - A Short History of Shotts Iron Company (1952, Edinburgh), p. 25

notably Glasgow, Edinburgh, Paisley, Kelso, Kilmarnock and Berwick, specialised in providing gas apparatus and also in engineering gasworks in Scotland. The most important of these in designing and encouraging the development of new gasworks were Messrs. Fulton and Neilson of Glasgow,[1] Andrew Liddell and Co. of Globe Foundry, Glasgow, Messrs Laidlaw of Glasgow, Messrs Hooper and Miller of Kelso, and Messrs Guthrie and Robertson[2] of Tweedmouth Foundry, Berwick. Competing with them as consultant design engineers and construction supervisors, were several gasworks managers of whom the most important were Archibald Cook[3] of Paisley who designed fifty gasworks from 1823 to 1844, mainly in Scotland, Mr Ritchie of Ayr gasworks, and Mark Taylor of Kelso gasworks. They supplemented their income by these fees, and were strongly motivated to encourage the rapid expansion of the gas industry.

Andrew Liddell and Company[4] began as an iron and brass founding

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1. Walter Neilson was engineer for new works at Hamilton and Paisley in mid-1840s. Vide infra 'Chartered Companies' Appendix XVI pp.139,1797. He was trained by J.B. Neilson of Glasgow gasworks. In late 1830s, his cousins W. and Wm. Neilson took control of Summerlee Iron Works, Coatbridge, with money from Hot Blast licences, vide W.H. Marwick, Economic Developments in Victorian Scotland (1936) pp. 54-5.

2. Company later re-named J & A. Robertson. S. Lewis, Topographical Directory of Scotland (1847) p. 125. This foundry provided the gas apparatus for Berwick and Perth New companies, but remained a general engineering company and also built iron-works at Galashiels and Jedburgh.

3. House of Lords MSS. 1844 Vol 8 Paisley Gas Bill 2/8/1844 p.80.

4. Andrew Liddell 1786-1854. Born at Bainsford; laterclerk, first at Carron Ironworks, then with metal merchants at Leith. 1814 partnership with half-brother Robert McLaren. 1828 set up Globe Foundry, Glasgow. Pirated Russell's patent tubes, in a partnership with J. Eardie, and continued production when patent expired. Liddell's son, with Eardie, founded Clydesdale Tube Works, making boiler tubes. The son inherited Globe Foundry, and continued to make gas apparatus. He was succeeded there by his nephew Robert Maclaren, who in 1850s had been producing gas pipes at Eglinton

company in Glasgow in 1814, and by 1828 had become the largest malleable iron-pipe works in Scotland. Liddell provided gas apparatus to many Irish towns like Armagh and Kilkenny, and to Nova Scotia as well as Scotland. J. and R. Laidlaw set up an engineering firm in Edinburgh and began to sell gas fittings and meters when the gas industry commenced there. When J. Laidlaw died, David Laidlaw[1] became a partner with his father in 1837 and greatly increased the company's emphasis upon producing gas apparatus. Warehouses were opened in Glasgow in 1841, the Alliance Foundry for gas tubes and fittings in 1844, and in 1858 a second Glasgow Factory, the Barrowfield Works. From 1850-70 David Laidlaw travelled widely throughout Britain and the Continent, persuading companies to set up new gas and water works to consume their products, because the number of entirely new gasworks required in Scotland was beginning to decline.

Foundry.
Proceedings of Philosophical Society of Glasgow 1848-55 Vol.III p. 356.
British Association, 1876, Notice of Some of the Principal Manufactures of the West of Scotland pp. 72-4.
A. and N.L. Clow, The Chemical Revolution op. cit.
A. McLean, ed. Local Industries of Glasgow and the West of Scotland (1901, British Association) p. 80.

1. J.G.L. 24/11/1891 Obituary of David Laidlaw.
D. Laidlaw invented improved gaslight slides, to adjust the position of lights down from the ceiling (vide The Scotsman 31/5/1843, p.1) and moulded alloys for cast gas jets (Patent on 11/10/1852 vide The Practical Mechanic 1853-4, p. 70; Gas Journal Centenary 1849-1949 p. 164). From 1857 Laidlaw supplied mass produced 'German' paraffin lamps for James Young's oil industry (J. Butt, "James Young" (1963) op. cit., p. 161). Barrowfield operated under a new partnership, Messrs Laidlaw, Sons, and Caine, and was designed to supply gas equipment for the entire city of St Petersburg, the largest contract ever given to a British gasworks supplier (J.G.L. 5/4/1864, 1/3/1859). They also built the promenade piers of Deal, Lytham and Brighton, and the gasworks of Peel, Isle of Man (J.G.L. 10/10/1854), Tilsit and Naumberg in Germany (J.G.L. 2/2/1858), Gibraltar (J.G.L. 31/3/1857) and two towns in Jutland (J.G.L. 18/1/1859).

From the 1820s onwards, a wide range of other engineering firms joined the ancillary sector of the gas industry and if less influential in encouraging new companies, they were no less important in the logistics of providing a large variety of small items, from meters to tin and lead[1] service pipes, and of increasing the competition and hence reducing the price of large items, especially gasholders which were often the most expensive equipment required. In Paisley, the general engineering and iron boat-building firm of Messrs Reid and Hanna, diversified during the 1820s to produce gasholders for some of the earliest gas companies in Scotland and Ireland. The company of Messrs Hanna, Donald and Wilson from 1851 increasingly specialised in equipment for British and foreign gas companies.[2] At Leven, Henry Balfour[3] in 1810 opened a small foundry for general engineering, which soon accommodated the gas industry alongside boilers, bridges and steam engines. Balfour fabricated entire gasworks and by the 1850s was concentrating upon that type of production.

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1. Lead pipes vide D. Bremner, The Industries of Scotland (1869, Edinburgh) p. 140.

2. Gas and Water 26/9/1885 p. 405. Robert Hanna, son of the original partner, served his apprenticeship in engineering in Paisley and Glasgow; James Donald, son of a Paisley engineer, worked first as a water engineer in Paisley. Original Abbey Works greatly extended in 1865 by purchase of Abercorn foundry, and again in 1885. Built large structures, including bridges; 1850s made all equipment for Calcutta gasworks; 1842 built largest gasholder in Scotland, at Partick (Glasgow Chronicle 17/10/1842 p. 4); built much for Radcliffe Gas Co. of London, including in 1866 one of the early 3-lift gasholders; 1880s large scale suppliers of rotary gas-exhausters.

3. Balfour's family was in the Dundee jute trade. From 1850s, his sons Robert and Henry T. expanded the gas equipment trade to an important export business to Holland, Poland and S. America. Gas Journal Centenary 1849-1949 (1949), p. 154. Early records have been destroyed (personal communication from Mrs J.C.Beveridge, Information Officer, Henry Balfour and Co.Ltd. 5/1/1973)

The 'wet' gas meter was invented by Clegg[1] in London in 1815, but was not popular there. In 1820 the first meter in Scotland was used at the Caledonian Mercury offices in Edinburgh,[2] and abuses of the 'time-contract' system of providing gas between fixed times led Scottish gas companies to encourage this more advanced system of monitoring consumption during the following twenty years.[3] James Milne and Son, a brassfounding and ironmongery business in Edinburgh since the 1780s, was one of the earliest and later one of the principal meter-manufacturing companies to supply the market. Milne produced the earliest private gas apparatus for Edinburgh shops, invented block tin pipes in 1817 to eliminate the explosive corrosion which developed in the copper pipes of early London gas companies,[4] and devized improved gas burners including a special Argand, and the 'fish-tail' or 'union-jet' burner in collaboration with J.B. Neilson of Glasgow gasworks.[5]

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1. The most detailed history of gas-meter manufactories is in Gas Journal Centenary 1849-1949, pp. 159, 162, 165

2. Gas World 10/7/1886 p. 42 "History of Gas Lighting in Edinburgh"

3. Many Scottish companies by the 1840s refused to supply any small consumers with 'time-contract' gas and insisted on meters, yet in London the inflexible and, for the Company, loss-making contract system was the most usual, as in most parts of England. The 'dry' gas meter, using a flexible membrane instead of a submerged wheel to measure gas, was devised in 1844 by W. Richards and Alexander Croll, at the Chartered Company in London, but perfected by T. Glover, an engineer from Leith, who had been repairing meters since the 1820s. It was more reliable, because wet-meters could freeze in cold weather, and had to be frequently watered to remain accurate. Vide infra pp. 1225, 1777

4. Gas and Water Vol. II 1885, p. 11; Edinburgh Philosophical Society 1821 Vol. V pp. 120-2. In 1817 Milne travelled to London to gain practical experience of the gas industry.

5. D. Lardner, The Cabinet Cyclopaedia (1834, London) Vol. III, p. 241; D. Chandler, Outline of History of Lighting by Gas (1936, London) p. 87.
He also devized a 'wet gas regulator' to equalise gas pressure on the different floors of a multi-storey factory - Mechanics Magazine 1843 Vol. 38 p. 78; Civil Engineer & Architects Journal, 1840, p. 386; 1840 British Assn. Part II p. 213; Min. Proc. Inst. Civil Engineers 1840 Vol. I.

Milne had to devise his own form of wet meter, after being sued for patent infringements by J. Malam[1] of London in 1819. In 1825 W. and B. Cowan opened a rival meter factory in Glasgow,[2] and the two cities dominated the supply of small gas fittings, with the formation of companies with high technical expertise like Fullerton, Alder and Company[3] in Edinburgh in 1850 which patented advanced dry meters in 1864, and Bruce Peebles which from 1866 made sophisticated pressure governors there.[4]

One source of cheap gas apparatus for lighting small towns, which may have contributed significantly to the spread of gas lighting, was the private gasworks of large companies which were offered for sale when they obtained a cheaper gas supply from the gas company of a neighbouring town. Thus the Interim Committee of Bo'ness gas company obtained its first plans in 1843 from Mr Sinclair of Shotts Iron Company, but later chose to purchase and transport a second-hand

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1. Malam's design was little different from Clegg's. Gas and Water Vol. II,p. 43. The London Encyclopaedia or Universal Dictionary of Science, Art, Literature (1829, T. Tegg, London) Vol. X p. 11.
   James Milne died 1863; his son John worked in the firm 1823-85 and trained in metal-casting in Paris. In 1860s the business was expanded in S. England. D.Bremner Industries of Scotland (1869) p.137

2. Gas Journal Centenary 1849-1949 (1949) p. 162

3. Originally 'Fullerton, Alder & Co'; operated the Sciennes meter works, Edinburgh; later 'Alder and Mackay'. Gas and Water 1885 Vol. II p. 403.
   Gas Journal Centenary 1849-1949 (1949) p. 153. Late nineteenth century producers of pre-payment gas meters.

4. David Bruce Peebles (1826-1899), of Dundee, worked in steam loco-works at Swindon and in France; in 1857 became partner in Fullerton & Co. in Edinburgh, and in 1866 set up own gas engineering works, at Fountainbridge.
   The Story of Bruce Peebles 1866-1954 (1955, Bruce Peebles Ltd., booklet 104).
   Improvements in fire-clay retort manufacture were also very important by 1830s in reducing the running costs of Scottish gasworks, but are considered elsewhere. Vide infra, 'Technology' p.289

apparatus from Glasgow.[1] Again the Banchory gas company in 1853 obtained estimates for a new works from James Leslie, the manager of nearby Aberdeen Gas Company, but subsequently, with the concurrence of Leslie, purchased a used gas-apparatus for only £85 from the Bleachfield of Messrs Richards and Company of Aberdeen. Leslie supervised the re-building of this equipment which could produce 400,000 cu ft a year, "considerably above what is manufactured in most of the small Towns in the North, and quite sufficient for Banchory for some time to come."[2]

Most companies, however, relied upon the competence of available engineers and built entirely new gasworks. Civil engineers who had learned the rudiments of gas-lighting were chosen in the early 1820s. Edinburgh Oil gas company[3] employed Mr Jardine, C.E., of that city, with an architect, W. Burn, to build the Tanfield works in 1824, while the Dalkeith company in November 1826 employed William Tait, C.E., to design their gasworks.[4] In July 1827 Tait[5] was rebuked for failing to supervise the contractors building the gasworks, and Archibald Cook of Paisley was employed to advise on construction and cure

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1. S.R.O., Boness Minute Book (GB1/11/1), 18/10/1843
2. S.R.O., Banchory Minute Book (GB1/5/1) 9/7/1854. Though data is lacking, small gas companies may have converted private equipment of this type from the 1820s onwards.
3. Committee of Proprietors at Tanfield - op. cit; 'Oil Gas' p.419; Architectural Review, 1945 Vol. 97, pp. 131-4
4. S.R.O. Dalkeith Minute Book (GB1/24/1) 2/11/1826, 13/7/1827, 19/1/1828, 24/3/1828.
   In 1824 a William Tait was employed as engineer of the British Gas Lighting Company when it unsuccessfully petitioned to start a new gasworks in Edinburgh, vide Edinburgh City Archives, Council Record Vol. 190 13/11/1824, p. 292.
5. In a legal battle, Tait achieved a settlement of £200 out of court.

problems with the tar well. When two ovens, holding three retorts each, collapsed later in the first year, Dalkeith employed skilled bricklayers from Edinburgh and Leith gas companies to rebuild them. Thus while unreliable engineers harrassed new companies, skilled employees from established gas companies and contractors[1] were available to restore operations, and Cook travelled throughout Scotland to provide his services.

The Dunfermline company in 1828, after "copious correspondence" with various engineers, obtained two alternative plans and cost estimates, from Mr Neilson of Glasgow and Mr Renny of Arbroath. Neilson was solicited on a personal basis, which may indicate the degree of competition by gas companies for his services.[2] With the Directors, Neilson surveyed the town in January 1829, and sent plans a month later which were approved by a general meeting and the work commenced.[3] Neilson continued to visit in person, but the Directors became nervous when manufacturers who had been requested to provide tenders reported omissions in Neilson's specifications, and Neilson himself tendered estimates to supply the equipment.[4] Consequently, Renny of Arbroath was employed to "revise the specifications", and he

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1. Dunfermline company in 1829 independently purchased bricks and fireclay from Captain Stuport at Alloa, and from Inverkeithing, and supplied labourers, but employed a specialist bricklayer, Mr Jackson of Portobello, to construct four retort ovens and a chimney at the works.
   Dunfermline Ref. Lib. Dunfermline Gas Company Minute Book 24/7/1829.

2. Dunfermline Minute Book op. cit., 22/12/1828; 1/1/1829 Mr Ker of Dunfermline requested "his friends Fleming and Watson of Glasgow" to see Neilson.

3. Ibid., 6/1/1829, 6/2/1829, 12/2/1829

4. Ibid., 11/3/1829, 30/3/1829

assisted the Directors in choosing which manufacturers gave the best value for money.[1] Neilson was excluded, and even the request for him to appoint a 'superintendent' to oversee the construction and pipe-laying was revoked.[2] John Oliphant, an Edinburgh engineer,[3] was appointed superintendent and Renny remained as consulting engineer. Oliphant himself designed the service-pipes, and minor apparatus like dry-lime purifiers, argand gas-burners, and a furnace tar-burner.[4] He was employed for a second year to plan extensions to the gasworks, but with an understanding that he could "pay an occasional visit as Engineer in the erection of the proposed gasworks at Kirkcaldy or elsewhere not at an inconvenient distance."[5] In this fashion, gas technology expanded radially from the earliest towns to adopt the industry. In 1831 when Oliphant requested a wage of £120 plus three per cent of the profits, the Directors over-ruled those shareholders who supported him, decided they could not afford a man with "his talents as an engineer", and appointed an unskilled manager for the routine operation of the works.[6]

An Interim Committee at Hawick[7] in 1830 also obtained their

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1. Ibid., 7/4/1829, 8/4/1829, 16/4/1829
2. Ibid., 12/3/1829. This is probably W. Neilson of the firm 'Fulton & Neilson'. Vide infra p.599
3. Ibid. 16/4/1829, 20/3/1829. Oliphant was described as an 'engineer but may have only been a 'mechanic' at that time. John Oliphant, "wright at Tanfield", was employed by Edinburgh Oil Gas Company in 1825, and may have been the same person.
   S.R.O. Court of Council and Session (P.R.1019.244) Sasine 9/6/1824
4. Dunfermline, ibid., 27/5/1829, 30/6/1829, 6/8/1829.
5. Dunfermline Minute Book, op. cit., 24/12/1829.
6. Ibid., 16/12/1830, 17/1/31. Vide infra, 'Labour' p.666
7. R.E. Scott Transactions of Hawick Archaeological Society 1969 op. cit. N.B. other sources place the origin of Irvine gasworks at a date in the mid-1830s.

estimate of costs from the engineering firm of Fulton and Neilson, but then checked it against data from Irvine and other gasworks. They employed Archibald Cook of Paisley to supervise the construction of retort benches. At Dalry the Interim Committee employed Mr Cook in November 1833 to survey the village, but a Committee member personally visited the gasworks of Stewarton, Barrhead, Paisley, and others in the area, to make checks before Cook's plans were accepted.[1] Two of the first Directors at Bathgate, an ironmonger and an innkeeper, travelled in March 1834 to nearby Airdrie gasworks to gain preliminary information on the construction and operation of such a works. Later that month invitations were sent to Andrew Liddell of the Globe Foundry in Glasgow, John Baird of Shotts ironworks, and Mr King of Falkirk, to visit Bathgate and offer their services to plan the works. Only Liddell replied,[2] and the company sent his plans to Shotts' Calton Foundry for a second opinion. Shotts refused, but suggested that the Bathgate Company should apply to J.B. Neilson of Glasgow, who accepted, visited Bathgate and suggested modifications.[3] A copy of the final version was sent to Mr Blaikie of Shotts, Liddell, and Neilson who agreed to take tenders from Glasgow companies known to him. Later, Liddell was given the contract for gas apparatus worth £500, and Shotts for gas pipes worth £320.

Selkirk gas company[4] was in part inspired by Mr Blaikie of

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1. Dalry Minute Book (GB1/25/1) 20/11/1833, 6/6/1834. N.B. on 8/7/1834 a 'William Cook' apparently of Paisley, and possibly a relative of Archibald, was appointed manager of the works, but soon dismissed for incompetence.
2. Bathgate Minute Book (GB1/8/1) 7/3/1834.
3. Ibid., 14/4/1834, 21/4/1834
4. Selkirk Minute Book (GB1/72/1)

Shotts. While supplying ironwork for Montrose gasworks which he had designed, Blaikie explained the gas process to Mr Clarkson, a visiting magistrate from Selkirk. He agreed to visit Selkirk and make an estimate for building a gasworks, and in return Clarkson offered £5 compensation if the inhabitants opposed the scheme or were unwilling to purchase the ironwork from Shotts. Several inhabitants met Blaikie when he arrived, were persuaded by him of the desirability of gas, and later formed a Committee of three who canvassed the town to discover the probable number of lights required. Given that data, Blaikie made his estimate. The Committee of Management, appointed at a subsequent public meeting in March 1835, then obtained data for comparison from the new gas companies at Jedburgh and Galashiels. They also received an offer from Messrs Guthrie and Robertson of Berwick Foundry to provide estimates for the works. Mr Guthrie arrived personally, with standardised plans which he promised to modify to suit thelocal topography.[1] Blaikie complained of this, but nevertheless completed his own plans. The following month, Mark Taylor of Kelso also made an appearance, and offered to plan the Stranraer works on condition that he received £10 compensation if he was not appointed to supervise the construction.[2] The Committee thought more highly of Taylor, and approved. They sent him sketches of the town, but he preferred to make a personal visit,[3] and in May 1835 his plans were accepted. Although tenders were taken from Shotts, Leith Walk Foundry, and the Berwick and Dalkeith foundries,

1. Ibid., 21/3/1835
2. Ibid., 28/4/1835
3. Ibid., 29/4/1835, 30/4/1835

the contract for gas apparatus worth £375 was placed with Messrs Hooper and Miller of Kelso, and gas pipes worth £259 with Berwick foundry. Outright competition between suppliers was the order of the day.

At Dunse[1] in 1835 Mr Cook of Paisley presented the first gas plans, but the Interim Committee was instructed by a general meeting to obtain comparable data elsewhere, and did so from W.K. Hunter and from the gasworks at Kelso, Galashiels and Jedburgh. On that basis, cost estimates were taken from Mark Taylor and James Blaikie, who requested fees of twenty and ten guineas respectively to provide detailed plans. Taylor was accepted but the contract for apparatus went to Berwick Foundry at £375, because Messrs Hooper and Miller required £436. Berwick also supplied the pipes, at a cheaper rate than Shotts offered. Stranraer Committee of Management in 1836 requested Mr Ritchie, the manager of Ayr gas works to visit the town personally in order to take measurements and give an estimate for construction, specifically in preference to simply sending him a plan of the town.[2] Ritchie had recently designed Maybole gasworks, and provided similar successful plans for Stranraer at a fee of £25.

Gas companies which made inadequate inquiries could still find unreliable engineers. The Annan company in 1837 made only one inquiry, with Mr Murray of Carlisle to inspect the town and make esti-

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1. S.R.O., Dunse Minute Book (GB1/27/1) 29/4/1835.
2. S.R.O., Stranraer Minute Book (GB1/78/1) 4/6/1836, 16/7/1836. The success of Maybole's advanced design led to Ritchie's subsequent appointment as gas manager at Sheffield. He defended his apparently high fee because of the quality of his work, and the fact that Cook of Paisley had charged £120 to plan Johnstone gasworks.
Vide infra p. 632

mates. Murray had taken £100 for planning Maryport gasworks, and persuaded Annan to pay £120. Fortunately he soon resigned,[1] and new plans were obtained from Liddell of Glasgow for only £26. Andrew Liddell and Company later supplied bricks and ironwork worth £1,180, though not until the Annan company had compared tenders from several competitors. Leven Company[2] in Dunbartonshire fell under the more benign spell of Mr Cook of Paisley, who provided the designs for £25 in 1839, and advised the promoters how much capital-stock was required. The masonry tank, which cost £918 from Barr and Craig, he nevertheless placed over unsuitable subsoil, and the advice of Mr Neilson of Glasgow gasworks was required for a remedy.

By the 1840s the number and skill of gasworks managers had grown considerably,[3] and their relative importance as consulting engineers grew proportionally. At Lesmahagow the Interim Committee in 1844 surveyed the potential lighting requirements of inhabitants in the Old and New towns before inviting John Ritchie,[4] gas manager of Ardrossan, to estimate the cost of a gasworks.[5] Ritchie later supervised the erection of the works, and although tenders were taken in the normal way, the contract for gas apparatus and pipes worth £407 was awarded to John Ritchie of Fairley Colliery, Kilmarnock, instead of his rivals Messrs Robertson and Lester of Glasgow.[6] New

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1. S.R.O., Annan Minute Book (GB1/1/1) 20/5/1837, 26/2/38
2. S.R.O., Leven Minute Book (GB1/82/1) 17/3/1840
3. <u>Vide infra</u> 'Labour' p. 631
4. Possibly a relative of Mr Ritchie, the former manager at nearby Ayr.
5. S.R.O., Lesmahagow Minute Book (GB1/54/1) 2/9/1844, 4/9/1844, 6/9/1844
6. <u>Ibid</u>., 17/9/1845, 23/9/1845, 26/9/1845, 4/2/1846

competitive manufacturers were helping the gas industry to acquire cheaper equipment.

Eyemouth gas company obtained engineering plans in 1845 from D. Ferguson, the manager of Dunse gasworks, who appeared personally to explain them to the Interim Committee.[1] Tenders were requested by advertisement in the Berwick Advertizer and Border newspapers, and the contract for ironwork and apparatus placed with J. and A. Robertson of Tweedmouth Foundry, Berwick. At Stornoway in 1847 the Interim Committee[2] at first chose one of their own members, T. Smith, to plan the gasworks and inquire into the possibility of using peat. Five months later, however, in April 1848 they saw the need for professional advice and invited Messrs Laidlaw of Glasgow to survey the town. Tenders were taken from four companies, but the contract worth £1,440 was awarded to Laidlaws, and the work completed by September. At Muirkirk in 1859 the public meeting to form a company appointed a single agent, W. Whiter, instead of an interim committee, and by the 1850s and 1860s it appears likely that opening a gasworks to serve a small rural community had become a very routine operation. Whiter chose to obtain plans only from Messrs Laidlaw of Glasgow[3], and a general meeting agreed to purchase Laidlaws apparatus at £330, and to employ them also to supervise the entire construction and pipe-laying. As city gasworks grew larger, and gas-apparatus manufactures were geared to producing large equipment of increasingly sophisticated design for them, and also for foreign cities setting

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1. S.R.O., Eyemouth Minute Book (GB1/31/1)
2. S.R.O., Stornoway Minute Book (GB1/77/1) 18/11/1847, 4/4/1848, 15/4/1848.
3. S.R.O. Muirkirk Minute Book (GB1/62/1) 16/7/1859

up their first gasworks, the supply of relatively small-scale but reliable equipment to the small, new Scottish gas companies, became a very simple and minor operation.

Promotion by willing sponsors was the immediate trigger for company development. These were local sponsors since there is no evidence before the late 1860s of outsiders investing heavily in completely new gas companies. Moffat,[1] a typical gas company with a nominal capital of £1,000 in £5 shares, was first mooted in 1837, and promoted chiefly by two local proprietors, R.N. Captain W.J. Hope-Johnstone and John J. Hope-Johnstone.[2] All but nineteen shares were subscribed by January 1839, when the works were under construction. Other leading sponsors since 1837 had included four merchants, two blacksmiths, a dyer, a tailor, two millwrights, a builder, a farmer, a butcher, and three local gentlemen. In effect, a cross-section of the inhabitants of this small rural town[3] was actively involved. The first Board of Directors, in January 1840, installed the Reverend J. Monteath as President, J. McMillan, merchant, as Treasurer, and W. Tait, merchant, as Clerk, aided by R. Burnie, merchant, A. Morrison,

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1. S.R.O., Board of Trade Records (BT2/160)

2. John James Hope-Johnstone (1796-1878) was a Tory MP for Dumfriesshire and a leading promoter of the 'Annandale route' over Beattock summit for a Carlisle to Glasgow railway line in 1836. In 1844 he joined the promoters of the Caledonian Railway, which completed that line in 1847, to the benefit of Hope-Johnstone's Annandale Estate.

   J. Butt and J.T. Ward, "The Promotion of the Caledonian Railway Company" Transport History 1970 Vol. 3, pp. 165, 186, 178, 235.

3. 2199 persons in Moffat parish in 1841 Census. Similarly the small Kilsyth company in 1835 was financed by local tradesmen, especially weavers who used the light in dwellings and loom shops. A. Anderson, A History of Kilsyth (1901, Edinburgh), p. 129.

builder, and J. Hamilton, millwright. This transfusion of talent from existing occupations into the new joint-stock venture probably resulted in high contemporary standards of management, and possibly raised the technical and entrepreneurial skills of participating members in their own industries and trades, as a result of experience gained. This self-enhancing educational aspect of joint-stock gas companies may have contributed significantly to the national process of industrialization.

In 1816 Kincaid Mackenzie, merchant and chief magistrate in Edinburgh, led a deputation of ten local merchants and tradesmen to petition Edinburgh Council[1] for permission to supply gas in the city. The members included P. Baxter, insurance broker, A. Henderson, seedsman, and J. Manderston, druggist. All owned property or were residents in the city and had first met in May 1816 to consider developing the new light which they knew had proved successful in London. A preliminary committee was formed to acquire more data from London, and in November they invited John Grafton from London, "one of the most prominent gas engineers of the time"[2] to survey Edinburgh and

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1. Edinburgh City Archives Council Record 1816-17 p. 160 29/1/1817 Vide infra 'Chartered Companies' pp. 984, 1009
   James Ludovic Grant first suggested the possibility of a gaslight company in Edinburgh to James Innes in 1815, but is not recorded among the promoters in 1817.
   J.L. Grant, together with the Duke of Atholl and Prince of Wales, was among F.A. Winsor's principal supporters in 1805, and Grant led the campaign for the ill-fated National Patriotic and Imperial Gas Company of London in 1809.
   Captain Charles Thomas Grant of Musselburgh was an important shareholder in Winsor's London and Westminster Chartered gas company of 1812.
   Mechanics Magazine 1837 Vol. 27 p. 338
   S. Everard, History of the Gas, Light and Coke Company 1812-1949 (1949) pp. 22, 56.
   S.R.O., Roxburgh papers 10542 (p. 24)
2. Gas World 10/7/1886 p. 42 "The History of Gas Lighting in Edinburgh"

estimate the cost of a gasworks. Having obtained the Council's consent, a Prospectus[1] was issued in newspapers in March 1817 inviting citizens to subscribe to the joint-stock enterprise which commenced with a capital[2] of £20,000 in shares of £25. Several prominent personages had been attracted to the Committee of Management by that date, in order to entice prospective shareholders.[3] These included W. Arbuthnot, the Lord Provost, Sir John Marjoriebanks of Lees, Sir Geo. S. Mackenzie of Coul, and Sir Patrick Walker.

Gas was being sold in Edinburgh in the spring of 1818, some time before the Act of Incorporation acquired in May to give greater protection, especially limited liability.[4] Shareholders recorded in the Act included Lord Gray, William Dundas,[5] A. Henderson the Lord Dean of Guild, H. Jardine Deputy King's Remembrancer, J. Simpson advocate, J. Leslie (1766-1832) Professor of Mathematics,[6] and T. Brown, M.D., Professor of Moral Philosophy in the city.

Cotton manufacturers, already familiar with private gasworks,[7]

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1. Vide infra 'Company Organization' p. 901
2. Scots Magazine, 1817 Vol. 79, p. 314
3. Bogus or 'decoy' Directors were uncommon before 1825. B.C. Hunt, The Development of the Business Corporation in England (1800 - 1867) (1936, Cambridge, Mass.) p. 36
4. Unextracted Process (S.R.O.) S. Reid v. Gas Light Company 1822 (McNeill R.16/2). The delay in applying to Parliament despite seventy per cent of capital having been called up by March 1818, was not due to Standing Orders which even for Railway Companies only required 5/6 of shares to be subscribed but not paid-up in advance of applications. Vide Journal of Transport History 1973 Vol. 6
5. W. Dundas (1762-1845), MP for Edinburgh 1812-31. D.N.B.(1908) VI p. 197
6. J. Irvine, The Book of Scotsmen (1881, Paisley) p. 273
7. Vide infra Chapter I

played a leading role in the organization of Glasgow gas company, which was promoted during 1816 by Kirkman Finlay,[1] Henry Monteith[2] of Carstairs, and Andrew Mitchell. Proposals were not submitted to the Town Council until October. By December, possibly out of rivalry with Edinburgh, the Council[3] agreed to give support, and James Dennistoun,[4] founder of the Glasgow Bank, subscribed £500.

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1. Kirkman Finlay (1773-1842), son of James Finlay a yarn merchant who employed Glasgow weavers and exported to America and Europe. 1785 J. Finlay, and the Buchanan family, built Deanston Mills, where Kirkman took the management. They bought Catrine Mill in 1802, and Ballindalloch in 1808. Kirkman became a leading Scottish manufacturer like the Buchanans, Monteiths, and David Dale, in what became the main Scottish industry by the 1830s. Kirkman Finlay was a leading architect of Glasgow's commercial revival after the decline of the tobacco trade. He was Lord Provost in 1812, M.P. from 1812-18, Governor of the Forth and Clyde Canal, President of Glasgow Chamber of Commerce, Dean of Guild, and Rector of the University.

   H. Hamilton, The Industrial Revolution in Scotland (1966) Dictionary of National Biography (1908) Vol. II p. 32

   Mackie incorrectly calls the Gas company director Alexander Finlay, carver and guilder of Trongate; P. Mackie, Reminiscences of Glasgow (1890, Glasgow) Vol. II p. 145. Vide infra p. 1361

2. Monteith's wealth was derived from Blantyre cotton mills. Scottish Historical Review, 1925 op. cit., p. 105

3. Vide infra 'Municipal Organization' p. 1007

4. James Dennistoun of Colgrain, a Glasgow merchant, was a partner in the Ship Bank in 1775, and in 1809 a founding member of Glasgow Bank Company. With ten shares of £5,000 he was the largest shareholder, and Manager from 1809-29. He had commercial contacts with other founders of the gas company, and in 1818 the Glasgow Bank issued one share to each of seven important local businessmen including Henry Monteith of Carstairs, James Ewing of Levenside (vide infra), Robert Dalglish and Robert Findlay. One of his sons, John Dennistoun of Golfhill, Glasgow M.P. 1837-47, was later a promoter of the Caledonian Railway Company.

   R.S. Rait, The History of the Union Bank of Scotland (1930, Glasgow) pp. 38, 51, 202, 204, 207, 208.

   J. Butt and J.T. Ward, "The Promotion of the Caledonian Railway Company", Transport History (1970) Vol. 3 p. 188.

   James Dennistoun was a partner in Westmuir Coal Company. Vide B.F.Duckham Scottish Coal Trade (1970) p.236

   James Dennistoun 1st had been a merchant in the Virginia trade; Vide S. Stewart Curiosities of Glasgow Citizenship (1881) p.195

Others quickly joined, and the Bill for Incorporation which was prepared in February 1817, long before the first call made on shares in April, included R. Jarvie, merchant, W. Ferguson, clothier, J. Hamilton, grocer, W. McGavin, manager of the British Linen Company, Thomas Grahame and John Robison on the Committee of Management.[1] Robison[2] was possibly a leading promoter of the company. The Magistrates and Town Council[3] were also on the Committee in June 1817. The first Directors[4] included J. Dinning, solicitor, Henry Houldsworth[5] and William Dunn cotton spinners, Andrew Templeton, banker, James Buchanan[6] of Dorran hill, and James Ewing[7], merchant.

Hutton and Creighton engineered the Glasgow gasworks[8] from 1816 to 1823. Creighton was an experienced engineer from Soho, and

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1. The Gas Supply of Glasgow (1935, Glasgow)

2. University of Strathclyde Library, 'Andersonian Institution Minute Book' Vol. III 22/9/1818 p. 133. Vide infra pp.1248, 1273
Robison, chairman of the Glasgow directors in 1818, was Sir John Robison (1778-1843), son of J. Robison, Professor of Natural Philosophy at Edinburgh University. Educated at Edinburgh University; friend of James Watt jn; resident near Hamilton in 1815; 1816 Fellow of Royal Society of Edinburgh; 1821 a founder of Scottish Society of Arts. Early connection with the cotton industry, assisting Mr.Houston of Johnstone (c.1783) with spinning mills using Arkwright's machinery; and later at Manchester. Merchant at Madras (1802); wealth as artillery contractor at Hyderabad.
Dictionary of National Biography (1909) XVIII p.58

3. The Principal of the College of Glasgow was also named as a partner. The Gas Supply of Glasgow (1935 Glasgow Corp.Gas Dept.) Vide infra p.1007

4. An Act for Lighting the City and Suburbs of Glasgow with Gas (16/6/1817) III George Ch.XLI Art.xxix . Vide infra p. 1008

5. Owner of North Woodside and Anderston Mills in Glasgow. Resident in Manchester until 1799. His brother Thomas founded Coltness Iron Works in 1836. Vide infra pp. 30, 1156
P.L.Payne Ed. Studies in Scottish Business History (1967) p.270

6. Possibly the son of John Buchanan, Arkwright's first Scottish agent. His brother Archibald was manager at Catrine Mill, and an important member of J.Finlay and Co. Alternatively, the son of Andrew of Ardicannal and Jane Dennistoun of Colgrain. H. Hamilton The Industrial Revolution in Scotland (1966)p.127; J.Burke A Geneological and Heraldic History of the Commoners of Great Britain(1836) III p.654

7. Probably James Ewing (1774-1853) the West Indian merchant and banker at Strathleven. A promoter of the Caledonian Railway,and Chairman of Muirkirk Ironworks. W.H.Marwick Economic Developments in Victorian Scotlan (1936) op.cit.p.61; J.Butt and J.T.Ward Transport History(1970) op.cit. p.

8. The Gas Supply of Glasgow (1935) op. cit.

Hutton may have been related to another engineer of that name, also from Soho, who worked as an adviser and maintenance mechanic for Boulton and Watt's Scottish operations for several years.[1] Not until 1822 were gasworks built elsewhere in Scotland, and the industry at first faced severe technical problems. The alleged incompetence and high premiums of the Glasgow company were challenged by a rival consumers company[2] in 1819, which collapsed almost immediately. Edinburgh gasworks were run from 1818 to 1859 by John Watson, a non-scientist but an acute businessman[3] who left the technological aspects to J. Grafton. Local brassfounders and metalworkers, especially the elder Milne, soon produced imaginative gas fittings in Edinburgh, installing the first consumer's gas meter at the Caledonian Mercury office[4] in 1820. Despite this advantage in marketing, the manufacturing process created an obnoxious nuisance, especially during the charging of retorts, and the escape of lime water from purifiers into the common drains, from which hydrogen sulphide fumes invaded nearby houses. New Street works, in Edinburgh's Canongate, greatly depressed property values and many aristocrats converted their former homes to flats.[5] For this reason alone, Leith Police Commissioners[6] in 1820 forbade John Busby from financing a gasworks

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1. Vide infra 'Appendix I
2. Vide infra 'Consumer Relations' p.1111
3. Born 1790, son of first President of Scottish Royal Academy; educated in Edinburgh and London; 1812-18 merchant in Leith.
4. Meters consequently became popular and widely used in Edinburgh at a much earlier date than in London. Vide Gas World 10/7/1886 p. 42
5. J. Ker, Considerations Relative to the Nuisance in Coal Gas Works (1828, Edinburgh) p. 22 (Edinburgh Ref. Library)
6. Edinburgh City Archives Leith Police Scroll Sederunt Book Vol. I 10/4/1820; Vol. II 10/7/1822; General Minute Book of Leith Police Vol. 2 p. 368 26/7/1820

to supply that town. Public agitation in favour of gas-light did not prevail upon them to reconsider until 1822, and even then the less offensive oil-gas method was chosen.[1]

In 1821 The Scotsman[2] published a complaint of inadequate public lighting in Edinburgh because of the "prodigiously high price" of gas compared to other towns which had a supply. John Kirkham was appointed Superintendent of Edinburgh gasworks in 1820, while Grafton remained engineer, but Kirkham soon moved to the Leith gas company as manager[3] whence he was sent to London to observe improvements in gas technology. He recommended evaporation of waste lime-water under the furnaces, a scoop instead of shovels for charging the retorts more rapidly, and coke instead of tar as furnace-fuel in order to reduce smoke pollution.[4] In Glasgow meanwhile, J.B. Neilson as foreman of the gasworks, instituted a novel educational programme among the workmen,[5] and advanced his own technical knowledge to the point where he was promoted Engineer in 1823, and thereafter trained other Scotsmen to high technical standards. Many became the managers in other Scottish gasworks at a later period.[6] Neilson devised improved methods of burning tar and coke in the furnaces below

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1. Ibid., Police Scroll Sederunt Book Vol. II 7/2/1822; Leith Police Minute Book III, p. 32 13/2/1822; vide infra 'Oil Gas' p.411
2. The Scotsman 6/10/1821
3. In 1831 he went to London as manager to the Imperial Company; he was succeeded at Leith by F. Lyon.
4. J. Ker, Considerations (1828) op. cit., p. 25
5. Vide infra 'Labour' p. 683
6. Vide infra 'Chartered Companies' p.955; also p. 634
They ran many of the new gasworks of the 1830s and 1840s.

retorts in the early 1820s of purifying with both lime and a solution of iron sulphate, and evaporating waste lime-water below the furnaces to avoid creating a public nuisance.[1] Edinburgh shareholders received a dividend[2] of six per cent in 1820, whereas in Glasgow[3] a five per cent dividend was declared in 1817, rising to ten per cent in 1825. This demonstration of potential profit awakened sceptical investors in other towns.

In Alloa,[4] where several people had private gas apparatus for lighting houses and shops William Spittal tried to form the third joint-stock company in Scotland in 1821. He criticised as short-sighted the proposals for more private gasworks, which would light public lamps in a few streets, and obtained estimates for building a large central works. A discount on the cost of gas was proposed for those who supported the company, from five per cent for one share to fifteen per cent for ten shares, in addition to the predicted dividend of ten per cent. Lack of support, however, delayed the foundation of a company at Alloa until 1829. At Kilmarnock,[5] however, a large gas company was successfully formed in 1822 by the efforts of Thomas

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1. New Statistical Account Vol VI p. 162
   J. Cleland, City of Glasgow Statistics (1832, Glasgow) p. 142
   Neilson was assisted by "many scientific gentlemen" in 1823, including John Hart, Robert Hastie, and John Thompson, who acted gratuitously. 40,000 single jet burners were supplied, compared to 8,000 Argands in Edinburgh. Annals of Philosophy 1823 Vol. VI p 402
   John Thompson was Clerk and Collector to the company 1817-30.

2. Gas World 10/7/1886

3. Glasgow City Archives, Miscellaneous Papers Vol. 18 pp. 215-7

4. S.R.O., (Coal Board Records CB10/13) 'Alloa - Heads of Proposals (1821)'

5. A. McKay, The History of Kilmarnock (1909, Kilmarnock) p. 361; J.G.L. 23/3/1884.

Morton who had gained experience operating his own private gas apparatus.

Johnstone[1] gas company also formed in 1822, was mainly a coterie of local industrialists who required a gas supply for their own premises. This narrow basis of promotion was unusual, however, and an effective mechanism for the promotion and marketing of gas shares was already available. It was very similar to that which, according to H. Pollins,[2] was later used for railway shares. As in other public utility companies, adequate money usually could not be raised privately, heavy capital investment was required at the outset, and the ploughing back of profits was impractical for many years because turnover[3] was small in relation to total capital outlay. Public-spirited men, merchants, manufacturers or even landowners, who recognized the potential benefits of gas lighting subscribed among themselves to finance a survey, and formed a provisional Committee as at Edinburgh and Glasgow, which acquired all necessary information. They subsequently called public meetings in the locality to arouse support and obtain subscriptions. Thereafter the proceedure varied, because gas companies were not bound by the Parliamentary etiquette of Railway Companies.[4] A Prospectus was issued either before or after the

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1. <u>Vide infra</u>, 'Chartered Companies' - Paisley. p.955
2. H. Pollins, "The Marketing of Railway Shares in the First Half of the Nineteenth Century" <u>Economic History Review</u> 1954 Second Series, Vol. 7 p. 230
3. <u>Vide infra</u> 'Finance' p. 742
4. <u>Vide infra</u> 'Company Organization' p. 895
   With Railways, a route was chosen by promoters, public meetings held to sell scrip, and a Committee controlled local agents who obtained subscriptions with deposits. Sometimes 'letters of allotment' preceded the scrip, when potential subscribers exceeded the available shares. The scrip holders were subsequently required to sign a subscription contract, and application was then

public meeting describing the advantages of gas lighting. In some cases, like Dunfermline in 1828, the first public meeting decided that subscribers were not bound to pay installments, or pay any of the cost of forming the Company until an adequate threshold of subscription had been reached, in that case £3,000, after which a second general meeting was to be called to decide "the principles upon which the Company is to Act".

The public response to gaslight proposals varied tremendously. Whilst Paisley (1823), Dundee (1823) and Hamilton (1830) were at first sceptical of gas lighting and regarded it as a risky speculation, in Perth[1] despite prevailing gloom over dull trade and declining industries, £7,000 was raised within three days of a gas company being promoted in 1822. They were inspired by the "great success and profit" of other gasworks, and the compact location of the town which minimised the pipes required. The first public meeting in Perth regarding gas agreed to form a joint-stock company, and fixed

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made to Parliament for a private Act of incorporation.
The resolution to form a Company, and decisions upon its capital, the number of shares, when to open the subscription book, what deposits to require, the appointment of an engineer, banker and solicitor, and the choice of a Committee of Management in a transport company, was normally delayed until the second public meeting.
Vide G.H. Evans, British Corporation Finance 1775-1880; A Study in Preference Shares (1936, Baltimore)
'Deposits' for scrip were small first instalments on the shares, but the Stirling and Suburban gas company in an emergency situation in June 1845, when hard pressed by the Stirling Old company, called up 10s per share on the scrip, and refused to exchange it for Stock Certificates until a receipt for that call was produced, and the Contract signed in the Secretary's office.
Vide Stirling Journal, 27/6/1845.

1. Perthshire Courier, 13/12/1822 p. 3. The total capital requirement was £10,000

the capital stock at £10,000 in £25 shares. Eight supporters were elected as "a Committee for procuring Subscriptions, with instructions to collect every requisite information ... by employing a civil engineer or manager of a gaswork, from whom they could obtain an exact estimate of all expenses". They were also to call a General Meeting of subscribers once half of the capital was subscribed.

Letters to the Perthshire Courier[1] indicate that several residents were aware of a general procedure which the nascent Perth company ought to adhere to. "Before any of the funds are expended, a general meeting of the subscribers ought to be called, and a committee of management with the proper office bearers ought to be elected", including a person with technical knowledge of the gas industry, and they would be empowered to conduct the company's affairs. Just such a general meeting was held on 21 December 1822 when Directors were elected and empowered to spend £100 obtaining technical data on gasworks. The meeting questioned whether shareholders would have limited liability, and decided to petition Parliament for a Bill, although this was later dropped, and in June 1823 a normal contract of co-partnery signed.[2] At the December meeting, the Courier had "never witnessed so much cordiality and unanimity of opinion at any public meeting, where there were so many interests and so large an amount", and in due course a most efficient gasworks was built.[3]

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1. e.g. from "L", Perthshire Courier, 20/12/1822, p. 3.
2. Perthshire Courier, 27/12/1822 p. 3., 20/6/1823, p. 3
3. Vide infra pp. 413, 282

Company promotion was often quite slow. Paisley*, which acquired a gas supply in 1823, reached the stage of the first Committee report on probable expenditure and revenue, in February 1820. A meeting of "Proprietors and Shopkeepers", presided over by W. Waterston, painter, and with P. Jack, solicitor, as clerk was shown the town survey which had been made and predicted a dividend of thirteen per cent. The meeting "ordered the Report to be printed and circulated throughout the Town and Suburbs", and inserted the minutes of their meeting in the Glasgow Chronicle and Courier to solicit subscriptions.[1] Potential subscribers could view the Reports and sign subscription papers at the shops and offices of the main promoters. These were J. Jackson merchant, J. Neilson and Sons grocers, A. Barr and G. Browning druggists, W. Stirling merchant, D. and J. Cunningham ironmongers, J. Lymburn merchant, J. Robertson china merchant, G. Cuthbertson bookseller, and P. and J. Jack writers.

The rash speculation made in many joint-stock ventures in 1825 almost entirely ignored the gas industry. The Edinburgh Oil Gas Company, despite its spectacular failure, was founded in 1823 and the technical arguments supporting oil-gas were sufficient to induce Aberdeen in 1824 to adopt the same expensive process.[2] Only the Edinburgh Portable Gas company may be directly ascribed to unfortunate speculation in 1825. At Ayr[3] in that year was built the

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1. Glasgow Chronicle, 18/4/1820, p. 3
2. Vide infra 'Oil Gas' p.426
3. The Company was granted exclusive rights by Ayr magistrates, and gas was first supplied in April 1826. Centenary of the British Gas Light Company Limited - A Short History, p. 7 (N.D., Patent Office Library)

* Much of the land for Paisley gasworks, purchased during extensions in 1825 (above 3 acres for £552; £180 per acre), was from James Buchanan, merchant of Northbar, who was probably also a shareholder. S.R.O. Sasine 2015 (P.R.369.47) 25/2/1825. Vide infra p. 1363

only Scottish gasworks owned by a national company, the Chartered British Gas Light Company. In Stirling, the magistrates were responsible for gathering the first data on gas lighting,[1] and called a public meeting in March 1825 which formed a Committee to inquire the best way to provide gas lighting. The press noted "the very liberal manner in which the undertaking is left open, so as to embrace the co-operation of all classes of the inhabitants" despite the fact that wealthy supporters at the meeting had been willing to subscribe the entire stock.[2] A second general meeting in June approved the proposed articles of co-partnery, and the capital stock of £6,000 in £10 shares, of which £2,000 were subscribed at the meeting. A Committee of ten was appointed to collect subscriptions and commence the company's operations. To create maximum local participation in the venture by consumers of gas, the Meeting also decided that for the first month no person could hold above twenty shares "unless any part of the Capital shall remain unsubscribed for by the Inhabitants of the town, or Feuars on the Town and Hospital's lands".[3]

Newspapers played an important role in disseminating ideas about

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1. <u>Vide infra</u> 'Municipal Organization' p. 1013
   <u>Stirling Journal</u> 13/1/1825

2. <u>Stirling Scrapbook</u> (Stirling Public Library) 26/3/1825 <u>Stirling Observer</u>(?)

3. <u>Stirling Journal</u> 16/6/1825
   Likewise at Dunfermline where the stock was increased in February 1829, a year after the company began, and for two weeks existing shareholders were denied the right to purchase, "to afford an opportunity to the inhabitants of the Town and neighbourhood, who have not yet subscribed, and who are likely to become Consumers of Gas, to subscribe."
   Dunfermline Ref. Library. Dunfermline Gas Co. Minute Book 12/2/1829.

gas lighting in an encouraging, prophetic tone. The Stirling Journal[1] drew attention to inquiries made by Montrose Gas Committee about Anderson's system being used in Perth where it saved £500 a year. The Dundee press was scandalized by poor public lighting, and recounted an incident from 1817 when a servant's shawl was cut to pieces by an untraced assailant during a church service lit by only five candles.[2] In 1822 the Inverness Courier[3] published a booklet describing "New Institutions and other improvements practicable or desirable in Inverness" which included gas lighting, with a rejoinder that Leith which had just built a gasworks was little larger than Inverness in population. However, the public meeting which finally agreed to form a gas company was not held[4] until 14 December 1824, in the Town Hall of Inverness, when it was combined with proposals to supply water. A capital of £10,000 in £10 shares was agreed upon, and an "Interim Committee of Management" of fourteen members formed to obtain surveys, estimates and other data. The Committee included the Provost, J. Robertson, two gentlemen of independent means, W. Hughes and J. Grant of Bught, as well as A. Anderson,[5] banker, three solicitors, J.I. Nicol surgeon, R. Murray accountant, and R. Smith merchant. The public meeting was also attended by Colonel Nicholson, N. Maclean land-surveyor, a fourth solicitor, D. Mackenzie,[6] and other prominent local citizens.

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1. Stirling Journal, 17/2/1825
2. Gas and Water Vol. II 4/7/1885, p. 10
3. Memorabilia of Inverness (1822, Inverness)
4. Prospectus in Inverness Journal 17/12/1824, p.1
5. Agent for the Bank of Scotland in Inverness; he was elected Treasurer of the Company.
6. Mackenzie was appointed Secretary to the Company.

Subscription papers were lodged at the "Banking Office", with the Secretary, and with each member of the Committee. These members may have done some canvassing, but unlike later Consumers Companies[1] no intensive programme of canvassing was planned and subscribers were expected to make their own inquiries rather than being talked into joining the venture. By December 29, 399 shares had been subscribed, but applications "from Edinburgh, Leith, London and other places" were not accepted by the Committee until January 14, 1825, in order to obtain as many local residents as shareholders as possible.[2] Meanwhile the Inverness Courier[3] began to illustrate the advances in gasworks design made by Mr Anderson of Perth, and may have prompted the choice of Anderson as engineer in Inverness. A general meeting[4] in February 1825 raised the capital stock to £13,000, transformed the 'Interim Committee' into 'Interim Managers and Trustees' and resolved to apply to Parliament for an Act of incorporation. No specific advantages of such an Act were discussed. For two weeks, only local residents could purchase the extra shares, to a maximum of ten each, but thereafter "the competition be entirely open." Engineering surveys by Anderson were delayed while he gave evidence regarding London gas companies, before a Committee of the House of

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1. Vide infra p.1111

2. Inverness Courier, 30/12/1824; Inverness Town Clerk's Office Town Council Records 1824-1834, 29/12/1824
   All but £500 stock was subscribed by local residents. Vide Inverness Courier, 3/2/1825

3. Inverness Courier, 6/1/1825, p. 4, reporting data from Edinburgh Philosophical Journal

4. Inverness Journal, 18/2/25, p. 3; Inverness Courier, 17/2/1825, p. 3

Commons.[1] This delayed the entire project by a year. The survey was completed in October[2] 1825, and the works built during 1826.

The press maintained an active interest and in 1826 described the great saving of fuel made at Paisley gasworks[3] by A. Cook's use of gas-tar as furnace fuel. The lectures given by Anderson in January 1827 to explain the principles and benefits of gas lighting met "apparent indifference"[4] in the town of Inverness, although they were given in detail by the press, as was an article by Anderson on the "Advantages of Lighting by Gas". A letter from W. Lowry,[5] the Dumfries gas manager, was reprinted from the Dumfries and Galloway Courier, to show that several Scottish towns experienced the same initial prejudice against new inventions such as gas lighting. Anderson and Lowry described the process of carbonization, and how cheaply gas could be produced compared to candles.[6] They stressed that it was almost impossible for sufficient gas to leak in a house to cause an explosive mixture, that pure gas would not tarnish shop goods, and that combustion products would not produce respiratory diseases among those using gas-lights. Dumfries[7] and Perth inhabitants had remained heavily prejudiced against gas lighting for some time after it was introduced, but Anderson reassured the Inverness

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1. Inverness Courier, 5/5/1825, p. 3. Meanwhile water samples were sent for analysis by London, Edinburgh and Glasgow chemists, and Henry Bell the steamship pioneer provided extra data on water supplies.
2. Inverness Journal, 16/9/1825, p. 1
3. Inverness Journal, 21/7/1826
4. Inverness Courier, 3/1/1827 p. 3
5. Inverness Courier, 3/1/1827, reprinting Dumfries and Galloway Courier 18/12/1826
6. Vide infra 'Use of Gas' p.1208
7. Dumfries gasworks was designed in 1824 by W. Lowry. S.R.O.(B.T.2/22) Printed copy of Regulations (1827)

shareholders that "the gradual but sure operation of experience and self-interest" would eventually prevail in shops and taverns.[1]

Such prejudice against gas lighting was a very considerable discouragement to those who would have sponsored new companies in the 1820s. Far more active campaigns were therefore required by later Companies to encourage subscriptions. A public meeting in Dunfermline[2] on 21 October 1828 took inspiration from what appeared already to be "numerous Gas Companies throughout the country". They formed a committee of fifteen, led by Provost J. Blackwood, to collect subscriptions and draft a contract of co-partnery with suitable regulations. This Committee provides the first evidence of virtually door-to-door canvassing by its members to sell shares. They appointed"Messrs Russell and Meldrum for the district consisting of the High Street from the Cross westward, and Kirkgate, - Messrs Rutherfurd and Reid for Bridge and Chalmers Street &c, Messrs Malcolm and Campbell for Collier-row, Back of Dam, and North part of the town", and so on with six groups of the Committee assigned to specific

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1. This uncertainty did not prevent speculation in shares, leading to very high premiums in Inverness.
   'Burgess', while urging the company to employ an Inspector to check the safety of gas fittings, accused the shareholders of having made "transfers upon transfers". "The same things have taken place in our exchange here as on that of London", and traders could not know if the Company had fallen into the ownership of a few "men of straw", and widows. Vide Inverness Journal 5/1/1827, p. 3

2. Minute Book of Dunfermline Gas Company 1828 to 1845 (Dunfermline Ref. Library) 21/10/1828.
   Dunfermline Press 9/11/1929 p. 5 "Dunfermline Gas Works - Centenary Celebrations"
   E. Henderson, The Annals of Dunfermline A.D. 1069 - 1878 (1879, Glasgow) p. 627
   P. Chalmers, Historical and Statistical Account of Dunfermline (1844, Edinburgh) p. 393
   J.G.L., 28/8/1883

sections of the town. By the middle of November they had taken the town by storm,[1] and with £4,450 subscribed, a second general meeting resolved to finalize the Company. A printed copy of the Draft of Co-partnery was then circulated "among the Subscribers for further consideration, requesting each subscriber to note on the margin ... any alteration or addition which he may deem proper". Two general meetings in December 1828 finalized the Contract and appointed Directors who during 1829 obtained engineering plans, purchased land and completed the gasworks. In May 1830 a dividend of three per cent was paid, and the company's success had "exceeded the most sanguine expectations."[2]

At Greenock in November 1826, the first public meeting on gas lighting was attended chiefly by "manufacturers, shop keepers, inn keepers and other inhabitants", though they later supported municipal control of the gas supply rather than a joint-stock company.[3] Trustees representing 'Subscribers' who raised money for the original gasworks as a "loan" to the Council, were superseded by the Council itself in 1830 when the works had already proved their profitability. This was an important symbolic gesture, making a section of the gas industry part of the 'Establishment', a profitable venture which public funds could sponsor without danger. The nascent Scottish gas industry thus moved into the 1830s with a new aura of respectability and

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1. Dunfermline Minute Book, op. cit., 19/11/1828
2. Ibid., 26/5/1830
3. Vide infra 'Municipal Organization' p. 1015
S.R.O., Sheriff Court Sasine Records (4624, P.R. 475.3)
Purchase 22/10/1827. Trustees arrangements explained in detail.

growing public confidence in its achievements. Civic dignitories often assisted gas company formation. John King and Andrew Reid,[1] who helped to obtain Burgh status for Motherwell, arranged the meeting of local inhabitants on 7 October 1849, which initiated the gas company.

Wealthy supporters remained important in the formation of several companies. At Dalkeith a preliminary meeting of supporters was held in October 1826, and an Interim Committee of nine members[2] appointed to obtain land from the Duke of Buccleuch, and to appoint a qualified engineer. Both the Marquis of Lothian and the Duke of Buccleuch were persuaded to sit on the new committee[3] appointed in January 1827. Scott Moncrieff[4] of Fossoway, Chamberlain to the Duke of Buccleuch, was a leading promoter of the Dalkeith company and served as a director for thirty-four years. At Stornoway[5] the gas company which was promoted in 1838 wrote to W. Mackenzie of Edinburgh, requesting him to acquire for them the patronage of the Trustees of Seaforth, in return for votes in Parliamentary elections. "Without some support from other quarters than the Town", the company was unable to raise sufficient finance, and in fact collapsed until new

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1. T. Orr, Historic and Descriptive Sketches of the Joint Burgh of Motherwell and Wishaw (1925, Motherwell) Motherwell Ref. Library. Vide infra 'Municipal Gasworks'- civic dignatories p.1006
2. S.R.O., Dalkeith Gas Co. Minute Book (GB1/24/1) Preface.
3. Ibid., 19/1/1827, 15/10/1827
   The Marquis later sold coal to Dalkeith gasworks.
4. Ibid., 29/6/1869
5. S.R.O. (GD.271/251) Letter of 26/10/1838 from A. Mercer (misnamed A. MacRae) to W. Mackenzie; Stornoway Gas Co. Minute Book (GB1/77/1)

proposals were made in 1847. At Rothesay, Lord Bute[1] himself campaigned for a gas company in 1834, but support was lacking until 1840. The Earl of Glasgow[2] owned half of the shares in Cumbrae Gas Company, Millport, when it commenced in 1851 and remained chairman until after 1885. Weavers at Dunshalt[3] village in Fife formed a committee to canvas the village and neighbourhood selling shares in 1852, but although the works only cost £700, they required and obtained substantial assistance from a local landowner, D.T. Bruce of Falkland House.

Individual initiative was the catalyst of change. At Bo'ness[4] the company of 1843 was promoted largely by John Anderson who spent much of his time and money visiting gasworks "in the neighbourhood and at a considerable distance". He was later commended for preventing mistakes in the construction, and introducing improvements in design.

In Hawick,[5] local businessman W. Wilson promoted a company from 1827, but was unable to organize a public meeting until 1830, when he obtained the support of the magistrates. The mechanism of promotion was then adhered to. A Committee was formed which reviewed the number of gas-lights probably required and sent a plan of the town to an engineering firm, Fulton and Neilson, for estimates which were then

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1. Provost Sharp, "The Cotton Industry in Rothesay" Trans. Bute Natural History Soc., 1908-9 Vol. II p. 18
2. J.G.L., 1/9/1885
3. The Builder, 1851, p. 807
4. S.R.O., Bo'ness Minute Book (GB1/11/1) 9/6/1845.
5. R.E. Scott, "The Story of the Hawick Gas Company" Transactions of Hawick Archaeological Society 1969 p. 26
   J.G.L., 26/10/1886

compared with data gleaned personally from Irvine and other gasworks. The Committee itself included the Magistrates and Town Clerk of Hawick, four hosiers, one banker, one carrier, one surveyor, one draper, one grocer, and one gentleman, a representative selection of the important local inhabitants, from manufacturers to shopkeepers. When they reported to a second general meeting in March 1830, a Subscription Committee of ten members plus the Magistrates was elected to test the possibility of raising £1,200. Within five days they were forced to call another general meeting, as £1,575 had been subscribed, and only at that stage was the final capital stock agreed upon, at £1,800. Directors were appointed, who managed to get the works built and operational by January 1831.

Extant records illustrate a very similar procedure for company formation[1] at Bathgate in 1833, at Annan in 1836 with the Magistrates as part of the Subscription Committee, at Stranraer also in 1836, at Bo'ness in 1843, Lesmahagow in 1844 and Eyemouth in 1845. The proceedure was a safeguard against having dubious proposals foisted upon the proposed company. A meeting of the inhabitants of Bonhill and Alexandria, Dunbartonshire, which in 1839 agreed to form the Leven Gas Company,[2] innocently accepted the engineering estimates already made

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1. S.R.O., Bathgate Minute Book (GB1/8/1); Annan Minute Book (GB 1/1/1); Stranraer (GB1/78/1); Bo'ness Minute Book (GB1/11/1); Lesmahagow Minute Book (GB1/54/1); Eyemouth Minute Book (GB1/31/1)

2. S.R.O., Leven Minute Book (GB/82/1)
J. Neill, <u>Records and Reminiscences of Bonhill Parish</u> (1912, Dumbarton) p. 114.
The first president was G. Kinloch, agent of Clydesdale Bank in Alexandria, and the vice president John Orr-Ewing, head of a local firm of Turkey-Red Dyers. Other Directors included J. McKinlay retired banker, L. Guthrie grocer, G. Lang owner of 'Wee Field' Printworks, D. Maxwell draper, and J. McFarlane engraver. The Company was geared to meet the lighting requirements of local industrialists, several of whom already had private gas plants.

by Mr Cook of Paisley for Mr Ewing, the principal promotor of the company. However, the more typical, cautious reaction[1] was the "method of comparisons", checking information with other companies. It was very widely used in the Scottish gas industry as a basis for financial and technical decisions.

Prejudice against gas lighting as being physically dangerous, persisted into the 1840s, and companies like that at Fraserburgh[2] in 1840, promoted chiefly by Bailie L. Chalmers, mounted large publicity campaigns to allay the fears of reactionaries, like the fishermen. Crowds gathered to see the display when Chalmers' house was first illuminated.[3] In Crieff residents considered a gas enterprise from 1818 onwards, but local weavers were most hostile to the proposal, and a company was not formed until 1842 when Captain A. Porteous (1783-1860) and another prominent local dignitary, J. Gowans writer and procurator-fiscal, exercised their powers of persuasion.[4] The 'hard sell' was also practised in the 1830s, as at Dalry[5] in 1833 when the Interim Committee of ten, including a portioner, a flax-dresser, a

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1. e.g. Dunse Minute Book (GB1/27/1)

2. J. Cranna, Fraserburgh - Past and Present (1914, Aberdeen) p. 450

3. Publicity of this type was common. In September 1818, James Hamilton grocer in the Trongate and a founder of Glasgow Gas Company, was the first to show how shop windows could be lit by gas in that city. Vide The Gas Supply of Glasgow (1935, Glasgow). At Stirling in 1826 a shoemaker used a gas jet fixed in the heel of a boot as advertisement, and a tobacconist placed a jet in the cigar in the mouth of a bust, in the shop window. Vide Industries of Stirling and District (1909, Stirling) p. 106

4. A. Porteous, The History of Crieff (1912, Edinburgh) p. 186

5. S.R.O., Dalry Minute Book (GB1/25/1)

surgeon, a teacher and a merchant, divided into five teams to canvass Newton, Courthill, Vennall, Sharon Street, and North Street for subscribers. Local industrialists helped to promote the industry, but normally did not overwhelm other interested inhabitants. Thus the Campsie company, where the Alum Company was of particular importance, was promoted by R. Clarke of that Company in conjunction with J. Bishop, banker, G. Wilson, and the Reverend W. Wood.[1] In comparison, at Thornliebank where the Crums[2] owned most of the village, their benevolence provided it with all amenities from gas and water to baths and gardens.

Gourock[3] gas and water company in 1845 named twenty-four promoters on its provisional committee. General Darroch and Major Darroch headed a list which included twenty-two gentlemen, mainly local residents but also T. Leadbetter of Glasgow. The remainder comprised a solicitor, a merchant, three builders, a glass merchant, a surgeon, a grocer, and a naval lieutenant. Only 2s 6d deposit was taken on shares, and the promoters had divided the nominal capital of £4,000 into shares of only £2 "in order that all classes of inhabitants might have an opportunity of securing an interest in it." At Portobello in 1845 the Interim Committee of twelve listed in the Prospectus[4] comprised several important industrialists of the town, like W. Bailey of the Mid Lothian Glass Works, T. Craig paper manu-

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1. J. Cameron, The Parish of Campsie (1892, Kirkintilloch)
2. W.H. Marwick, Economic Developments in Victorian Scotland (1936) p. 174
3. Greenock Advertizer, 2/5/1845
4. The Scotsman, 14/5/1845, p. 3

facturer, and S. Rathbone, earthen-ware manufacturer. Four town councillors were involved, two of them merchants, and two bailies, a builder and a housefactor. A local corn-merchant, and a baker also sat on the Committee. Investors were urged to purchase shares, or at least apply for consideration through the Secretary J.L. Hill, W.S., from Mr Fox, a local bookseller, or from W. Bell, sharebroker of South St Andrew Street, Edinburgh.

Gas lighting also proved an attraction in tourist towns, like Cullen[1] where a company began in 1841. It was introduced at Cove and Kilcreggan in 1871 because "the use of oil and candles by families and servants accustomed to the convenience of gas in towns is a great drawback to a coast residence."[2] Elsewhere independent gas companies remained typical even in communities which were not widely separated, since the economies of scale[3] were offset by heavy leakage, above thirty per cent, and the high pressure involved in long-distance transportation of gas. However some gas companies did not manufacture their own gas. At Inverkip[4] on the Ardgowan estates in Renfrewshire, a public meeting called, and addressed by Sir Michael R. Shaw, agreed to form a company to light the village with gas piped from Shaw's existing gasworks at the 'home farm' at Bankfoot. Laidlaws of Glasgow provided the pipes, for £380, and Mr Stewart the

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1. New Statistical Account Vol. XIII p. 321
2. J.G.L., 7/11/1871
3. Vide infra 'Technology' p. 325; pp. 1150, 798
4. Ardgowan Estate Office, Greenock, Inverkip Gas Company Ltd. Minute Book.
   S.R.O., Board of Trade Records (BT2/315)
   Sir Michael Robert Shaw-Stewart himself held 200 shares in the Inverkip Company.

gas manager at Gourock supervised them being laid.

The Scottish Stock Exchanges took very little part in promoting the gas industry. Companies were not floated on an Exchange, but were organized on a purely local basis and normally tried to exclude those who would not consume gas. After their establishment, speculation in shares did occur,[1] but only the shares of very large companies were quoted on the exchange. In 1844, for example, when many of the gas companies had been formed, or were in the process of so doing, the Glasgow Herald quoted twenty types of bank shares, twelve Insurance Companies, twenty-three railways, and eighteen miscellaneous companies which included only seven gas companies:-

Table 2.10 Scottish Gas Shares Quoted in 1844

Company	Shares: Nominal	Shares: Paid Up	Shares: Quotation
	£	£	£
Aberdeen New Company	5	3	3 9 0
Glasgow City and Suburban	10	5	9 4 0
Dundee New Company	5	1 2 6d	1 7 0
Glasgow Old Company	25	25	52
Paisley Old Company	5	5	7 10 0
Paisley General new company	10	1	No sales
Perth New Company	5	0 2 6d	0 7 6d

Source: Glasgow Herald, 9/9/1844

The number of 'Consumer Companies' which appeared in the 1840s to challenge existing gas companies inflated this list by the possibility of competitive speculation, but Minute Books of many gas companies indicate a very slow rate of turnover in shares. Transfers were normally made by private bargains between shareholders and their relatives or other local residents, and concerned very small lots of

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1. Vide infra 'Consumer Relations' p. 1115 et seq.

shares.

Early railway companies also lacked an organized market for floating shares, and tried to minimise the influx of speculators.[1] The Circular to Bankers[2] in 1835 stated that the development of railways was wholly unaided by the Stock Exchange. The informal organization of share sales which did develop was similar for both railway and gas companies. Edinburgh[3] had 'stock brokers' by 1815, and individuals acted part-time in this capacity in the large Scottish towns by the 1820s and 1830s. In 1836, for example, J. Watson[4] accountant of Glasgow advertised in the press that he wished to sell twenty shares in Glasgow gas company, as well as bank, water, insurance and canal shares. In 1849, Russel and Aitken,[5] Writers in Falkirk, advertised shares in the old Falkirk gas company for sale by private bargain. Because almost all gas shares were sold through such informal "exchanges" the system was for a long period of greater importance than the Stock Exchanges.

The individuals who canvassed to sell gas and railway shares were a hetrogenous group drawn from many social classes, from sharebrokers

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1. G.H. Evans, British Corporation Finance op. cit., pp. 15, 21. Up to the 1840s, potential railway shareholders were scrutinized by the Directors, and had to provide references. Vide infra 'Company Organization' p.912

2. Evans, ibid., pp. 16, 28, 30. Moreover, as in gas companies, no shareholder had a large proportion of the total stock, and a maximum number of shares was often set for any individual to hold.

3. The Edinburgh Stock Exchange 1844 to 1944 (N.D. Edinburgh Public Library) p. 11

4. Glasgow Herald, 25/1/1836

5. Falkirk Herald, 14/6/1849, p. 1. Russel was later an important coal-master, vide infra p.492 Aitken vide infra p.572

and shopkeepers to engineers and local manufacturers.[1] Bankers took a more passive role, receiving subscriptions but not actually canvassing.[2] Solicitors, however, actively encouraged their clients to subscribe[3]. Additional capital was later raised by loans, or by new shares which were issued preferentially to existing shareholders, so that few new shares came onto the open market.[4] New shares which existing shareholders ignored were disposed of at the discretion of the Directors.

J.O.N. Rutter[5] wrote in 1833 that local shareholders were the best basis for a joint-stock gas company, both in order to choose a suitable site for the works, and to control the quality, price and mode of supply of the gas. He emphasised that the patronage of wealthy residents was far less important than that of tradesmen, "Gentlemen of independence, bankers, merchants, and others of similar character." He advised that a new gas company should have as many shareholders as possible, and not be monopolised by three or four individuals -

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1. G.H. Evans, Corporation Finance op. cit., p. 16
Insurance agents in the early nineteenth century also came from several social classes. Solicitors and bankers were significant, but also shopkeepers, especially booksellers, grocers and drapers, and builders.
Vide B. Supple, The Royal Exchange Assurance. A History of British Insurance 1720-1970 (1970, Cambridge) p. 154

2. Hence bankers rarely held mandates for voting from investors they had persuaded.

3. G.H. Evans, op. cit., pp. 18-20

4. Chartered companies however were obliged to sell to the highest bidder.
Vide infra 'Finance', and 'Chartered Companies' pp. 808, 980
From the 1850s the Journal of Gas Lighting produced frequent lists of share quotations for gas companies throughout Britain.

5. J.O.N. Rutter, Practical Observations on Gas Lighting (1833)

> By securing a large propriety, the company will possess a somewhat corresponding degree of influence in parochial decisions connected with the public lights; for, although, in respect to profit, the street lights are scarcely worth its consideration, yet it will be found that many persons will become shareholders for the sole purpose of having the streets well lighted.

A large number of shareholders further ensured a large number of customers, who by example would overcome the prejudice of their neighbours against the light.

In 1849 Rutter[1] presented the obverse view that -

> excepting in very small towns, it is well known that the principal part of the capital invested in gas-works has been provided by strangers to the localities. Many a town would have remained to this day in darkness, if it had been left to the spirit of its inhabitants to provide the means of lighting it with gas.

Based at Brighton gasworks, Rutter was speaking of the English experience, but in Scotland the evidence of shareholding suggests that both views were correct though at different times. In the 1820s gas companies in large towns did acquire almost their entire capital requirements from their own residents, but where the industry developed later in smaller towns it attracted considerable investment from people residing in other towns, usually in the immediate vicinity, who had acquired confidence in the use of gas lighting and were able to foresee the market potential in the more conservative inhabitants of the smaller town or village.

Many Scottish gasworks were so small[2] that no records remain of their existence, and more communities were served than can be

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1. J.O.N. Rutter, Gas Lighting - Its Progress and its Prospects (1849)

2. Vide infra p. 788

illustrated. At Rhynie in 1876 a small works re-opened after a closure of three years, when coal prices fell and paraffin oil prices rose.[1] Aberuthven company in Perthshire began in 1857, and charged high prices, but up to 1877 when the company was dissolved and the works sold and transported elsewhere, dividends were paid only twice.[2] The New Pitsligo company, where in 1887 the shareholders vetoed a move by the Directors to liquidate the company, had a capital of only £400 of which £243 was held by Lord Clinton.[3] At Portsoy in Banffshire, the gasworks was built about 1838, but by 1888 the shares were largely held by the trustees of Colonel Moir who wished to liquidate the company.[4] Annual production was only 451,000 cu ft in 1880 and 926,000 in 1888, and the company would have passed into oblivion but for the protests of the inhabitants who were unable to raise sufficient capital themselves to form a Limited Company and purchase the works. These had already been offered at public auction for £700 and £500, but the only offer made was £350, an indication of the size of gasworks involved.

The small Dufftown gasworks[5] in Banffshire were also threatened with closure in 1891 because a large neighbouring distillery wished to use the land for construction. They offered to pay £500, but the company with a capital of £498 in £1 shares, had ploughed back profits to build a works worth £800. At Thurso[6] the small gasworks,

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1. J.G.L., 10/10/1876
2. J.G.L., 14/8/1877
3. J.G.L., 27/9/1887
4. J.G.L., 30/10/1888
5. J.G.L., 29/9/1891
   A Dufftown clothier aimed to set up electric lighting instead for £1,500 by a Wolverhampton firm.
6. Journal of Artificial Light, 25/10/1879

built in 1842, were leased in 1871 for fifty years to T.W. Stears of Hull, with the option for him to purchase them at £1,200 during that period. Thurso developed rapidly in the mid-1870s, and by 1879 when the works were wholly inadequate, a company with £15,000 capital was floated by Mr Dempster, Parliamentary agent in London, to purchase what had been an insignificant gasworks. At Chirnside[1] in Berwickshire, a company with £400 capital stock was recorded in 1866, and Ochiltree[2] company in Ayrshire with £800 in £1 shares was dissolved in 1891, but no other details are extant on these gasworks. F.H. Groome[3] in 1882 recorded gasworks in small centres like Abernethy, Auchencairn in Renwick parish, and Blackford in south east Perthshire, where the size and duration of gas supply is entirely unknown.

Although Scottish population statistics are difficult to interpret for small villages[4] an approximate comparison can be made with statistics used by Falkus for Britain as a whole, to correlate the date of company formation with the population of urban markets which gained a supply of gas. During the 1830s, more Scottish towns with a population of less than 4,000 obtained gas than was previously recorded for the whole of Britain. This is also true of Scottish towns and villages with less than 2,500 inhabitants in the 1840s.

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1. The Southern Counties Register and Directory (1866, London) Scot. Nat. Library.
2. J.G.L., 15/12/1891
3. F.H. Groome, Ordnance Gazetteer of Scotland (1882) Vol. I pp. 29, 82, 161
4. Vide infra Appendix III.7

Table 2.11 Date of Gas Supply compared to Market Population

Town Size	BRITAIN 1818-25	BRITAIN 1831-7	BRITAIN 1842-6	SCOTLAND 1818-25	SCOTLAND 1831-7	SCOTLAND 1842-6
Above 50,000	12	-	-	1	0	3
20 - 49,000	22	-	-	4	0	1
10 - 19,000	40	6	3	3	0	0
4 - 9,900	19	48	11	4	9	6
2,500 - 3,999	2	17	25	0	22	7
Under 2,500	-	11	7	0	15	21

Sources: Britain: M.E. Falkus, Economic History Review 1967 op. cit.

Scotland: Vide infra Appendix III

The gas industry was consumer-oriented, and although demand was elastic, gas-company development reflected spatial and economic developments in Scotland as a whole.[1] The premature boom in company formations in Edinburgh during 1824 produced a lasting slump from 1826 which led to few new gas companies commencing until the late 1820s. The concentration of cotton manufacturing industry, and agriculture, in the 'Midland Belt' or Forth and Clyde valleys, and flax spinning in the North East, especially around Dundee, produced a growth of wealth and population in those areas which financed a large number of gasworks. A rapid expansion of iron production around Motherwell

1. R.H. Campbell, Scotland Since 1707 - The Rise of an Industrial Society (1965, Oxford)
W.H. Marwick, Economic Developments in Victorian Scotland (1936)
W.H. Marwick, Scotland in Modern Times - An Outline of Economic and Social Development since the Union of 1707 (1964) p. 36
H. Hamilton, The Industrial Revolution in Scotland (1932, Oxford.)

and Coatbridge especially in 1830-50, and of shipbuilding and engineering on the Clyde in 1850-75, reinforced the pattern of population distribution and hence of gasworks locations.

Steam power instead of water power[1] produced larger industrial communities where gas companies developed the advantages of scale and sold cheaper gas than elsewhere. But demand reflected local prosperity, and declined at Greenock,[2] for example, in the sugar and engineering depression of 1884-5. By 1891 two-thirds of the Scottish population was concentrated in the heavy industrial growth sector along the River Clyde, and almost all had access to gas supplies. As late as 1949, the Midland Industrial Belt[3] covering one-seventh of the area of Scotland, consumed eighty-seven per cent of gas production, and the distribution and development of gas companies reflected this pattern.

By issuing shares in small 'lots',[4] new gas companies achieved a large ownership, and minimised the influx of speculators. Many shareholders were long-term investors, and the slow turnover of shares normally prevented concentration in a few hands.[5] The migration of shareholders to other parts of Britain, and the dispersion of shares

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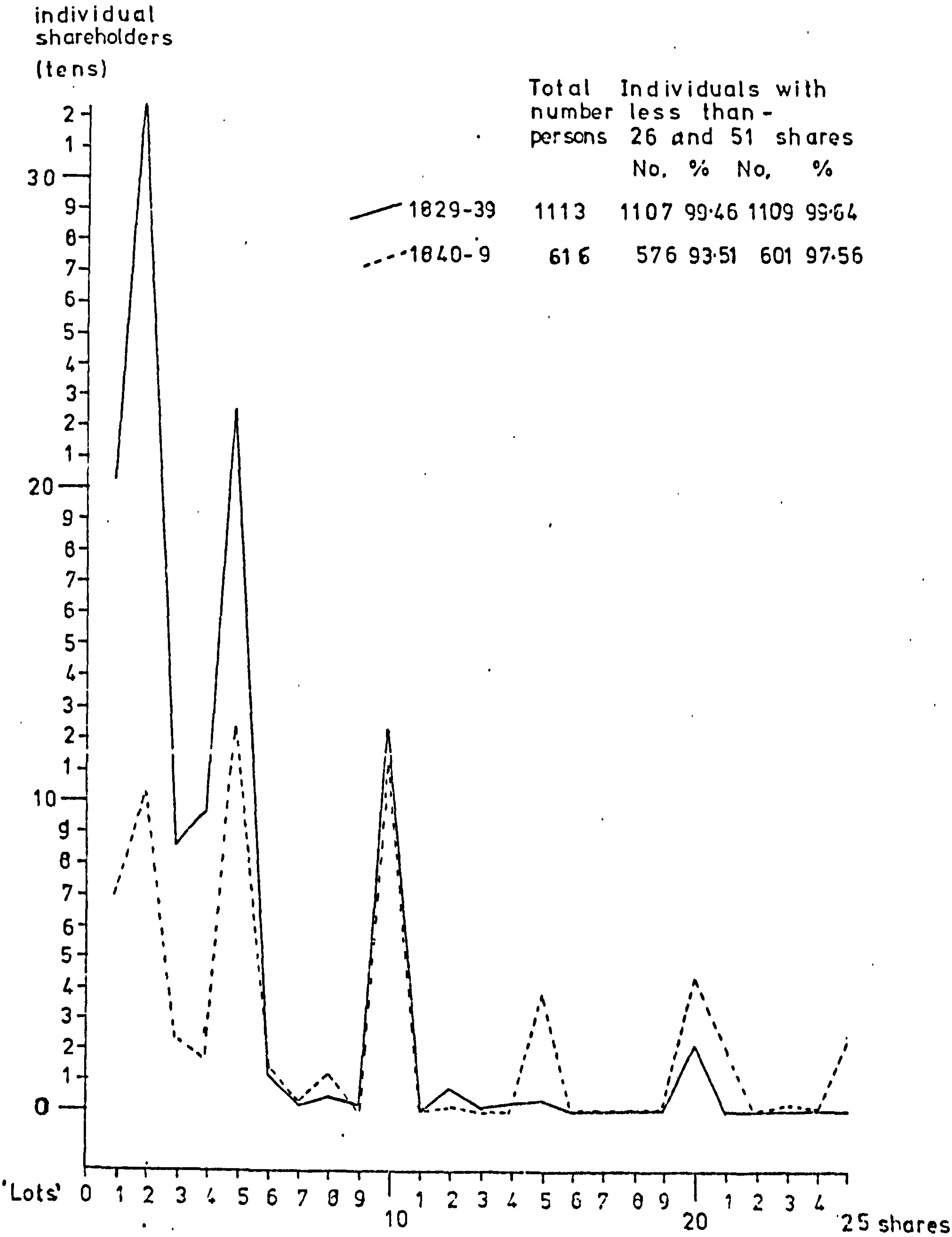
1. W.H. Marwick, "The Cotton Industry and the Industrial Revolution in Scotland" The Scottish Historical Review 1924 Vol. 21, p. 207
   G.M. Mitchell, "The English and Scottish Cotton Industries" The Scottish Historical Review 1925 Vol. 22, p. 101
2. J. Mackinnon, The Social and Industrial History of Scotland from the Union to the Present Time (1921)
   Gas and Water, 19/12/1885
3. Scottish Gas Board - The First Reported Statement of Accounts Jan. 1949 - March 1950, p. 5 (Edinburgh Ref. Library)
4. Vide infra Appendix III.12
5. Vide infra Appendix III.11

to the relatives or trustees of deceased shareholders resulted in a more disparate pattern of ownership after the company had been in existence for two or more decades. The purchase of shares by non-residents who could judge the past performance and dividends of the company increased this dispersion. Only lists of shareholders made soon after the company commenced can therefore reflect accurately the sources of capital which promoted the original venture. This restricts the number where occupations can be stated, to seventeen for the most important period before 1850, itself the 'Great Unknown' in Scottish economic statistics. The geographical spread of these is, however, representative, and the pattern of share ownership indicates that they closely resemble companies in the 1850s and 1860s on which far more information is extant. The variety of occupations, the overwhelming predominance of small 'lots' of shares held by each individual, normally less than eleven and rarely more than twenty, and the absence of anomalies like very heavy investment by industries or individuals, show that they fit into the mainstream of ownership patterns which predominated until the 1870s. Moreover, ownership data for three further companies formed in the 1830s, Airdrie, Kirkintilloch and Peterhead, and four from the 1840s, New Pitsligo, Coatbridge, Kirkintilloch and Gourock, is available for the 1860s and 1870s, and shows a similar diverse pattern of ownership in small 'lots'.

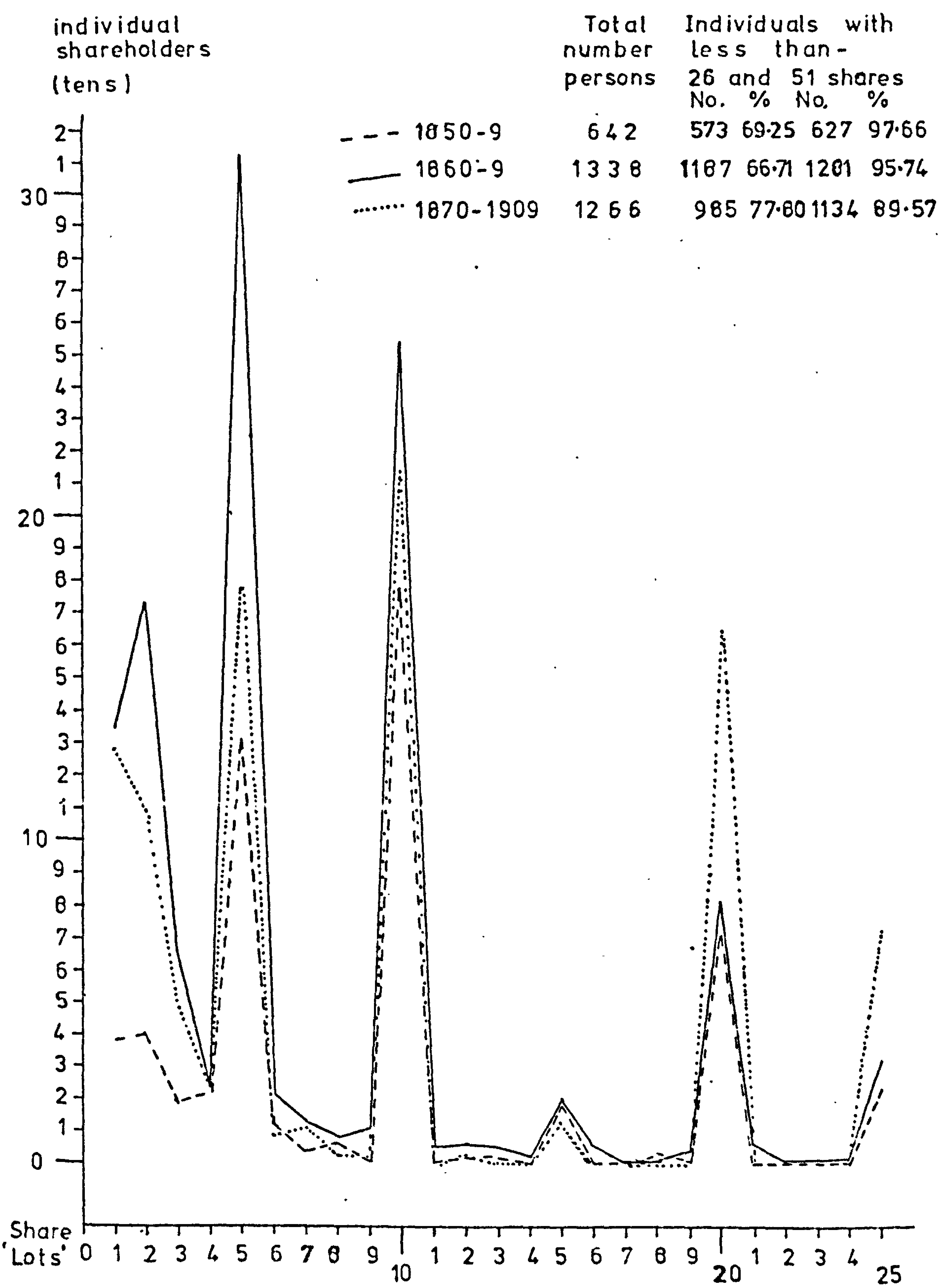
A large number of extant contracts of co-partnery provide details of occupations of original shareholders who signed the first contract. 'Intermediate' contracts also provide details about individual shareholders, but have been examined separately because they were drawn up at an intermediate period in each company's

Fig.2.12 The Size of Investment 'Lots' of Shares 1829-49



Source - vide infra Appendix III.12

Fig. 2.13 The Size of Investment 'Lots' of Shares 1850 - 1909



Source - vide infra Appendix III.12

development, often at the time of taking Limited Liability, and describe investors at that time rather than when the company first commenced. The original shareholders in Consumer Companies[1] at Denny, Lanark and Newmilns, are also placed in a separate category to examine any differences in the occupations of investors compared to other gas companies.

Eleven occupational categories (Table 2.14) illustrate the sources of capital invested in the gas industry, and the number of individuals participating. The professional class includes all persons with gainful occupations in positions of responsibility, unconnected with specific industrial enterprises. The gentry were proprietors of land and property, and include all men who did not record any occupation when signing the gas-company contract. Women have only been recorded as a separate category where they lacked specific gainful occupations, and the source of their capital cannot be determined. Retail shopkeepers include several persons, like spirit dealers, who inaccurately termed themselves "merchants"; in some cases they are difficult to distinguish from wholesale merchants.

Corporations, companies and partnerships comprise a category in which investment was by an institution instead of an individual. Few companies or partnerships did invest in their own names after 1840, until the 1880's, and the sums involved do not detract appreciably from other categories in which such institutions could be placed. Only two industrial companies were involved before 1840, with £350 stock at Grangemouth and Dunfermline gasworks; and also four Dunfermline merchants with £110 stock. Other important items

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1. _Vide infra_ p. 200

in the category were a partnership of Maxwelltown artizans with £25 stock and one Ayr merchant with £100 stock in 1840-9; and one artizan partnership with £10 stock as well as two industrial companies with £550 stock in the period 1860-9.

Table 2.14 Classification of Occupational Groups of Shareholders

(1) Professional -

Accountant, Academic Rector, Advocate, 'Agent', Architect, Army Officer, Auctioneer, Banker, Barrister, Broker, Burgh Collector, Cess Collector, Church Minister, Clerk, Collector, Commission Agent, Contractor (industry unspecified), Customs Clerk, Doctor (Surgeon), Excise Collector, Factor, Grieve, Harbour Master, House Factor, Inland Revenue Officer, Insurance Agent, Land Surveyor, Land Valuer, Lord of Session, Messenger at Arms,Money-Lender, Music Teacher, Naval Officer, Prison Keeper, Registrar, Secretary, Share Broker, Sheriff Court Clerk, Sheriff Substitute, Ship Broker, Ship Captain, Superintendent of Poor, Tax Collector, Tax Surveyor, Teacher, Treasurer of Police, Town Clerk, Town Provost, Veterinary Surgeon, Writer to the Signet.

(2) Gentry -

Feuar, 'Gentleman', House Proprietor, Landed Proprietor, Persons with no recorded occupation, 'Proprietor', pensioner, 'Resident', schoolboy, 'Tenementer'.

(3) Women -

All women with no recorded occupation (others placed in occupational categories).

(4) Retail Shopkeepers -

Apothecary, Baker, Bookseller, Boot and Shoe Maker, Confectioner, Coal Agent, Clothier, Clog-maker, Druggist, Draper, Flesher, Glover,

Table 2.14 , continued

Grocer, Haberdasher, Hairdresser, Hatter, Hotel Keeper, Inn Keeper, Ironmonger, Jeweller, Meal-Seller, Milliner, Pawnbroker, Perfumer, Portioner, Post-man, Seedsman, Spirit-dealer, Spirit 'Merchant', Stationer, Tailor, Tobacconist, Vintner, Watchmaker; Retail 'merchants' of stoneware, coal, wood, timber and china.

(5) Wholesale Merchants -

'Merchant' unspecified; Merchants of Corn, Grain, Flax, Flour, Hardware, Iron, Leather, Provisions, Seeds, Slate, Tea, Wine; Shipowners

(6) Industry - Employers -

'Manufacturer' unspecified; Bleacher, Boot manufacturer, Brass founder, Brewer, Brickmaker, Calanderer, Carpet manufacturer, Colliery Master, Cotton-Spinner, Distiller, Dyer, Flas-Spinner, Founder, Gas Apparatus Maker, Hat manufacturer, Iron-Founder, Ironworks, Lime Burner, Machine-Maker, Quarrier, Paper manufacturer, Printer, Publisher, Road Contractor, Sail-cloth manufacturer, Ship-Builder, Soap manufacturer, Starch manufacturer, Thread manufacturer. (Sometimes difficult to distinguish from Artizans and Industrial Employees)

(7) Industry - Employees -

All employees of large-scale industry like ironworks, coal mines and railways; Brewer, Civil Engineer, Collector of canal dues, Cork-cutter, Engineer, Flax-dresser, Industrial Chemist, Lath-splitter, Manager (of mill, brewery, gasworks, ironworks, mines, etc.), Miner, Moulder, Mill-spinner, Potter, Soap-maker, Stocking-maker, Stock-taker, Thread-lapper, Weaver's Agent, Warehouseman, Yarn Boiler, Yarn Spinner.

(8) Corporations &c. -

Corporate bodies, Partnerships, Companies; all social and commercial

Table 2.14, continued

organizations with two or more members (excluding joint ownership of shares by members of one family).

(9) Artizans -

Skilled craftsmen, usually self-employed or working outside the factory system. Basket-maker, Bell-hanger, Book-binder, Builder, Carpenter, Cabinet-maker, Chandler, Coach-builder, Cooper, Currier, Engraver, Gardener, Grain-miller, Joiner, Lace-maker, Mason, Millwright, Nailer, Painter, Plasterer, Plumber, Rope-maker, Saddler, Sail-maker, Sawyer, Slater, Smith, Silversmith, Tanner, Tinsmith, Umbrella-maker, Upholsterer, Weaver, Wright.

(Some overlap with skilled retail-shopkeepers like shoemakers)

(10) Agriculture -

Farmers, Bacon-curer, Cattle-dealer, Dairyman, Dreyman, Estate Overseer, Farm Servant, Forester, Game Keeper, Ground-officer, Ham-curer, Horse-dealer, Land Steward, Mole-catcher, Woodman.

(11) Miscellaneous -

Butler, Carrier, Carter, Coach Guard, Coach Proprietor, Customs-boatman, Fisherman, Gatehouse-keeper, Grave-digger, Labourer, Mariner, Messenger, Police-constable, Post-runner, Road-man, Servant, Turnkey, Watchman.

Taking six dimensions of time - before 1840, 1840-9, 1850-9, 1860-9, 1870-9 and post 1880 - four groups of investors continually provided the main financial support for Scottish gas companies. Before 1840, wholesale merchants (24%) and retail shopkeepers (23%) followed closely by the Gentry (19%) were of paramount importance. Retail shopkeepers retained a 20% share in 1840-9 and 1860-9, while wholesale merchants declined considerably in importance. Their place was taken by the professional classes, with 23% in 1840-9 and 31% in 1870-9. In 1850-9 the Gentry provided most capital (20%) and were level with the professional classes at 17% in 1860-9, falling to only 8% after 1880 when employees in large-scale industry first became significant, and indeed leading investors at 22%. Where 'Intermediate' lists of shareholders alone are available, the Gentry and professional classes both provided 21% of investment, followed closely by women (20%) who reflected the confidence placed in established gas companies as 'safe' investment, and also the effect of inheritance which did not appear in original sponsorship of companies.

Although the class of 'gentry' may have been exaggerated by the pretentions of shareholders, and 'Wholesale Merchants' may include a number of grocers who termed themselves 'merchants', both categories are nevertheless substantially correct and indicate that gentlemen of independent means were active supporters, often as much so as business men. Retail shopkeepers obtained considerable benefit from gas-lighting of their premises, reinforcing local consumer support for companies. Industrialists provided relatively little financial support, their maximum of 11% being achieved before 1840. Artizans invested in quite large numbers, 15 to 16% of all shareholders in 1840-59, but although they broadened the class structure of support, they never constituted above 10% of the capital.

Table 2.15 Nominal Value of Shares (£) held by Various Occupational Groups in Sample of Scottish Gas Company Shareholders

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Professional	2575	4245	1851	2571	3030	4269
Gentry	6410	2391	2046	2579.5	1536.5	2486
Women	1110	1416	844	803	330	3256
Retail Shopkeepers	7700	3760	1394	2911	1688.5	3755
Wholesale Merchants	8275	2741	1157.5	2113	1462	2355
Industry - Employers	3730	1283	700	881	600	2385
- Employees	635	249	220	657	256	7170
Corporations &c	1070	150	0	710	0	3900
Artizans	1920	1795	894	790	274.5	1370
Agriculture	520	477	1090	686	429	1055
Miscellaneous	270	244	201	117	163	170
Total	34,215	18,751	10,397.5	14,818.5	9,769.5	32,171

Sources - S.R.O. Board of Trade Records (vide infra Appendix):

Before 1840 - Dundee 1824, Dunfermline 1828, Cupar 1830, Kirkcaldy 1830, Musselburgh 1830, Bathgate 1834, Kirriemuir 1836, Annan 1837, Grangemouth 1837, Biggar 1839.

1840-9 - Dysart 1844, Banchory 1845, Dunning 1845, Ayr 1845, Maxwelltown/Dumfries 1845, Falkirk Joint Stock 1845, Innerleithen 1846.

1850-9 - Dunoon 1852, Newport 1856, Cumbernauld 1858, Lasswade 1858, Lochmaben 1859, Carnwath 1859, Dalbeattie 1859, Bridge of Earn 1859, Bothwell 1859.

1860-9 - Aberlour 1860, Muirkirk 1860, Gorebridge 1861, Ecclefechan 1861, Kamesburgh 1863, Meigle 1863, Stow 1863, Grantown 1865, Armadale 1866, Errol 1866, West Kilpatrick 1867, 1860-9, cont'd - Aberlady 1868, Slamannan 1868, Buckie 1868, Inverkip 1869.

1870-9 - Fortrose 1870, Innellan 1870, Langbank 1870, Cove/Kilcreggan 1872, Strichen 1873, Mearns 1873, Invergordon 1873.

Post 1880 - Costorphine 1880, Tranent 1885, Eaglesham 1895, Loanhead 1897, Monifieth 1898, Stane/Dykehead 1903, Kelty 1905, Cardenden 1909, Fauldhouse 1909.

Table 2.16 Individuals in Occupation Groups in Sample of Gas Company Shareholders

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Professional	90	94	76	113	61	71
Gentry	141	91	64	51	36	24
Women	40	52	34	46	30	51
Retail Shopkeepers	231	167	110	163	76	62
Wholesale Merchants	141	53	42	66	52	20
Industry - Employers	91	40	23	20	15	19
- Employees	18	9	17	41	6	98
Corporations &c	19	3	0	4	0	2
Artizans	103	109	80	77	27	30
Agriculture	27	29	63	64	13	12
Miscellaneous	11	20	23	15	8	6
Total	912	667	532	660	324	393

Table 2.17 <u>Original Ownership of Scottish Gas Companies</u>

I Per-Centage Nominal Stock held by Different Occupation Groups

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Professional	8	23	18	17	31	13
Gentry	19	13	20	17	16	8
Women	3	8	8	5	3	10
Retail Shopkeepers	23	20	13	20	17	12
Wholesale Merchants	24	15	11	14	15	7
Industry - Employers	11	7	7	6	6	7
- Employees	2	1	2	4	3	22
Corporations &c	3	1	0	5	0	12
Artizans	6	10	9	5	3	4
Agriculture	2	3	10	5	4	3
Miscellaneous	1	1	2	1	2	1
Total %	102	102	100	99	100	99
Total Nominal Cash (£)	34,215	18,751	10,397.5	14,818.5	9,769.5	32,171

II Per-Centage Total Individual Shareholders in Each Occupation Group

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Professional	10	14	14	17	19	18
Gentry	15	14	12	8	11	6
Women	4	8	6	7	9	12
Retail Shopkeepers	25	25	21	25	23	16
Wholesale Merchants	15	8	8	10	16	5
Industry - Employers	10	6	4	3	5	5
- Employees	2	1	3	6	2	25
Corporations &c	2	0	0	1	0	1
Artizans	11	16	15	12	8	8
Agriculture	3	4	12	10	4	3
Miscellaneous	1	3	4	2	2	2
Total %	98	99	99	101	99	101
Total Persons	912	667	532	660	324	393

Within the broad occupational categories, particular occupations provided frequent and substantial support to the companies. Amongst those in professional positions, the legal profession was by far the most important until 1850, and again prominant after 1870. Surgeons or doctors were the second most important investors before 1840, followed by teachers, bankers, and accountants. Bankers took the second place in 1840-9, followed by surgeons, but were superseded by clerks in 1850 as expanding businesses increased the opportunities for such employment. Church ministers, important investors in 1850-9, took first place in 1860-9, but from 1870 the legal profession regained its position, though surgeons were the principal investors after 1880. 'Intermediate' share lists show the legal profession, followed by bankers, as the chief investors; followed at some distance by clerks and then surgeons.

Amongst retail shopkeepers[1], grocers were by far the main investors before 1840, followed successively by innkeepers or spirit-merchants, bakers and confectioners, tailors and drapers, booksellers and stationers, boot and shoe makers, ironmongers, and fleshers or butchers. All of those occupations remained important investors during the century. Innkeepers, followed closely by ironmongers and grocers, led in 1840-9, and by a larger margin in 1850-9, but grocers, and bakers, were more important in 1860-9 and 1870-9. After 1880 innkeepers took a considerable lead with almost three times the investment of their nearest rivals, tailors and drapers. On the 'intermediate' share lists, ironmongers were the main investors,

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1. 'Portioners' who were sub-feuars with small retail premises, are included as retail shopkeepers in this classification. Their small total importance is shown in Table 2.19

followed closely by tailors, and then innkeepers.

The artizans who invested most capital were either in the building trades, or smiths and wrights. Before 1840, smiths and wrights were the main investors, followed closely by masons/builders, then painters/slators/plasterers, and plumbers/joiners/tinsmiths, the last group having a potential interest in the provision of consumers' gas-fittings. Masons and builders took the lead in 1840-60, smiths and wrights in 1860-9, whilst joiners and tinsmiths were the predominant investors after 1870. Among 'intermediate' investors, plumbers and tinsmiths invested most, followed by masons and builders.

Table 2.18 Particular Occupations Which Provided Persistent and Significant Support to Gas Companies

I Nominal Capital Investment

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Professional -						
Solicitor/Lawyer/ Advocate	1390	1580	335	475	860	650
Banker	465	659	180	352	351.5	255
Accountant/Town Clerk	345	281	0	120	17.5	125
Church Minister	160	199	340	575	79	195
Teacher/Rector	545	383	153	180	5	395
Surgeon/Doctor	820	555	290	245	348	1000
Clerk	160	0	410	115	215	381
Retail Shops -						
Grocer	1186	456	171	812	390	360
Innkeeper/Spirit Merchant	920	550	412.5	441	157	1502
Books/Stationary	500	160	52	20	155	3
Tailor/Draper	765	437	195	360	43	550
Boots/Shoemaker	430	264	80	289	26	150
Baker/Confectioner	785	431	192	449	347	170
Flesher (Butcher)	255	117	47.5	78	90	275
Ironmonger	400	470	50	12	70	100

Table 2.18 , I, continued

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Artizans -						
Painter/Slaterer Plasterer	285	117	80	51	17	110
Smith/Wright	350	236	239	228	63	55
Mason/Builder	345	763	245	160	18.5	355
Plumber/Joiner/ Tinsmith	235	249	190	169	80	815
Agriculture -						
Farmer	355	320	1025	592	369	1005
Total	10,696	8,227	4,687	5,723	3,701.5	8,451
% Total Investment	31	44	45	39	38	26
Total Investment in Companies £	34,215	18,751	10,397.5	14,818.5	9,769.5	32,171

II Number of Persons

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Professional -						
Solicitor (Writer)	37	31	14	21	11	10
Banker	12	11	9	11	10	9
Accountant/Town Clerk	6	6	0	3	2	5
Church Minister	5	8	12	19	9	4
Teacher/Rector	13	15	8	11	1	13
Surgeon/Doctor	20	9	9	17	8	4
Clerk	2	0	6	7	4	12
Retail Shops -						
Grocer	42	25	18	23	8	10
Innkeeper/Spirit Merchant	27	24	20	34	6	13
Books/Stationary	11	3	2	3	4	1
Tailor/Draper	31	19	14	29	7	13
Boot/Shoemaker	13	26	6	21	2	5
Baker/Confectioner	33	31	15	24	10	7
Flesher	11	9	5	10	7	5
Ironmonger	15	6	4	2	5	1
Artizans -						
Painter/Slaterer/ Plasterer	18	13	6	4	2	3

Table 2.18 , II, continued

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880
Artizans, cont'd -						
Smith/Wright	23	17	20	19	4	3
Mason/Builder	20	16	21	17	3	5
Plumber/Joiner/ Tinsmith	11	14	17	17	6	14
Agriculture -						
Farmer	23	22	58	47	14	9
Total	373	283	264	339	123	127
% Total Investors	41	42	50	51	38	35
Total Individual Investors	912	667	532	660	324	393

Despite the importance of tailors and drapers, and builders, associated trades which could have invested in the gas industry were conspicuously absent. Contractors especially were only an important group of investors in 'intermediate' lists of shareholders, and did not actively promote new companies. Weavers, despite their national importance, had inadequate savings to invest.

Table 2.19 Minor Categories of Investors

(i) Amount of Stock (£)

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880	Consumers Companies	Intermediate
Professional -								
Contractors	0	10	72	53	50	135	25	1600
Retail Shops -								
Portioners	0	80	102	290	0	200	62	50
Artizans -								
Weavers	65	82	45	6	2	0	459	30
Carpenters	5	0	5	20	25	0	0	32

Table 2.19 , continued

(ii) Number of Persons

	Pre 1840	1840-9	1850-9	1860-9	1870-9	Post 1880	Consumers Companies	Inter-mediate
Contractors	0	1	3	6	1	3	4	6
Portioners	0	2	5	2	0	2	11	1
Weavers	3	25	6	2	2	0	188	2
Carpenters	1	0	1	4	2	0	0	4

In the Consumers' Companies[1] of 1861-73 at Lanark, Denny and Newmilns, and that of Partick, Hillhead and Maryhill in 1871, the pattern of investment by various occupation groups was not vastly dissimilar to other gas companies. In 1861-73 retail shopkeepers took the lead, with 20% of the investment compared to 25% in other new companies in that period. Artizans, however, made up 36% of the total number of investors compared to 12% in other companies and provided 17% of the finance compared to 5% elsewhere. Weavers were the main investors amongst those artizans, and were of negligible importance in other gas companies. However, the professional classes contributed 16% of capital, compared to 17% in normal companies, the gentry 4% instead of 8%, and employees in large-scale industry 4% instead of 6%. Artizans thus gave considerable vocal support to the consumers companies of 1861-73 but were unable to achieve predominant financial control.

Partick consumers company, in contrast, was financed in a very similar manner to normal companies, and was formed in very different circumstances[2] to the Consumers' Companies of the 1860s. Wholesale

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1. Vide infra p. 116 8
2. Vide Infra p.1195

merchants provided 35% of the capital at Partick, followed by 20% from the professional classes, 17% from industrialists, and 14% from the Gentry. Within the professional classes, surgeons provided most capital followed by the legal professions and then bankers. Retail shopkeepers and artizans both provided only 3% of the Company's capital.

Table 2.20 Occupations of Investors in Consumers' Companies, and 'Intermediate' Companies

	Consumers Companies (1861-73)		Consumers Companies (Partick/Hillhead/Maryhill)		'Intermediate' Companies	
	£ Stock	Persons	£ Stock	Persons	£ Stock	Persons
Professional	815	38	9755	65	9701	117
Gentry	277	70	7135	38	9623.25	133
Women	352	30	2270	18	9089.25	128
Retail Shopkeepers	954	141	1535	23	4670	86
Wholesale Merchants	412	23	17245	55	1894	34
Industry - Employers	219	21	8300	31	3392	41
Employees	202	66	880	12	4450	29
Corporations &c	690	4	0	0	1284	9
Artizans	856	276	1380	11	2125	60
Agriculture	245	38	1250	5	477.25	25
Miscellaneous	96	41	0	0	61	8
Total	5118	747	49750	258	46766.75	670

Sources - S.R.O. Board of Trade Records (vide infra Appendix)

Table 2.21 Per-Centage Importance of Various Occupation Groups

	Consumers Companies (1861-73)		Consumers Companies (Partick/Hill-head/Maryhill)		'Intermediate' Companies	
	£ Stock	Persons	£ Stock	Persons	£ Stock	Persons
Professional	16	5	20	25	21	17
Gentry	4	8	14	15	21	20
Women	7	4	5	7	20	19
Retail Shop-keepers	20	20	3	9	10	13
Wholesale Merchants	8	3	35	21	4	5
Industry - Employers	4	3	17	12	7	6
Employees	4	9	2	5	10	4
Corporations &c	13	1	0	0	3	1
Artizans	17	36	3	4	5	9
Agriculture	5	5	3	2	1	4
Miscellaneous	2	5	0	0	0	1
Total %	100	99	102	100	102	99

Table 2.22 Particular Occupations Which Provided Persistent Support to Gas Companies

	Consumers' Companies Newmilns, Lanark & Denny		Consumers' Companies (Partick/H/M)		Intermediate Companies	
	£ Stock	Persons	£ Stock	Persons	£ Stock	Persons
Professional -						
Solicitor/Lawyer	15	2	210	6	2767.5	28
Banker	30	1	200	8	2111	16
Accountant/Town Clerk	0	0	70	5	60	1
Church Minister	59	7	100	3	486	9

Table 2.22 , continued.

	Consumers' Companies Newmilns, Lanark & Denny		Consumers' Companies (Partick/H/M)		Intermediate Companies	
	£ Stock	Persons	£ Stock	Persons	£ Stock	Persons
Teacher/Rector/Prof.	44	6	145	6	59	6
Surgeon/Doctor	27	3	290	4	611.25	10
Clerk	76	8	166	11	900.25	11
Retail Shops -						
Grocer	257	36	25	2	335	13
Innkeeper/Spirit Merchant	291	32	15	2	733	17
Books/Stationary	40	3	75	5	200	1
Tailor/Draper	140	17	5	1	842	10
Boots/Shoemaker	71	22	20	1	163	14
Baker/Confectioner	75	11	25	2	550.25	13
Flesher	33	5	20	1	228	7
Ironmonger	0	0	80	2	1080	4
Artizans -						
Weaver	459	188	0	0	30	2
Painter/Slaterer/Plasterer	60	9	65	3	135	5
Smith/Wright	102	26	100	2	254	11
Mason/Builder	68	14	30	1	329	12
Plumber/Joiner/Tinsmith	65	15	10	1	572	13
Agriculture -						
Farmer	188	25	40	3	473.25	24
Total	2100	430	1691	69	12919.5	227
% Total Investment	41	58	3	27	28	34
Total Investment	5118	747	49750	258	46766.75	670

Source - S.R.O. Board of Trade Records (vide infra Appendix)

Consumers' Companies -

Lanark 1861, Denny 1861, Newmilns 1873, Partick/Hillhead/Maryhill 1871

'Intermediate' Shareholding Lists -

Lochgilphead 1857, Peterhead 1863, Coatbridge 1865, Airdrie 1866, Lockerbie 1867, Inverkeithing 1868, Kirkintilloch 1869, Gourock 1873, Ardrossan 1876, New Pitsligo 1876.

The sparse evidence available on shareholders in the Edinburgh gas company suggests that the Gentry and Professional classes were even more important to the earliest gas companies than during the 1830s. A 'List of Proprietors' of the Edinburgh company for 1821 shows four categories of investment: those with 12 shares (£300) or above (I); with 8 shares (£200) and above (II); with 6 shares and above (III); and the remainder (IV).

Table 2.23 Principal Investors (I) (with above 12 shares each) in Edinburgh Gas Company (1821)

Adam Anderson*	John Anderson, merchant
Archibald Anderson, merchant	William Arbuthnot*
John Baird, Camelon House, Falkirk	Andrew Beath, pawnbroker
Carlylle Bell, W.S.	Dr. Thomas Brown*
Walter Brown,* merchant	Rev. Dr. Buchanan
Thomas Burn, W.S.	Archibald Campbell, brewer
R.B.Campbell	John Clapperton, merchant
Charles, Cunningham, W.S.	William Denniston, Lasswade
James Denholm,* Treasurer Heriot's Hospital	
Francis Dufresne, French Teacher	William Dundas, M.P.
Robert Dundas, W.S.	David Ewart, Chancery Office

Table 2.23 , continued

P.Ferguson, money-lender	William Ford, glass manufacturer
William Fraser, gentleman	David Freer, W.S.
John Geddes	James Gibson, dyer
Alexander Gordon, gentleman	Archi. Haig, baker
Robert Hall*, merchant	Alex. Henderson*, seedsman
William Henderson, grocer & oil-man	John Henderson, W.S. of Dunse
William Inglis*, W.S.	Alex. Lawrie, bookseller
Professor Leslie*	James McBraire, merchant
William Macintyre, County Tax Office.	Kincaid McKenzie*, merchant
Archibald Mackinlay, merchant	John Munderston*, druggist
Sir John Marjoribanks of Lees, M.P.	Josiah Maxton*, saddler
Alexander Munroe, gentleman	John Murray
Walter Nicol, teacher	John Orphoot, printer
William Purves, clothier	James Reid, merchant
John Reoch*	Daniel Robertson, of the Black Bull Inn
John Robertson	Robert Scott, apothecary
George Spence, merchant (wines, grocer), tax-collector	Henry Scott, hatter
Robert Sutherland	David Thomson, W.S.
William Trotter*, upholsterer	John Veitch, cork manufacturer
William Waddel, King's Printing Office	John Watson, 'Manager' of Gas Company
John Whigham, Newington	

Note - Edinburgh or Leith residents unless otherwise stated.
* Governor, Deputy-Governor and Directors marked by asterisk (J.Geddes may have been a member of the Adjutant-General's Office)

Source - (Edinburgh Ref. Lib.) 'List of Proprietors' 15/5/1821

Of the twenty five Directors listed in the Edinburgh company's Act of 1818, only Sir George MacKenzie of Coul had withdrawn his support by 1821. All of the remainder were genuine investors, many of them still Directors. Bankers invested only small cautious sums in the company and comprized C.Archibald (III), H.Auld (IV) and J. McGregor (III) of the Commercial Bank, James Blair (III) and J.Mac-laren (IV) of the Perth Banking Company, and Thomas Allan (III). The main centre of support was nevertheless the professional classes and the gentry. 79 investors from the former included 31 solicitors and lawyers, and the professional class dominated the highest investment bracket. As heavy investors they were closely followed by the gentry of whom 88 invested over all categories. Although the number of 'Gentry' may have been inflated by individuals who witheld their occupations, comparison with the Post Office Directory[1] of 1821 has eliminated most anomalies. The third principal source of finance was from retail shopkeepers with 41 investors including 10 in the highest bracket, followed by wholesale merchants, and then industrialists.

Table 2.24 Shareholders in Edinburgh Gas Light Company (1821)

	Above £300 (I)	£200 (II)	£150 (III)	Under £150 (IV)
Professional	20	20	20	19
Gentry	12	24	24	28
Women	0	0	0	34
Retail Shopkeepers	10	8	17	6
Wholesale Merchants	9	4	4	0
Industry - Employers	6	3	5	1
- Employees	0	0	0	0

1. Post Office Directory for Edinburgh and Leith 1821 (1821, Edinburgh)

Table 2.24 , continued

	Above £300 (I)	£200 (II)	£150 (III)	Under £150 (IV)
Corporate Bodies	0	0	0	0
Artizans	3	3	3	1
Agriculture	0	0	0	0
Miscellaneous	0	0	0	0
Total (284)	60	62	73	89

Source - Edinburgh Ref. Lib. op cit

Those in professional occupations included James Wilson (III) Sheriff Clerk, Henry MacKenzie (III) General Surveyor of Taxes, Henry Jardine[1] (III) and Alex. Kidd[2] (II) Writers to the Signet, George Young (II) Excise accountant and two others who described themselves as 'Accountants', Claud Russel (III), and John Stuart (III) accountant to the Board of Trustees. Others were P.Baxter (III) an Insurance broker, Robert Young (II) of the General Post Office, James Spittal[3] (II) merchant, Dr. Brewster[4] (IV) and Sylvester Reid[5] (III) Depute Clerk of Teinds. The Gentry included Sir John Marjoribanks of Lees (I), Sir Patrick Walker (III), Lord Gray (III), Robert Downie of Appin (II), and the James Innes[6] senior (II) and junior (III) of Princes Street.

Very few investors lived outside Edinburgh, and the Rev. J. Abernethy (III) of Bolton and J.Barker (III) of Oldham were the only Englishmen. Non-resident Scottish investors comprized A.Barrie (IV) of Bankfoot, James Monroe (IV) of Fortrose, Miss B.S.Stevenson (IV)

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1. Vide infra p.1504
2. Secy. of the Gas Co. in 1818 and 1824. Vide Edinburgh City Archives "Minute Book of Lighting Committee" 22/12/1818; Illuminating Powers of Gas(1824) op cit
3. Possibly associated with a planned gas-company in Alloa vide infra p.758
4. Vide infra p.422

Table 2.25 Particular Occupation Groups Holding Shares in Edinburgh Gas Company (1821)

	Above £300 (I)	£200 (II)	£150 (III)	Under £150 (IV)
Professional -				
Solicitor/Lawyer	7	9	8	7
Banker	0	0	5	1
Accountant/Town Clerk	0	1	2	0
Church Minister	1	0	2	1
Teacher/Rector	1	2	0	0
Surgeon/Doctor/Optician	1	2	1	6
Clerk	0	0	0	0
Retail Shops -				
Grocer	0	0	0	1
Innkeeper/Spirit Merchant/ Vintner	1	0	2	0
Books/Stationary	1	1	3	1
Tailor/Draper	0	0	1	0
Boots/Shoemaker	0	1	0	0
Baker	1	3	2	1
Flesher	0	0	0	0
Ironmonger	0	0	1	0
Artizans -				
Painter/Slaterer/Plasterer	0	0	1	0
Smith/Wright	0	0	0	0
Mason/Builder	0	1	0	0
Plumber/Joiner/Tinsmith	0	1	0	0
Agriculture -				
Farmer	0	0	0	0

Source - Edinburgh Ref. Lib. op cit

of Perth, Thomas Balfour (III) a Stirling merchant, T.Trotter (II) of Blackford, and five manufacturers who probably had trade connections with Edinburgh: J.Baird[1] (I) coal and iron master (1802-76) of Falkirk, A.Annadale (II) and J.Muir (III) of Polton Mill in Lasswade, J.Smail (III) of Broom-House Mill near Dunse, and James Hislop (III) hat-maker of Dalkeith. All other investors were resident in Edinburgh.

Three Edinburgh manufacturers who supplied equipment to the Company were only minor shareholders:- John Anderson (III) of Leith Walk Foundry, James Milne[2] (III) brassfounder, and John Patterson (II) of Edinburgh Foundry. The glass industry was represented by W.Ford (I), printing by W.Waddel (I) and J.Orphoot (I), and another important local industry, brewing, by A.Campbell (III), P.Dick (II), and John Hunter (III) with the Misses A. (IV) and E. (IV) Hunter. Occupation groups appear in Table 2.14 .

Two extant lists of shareholders[3] in Glasgow gas company show only the 'intermediate' investors of 1825 and 1839. In 1825 the Committee of Management comprized Dugald Bannatyne, J. Jamieson Craig, Alexander Finlay, Thomas D. Douglas, Walter Ferguson, John Hart,

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4. Vide infra p. 774
5. Vide supra p. 153

1. P.L.Payne, Ed., Studies in Scottish Business History (1967) p.268
2. Vide infra pp. 142, 410, 1256
3. 1839 List of Proprietors, stating names but not addresses, or the quantity of shares.
   Glasgow City Archives (D-GE 24)
   List dated 1/6/1825, Glasgow Mitchell Library (G.665.7*)

James Hamilton,[1] Robert Jarvie, Andrew Templeton,[2] James Mackenzie, John Maxwell, and James Oswald. Other partners included William Anderson senior and junior, James Buchanan, James Buchanan III, heirs of George Buchanan, heirs of D. John Baird, William Baird,[3] James Dennistoun,[4] Robert Dalglish,[5] James Ewing, James L. Ewing, Kirkman Finlay,[6] John Hamilton[7], Jane B. Hamilton, Alex. Hamilton, Professor George Jardine, heirs of James Laird, Miss Agnes Monteith, Professor James Mylne, trustees of John McIlquhan, Charles McIntosh,[8] Alexander McIntosh, James B. Neilson,[9] John Neilson,[+] Mrs John Neilson, heirs of James Spreull,[*] Hugh Tennant, Alexander Ure, J. and H. Wardrop,[10] and the West of Scotland Insurance Company..

Out of 331 Glasgow company shareholders in 1839, 144 were women, who were often joint shareholders as in the cases of Misses Catherine and Jane Barland, and Misses Agnes, Marion and

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1. Vide infra p. 1211
2. Vide infra pp. 672, 1007
3. Vide infra p. 1142
4. Vide infra p. 1008
5. Vide infra pp. 1154, 1157, 1163, 1249
6. Vide infra p.155
7. Possibly John Hamilton (1756-1829) West India merchant; Merchant Bailie 1793; Dean of Guild 1809-10; Lord Provost 1801-3, 1810-11.
   S. Stewart Curiosities of Glasgow Citizenship (1881, Glasgow) op cit p. 221
8. Vide infra p. 543
9. Vide infra p. 956
10. Solicitors for Charles Macintosh, vide infra p. 546.

* Vide supra p. 30 Glasgow Philosophical Society

\+ Probably the elder brother of J.B. Neilson. John followed his father's trade as an engine-wright, and built one of the early sea-going iron ships, the 'Aaron Manby'(1820) Institution of Civil Engineers Proceedings 1869-70 p. 452

Martha Blackburn. The Lock Hospital, Caledonian Insurance Company, Royal Bank of Scotland, and College of Glasgow held shares, as did Robert Gowan and Company and Moses McCulloch and Company. Five church ministers and three doctors, and several army officers held shares, including Captains Andrew Lockhart and Andrew Hamilton, Major A.D.Monteath, and Lieutenant Colonal T.Hill. James Beaumont Neilson had retained a shareholding, and other prominent public figures remaining members of the company[1] included Kirkman Finlay, Robert Dalglish, James Ewing, James Lumsden, Walter Ferguson, George More Nisbet, Patrick Tennant and James Inglis. The executors of John Wilson, and of Professor James Miller also retained shares.

The scale on which commercial companies invested in early gas-companies indicated approval of their development rather than the desire to acquire a controlling influence. Dundee Union and New Banks each took ten shares in the Dundee gas company in 1824; the Forth and Clyde Canal Company took twenty shares in Grangemouth gas company in 1835, and fifty in the West Kilpatrick Company of 1867. The North British Railway Company acquired fifty shares in Gorebridge gas company in 1861, while in 1866 the Monkland Iron and Steel Company held eleven shares in Airdrie gas copany, and in 1865 Messrs. Wilson and Company, ironmasters, held

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1. c.f. sponsorship of company in 1817 <u>vide infra</u> p. 1361

fifty in Coatbridge gas company.[1] Coatbridge indeed was well supported by local industrialists, but this was a reflection of the character of the town rather than a special clique of investors. J. Begg, ironmaster of Coatbridge held twenty shares, J. Wilson ironmaster eleven, the executors of J. Wilson senior of Dundryvan ironworks eighty-three, George Baird ironmaster of Glasgow 106, Neil Robson ironmaster of Glasgow nineteen, R. Addie ironmaster of Langholm Works thirty-eight, P. Rankin coalmaster of Daingaret 143, and William Aitken, coalmaster of Chapell Colliery, sixteen.

Such a gathering of celebrities was not found in other gas companies, and 'interested parties' like coalowners, ironmasters, and gasworks engineers who could sell goods to the gas companies, appear only periodically as shareholders.[2] There is no evidence to suggest that companies supplying gasworks equipment received shares as part-payment for their services. R. Campbell, founder, held five shares in the 1829 Dunfermline company, while James Spowat of Wellwood Colliery held ten, and J. Patterson ironfounder of Leith held five in the Dunse company of 1835. J. Campbell, coalmaster of Lesmahagow, held

1. Coatbridge Company, founded in 1843, had James Miller among its original promoters. J. Miller had worked under G. Stephenson on the Liverpool/Manchester railway, and operated as a general building contractor in Coatbridge from 1836. His father, A. miller, opened Ronald's Forge there in 1840, and James purchased it as North British Ironworks in 1866.
   T.R. Miller, The Monkland Tradition (1958) p. 37

2. Regulations in gas company contracts of co-partnery prevented Directors using their powers to further their private advantages in contracts for equipment.

   Vide infra 'Company Organization' p.929

jointly with two other people 100 shares in the Langbank company of 1871. Investors of this type, like gas engineers, found through their experience in the trade that this was a safe and profitable investment and could join a company when it commenced. B. McCrae, gas manager of Airdrie, thus bought twenty shares in the Armadale company of 1866, while in the 1872 Cove and Kilcreggan company S. Stewart gas engineer of Greenock, bought five shares, and W. MacKinlay, treasurer of the nearby Levan gas company at Alexandria, bought ten shares. J.Z. Kay, gas engineer of Dundee, held fifty shares in the Errol company of 1866, and his wife also held fifty. Kay also held ten shares in the 1863 Meigle company, where G. Tait a gasfitter[1] also from Dundee, held five. Other small examples of shared investment knowledge in supplying industries also occurred. At Gorebridge in 1861, J. Christie[2] coalmaster of Arniston held twenty-five shares, and J. Davidson coalmaster of Newbattle held

1. Another gasfitter, J. Daskein of Leven, held 3 shares in the 1859 Bridge of Earn company.
J. Young, "engineer", but probably the well-known gas engineer of Dalkeith, held five shares in the 1858 Lasswade/Bonnyrigg company.
J. McIntosh, gasworks manager at New Pitsligo, held one share in that company in 1876.
J. Ritchie, gasmanager of Sheffield (formerly of Ayrshire) held 15 shares in 1845 Ayr company.
J. Wyper, gasworks manager of Denny, held six shares in that company in 1862.
A. Ritchie, gas manager of Greenock, had ten shares in Gourock gas company in 1873, while J. Mahoy, gas fitter of Glasgow, had five.
A. Watson, gas manager of Banff, held five shares in 1869 Buckie gas company.
J. Macpherson, gas manager of Cupar (Fife) held ten shares in 1898 Monifieth gas company.
M. Williamson, gas fitter, Dunfermline, held ten shares in 1868 Inverkeithing gas company.
Such small scale 'Inter-Industry Investment' was a mark of confidence rather than an important aspect of finance

2. Christie also owned 100 shares in 1858 Lasswade/Bonnyrigg company.

twenty. In the Loanhead gas company of 1897, R. Mitchell, gas engineer of Galashiels, held thirty shares, as did T. Langrick, oil-works manager also of Galashiels. T. Wilson, gas engineer of Coatbridge, purchased a block of 200 shares in the 1909 Fauldhouse gas company.[1] Among the gas apparatus companies, David Grant, meter manufacturer of Edinburgh, held ten shares in the 1874 Newmilns company, twenty in the 1868 Inverkeithing company, and fifty in the 1869 Buckie company. The 1880 Corstorphine gas company sold twenty-five, twenty-five and ten shares respectively to James, John L., and John Milne, of the Edinburgh brassfounding and gas-fitting company.

Promotion of a company by industrialists followed by their heavy investment in it was rare, though it did occur in 1839 at Leven, Alexandria, where John Orr Ewing and Company purchased sixty shares, Guthrie, Kinloch and Company sixty shares, R.D. Mackenzie forty, Gilbert Lang twenty, and A. Smollet of Easter Auchincarroch forty. Normally industrialists held 'lots' of similar small value to private individuals, like the Millport Spinning Company with five shares in the 1829 Dunfermline gas company, John Affleck and Company shoemakers with five shares in the 1845 Maxwelltown and Dumfries company, T. and J. Oliphant engineers with ten shares in 1862 Denny Consumers Company, and J.F. Smith, secretary of the Glasgow and Ayr Railway Company with twenty shares in the 1845 Ayr gas company. J. Luke, manager of the Carron Grove Mills which had pioneered private gasworks in the area, held five shares in the Denny Consumers gas company of 1862. Occasionally the investment was greater, like Campbell, Laird and Company,

1. Similarly but on a smaller scale, J. McNair, gas manager of Glasgow, held twenty shares in the 1903 Stane and Dykehead Gas Company.

calico printers, with 150 shares in that Denny company. Only in the late nineteenth century, when large companies were formed in a few areas of heavy industry to meet the needs of those communities, was massive investment involved. The main example was at Kelty in 1905, where 1,950 shares were owned by the Fife Coal Company Ltd. of Leven, and 1,950 by Kelty Co-operative Society.

Mercantile partnerships invested frequently in the early gas companies, but again normally in small lots, as did manufacturing partnerships. Thus at Dunfermline in 1829 Bain and Lay merchants held two shares, G. and T. Beveridge merchants five, Colville and Robertson merchants two, and among the manufacturers R. and G. Birrell one, J. and W. Morris two, J. and T. Russell two, W. and J. Swan two, A. and J. Wilson five. Carron and Co., wine merchants at Ayr, held twenty shares in their local gas company in 1845. Only one firm, Miles Leighton and Sons, merchants and drysalters of Dumfries, invested in several gas companies, with two shares in both Lochmaben and Dalbeattie companies in 1859. Indirect evidence suggests that trade connections were an important incentive to distant investors, and that the prospects for investment were discussed by persons who met in the course of their occupations. Thus the Bridge of Earn company had two local fishermen holding shares, an unusual occupation among investors, but also a Perth fishmonger with ten shares. At Buckie in 1869, four local solicitors purchased ten shares each, two solicitors from Keith bought ten each, and one from both Banff and Macduff purchased ten each. The Sheriff Clerk of Banff also purchased ten shares for himself, and forty for his grandson. Smith and Wharrie, C.A., held ten shares in the 1872 Cove and Kilcreggan company, as did D. and G. Graham bellhangers. The Strichen company in 1873 was supported by several partnerships of merchants, like Jamieson and Mitchell with five shares, J. and A. Gibb with ten, Leith and Paterson with five, and J. Leith and Sons with five. W.J. and J. Cousland merchants held thirty shares in the 1862 Denny Consumers Company, J. and S. Forrester merchants twenty-one shares in the Coatbridge company in 1865, and J. and J. Forrester merchants fourteen shares in the Airdrie company in 1866. In all cases, these merchants and manufacturers resided, or had premises, in the town where they supported the gas company.

Trade organisations took a similar role in encouraging the gas industry. At Dunfermline in 1829 the Incorporation of Bakers held two shares, the Incorporation of Hammermen held two, and the Incorporation of Shoe Makers held one. The Society of Operative Masons held ten shares in the Airdrie company in 1866. Other civic and religious bodies also saw a safe depository for their savings in the gas industry. At Musselburgh in 1831 the Musselburgh Rogues Club, a law enforcement agency, held eight shares, and the United Association Congregation held two. The Dunfermline Court of Commerce in 1829 held one share in that local company, and in 1836 the Kirriemuir Commissioners of Police held twenty shares in their local gas company. Aberlady Militia Fund purchased 150 shares in the 1868 Aberlady gas company, Peterhead Free Church in 1863 held thirty-six shares in Peterhead gas company, Inverkeithing Burgh held fifty shares in the Inverkeithing company in 1868, and the Magistrates and Town Council of Lanark[1] purchased 500 shares in the Consumers Company there in 1861.

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1. Further details on the role of municipal authorities in encouraging companies - <u>vide infra</u> 'Municipal Gasworks'. pp. 1004 - 15

Because these organizations *per se* contributed such a small amount to the great majority of gas companies, the true basis of the industry was widespread support by individuals from all sectors of the community who made their personal decisions upon consideration of the advantages they would gain as individuals from gas-lighting, of the return upon their capital investment, and especially of the safety of their monies, both in regard to their legal position and the technological climate, the possible failure rate among gas companies.

Two important topics remain, the role of women investors and the role of the aristocracy and individual heavy investors. Because company failure was rare in the industry, family investment became and remained a common feature, with several members of a family holding shares, and those who migrated away from the town often continued to hold their shares, or were even introduced as new distant but not 'blind' investors. Although women frequently held shares, it was normally their husbands who decided and voted on their behalf, by mandate.[1] At Dunfermline in 1851, J. Inglis, P. Chalmers, R. Sanders and J. Davie, for example, all voted on behalf of their wives. At Biggar in 1839 Robert Veitch, mason, held one share, and his daughter Mary one share. At Dunfermline in 1851 the executors of H. Turnbull, merchant, had sixteen shares, Magdalene Turnbull one share, Miss J. Turnbull ten, and Miss M. Turnbull four. T. Inglis, yarn-boiler there, had given five shares to each of his two daughters.

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1. Rules often prevented non-shareholders holding mandates, possibly to force husbands to become partners as well as their wives. *Vide infra* 'Company Organization' p. 916

Such gifts to relatives, especially maiden ladies, make it impossible to determine the original source of capital, when a list of shareholders is only available several years after a company has been formed.

In the Dumfries and Maxwelltown company of 1845 Agnes and Janniet Welsh each held two shares, but John Welsh had the mandate for both. Joseph Welsh held one share. J. McVittie, mail guard, held two shares and so did his wife, Mary. Susan, Nicholas and Margaret Rogerson each held one share. Jane and Eleanor McGhie each held one share. This pattern of safe investment for all the family was a recurrent theme, a definition of popular faith in the success of such investment. Helen and Ann Cruickshank each held twenty-five shares in the 1859 Bridge of Earn company, while J. Auchinvole, chemist, and his wife each held ten shares in the 1859 Bothwell and Uddingston company, where they were joined by J. Dunlop, commission agent, with fifteen shares, and his wife with five.

Table 2.26 Family Investment - (1859) Muirkirk

	Shares
C. Howatson, manager of Kaimshill ironworks,	100
and his wife	50
W. Howatson, farmer of Auchinleck,	5
and his wife	5
A. Aird of Crossflatt, Muirkirk,	50
and his wife,	20
his daughter	20
R. Paterson, cabinetmaker of Glasgow,	5
and his wife	5
R. Pearson, draper of Muirkirk,	20
and his wife	5
Hugh Smith, shoemaker, Muirkirk	10
Hugh Smith junior shoemaker and draper	5
and Hugh Smith junior, schoolmaster,	10

The Strichen company in 1873 had three tailors from Rathen, each with five shares, among the shareholders. They were J. Stewart, and his wife, and Kathleen Stewart. Ecclefechan company in 1861 included

J. MacConnell, merchant, with thirty shares, and Mary, Sarah and Jane MacConnell with six shares each. W. Scott, farmer of Croftside, had ten shares, Christina Scott twenty, and Janet and Christiana Benson who also lived at Croftside, ten shares each. Mary, Eliza and Agnes Slater, all of Castlebank, had ten shares each. J. Quigley, carrier had ten shares, and J. Quigley junior two. T. Charlton of Limbridgeford held five shares in the Ecclefechan company, and J. Charlton junior five.

At Pollokshaws in 1882, W. Gillies writer purchased fifty-five shares in the gas company, Miss M. Gillies fifteen shares, Miss C. Gillies fifteen, Miss E.A. Gillies five, and G.W. Gillies, law clerk, held fifteen. Mrs E. and Miss C.M. McLaren, of Edinburgh, each held twenty shares in the 1897 Loanhead gas company, while Mrs A. and Miss C.N. Ballantyne of Walkerburn each held sixty shares. Several families were also represented in the Monifieth company in 1898. Mrs J., David, and Eliza Colville, and Jemima Lyon, all of 'Viewforth', had five preference shares each. In the Keay family of 'Ardenlea', Annie, Grace and Bella, dressmakers, and Jessie a teacher, each held forty shares. In the Mathers family, Bessie, Mrs M., a book-keeper, and Jessie a shopkeeper, had ten shares each, while Mrs B.W. Mathers had 100 shares. G. Nicoll, mill manager of Monifieth, had sixty ordinary and sixty preference shares in the company, while J. Nicoll mill manager of Dundee had sixty ordinary and sixty preference shares also.

A. McLean, minister of Carnwath, held sixty-five shares in the Carnwath company of 1859, and his wife held forty. He may have been related to several other important shareholders who were attracted to that company. J. McLean, factor of Campbeltown, purchased forty shares, H.F. McLean Writer of Edinburgh thirty, and J.H. McLean, manufacturer of Glasgow, fifty. The Peterhead shareholders in 1863, included P. Anderson, clergyman of New Lanark, with twenty-eight shares, his wife with 120, and Elspit Anderson with twenty.

The landed aristocracy[1] was important in encouraging gas companies in small communities adjoining their property, and invested heavily in such concerns. At Carnwath in 1859, Lady M. McDonald Lockhart of Lee Castle held 150 shares, S. Lockhart, schoolboy, ten shares, and P. Currie coachman at the Castle five shares, while A. McDonald Lockhart,* gentleman of London, held fifty shares. D. Hazle, gentleman of Kames Castle, purchased 100 shares in the 1863 Kamesburgh gas company, and H.W. Hope, gentleman, 100 shares in the 1868 Aberlady company. G. Deas, Lord of Session, of Pittendriech, purchased 100 shares in the 1858 Lasswade company, and Colonel D. Laird, of Kinsdale in Ireland, fifty shares in the 1858 Cumbernauld company. Similarly D. Laird of Belmont Castle, and E.M.S. Wortley-McKenzie of Wortley Hall, Sheffield, each purchased fifty shares in the 1863 Meigle company. J. Gordon of Cluny Castle, Aberdeen, and R. Macdonald, his factor, took 150 and twenty shares respectively in the 1869 Buckie gas company. James Henderson[2] of Bibster, Caithness, was principal shareholder in the Wick and Pultneytown company in 1879.

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1. The importance of the Duke of Hamilton at Hamilton, and of M. Shaw at Inverkip is considered elsewhere. Vide infra pp.175,489,960

   From operating lime and brick kilns, estate management had increasingly progressed to overseeing coal and mineral operations, and gas manufacture was a further expression of active involvement in community affairs.

   F.M.L. Thompson, English Landed Society in the Nineteenth Century (1963) p. 171

2. J.G.L., 2/9/1879.

* Minor coal-owning family. B.F. Duckham Scottish Coal Industry (1970) Vol. I op cit p. 155

In small gas companies, contributions of this size may have been vital for the success of the venture. Miss McP. Grant, proprietress, took 100 shares in the 1860 Aberlour gas company. J.C. Grant, Earl of Seafield,[1] and John Grant, merchant of London, each took 100 shares in the 1865 Grantown gas company. John Grant, proprietor, and Thomas Moncrieff, proprietor, each took 100 shares in the Bridge of Earn company in 1859, and John Rollo, proprietor, took fifty shares. Miss Fulton of Inverkeithing held 120 shares in her local gas company in 1868.

A significant number of companies from the late 1850s onwards, with the advantage of Limited Liability, contained a small nucleus of substantial investors of this type. The Bothwell and Uddingston company of 1859 sold 200 shares to Lady Jane Montague of Bothwell Castle, R. Addie ironmaster of Viewpark 100 shares, T. Leadbetter merchant of Elder Bank 100 shares, R. Ker merchant of Auchenraith 150 shares, Geo. Miller[2] chemical manufacturer fifty, J.E. Poynter chemical manufacturer, twenty-five, and J. Poynter of the same trade, fifty. Stow gas company of 1863 was strongly supported by A. Abercrombie, manufacturer of Cove with 200 shares, A. Mitchell, proprietor of Earlston, with 100, and Mrs J. Mitchell, proprietress of Laidlawsteel, with 100 shares. Langbank company in 1871 attracted investment from T.J. Seath, shipbuilder of Langbank with 150 shares, T. Blackwood, shipbuilder of Port Glasgow with 100, D. Darroch barrister of Gourock with 100, and Colonel D. Buchanan of Coatbridge with 125.

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1. <u>Vide supra</u> - Edinburgh p.153
2. Miller was also a gas engineer, <u>vide infra</u> 'Chartered Companies' pp. 547, 964

Large investors were sometimes also local residents. Corstorphine company in 1880 included H. Beveridge, gentleman, with 100 shares, army Colonel O. Pelly with 300, and R. Tody miller with 300, all residents, and also W. Macfie gentleman of Clermiston with 200, and J.H. Dickson land valuer of Saughton Mains with 200 shares. In some cases, a small clique of distant investors did achieve predominance in company ownership. The Tranent company of 1885, which issued only 1,811 shares, included Alex. Donaldson of Edinburgh with 500 shares, George Simpson of Edinburgh with 200, John Polson of Paisley with 200, R. Hunter of Edinburgh and W. Duncan, S.S.C. of Edinburgh with fifty each, and T.A. David, of the British Linen Company in Edinburgh, with fifty shares.

Stornoway gas company in 1847 developed around the investment of James Matheson, with 305 shares, and Mrs Matheson also had ten shares. The 1841 company at Leslie, Fife, also included some heavy investors by 1860 when the first list is available.

Table 2.27 Large Shareholders - (1860) Leslie

David Lawrie, Dunfermline	80	Wm. Miller, Camelon	138
Mrs Borthwick, Leslie	100	Miss A. Anderson, Leslie	75
H. Crichton, gentleman, Leslie	100	J. Fergus, gentleman, Leslie	100
Agnes Goodall, Leslie	160		
Executors of Lord Rothes, Leslie	48	James Neaves, Leslie	102

Large investors were important in particular cases, therefore, especially in the 1860s andlater where companies were formed in villages with rural surroundings, but their significance should not be overemphasized.

Although gas engineers, iron founders, coalmasters and landed proprietors did invest, sometimes, considerable sums in gas companies, typically their influence was reduced by the greater value of stock held by other smaller shareholders. In only a few cases did such investors dominate gas companies. Two categories developed of 'inter-industry investment' and 'restricted membership', which contrasted greatly with the normal pattern of gas industry investment.

William Young, a renouned gas engineer,[1] in 1878 purchased the Falkirk Gas Light Company, which had begun in 1829 but had been in competition with a second Falkirk company[2] since 1845. In 1879 he registered it for limited liability in partnership with like-minded engineers and confreres.

Table 2.28 Inter-Industry Investment - Falkirk (1879)

	1880 Shares held	1887 Shares held
W. Young, oilworks manager, Clippens	290	435
A. Duncan, Musselburgh (later Langholm)	280	320
James McGilchrist,[3] gas works manager, Dumbarton	200	50
Samuel Stewart,[4] gas works manager, Greenock	50	125
W.S. Brown, iron-tube manufacturer, Glasgow	50	200
W. Sutton, draper, Newcastle-upon-Tyne	20	0
Alex Young, oil works manager, Musselburgh	10	0
Andrew Young, oil works manager, Uphall	0	15
James Aitken,[5] Writer, Falkirk	0	30
G. Howson, cutler, Sheffield	0	25

Source: S.R.O. (BT2/869)

The first five members were technologists who were banking upon their own skill to turn the old gasworks into a profitable concern. They failed, and in 1887 it was purchased by the other Falkirk

1. Vide infra 'Labour', 'Technology', 'Oil Gas'pp. 638, 377, 448
2. Vide infra 'Consumer Relations' p.1141
3. Vide infra 'Labour' p.640
4. Vide infra 'Labour' p.639
5. Vide infra 'Oil Gas' pp. 441, 272

company. Undaunted, the same entrepreneurs in 1883 had purchased the West Kilpatrick gas company near Bowling on the Clyde,[1] previously owned by twenty-one shareholders. Again it was a technical challenge because the works, which had been constructed by Mr Ritchie of Glasgow, were too large for the requirements and hence unprofitable. McGilchrist's team aimed to lay mains to Dalmuir, and sell gas in bulk to the new company there, and to exploit the growing residential suburbs of Glasgow. They were successful until 1887 when encroachment by Glasgow Corporation gasworks obliged them to sell the works to the Partick, Hillhead and Maryhill company.[2]

In 1887, members of the same group purchased two more gasworks, at Dunblane and at Earlston, both with limited liability, (Tables 2.29 and 2.30 below)

After the death of Andrew Duncan in 1894, all the other partners at Earlston sold their entire shareholding within two years, and ownership of the company reverted to a broad base of fifty shareholders, with small lots of shares, none more than twenty-five, and from a range of occupations almost equally diverse.

Busby gas company[3] in Renfrewshire was also acquired by 'inter-industry investment' in 1888 and remained a 'restricted membership' company even in 1908 when relatives of the original clique remained in control (Table 2.31 below).

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1. J.G.L., 4/9/1883. Also termed the "Old Kilpatrick" Company. That company had been a Limited Company since 1865, and the original owners are considered elsewhere, vide infra p.1196
   Their gas price had been so high that most households used paraffin oil instead.

2. Vide infra 'Consumer Relations' p. 1198

3. Board of Trade (BT2/1706); this company later took a Provisional Order under 1870 Gas and Water Facilities Act, vide infra 'Chartered Companies' p. 952

Table 2.29 Inter Industry Investment - (1887) Dunblane company shareholders

		Shares
W.S. Brown, iron tube manufacturer,	Glasgow	200
A. Duncan, gentleman,	Portobello	100
W. Young,[1] consulting chemist,	Peebles	100
S. Stewart, gas engineer,	Greenock gasworks	55
D. Terrance, gas engineer,	Maryhill gasworks	55
W. Mackenzie, gas engineer,	Dunfermline gasworks	50
T. Callander, gas engineer,	Old Kilpatrick gas-works	20
W. Thomson, gas engineer,	Falkirk gasworks	20

Source: S.R.O. (BT2/1649)

Table 2.30 Inter Industry Investment - (1887) Earlston company shareholders

		Shares
W.S. Brown, iron tube manufacturer,	Glasgow	50
A. Duncan, gentleman,	Portobello	50
R. Grant, Commercial traveller,	Glasgow	50
G. Howson, cutler,	Sheffield	50
A. Scott, gasworks manager,	Galashiels	25
W. Young, consulting chemist,	Peebles	125
R. Young, oil works manager,	Uphall	25
Alex. Young, oil works manager,	Uphall	25

Source: S.R.O. (BT2/1689)

1. This is the same W. Young as previously

Table 2.31 Inter Industry Investment

(1888) Busby Shareholders

		Shares
W. Young, consulting chemist,	Peebles	45
W. Thomson, gasworks manager,	Falkirk	10
S. Stewart, gasworks manager,	Greenock	20
D. Terrance, gasworks manager	Maryhill	20
T. Callander, gasworks manager	Old Kilpatrick	10
A. Duncan, gentleman,	Portobello	40
W.S. Brown, iron tube manufacturer,	Giffnock	70
R.S. Brown, engineer,	Giffnock	10
D.S. Brown, clerk,	Giffnock	5
W. Philip, banker,	Greenock	10

(1908) Busby Shareholders

J. Terrance, gasworks manager,	Middlesborough	80
H. Kelly, gasworks manager,	Busby	35
J. Mackenzie, gasworks manager,	Newcastle, New South Wales	6
G. Howson,[1] cutler,	Sheffield	270
R.S. Brown, engineer,	Old Kilpatrick	49
D.S. Brown, merchant,	Carmyle	20
W.S. Brown, retired	Giffnock	200
I.S. Brown, spinster	Giffnock	65
A.S. Brown, spinster	Giffnock	10
J.S. Brown, spinster,	Giffnock	20
J.S. Brown, medical student,	Giffnock	70
J.S. Brown, solicitor,	Giffnock	10
A. Youie[illegible], merchant,	London	70
J. Armour, mining engineer,	Leven, Fife	13
E. Mackenzie, widow,	Limekilns	15
G.J. Buchanan, barrister,	Bishopbriggs	67

Source: S.R.O. (BT2/1706)

By closely regulating the sale of shares, especially those within the Brown family, and allowing Howson to purchase so many since he was a partner with Brown in the Falkirk gas company of 1887, this was a clear case of 'restricted membership'. However two further impor-

1. See also Falkirk, 1887

tant cases of 'inter-industry' investment must be noted. In 1913 the Slamannan company, a limited company since 1867, was purchased by Slamannan New Gas Company comprising such investors, while in 1914 the Prestonpans company was likewise purchased.[1]

Table 2.32 Inter Industry Investment - Slamannon (1913) shareholders[2]

		Shares
D. Robertson, gas engineer,	Dunoon	350
W. Fairweather, gas engineer,	Kilmarnock	350
C. Fairweather, gas engineer,	Kilmarnock	300
D.A. Penman, M.D.,	Slamannan	50
D.A. Penman, coal owner,	Glasgow	300
Mrs. A. Penman,	Glasgow	50

Source: S.R.O. (BT2/8506)

Table 2.33 Inter Industry Investment - Prestonpans (1914) Shareholders

R.W. Cowie, gasworks manager,	Dalkeith	1,000
W. Thomson,[3] gasworks manager,	Musselburgh	1,000
D. Vass, gasworks manager,	Perth	1,000
J. Richardson, solicitor,	Musselburgh	1,000

Source: S.R.O. (BT2/9153)

Thomson, who had earlier been associated with W.S. Brown, may have inspired the Prestonpans group, but the Fairweather organization appears to have originated a decade earlier, in 1904, when a new

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1. Slamannan (BT2/75 and BT2/8506) was previously held by the normal diversity of shareholders, 31 in 1868 with no individual holding above 50 shares, and 26 in 1912 with no one holding above 63 shares. The 'inter-industry' investors were an alien group, who previously held no shares whatsoever in the company.
   Prestonpans (BT2/9153) was not a limited company until 1914; it was a 'private company'
2. The ownership did not alter until 1920
3. Probably the same investor as at Dunblane in 1887, and at Busby in 1888.
   The Prestonpans Company also supplied Cockenzie and Port Seton.

Mearns gas company purchased the old company there.[1] The old limited company had supplied the village of Newton Mearns since 1873, but even then had only twelve shareholders. All were local residents, as were the fifteen shareholders in 1903. The new company however had a strong contingent of distant investors in the gas and coal industries.

Table 2.34 Inter Industry Investment - (1904) Mearns new gas company shareholders

Residents of Newton-Mearns:

A. Gordon, Bleach Works	100 shares	J.C.R. Marshall	100
Miss J.P. Blackwood	50	R. Osborne, grain merchant	50
A. Gilmour, farmer	50	J. Strang, spirit merchant	50
R. Mackinlay, surgeon	50	N. Murdoch, grocer	50
J. Russell, joiner	50		

External 'Inter-Industry' Investors:

W. Fairweather,	Kilmarnock gasworks	80
C. Fairweather,	Kilmarnock gasworks	100
J.P. Carmichael, gas engineer	Barrhead	20
J. Ferguson, colliery agent,	Barrhead	100
Mrs A. Mains, widow of ship-owner,	Giffnock	50
D.A. Penman[2], coal owner,	Glasgow	100

Source: S.R.O. (BT2/5685)

Because the available data is confined to limited companies, the importance of 'inter-industry' investors in other gas companies in Scotland may have been more considerable. The existence of unofficial 'restricted membership' agreements, like that which was apparent at Busby, is more difficult to demonstrate although it apparently became more common in the period 1890 to 1914, and was not confined

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1. Mearns S.R.O., (BT2/386, BT2/5685)
2. Kelty company in 1905 had two shareholders named A. Penman, 'miners' of Kelty with 100 and 50 shares, and a W. Penman, retired miner, with 100, but no family connection can be proved with D.A. Penman.

to companies which registered as "private companies". It was characterized by a foreshortening of the variety of shareholders, and a concentration of the shares into the hands of a minority of large investors. At Lockerbie,[1] for example, seventeen shareholders held the stock of £1,200 in 1867, but by 1891 only eleven shareholders owned the enlarged stock of £2,440.

Table 2.35 Restricted Membership - Lockerbie shareholders (1867)[2]

(local residents unless otherwise stated)

J. Douglas, druggist	60	R. Whyte, minister,	26
J. Baird, writer/banker,	24	J. Wilson, surgeon,	24
W. Richardson, banker,	10	D. Matheson, banker,	10
A. Wallace, merchant,	5	A. McIntosh, innkeeper	5
W. Wright, writer,	5	Margt. Little, innkeeper,	4
C. Stewart, factor,	4	A. Ferguson, schoolmaster,	2
Ann Hardie, baker,	2	F. Moffat, merchant,	3
J. Blacklock, ironmonger,	2		
J. Kennedy, Captain 4th Hussars,		Edinburgh	20
R. Munn, manufacturer,		Manchester	10

(1891) Lockerbie shareholders

	Old £5 shares	New £1 shares		Old £5 shares	New £1 shares
J. Douglas, druggist	111	629	Heirs W. Dobie	1	0
Trustees J. Baird, solicitor	24	29	W. Dobie, draper	23	53
Trustees A. McIntosh, innkeeper	5	15	R. Jardine, builder	10	24
J. Cormack, solicitor	4	14	M. Little, widow	5	21
			D. Matheson, banker	0	11
Trustees of Mrs. E. McIndoe,			Sunderland	31	264
R. Munn, manufacturer,			Manchester	10	0

Source: S.R.O. (BT2/269)

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1. Board of Trade (BT2/269)Lockerbie; vide infra 'Municipal Organization' p. 1066

2. The type of shareholders at Lockerbie in 1867 was typical of the support given to most gas companies at that period.

This degree of concentration was not simply the result of offering new shares preferentially to existing shareholders,[1] and is also evident in the new Melrose[2] gas company in 1894.

Table 2.36 Restricted Membership - (1895) Melrose shareholders

(residents unless otherwise stated)

	Shares		Shares
A. Curle, Writer	703	J. Curle, writer	453
A., J. and J. Curle, (exors. Miss H. Gibson)	160	C. Erskine, gentleman	560
		M. Issac, spinster	160
L. Murray, widow	300	I. Henderson, spinster	160
L. Murray, spinster	60	T. Scott, baker	63
I. Boston, school mistress	7	J. Paterson, tinsmith	40
J. Scott, blacksmith	7		
A. Freer, merchant, London; J. Rutherford, doctor, Dumfries: A. Tait, bank Secretary, Edinburgh (Exors. J. Freer)			86
J. Simpson, brewer, Edinburgh; A. Simpson, brewer, Melrose (Exors. J. Simpson)			40
Violet Smith, Edinburgh; J. Smith, farmer, Kelso; A. Smith, farmer, Longniddry (Exors. J. Smith)			87

Source: S.R.O. (BT2/2634)

At South Queensferry[3] a different situation arose when Forbes Waddell, owner of the gasworks, sought to form and dominate a company which would give him personally the benefit of limited liability (Table 2.37 below). Although Birch and Mackie acquired more shares, the exclusive membership was maintained until after 1910 (Table 2.38 below).

At Dundonald, the gasworks were operated privately until 1907 by G.W. and R.B. Anderson, an engineering firm of London, who in 1908 formed a private Limited Company.[4] This was merely a blind to protect their own safety from debt (Table 2.39 below).

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1. <u>Vide infra</u> 'Finance' p. 774
2. Melrose S.R.O. (BT2/2634) limited company which purchased the existing company.
3. S. Queensferry S.R.O. (BT2/6847).
4. Dundonald S.R.O. (BT2/6859). The Directors were empowered to veto any transfer of shares of which they disapproved.

Table 2.37 Restricted Membership - (1908) South Queensferry shareholders

F. Waddell	6,000	W. MacKie, bonded warehouse manager	1
G. Birch, Inland Revenue supervisor	1	R. Ruthven, saddler	1

J. Watt, writer,	Edinburgh	1
W. Blair, writer,	Edinburgh	1
T. Christie, sack manufacturer	Broughty Ferry	1

Table 2.38 Restricted Membership - (1914) South Queensferry shareholders

F. Waddell, gas manager	62	R. Ruthven, saddler,	1
A. McLean, clerk,	15		

J. Christie, sack manufacturer,	Broughty Ferry	1
J. Watt, writer,	Edinburgh	1
W. Blair, writer,	Edinburgh	1
J. Dickson, gas manager,	Johnstone	100
J. Kennedy and J. Clark, bankers,	Edinburgh	5,900

Source: S.R.O. (BT2/6847)

Table 2.39 Restricted Membership - (1908) Dundonald shareholders[1]

G.W. Anderson, engineer,	London	1,000
Mrs J.H. Anderson,	London	1 Pref.
T. Benger, accountant,	Croydon	1 Pref.
Miss B. Wiseman,	London	1 Pref.
R.B. Anderson, engineer,	London	1,000
Mrs. K. Anderson,	London	1 Pref.
Miss L. Cutler,	London	1 Pref.

Source: S.R.O. (BT2/6859)

The Strathmiglo[2] gas company was sold in 1910 to an organized group of distant investors as a 'restricted membership' company (Table 2.40 below).

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1. Preference shares marked 'Pref.'
2. Strathmiglo S.R.O. (BT2/7557).

Table 2.40 Restricted Membership - (1910) Strathmiglo shareholders

J. Kincaid, engineer,	Kirkcaldy	198
Mrs. I. Kincaid, his wife,	Kirkcaldy	100
C. Ferns, commercial traveller,	Glasgow	198
Mrs. M. Ferns, his wife,	Glasgow	100
J. Brawn, widow,	Peterhead	1
J. Bell, insurance inspector,	Edinburgh	1
A. McGlashan, M.B.C.M.,	Kirkcaldy	1
W. McInnes, bleacher,	Kirkcaldy	1

Source: S.R.O. (BT2/7557)

A final example is that of Abernethy[1] where the gas company was purchased in 1911 by a similar external, organized group:

Table 2.41 Restricted Membership - (1911) Abernethy shareholders

R. Emmerson, coal merchant,	Glasgow	177
Mrs J. Emmerson, his wife,	Glasgow	10
R.M. Cairns, coal merchant,	Glasgow	177
Mrs H. Cairns, his wife,	Glasgow	10
J.R. Stevens, gas manager,	Elie	176
Mrs C. Stevens, his wife,	Elie	10

Source: S.R.O. (BT2/7777)

In 1914, the same partners owned the company, and while the wives each still held ten shares, their husbands each held 223 shares.

Hence although most Scottish gas companies began and remained in the ownership of a large variety of local residents, especially shopkeepers, merchants and professional men, a number of companies in the late nineteenth century were acquired by gas engineers and their associates as profitable ventures. In a larger number of companies the stock became concentrated in a very small group of shareholders who maintained their control by informal agreements to restrict the admission of new shareholders. Most of the initial capital was available locally.

1. Abernethy S.R.O. (BT2/7777)

CHAPTER III

Production

1. Technological Evolution

Until at least the mid nineteenth century, the British gas industry maintained a technological lead over its counterparts abroad.[1] London, with the earliest gas companies, and the larger British cities, developed the most advanced and efficient methods to meet heavy demands made by their markets and to baulk potential competitors. Many developments thus originated in England, and were imported into Scotland. The principal innovation in Scotland was that of clay-retorts[2] and high-temperature distillation. Scottish engineers also developed a considerable talent for modifying the large-

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1. Vide infra, Chapter II 'Laidlaws' p. 140
Many British companies were floated to build and operate continental gasworks, for example Messrs. Manby and Wilson's 'Campagnie Anglaise' in Paris (1820), and Messrs. Manby at Madrid (1844). The 'Imperial Continental', 'European Gas Company', 'Bombay', 'Imperial Ottoman' and many other continental companies were financed by Britain, and often employed Scottish engineers. Until the 1890s many parts of Germany, France, Holland, Italy, Denmark, South America , and even Vienna, were supplied with gas by British companies. The 'French National Gas Company' (1833) later renamed the 'European Gas Company' (1835) was run by G. Lowe and London bankers who, with T.G. Barlow as engineer, used British machinery to build works like Havre (1834), Caen and Amiens (1835), Nantes, and Rouen (1846).
G. Withers, engineer of Liège in Belgium stated in 1841 that Brussels, Amsterdam, Rotterdam, Ghent, Cologne, Hanover and Berlin were all lit by British companies, and although "the natives have the same machinery", they lacked the "expertness" to compete. Until 1850 when O. Pintsch began a factory, Germany imported all gas-meters mainly from Britain.
B.P.P. 1841 VII 1. First Report of the Select Committee to Inquire into the operation of the Existing Laws affecting the Exportation of Machinery. p. 83. Q. 1042-50.
W. Richards, Practical Treatise (1877) pp. 26, 31, 32: W.J. Liberty, "The Century of Gas Lighting and its Historical Development" The Illuminating Engineer (1913) Vol IV, p. 185: King's Treatise on the Science and Practice of the Manufacture and Distribution of Coal Gas (1878) T. Newbigging and W.T. Fewtrell Eds., Vol. I, pp. 46, 49, 54. Obituary of O. Pintsch, son of Julien, the founder of the Pintsch Gas Company J.G.L. 6/2/1912.

2. In the mid 1850s clay retorts were more common in Europe, e.g. Paris, than in England. J.G.L. 5/2/1856, p. 66; King's Treatise (1878) Vol. I op. cit., p. 47.

scale advanced designs to make them suitable for small town and village gasworks which predominated in the north. The variety of managers' skills in these small works, and limitations on the capital available for improved equipment, produced a great variety of apparatus. Standardization was further prevented by the normal practise whereby skilled managers, or consultant engineers, designed the equipment they required personally instead of choosing from patterns advertised by the manufacturers.

The multiplicity of variable factors influencing the quantity and quality of gas output retarded the innovation or adoption of new techniques, as did the absence of rigorous and prolonged competition for markets. The size of fixed capital investment to supply an immobile market made competition so strenuous, when it was attempted in Scotland, that price-cutting prohibited the accumulation of adequate profits for reinvestment[1] in improved equipment. Without any competition, the profit was available but the incentive was not. Consequently, coal shortages and labour problems were the main stimuli for rapid technological developments from the 1870s. Previously, competition between manufacturers for equipment contracts, and innovations by gas managers in their spare time, were the principal factors in the slow evolution of technology. The pace of change accellerated rapidly after 1872.

Production costs were greatly influenced by the price of coal, which varied according to the quality measured in terms both of 'candlepower' and 'potential' gas output. Actual candlepower and output per ton of coal, were related to the technology at a particular

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1. <u>Vide infra</u>, 'Finance' p. 819 et seq.

works, and like labour productivity, this was slowly improved. The candlepower required,[1] and the types of coal necessary to produce this, directly affected carbonization technology, as did the quality of coke produced by that coal. Scottish coal was prolific at high temperatures, but produced poor coke for the furnaces, unlike English coke. Consequently tar was burned in the furnaces, but the higher temperatures achieved were excessive for iron retorts, and instead clay retorts were developed, which were both far cheaper to purchase, and greatly increased the gas output per ton of coal. High temperature distillation meant that each 'charge' of coal was distilled in a shorter time than at English gasworks. This increased the through-put and productivity of each retort per day, and because all the retorts set in one 'oven' were re-charged at the same time, Scottish gasworks preferred a small number of retorts in each oven, to reduce the amount of distillation time wasted during recharging.

Expensive coal, and the pending exhaustion of the best coals, led to innovation by Malam, and by Aitken and Young who tried to enhance the candlepower of gas from poor coals. Oil enrichment[2] was also tried, but the main advance in reducing working costs was that of Siemens regenerative furnaces in the 1880s. These raised the out-

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1. Despite the much higher prices charged for coals which produced high-candlepower gas, and gave companies every incentive to supply cheaper, low-candlepower gas, most companies undertook no obligation to provide consumers with gas of a guaranteed minimum candlepower. This produced public debates and recrimination throughout the century, yet until the 1880s most Scottish companies did supply a very high quality gas of 25 to above 30 candlepower. Such quality was a result of public pressure, the self-interest of shareholders and directors who were local residents and consumers, and the fact that coals which had a high price per ton produced gas which was both large in volume and at the same time of high candlepower.

2. Vide infra, 'Special Gases' p. 440 et seq.

put from poor quality coals, at a time when many companies throughout Scotland were reducing the candlepower of gas.[1] Siemens' system also produced a large surplus of coke, which stimulated the development of water-gas[2] from coke, to 'enrich' coal gas. As the Welsbach mantle[3] replaced open-flame burners, and calorific power replaced candlepower as the market for gas-cookers and heaters developed, large vertical retorts were installed, producing far greater quantities of gas per ton of coal, from cheaper coals. Mechanical handling and automation considerably reduced the labour force despite the rising volume of material processed.

Other developments were also inter-linked. Telescopic gasholders were impractical in freezing weather until heating was available using waste steam from engines used to power gas-exhausters.

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1. Vide infra, 'Markets' p. 1307
The illuminating constituents of coal gas were ethylene (C_2H_4), Propylene (C_3H_6), Butylene (C_4H_8) Acetylene (C_2H_2) and Benzene (C_6H_6) which were diluted by other combustible gases of low luminosity like hydrogen, methane and carbon monoxide. Chemical terminology has in some cases changed since the nineteenth century, when the following terms were used -
'Light Carburetted Hydrogen' = Marsh Gas = Firedamp = Methane (CH_4)
'Olefiant Gas' = Elayl = Ethylene (C_2H_4)
Carbonic Oxide = Carbon Monoxide (CO)
Sulphuretted Hydrogen = Hydrogen Sulphide (H_2S)
Carbonic Acid = Product of Carbon Dioxide (CO_2) and water produced during combustion = H_2CO_3
Napthalene ($C_{10}H_8$), a gas which could condense as white, flaky crystals blocking gas-pipes.
King's Treatise (1879) Vol. II, op. cit., pp. 200-4
P.F. Frankland "The Composition and Illuminating Power of Coal Gas" Journal of the Society of Chemical Industry 1884 Vol. III, pp. 271-7.
W. Mathews, A Compendium of Gas Lighting (1832) pp. 108-34 "An attempt to explain a few of the scientific terms."
2. Vide infra, 'Special Gases' p. 459
3. Vide infra, 'Markets' p. 1305

These engines also provided mechanical power for 'washers', and for pumping water into 'scrubbers' which recovered by-products. They were therefore more rapidly introduced when by-product[1] prices made this an important source of revenue.

Standards were developed to measure the efficiency of equipment[2] but were not widely applied in small companies where profitability, or simply financial viability without losses, remained the principal standard. Gas output per ton of coal was the main criterion of the entire gasworks, but this was affected as much by the mixture of coals adopted as by the equipment. Variations in the size of retorts, in the fuel costs of various oven arrangements, and the speed of distillation adopted, prevent accurate comparisons between different gasworks from fragmentary statistics regarding retort output. Only generalized observations are possible, although it is evident that a small gasworks like Stow,[3] near Lauder, which produced 7,725 cu ft per ton in 1884 compared to about 10,000 cu ft elsewhere, was probably burdened with inefficient equipment rather than seeking greater revenue from liquid by-products.[4]

The apparatus used in a gasworks comprised several functional sub-sections, each of which was improved independently. Because company directors usually replaced a section only when deterioration made it dangerous or grossly inefficient, every gasworks contained a mixture of old and new designs.

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1. <u>Vide infra</u>, 'By-Products' p. 567
2. Viz. Working costs per 1,000 cu ft gas produced. <u>Vide infra</u>, 'Finance' p.793 et seq
3. <u>J.G.L.</u>, 22/7/1884
4. <u>Vide infra</u>, 'By-Products' p. 568

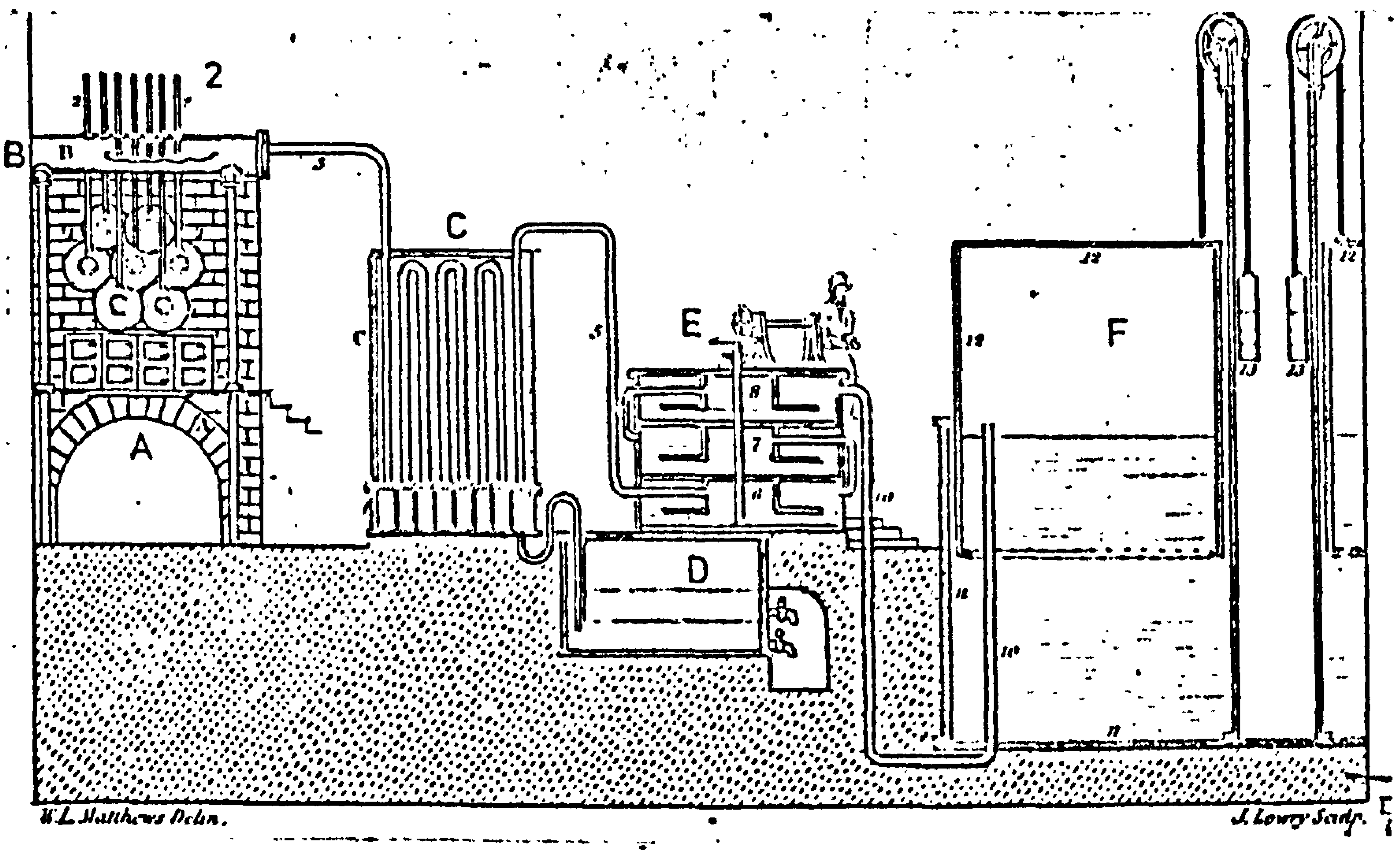
Table 3.1 Retort Efficiency

Date	Town	Cu. Ft. Gas per Ton Coal	Gas Output (cu ft) per Retort per Week
1825	Glasgow	8,960 (12,096 experimentally)	25,200
1831	Hawick	6,500	
1832	Glasgow		35,000
1839	Aberdeen	10,080 (13,440 experimentally)	
1842	(Anonymous)		31,666
1853	Haddington		35,000
1853	(Anonymous; after Hughes)	8,561 (Arniston)	31,666
1854	Stornoway	7,658.5	
1864	Ayr	10,000	87,500
1871	Kilmarnock	7,340	
1873	Dumfries	Malam's system 13,563 Malam's system and exhauster 15,125	
1874	Dundee	Normal 10,000 Malam's system 12,400	
1874	Glasgow	8,553	
1875	Kilmarnock	7,417	
1875	Glasgow	9,383	
1875	Galashiels	9,323	
1876	Glasgow	9,746	
1877	Glasgow	9,693	
1877	Broughty Ferry	10,670	
1878	Glasgow	10,028	
1883	Edinburgh/Leith	Siemens System 10,400	65,800
1880	Stirling	Regenerative Firing	56,000
1883	Arbroath	10,659	
1884	Stow	7,725	
1884	St Andrews	10,048	
1884	Kilmarnock	9,223	
1885	Dundee	10,474	
1885	Bothwell	10,479	
1911	Helensburgh	Vertical (Glover-West) 11,897	218,705
1913	Johnstone	Vertical (Wilson) 11,111	233,333
1913	Cambuslang	Vertical (Glover West)	227,500
1914	Hamilton	Vertical (Woodall-Duckham)	437,500

SOURCES: Vide infra, pp. 334 (Malam), 395 (vertical retorts); (Galashiels) J.G.L. 27/7/1875; (Broughty Ferry) J.G.L. 24/7/1877; Arbroath J.G.L. 10/7/1883; Dundee J.G.L. 23/6/1885; Glasgow J.G.L. 7/1/1879; Kilmarnock J.G.L. 12/8/1884; St Andrews J.G.L. 28/9/1884; Bothwell J.G.L. 14/7/1885; Stornoway Minute Book, op. cit., 16/5/1854; Hawick J.G.L., 10/7/1883

Aberdeen New Statistical Account Vol. XII

Fig. 3.2 Gasworks Design - 1832 (After W. Mathews)



A - coke cellar surmounted by 'stage' for workers to stand on, doors to furnaces and 7 retorts. Ascension pipes carry gas up from front of retorts to dip-pipes (2) which pass into the Hydraulic Main (B)

C - Condenser (inside a water-filled tank)

D - Tar Sump.

E - Purifier - lime and water mixture, with 'agitators' operated manually. Devised by Henry Creighton.

F - Gasometer[1] (gas-holder) suspended above a water tank (11) by the buoyancy of the gas, and the counterbalance weights (13).

SOURCE - W. Mathews, A Compendium of Gas Lighting (1832)
2nd Edn. Preface, and p.26

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1. The folding-gasometers and rotary-retorts designed earlier by S. Clegg (1781-1861) suffered excessive wear and tear, and were not widely used.
"Gas Lights" Supplement to the 4th, 5th and 6th Editions of the Encyclopaedia Britannica Vol. 4 (1824, Edinburgh) p. 448 et seq.
A glossary of technical terms used in the gas industry is given in B.P.P. 1893-4 (c.7063 V.c.) XXXVIII p. 100 (505)

From the retorts,[1] gas normally passed up vertical 'ascension pipes', around 'dip-pipes' which could be opened for cleaning, and into the 'hydraulic main' invented by Samuel Clegg.[2] This cast-iron pipe,[3] ten to fourteen inches in diameter, had one end sealed, and at the opposite end a semi-flanch 2½ inches high, above which an exit pipe removed the gas. The hydraulic main was placed horizontally, about two feet in front of the retort bench and level with the top of it. Inside it, 2½ inches of liquid was retained by the semi-flanch, and the dip-pipes released fresh gas below the water-level. Thus, when a retort ceased to operate the water acted as a lute to prevent the gas from other retorts which continued to enter the hydraulic main, from blowing back into the dip-pipe, where it could cause an explosion when a retort was opened for removing coke and 'charging' fresh coal. Previously, a separate valve on the ascension pipe of each retort had to be closed manually before a retort could be opened, and error was always possible.

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1. Coal thrown manually by a skilled 'stoker' into the retort, which was then sealed off from the atmospheric air, produced 'gas' as soon as the retort was sufficiently heated by a furnace.

2. Clegg first used a 'hydraulic main' at Greenway's Cotton Mill, Manchester, in 1811. In 1817 one was installed at Peter Street gasworks, London.
   J.G.L. 15/9/1874 pp. 362-4
   King's Treatise (1878) Vol. I, op. cit., p. 248
   S. Everard, Gas, Light and Coke Company (1949) op. cit., p. 64.

3. In 1819 Peckston estimated that twelve inches diameter was adequate for forty to sixty retorts.
   Wrought-iron was gradually introduced in the 1840s-50s, to give a lighter and stronger structure.
   T.S. Peckston, Theory and Practice (1819) op. cit., p. 176
   S. Hughes, Treatise on Gasworks (1853) op. cit., p. 115.

Creighton[1] failed to build a hydraulic main in the original Glasgow gasworks. Instead he placed a "square chest"[2] below each retort, fed by dip-pipes and inter-connected to remove the gas. The gas entered so hot that tar deposits rapidly hardened to pitch, and cleaning was dangerous. By 1825 Neilson[3] had replaced the system with one resembling Clegg's, with doors along the main for clearing it. Like Kilmarnock gasworks, he placed it nine feet horizontally away from the retort-bench, and used diagonal ascension pipes which helped to cool the gas and allowed some tar to trickle back to the retort.[4]

A 'condenser' extracted tar vapours from the gas. At first it was a straight pipe, cooled externally by air or water, but so much tar escaped and damaged the lime purifiers as well as threat-

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1. Creighton's failure to illustrate the hydraulic main in the 1824 Encyclopaedia Britannica Supplement was greatly criticised by Clegg. The absence of this feature at Glasgow gasworks supports the possibility that Creighton's diagram was one of Glasgow itself.
   S. Clegg, A Practical Treatise on the Manufacture and Distribution of Coal Gas (1853) p. 219.
   For Creighton's identity, see also:
   W. Henry, The Elements of Experimental Chemistry 1823 Vol. I, p. 420
   T.S. Peckston, Historical Sketch (1827) op. cit., p. 25
   King's Treatise (1878) Vol. I p. 175
   C. Hunt, History of Gas Lighting (1907) op. cit., pp. 41-4
   A.W. Mathews, A Biography of William Mathews (1899) p. 49
   J.G.L. 14/7/1874 pp. 42-4; Gas World 1/12/1900 p. 815

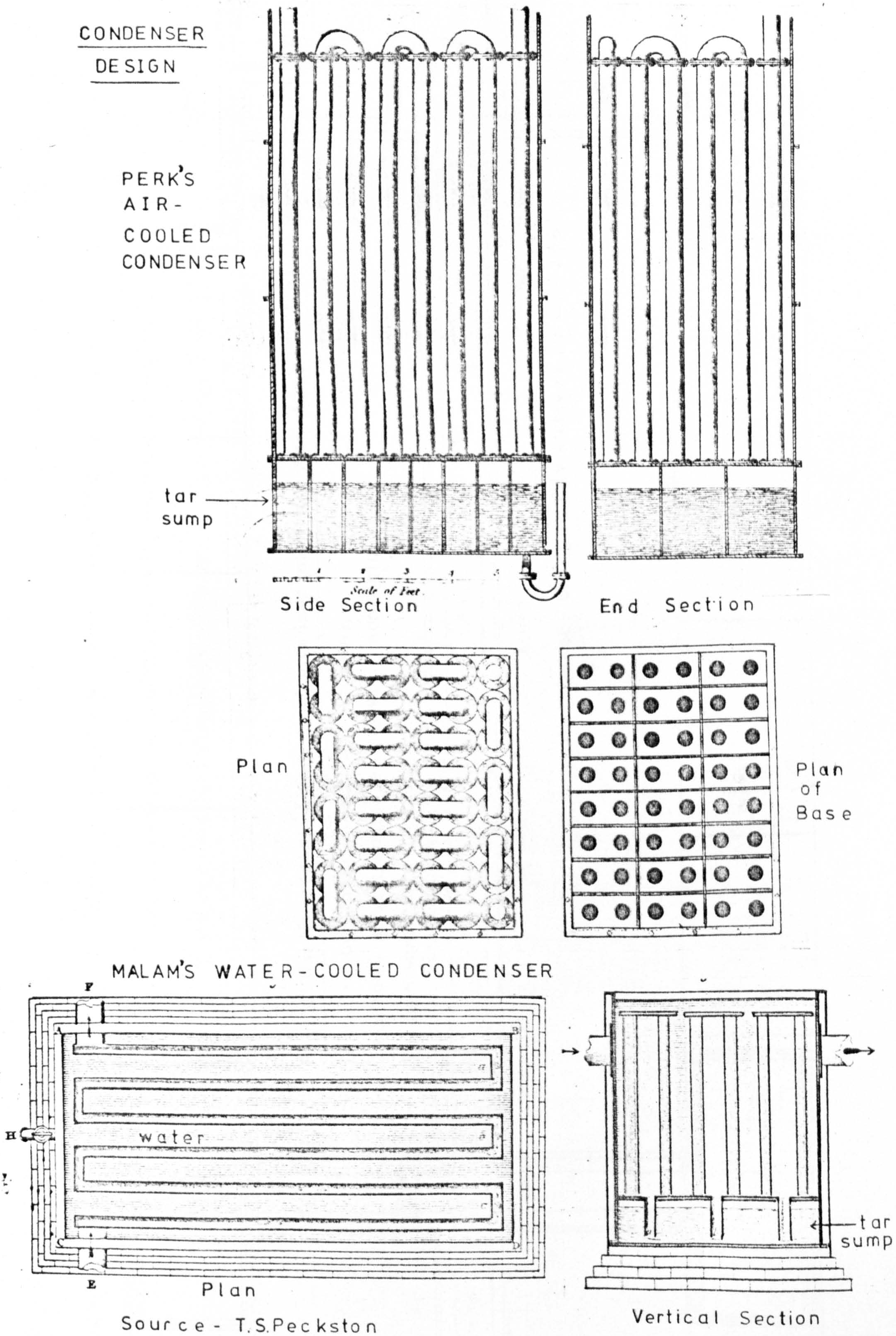
2. Diagrams extant in Glasgow City Archives

3. J. Neilson, "Manufacture of Gas", Glasgow Mechanics Magazine 1825 Vol. III.

4. He believed this tar would decompose and give extra permanent gas.
   Ascension pipes had to be carefully placed, because excessive heat caused blockage by pitch, which could only be removed with great difficulty, using a chisel on a chain, or red-hot implements. The front wall of ovens was made fourteen inches thick, or covered with iron, to protect the pipes from heat.
   J.G.L. 15/9/1874 p. 363

Fig. 3.3

CONDENSER DESIGN



Source - T.S.Peckston

Gasworks Theory and Practise (1819)

Fig. 3.4
Plan of the Horizontal "Long Air Condenser" at Tradeston 1842

Installed by Glasgow Gaslight Company.
Two rows of vertical boxes flanking horizontal pipe.
Thirteen boxes in each row.

Source - Glasgow City Archives (D. G.E. 286) ening to block the gas mains, that it discouraged many people from investing in early gas companies.[1] Worm-condensers were rapidly blocked with tar, pressing gas back towards the retort at excessive pressure which could cause leakage and explosions. The problem was solved in 1817 when John Perks[2] used a series of vertical inverted U tubes, with a separate tar-sump beneath each tube. This was widely adopted in Scotland.[3]

'Purifiers' in the earliest private gasworks used a water-wash to remove some ammonia, carbonic acid and hydrogen sulphide impurities. Murdoch, Winsor or Clegg added lime to the water to enhance the process, but Dr W. Henry[4] was the first to publish the efficiency

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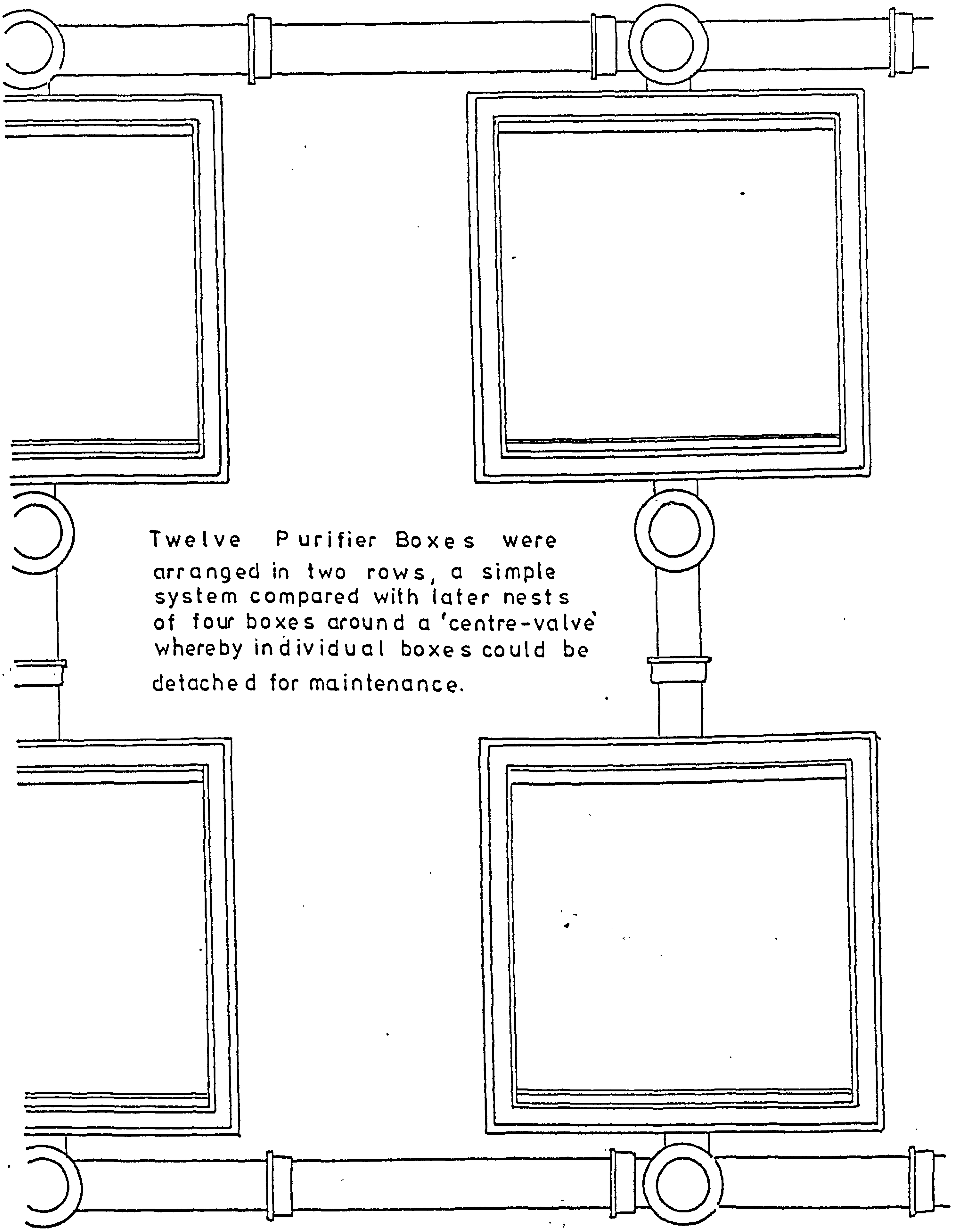
1. G. Atkins, "Origin and Progress of Gas Lighting", The Repertory of Patent Inventions 1827 Vol III pp. 160-2
In 1804 Winsor used a serpentine 'condenser' pipe inside the gasholder tank and no separate purifiers. W. Richards Practical Treatise (1877) op. cit., p. 108

2. 1817 J. Perks Pat. 4154
T.S. Peckston Theory and Practice (1819) op cit., pp. 185-187
Engineers tried many novel designs. A. Anderson at Perth in 1824 used 4 cylinders, each 8 feet high and filled with heather and broom to intercept tar and cool the gas. Disused gasholder-tanks, roofed over, were also used as at Innerleithen in 1883.
J. Ker, Considerations Relative to Nuisance in Coal Gas Works (1828) op. cit., p. 6
R. Miller "Utilizing an old Gasholder Tank for Condensation" N.B.A.G.M. 1885

3. Gas had to be reduced to 60°F before leaving the condenser, or the purifiers became less efficient. Scottish cannel coal produced little napthalene, the snow-like crystals which blocked pipes and reduced candlepower. Napthalene only became significant when cheaper coals were used in the 1900s and, as in England from the 1870s, condensers were extended as pipes along the retort-house walls to produce slower cooling and fewer crystals. Wall-pipe condensers were sometimes also used earlier as cheap extensions, as at Annan in 1867 where 3 million cu ft per year was being cooled with equipment designed for 1.2 million cu ft.
R.H. Patterson, Gas and Lighting (1877) op. cit., p. 162; N.B.A.G.M. 1912, p. 29; S.R.O. Annan Minute Book op. cit., 19/7/1867; King's Treatise (1878) Vol. I, op. cit., p. 305 (diag.)

4. Henry's idea was published in Nicolson's Journal (1805); J.G.L. 3/11/1874 p. 599. Vide infra, Chapter I p. 26
A detailed history of early purifiers is given by D. Chandler

Fig. 3. 5
PARTICK GASWORKS, GLASGOW — PURIFIERS 1856



Source - Glasgow City Archives (D.GE. 287) of a 'cream' made of quick-lime and water, in 1805. A special container for this, with 'agitators' to stir it manually,[1] was introduced by John Malam and improved by Clegg in 1817. Dry lime purifiers were first used in 1817 by Reuben Phillips of Exeter, who placed slatted-shelves in the purifier box[2] and covered each with six inches of damp burned lime through which the gas ascended. Purifiers were improved by Malam, who arranged several 'boxes' around a complex hydraulic valve to enable the gas to pass through several purifiers in series, or individual boxes to be detached for cleaning.

Municipal and consumer objections provided a considerable stimulus for better purification methods. At Edinburgh especially, the stench from lime containing hydrogen sulphide which escaped into town[3] sewers in 1820 caused great opposition. Lime was also used, however, at Glasgow and Perth, the cities reputed to have the purest Scottish gas in the 1820s. It was used in Scotland throughout the century in the less noxious 'dry' form. Glasgow in 1825 still used

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and A.D. Lacy The Rise of the Gas Industry in Britain (1949); King's Treatise (1878) Vol. I op. cit., p. 63.

1. Vide infra Diagram Fig. 3.2

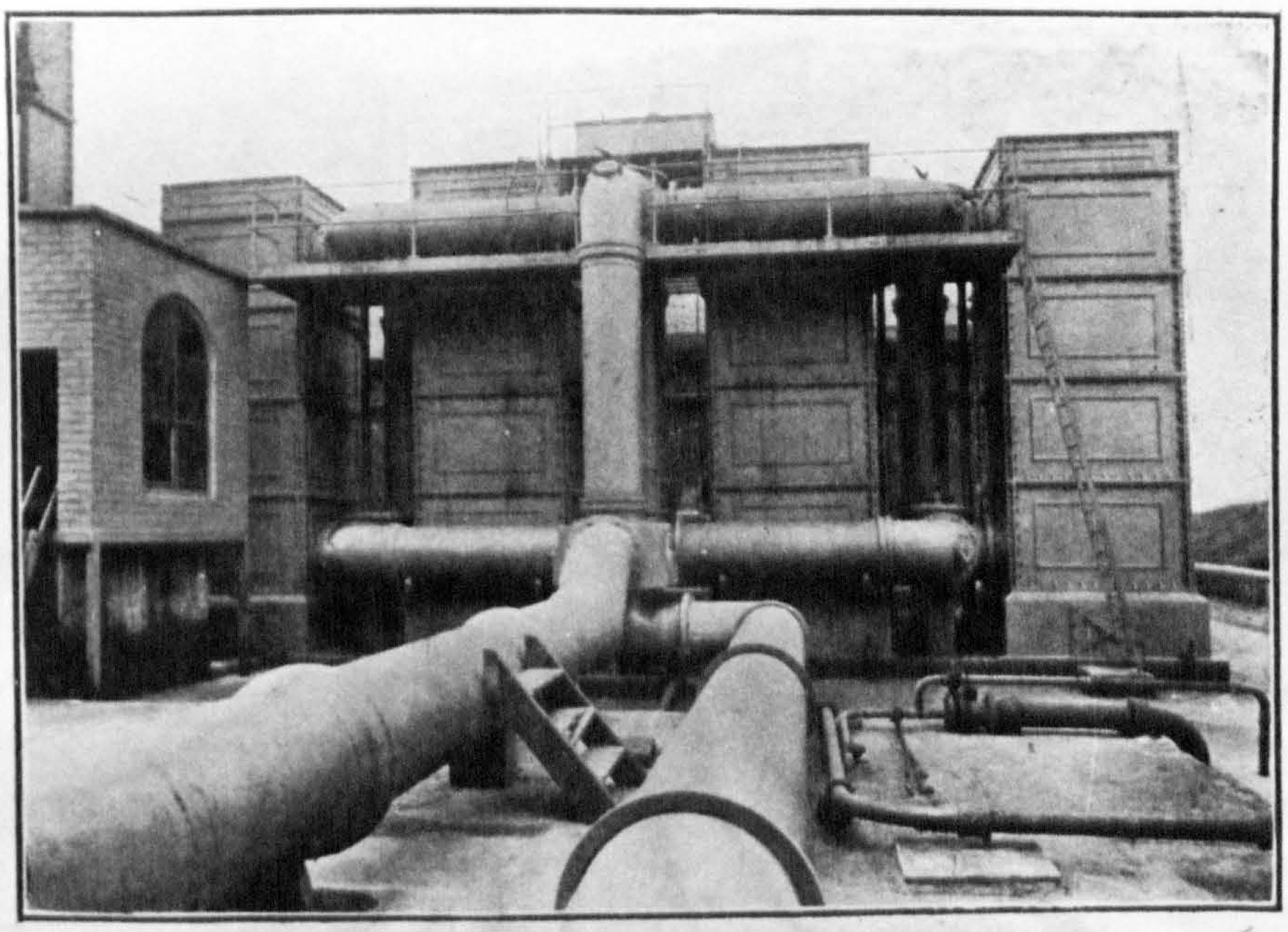
2. Purifier boxes were normally outdoors, to ventilate any explosive leaks, and remain cool. Annan gasworks in 1847 had warm purifiers inside the retort-house which were inefficient and had to be removed. Annan Minute Book op. cit., 19/7/1847, 27/8/1847.
King's Treatise (1878) Vol. I op. cit., p. 417 Diag. wooden grids.
Hydraulic rams to lift purifier box lids were invented by Mr Reid of Edinburgh Gas Works, and later manufactured by Messrs R. Dempster and Sons.
W. Richards, Practical Treatise (1877) op. cit., p. 144.

3. Early problems of purification vide "Gas and Gas Lighting" J.G.L. 10/3/1851 pp. 51-4. Neilson at Glasgow used "beds of charcoal" (possibly 'scrubbers' vide infra, p.341) and ferrous sulphate solution in his early experiments to improve gas.
S. Smiles, Industrial Biography - Iron Workers and Tool Makers (1868; reprinted 1967 Newton Abbot) p. 152; New Statistical Account - Lanarkshire pp. 162-5

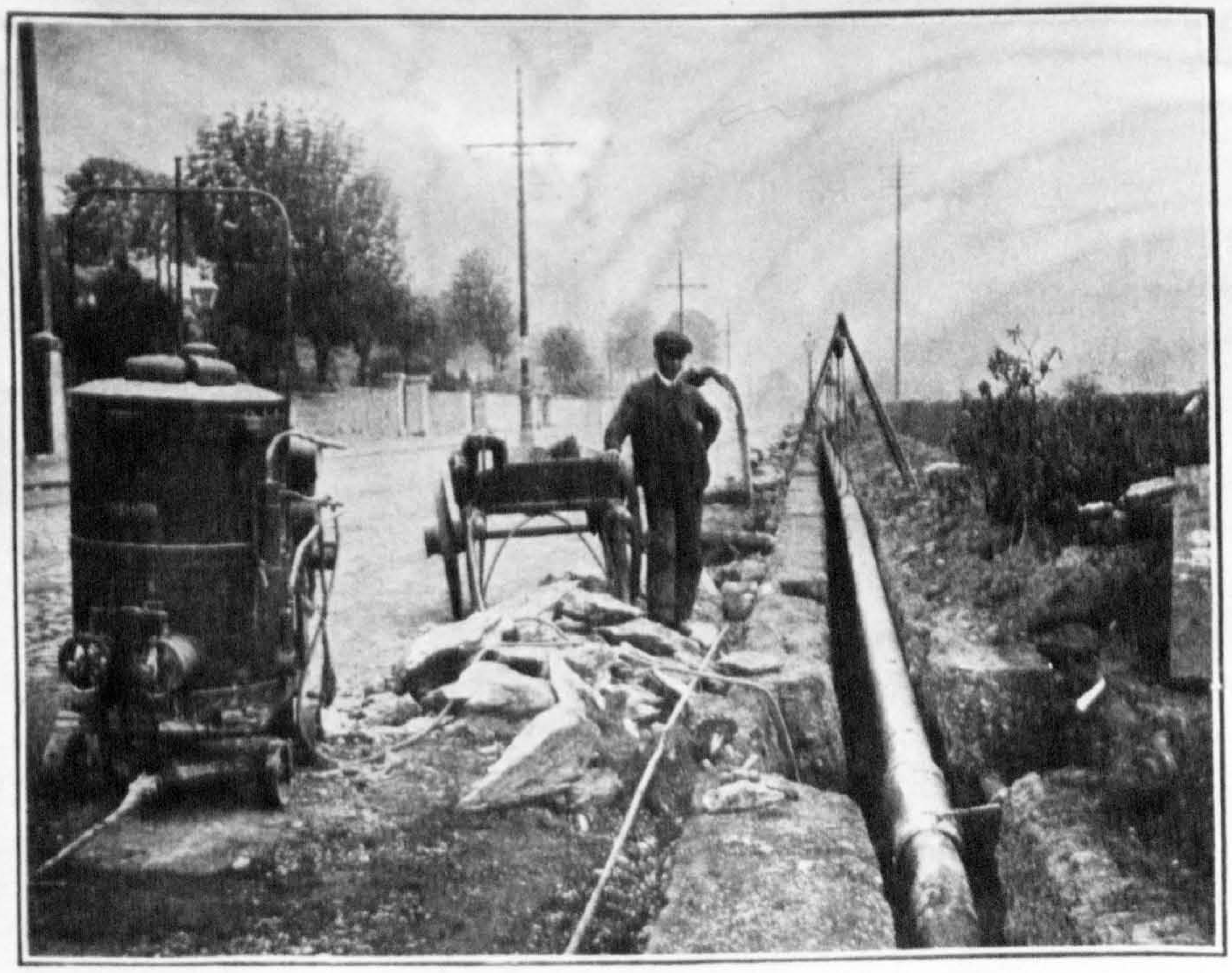
Fig 3.6 Condensers at Stranraer (1974) and Kirkconnel (1973)

Left - double row of air cooled condensers similar to early designs. Note overhead tar-storage above pump house on left, at Stranraer.

Right - annular condenser on right. Small "tower" washer/scrubber in foreground, at Kirkconnel.



Reversible Water-Cooled Condensers.



Steel Main, showing Hinged Cover to prevent melted bitumen falling on workmen when welding underneath.

Fig. 3. 7 Water Cooled Condensers and Steel Mains Pipes at Greenock Gasworks (1913)

Source - N.B.A.G.M. 1913

Vide infra pp. 382 (steel pipes), 584 (condensers)

'cream' lime[1] which Neilson believed thirty per cent stronger than dry lime, but when 'spent' it was difficult to dispose of and he advised drying it in iron pans[2] around the retort furnaces before carting it away. The Perth purifiers were kept secret by their inventor, Adam Anderson,[3] but he partly followed Phillips's method, with finely sifted slaked lime on perforated plates. Some waste lime was mixed with clay to make a cement for 'luting' retort lids gas-tight. Fresh lime[4] was calcined at the gasworks before use.

Diagrams of two early Scottish gasworks are extant, and show a large works, possibly Glasgow[5] in 1824, and Maybole[6] gasworks in 1833.

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1. The condenser and purifier at Glasgow were then large cisterns in the tar vault or cellar. Glasgow Mechanics Magazine (1825) op. cit.

2. London gasworks, like Peter Street, used similar pans still in 1842. Chandler and Lacy, Rise of the Gas Industry (1949) op. cit. p. 141.

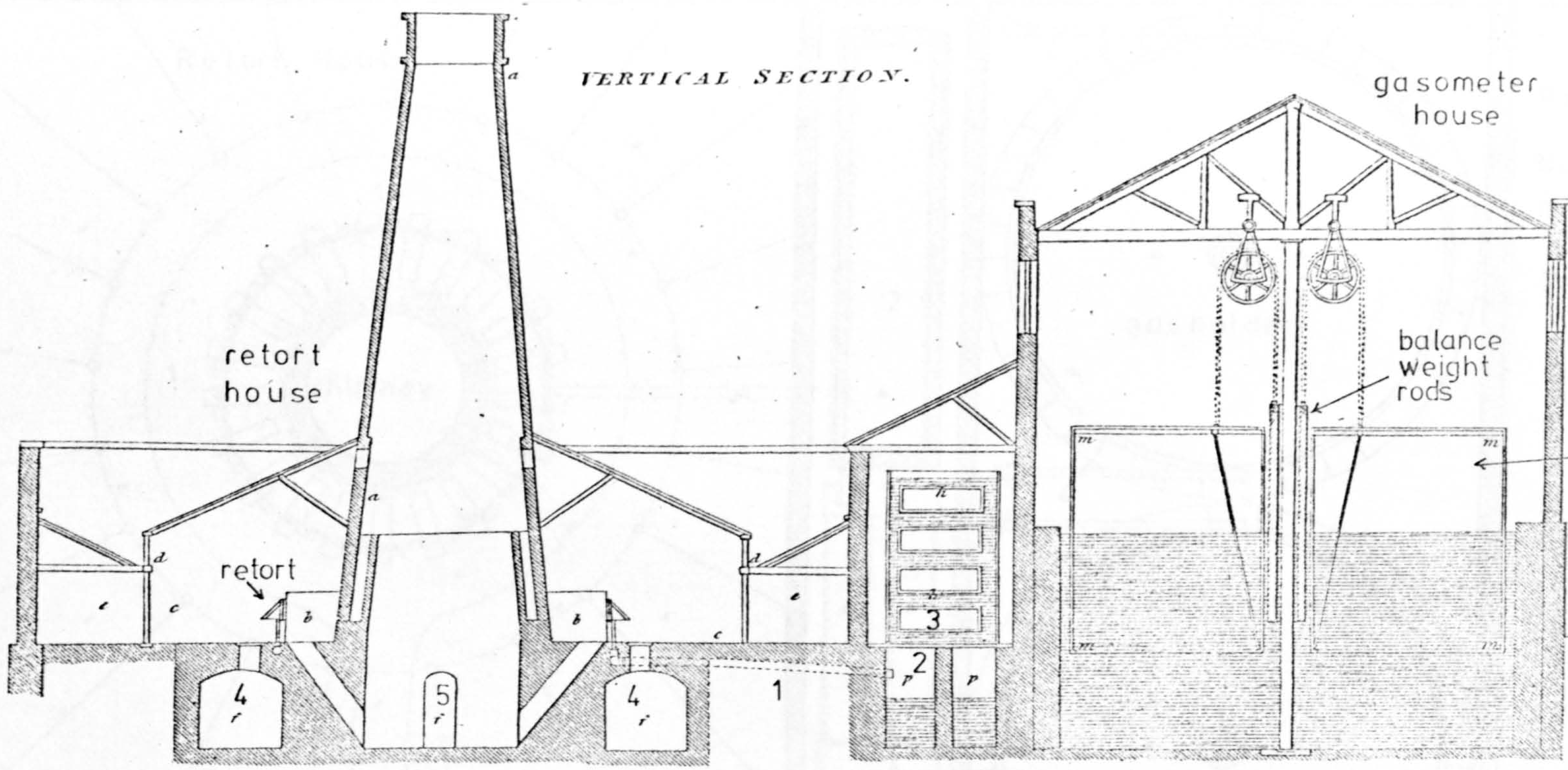
3. Anderson's evidence on the 1825 Westminster Oil Gas Bill, quoted by W. Mathews Compendium of Gas Lighting (1832) op. cit., p. 29.
Wet lime or 'Blue Billy' remained in use in London, polluting the Thames, in 1854, but many Scottish works adopted dry-lime purifiers by the 1840s. These did not require manual or mechanical agitation of the lime and were therefore cheaper. Dunfermline in 1829 installed one wet and two dry-lime purifiers, and Aberdeen used both types in 1839. Bo'ness still had wet lime in 1849, but used R. Laming's iron-oxide in the 1850s.
J.G.L. 10/11/1874 p. 632
W.J. Liberty, "The Century of Gas Lighting" The Illuminating Engineer 1913 op. cit., p. 187
Dunfermline Minute Book op. cit., 10/6/1829, 24/12/1829
Bo'ness minute book op. cit., 5/7/1849, 5/6/1856
(Aberdeen) New Statistical Account 1839

4. F. Accum, Description of the Process of Manufacturing Coal Gas Now Employed at the Gas Works in London (1820) 2nd edn. pp.161-2
T. Newbigging "Lime Burning" Gas World 13/12/1890
In 1887, Dawsholm gasworks in Glasgow had three lime kilns operating full time in winter, importing Irish lime along the Bowling Canal. Gas World 25/6/1887.

5. Encyclopaedia Britannica Supplement (1824) op. cit. Diagram of a gasworks on a scale of twenty feet to one inch, which may represent Glasgow.

6. Glasgow City Archives - Plans of Maybole Gasworks.
Vide supra p. 134; also p. 632

Fig. 3.8 GASWORKS DESIGN 1824 by H. Creighton



Note - 1 primary condensor from underground main-pipe collecting from retorts; no hydraulic-main. 2 tar sump ; 3 water-cooled condensor ; 4 tunnel for coke removal ; 5 tunnel for ash removal. The original Glasgow gasworks in 1817, also designed by H. Creighton, probably had a similar appearance.

Source - Encyclopaedia Britannica Supplement 1824 op cit.

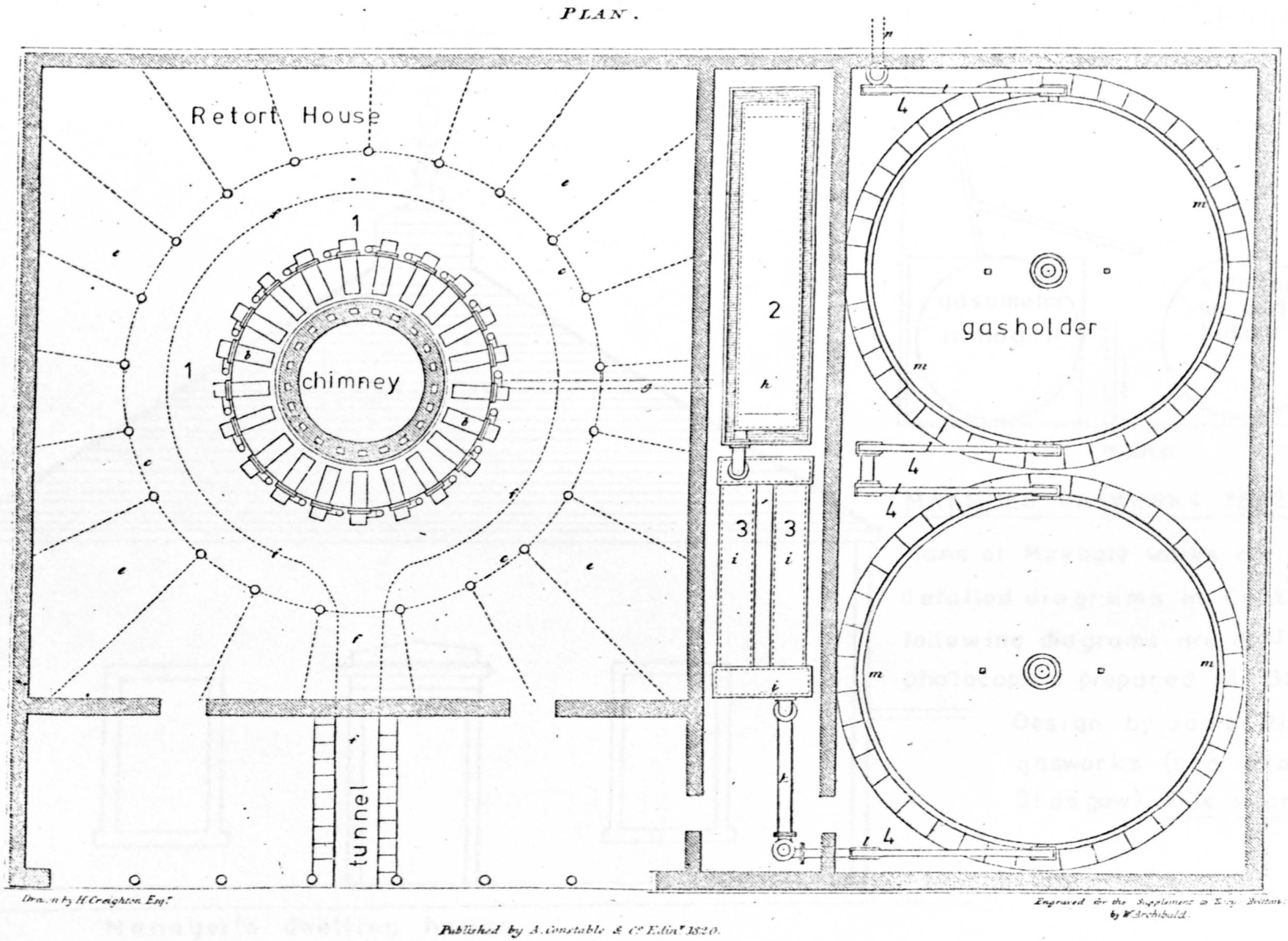
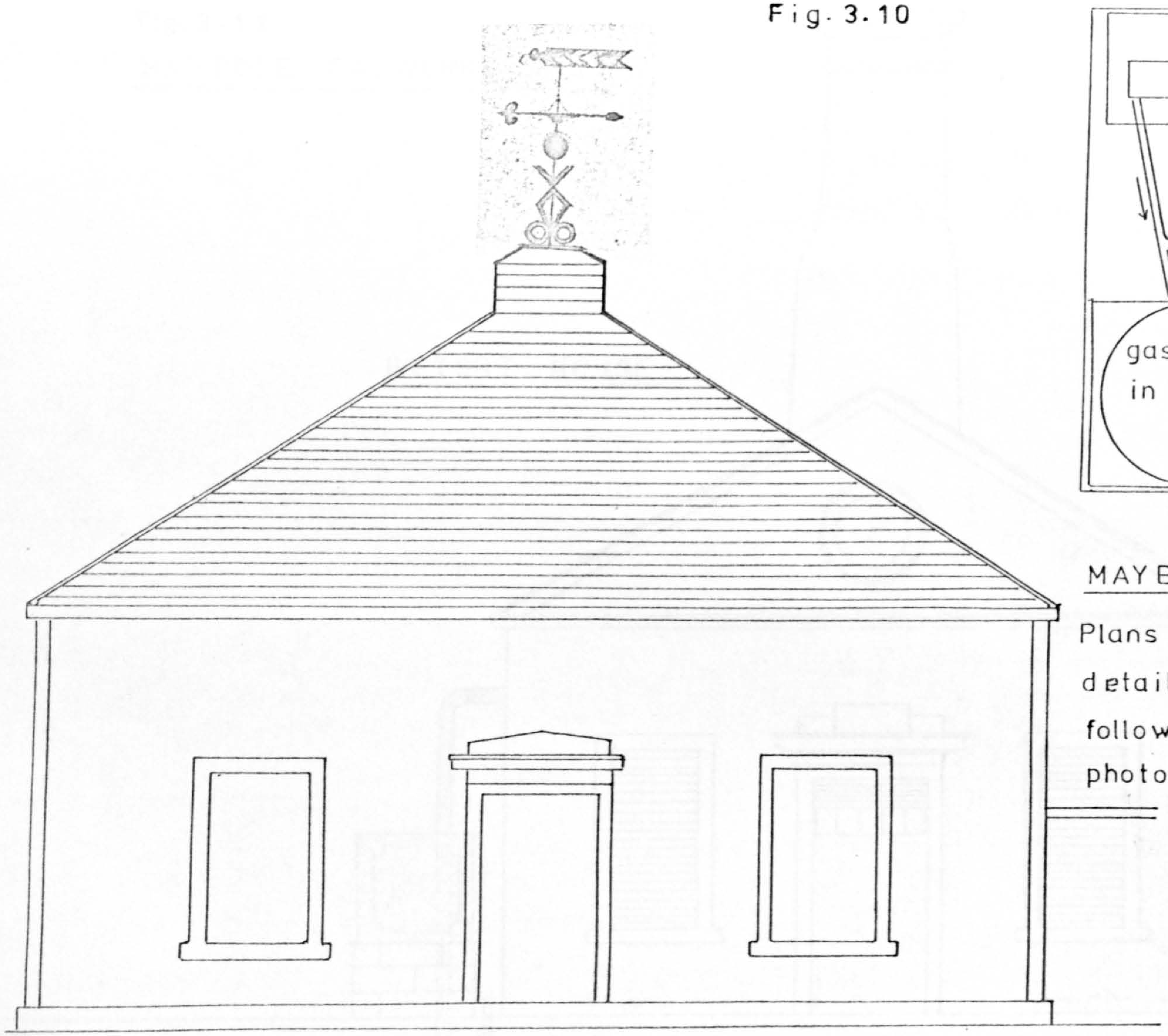


Fig. 3.9
GASWORKS DESIGN
1824
by H. Creighton

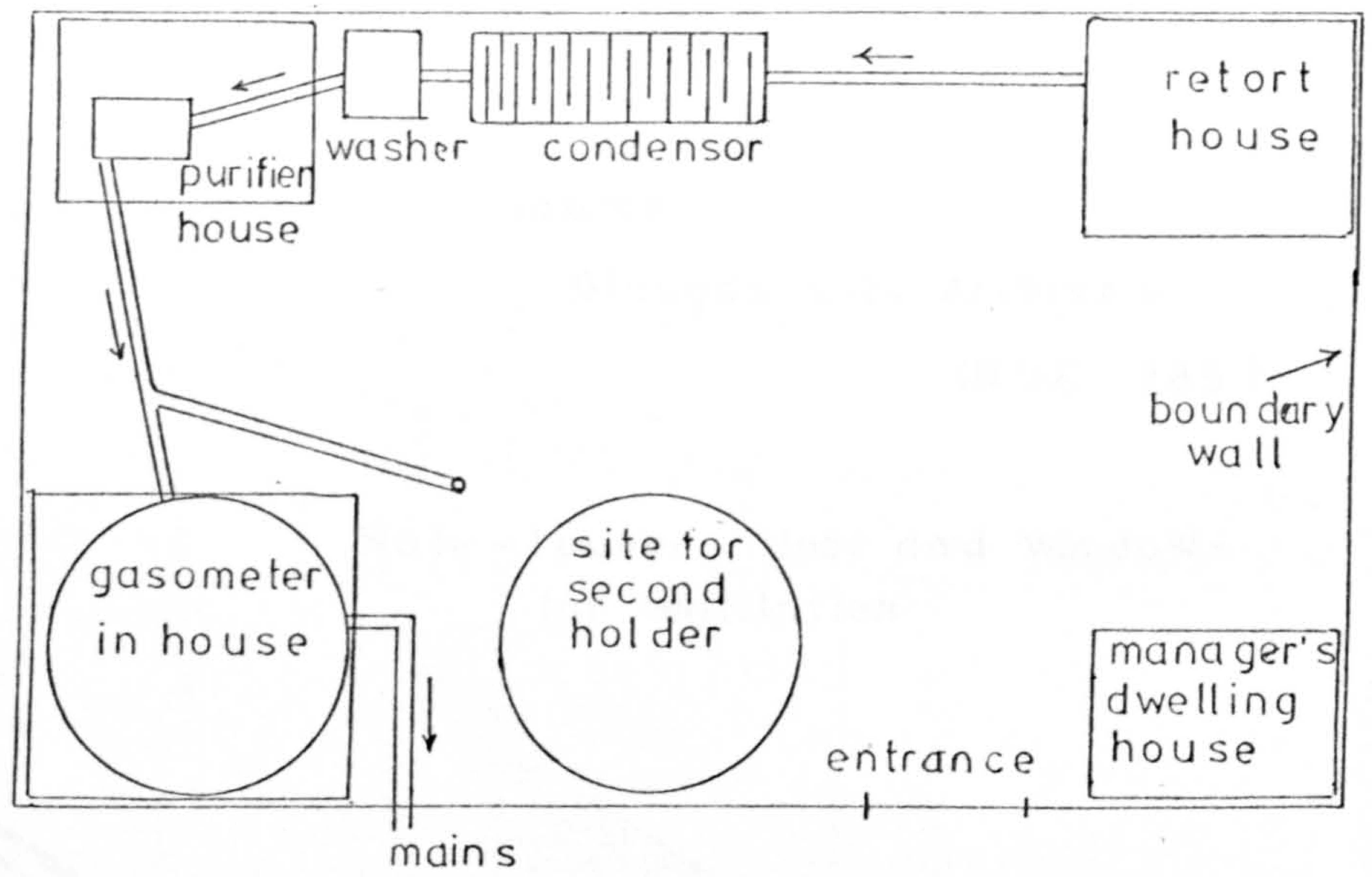
Note-
1- retorts in circular bench around chimney
2- water-cooled condensor
3- purifier
4- articulated gas-pipes as inlet/outlet to gasholder

Source - Encyclopaedia Britannica Supplement 1824 op cit (plate LXXXIV)

Fig. 3.10



Manager's dwelling house



MAYBOLE GASWORKS 1833 Schematic Plan

Plans of Maybole works are the earliest extant detailed diagrams in Central Scotland. The following diagrams are derived from photocopies prepared at Glasgow City Archives

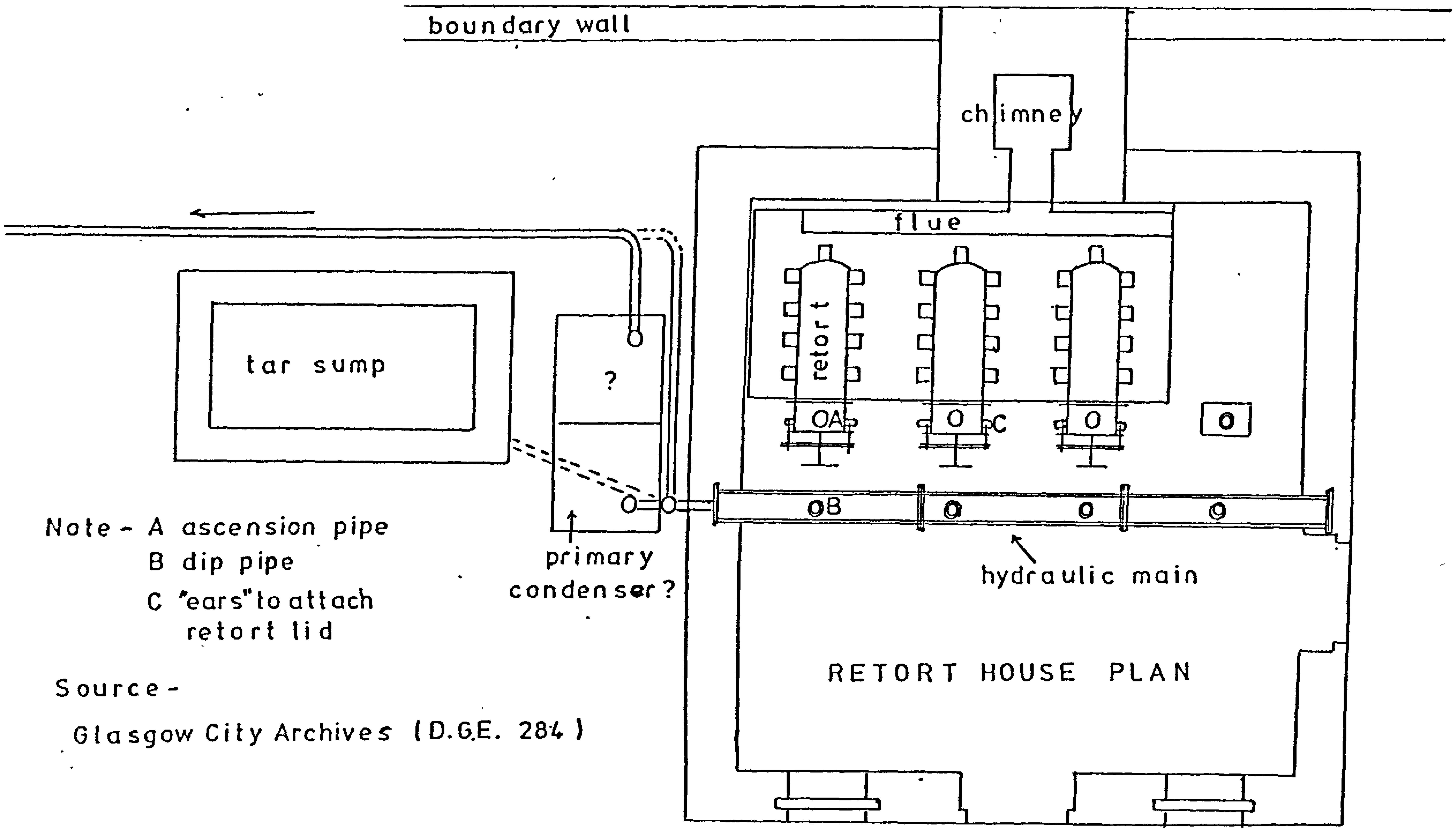
Design by James Ritchie, manager of Ayr gasworks (and later Sheffield and Glasgow) Vide supra p. 149

Fig.3.11
MAYBOLE GASWORKS 1833

Source -
Glasgow City Archives
(D.G.E. 285)

Note - louver door and windows for ventilation

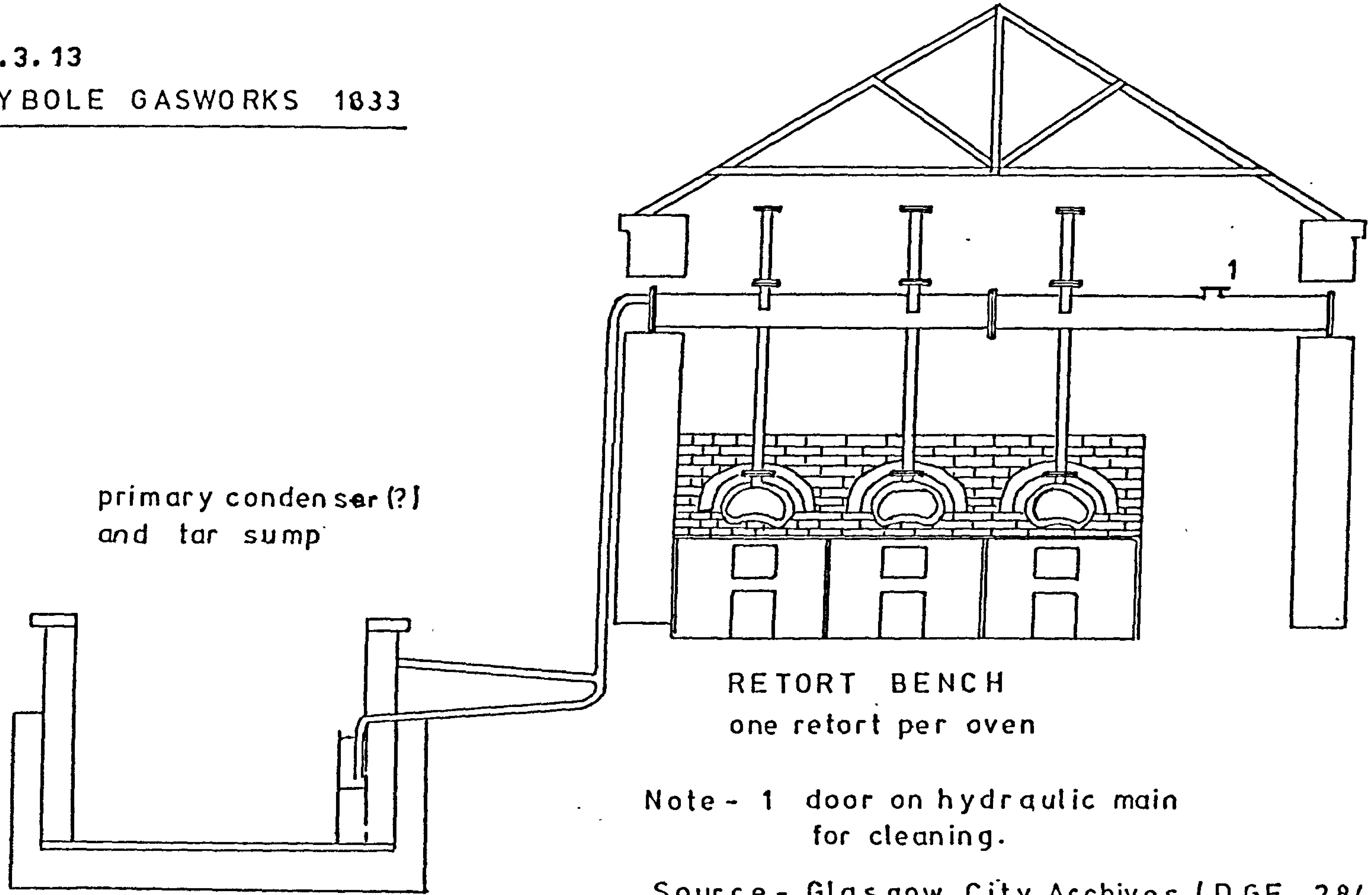
Fig. 3.12 MAYBOLE GASWORKS 1833



Note - A ascension pipe
B dip pipe
C "ears" to attach retort lid

Source -
Glasgow City Archives (D.G.E. 284)

Fig.3.13
MAYBOLE GASWORKS 1833



Source - Glasgow City Archives (D.G.E. 284)

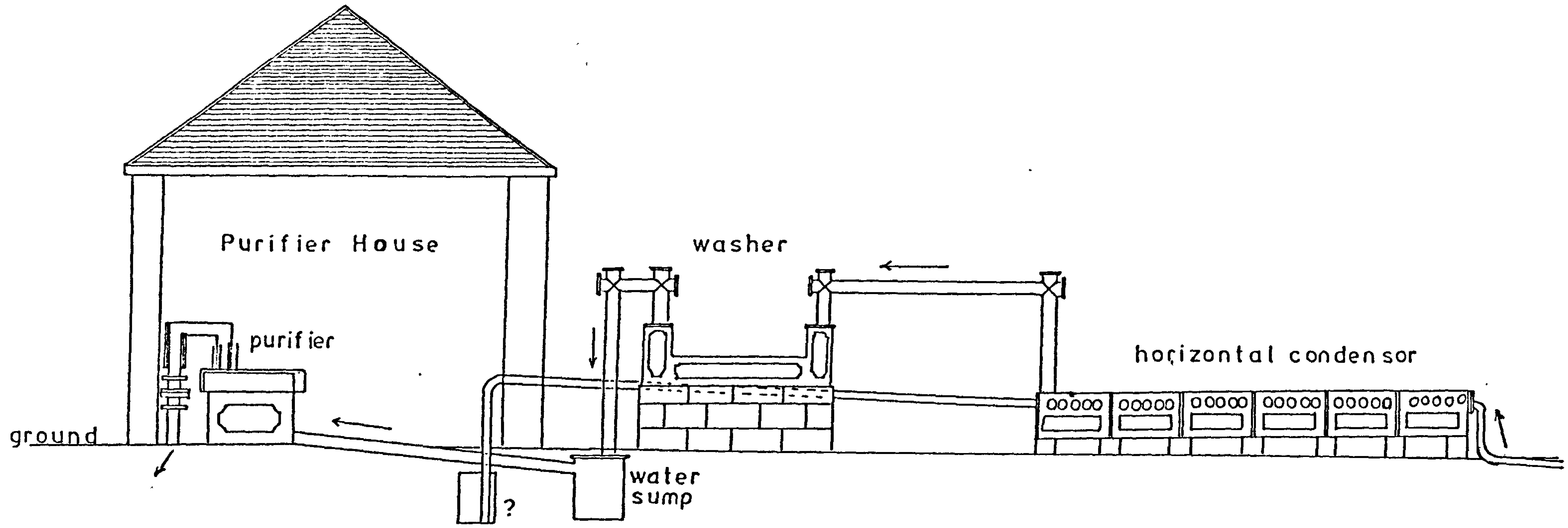
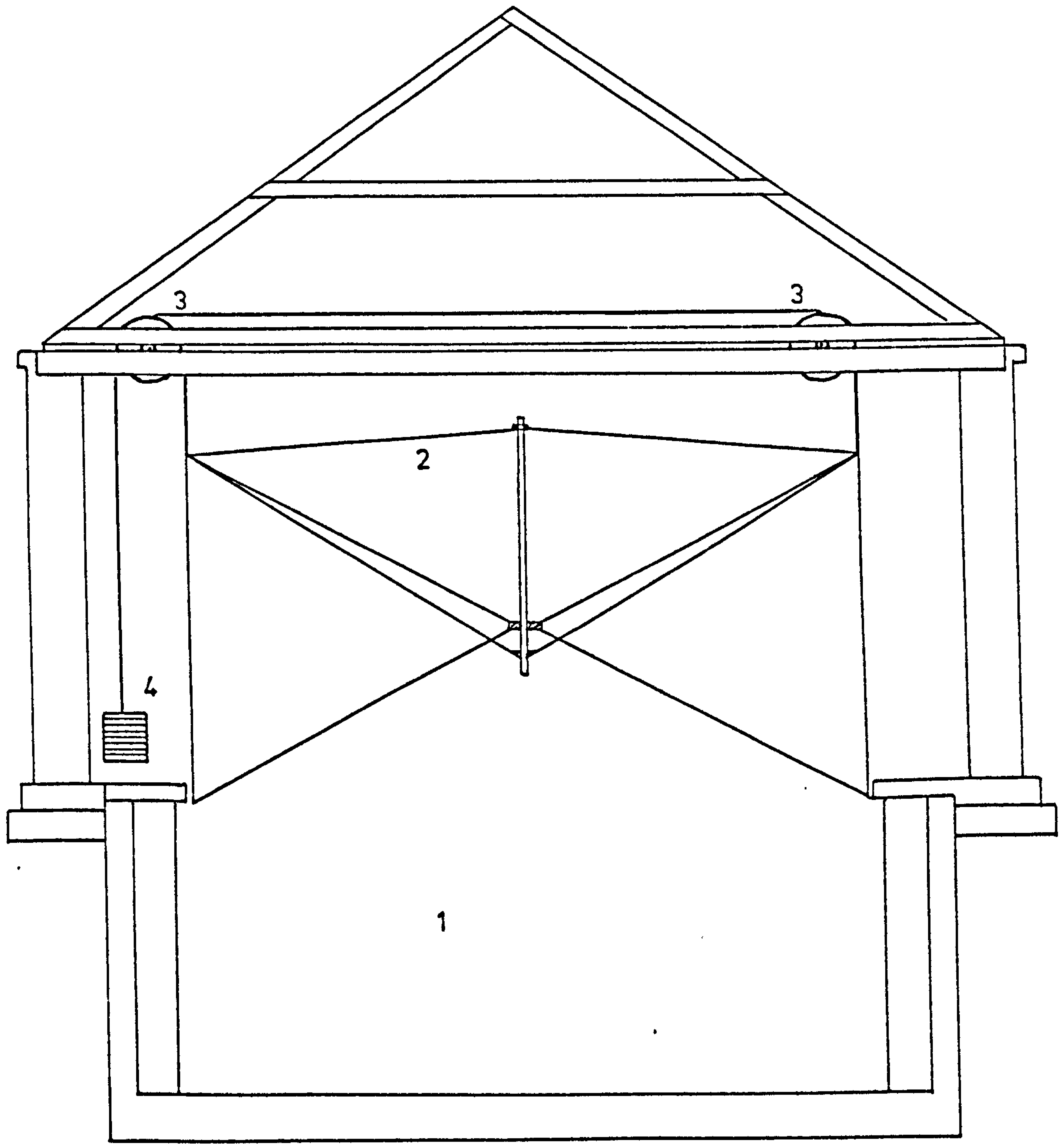


Fig.3.14 MAYBOLE GASWORKS 1833 Source - Glasgow City Archives (D.G.E. 285)

Fig. 3.15

MAYBOLE GASWORKS 1833 Gasometer House



Note - 1 Gasholder tank
2 Gasholder with heavy internal struts
3 Chain and pulleys
4 Counterpoise weights

Source - Glasgow City Archives (D.G.E. 285)

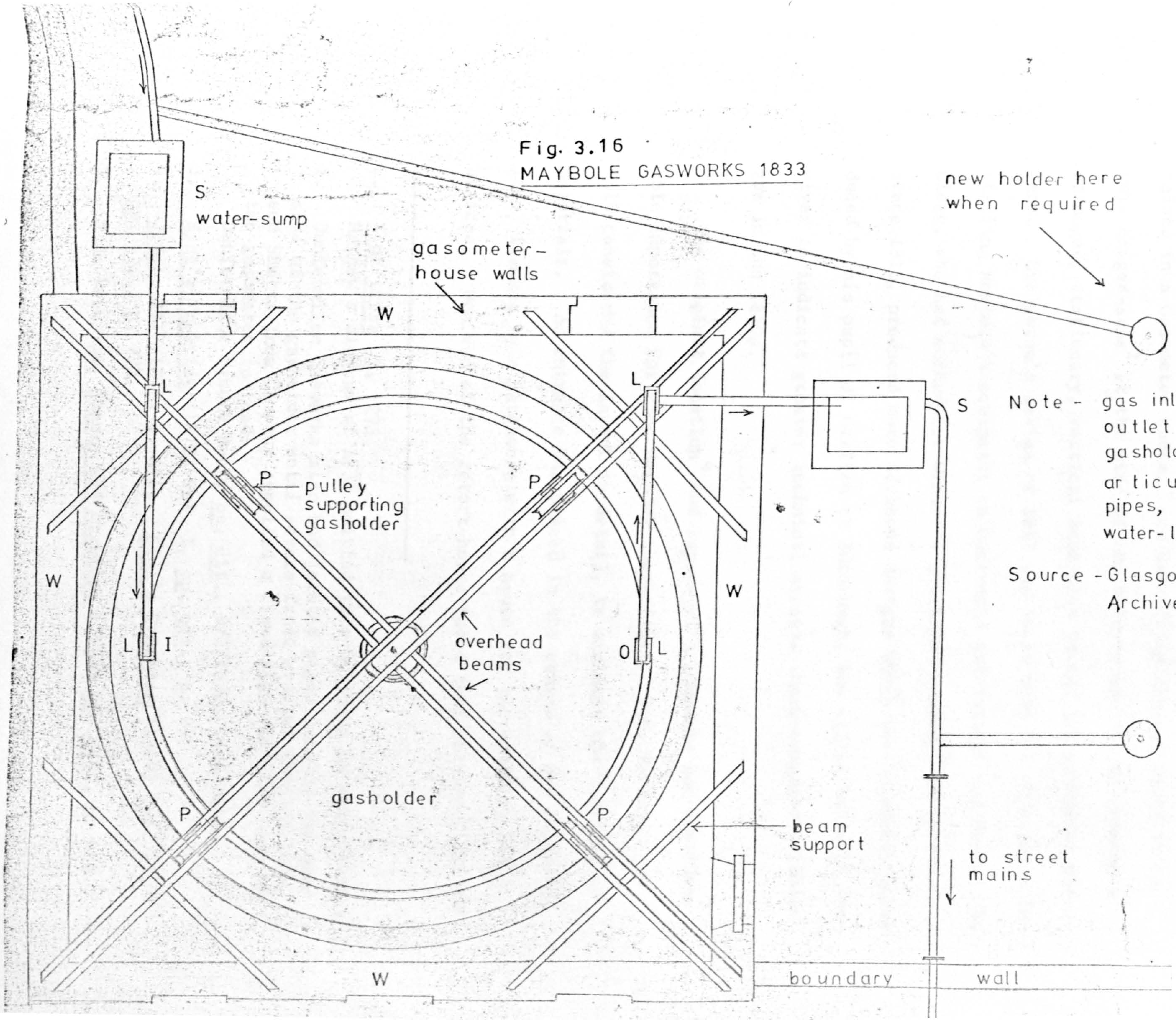


Fig. 3.16
MAYBOLE GASWORKS 1833

Note - gas inlet (I) and outlet (O) of gasholder through articulated lateral pipes, with water-lutes (L)

Source - Glasgow City Archives (D.G.E. 284)

Several similarities in design suggest that the Glasgow works by Henry Creighton had a considerable influence upon other, later Scottish gasworks. In both extant examples the gas-holder was contained in a Gasometer House,[1] and was filled through pipes which were hinged-arms[2] at the side of the holder, instead of forming a stronger, stationary, vertical base-pipe inside the gasholder water-tank. Creighton's design of 1817 was based upon his experience installing Murdoch's equipment on contracts for Boulton and Watt. S. Clegg, who had worked for Winsor's Chartered Company[3] in London since 1813, produced more advanced designs which were probably introduced by his pupil J. Grafton at Edinburgh, but little evidence survives to indicate greater technical success there compared to Glasgow in the 1820s.

The original location[4] and layout of a gasworks had considerable importance for many decades thereafter. T.S. Peckston[5] in 1819 considered the layout in detail, to minimise the handling of materials. An entrance was placed in the centre of one boundary line, flanked by a gatehouse with a house for the manager, and offices. One end of the retort-house faced that entrance, and the

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1. <u>Vide infra</u> p. 271
Mathew's diagram of 1832 omitted this building as superfluous.

2. Dunfermline gasworks also had jointed pipes joining the outside of the gasholder until severe frost cracked them in 1830, and Shotts Iron Company supplied a fixed pipe into the base of the gasometer instead.
Dunfermline Minute Book, <u>op. cit.</u>, 9/2/1830, 19/3/1830.

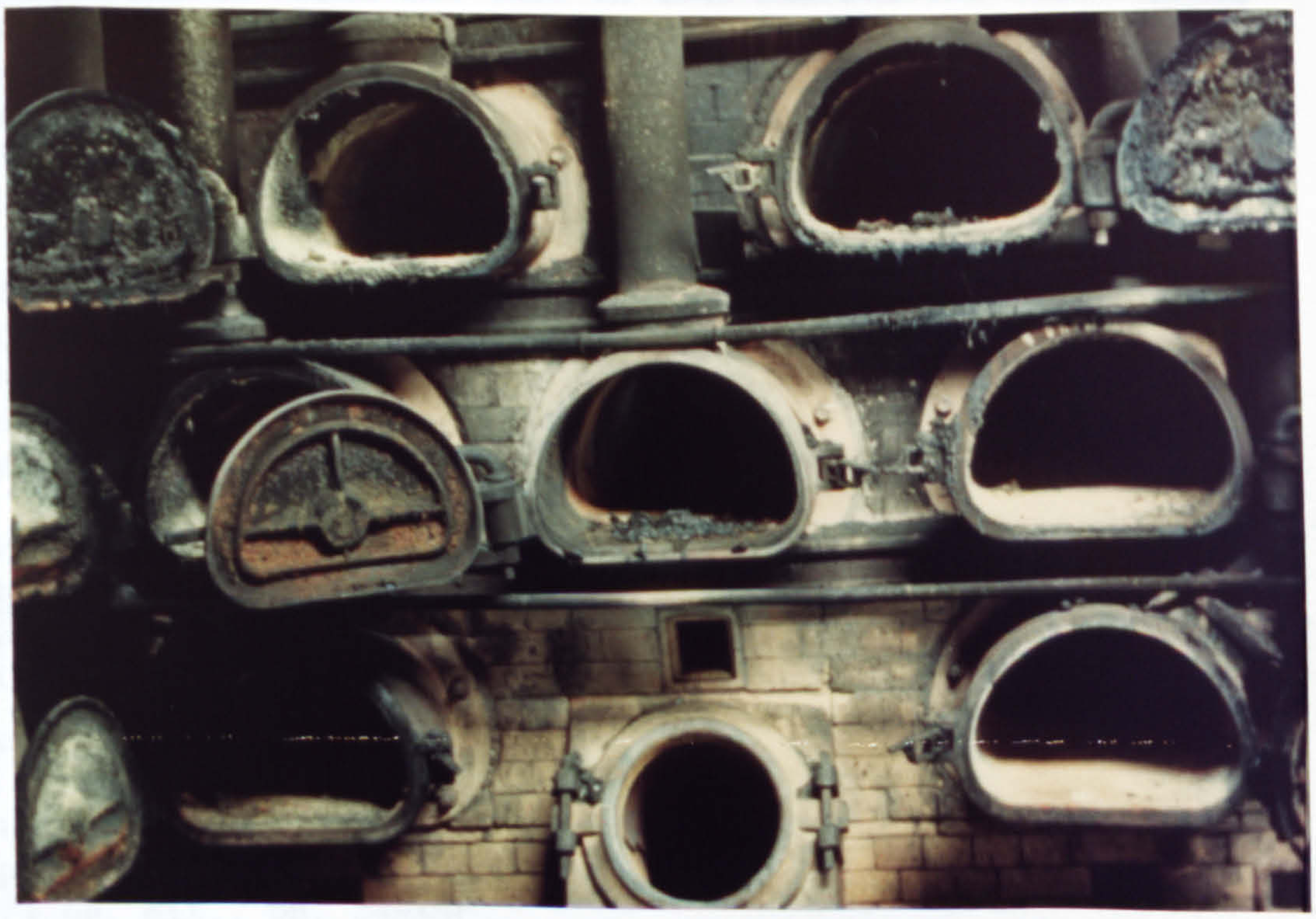
3. <u>King's Treatise</u> (1878) Vol. I, <u>op. cit.</u>, p. 29

4. <u>J.G.L.</u> 21/3/1876, p. 416. <u>King's Treatise</u> (1879) Vol. II, <u>op. cit.</u>, p. 272.

5. T.S. Peckston, <u>Theory and Practice</u> (1819) <u>op. cit.</u>, p. 416

Fig. 3.17 Horizontal Retorts and Retort House at Muirkirk (1973)

Purifier house in foreground, and retort-house with two chimneys (and store building near works entrance) on right hand side of courtyard opposite to gasholder. Note air-cooled condensers in right foreground, and ventilation of retort-house roof.



Seven D-shaped horizontal retorts in one oven; part of the retort-bench. Note circular coke-hole for internal 'producer' to heat the oven.

chimney was at the far end, while a track for horse-drawn carts circled the retort-house. On one side, parallel to that building was a second, with heavy stores and castings on the lower floor and mechanics' workshops above; on the opposite side a third building held coke and coal stores[1] on the ground floor. At the rear of the retort-house the condenser, tar vessel, purifiers, station meter and gasholders were grouped together.

Because gas expands during vertical ascent, authors like Accum[2] by 1819 advised engineers to choose a low-level site for gasworks, to avoid the high pressure and consequent leakage of forcing gas downhill to the consumers. However, engineers in Scotland were rarely trained chemists, and some high-level gasworks were built as at Kilmarnock and Arbroath.[3] Low level sites,frequently on river

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1. Dry coal was so important that in 1841 Dunfermline used a kiln, devised by Mr Webster the manager at Montrose, to dry coal before carbonizing it. Newbigging in 1883 estimated that poor storage and wet coal, though liable to spontaneous combustion, lost 20 to 50 per cent of its potential gas yield and heating qualities. H. Aitken of Falkirk and G.R. Hislop of Paisley reminded Scottish managers of this in 1885, when J. Hislop of Maryhill estimated that dry coal gave 12 per cent more gas, and the Forfar manager estimated 1,000 cu ft extra per ton. Adequate storage was essential to maintain gas supplies, and some gasworks like Rothesay in 1890 had to cease production when coal supplies were delayed.
   P. Chalmers, Historical and Statistical Account of Dunfermline (1844, Edinburgh) p. 393; T. Newbigging, The Gas Manager's Handbook (1883) op. cit., p. 47; Gas World 21/3/1885; 16/12/1890; J.G.L. 27/7/1886; R.H. Patterson, Gas and Lighting (1877) op. cit., p. 153.

2. Accum advised altitude measurements with an Eaglefield Mountain Barometer; gas mains at higher altitudes had to be larger, and therefore more expensive to provide a pressure equal to narrow pipes at lower altitudes. F. Accum, Gasworks in London (1817) op. cit., pp. 249-50.

3. Kilmarnock works (1822) had to use 2.7 inches gas-pressure, instead of the normal 1 inch, which caused over 17 per cent leakage. Even careful management could not reduce it below 16.5 per cent in 1873 and 10 per cent in 1884. Glasgow gasworks itself

Fig 3.18 EDINBURGH GASWORKS - Plan and Location

Source: Edinburgh Ref. Lib. Ordnance Survey 1852

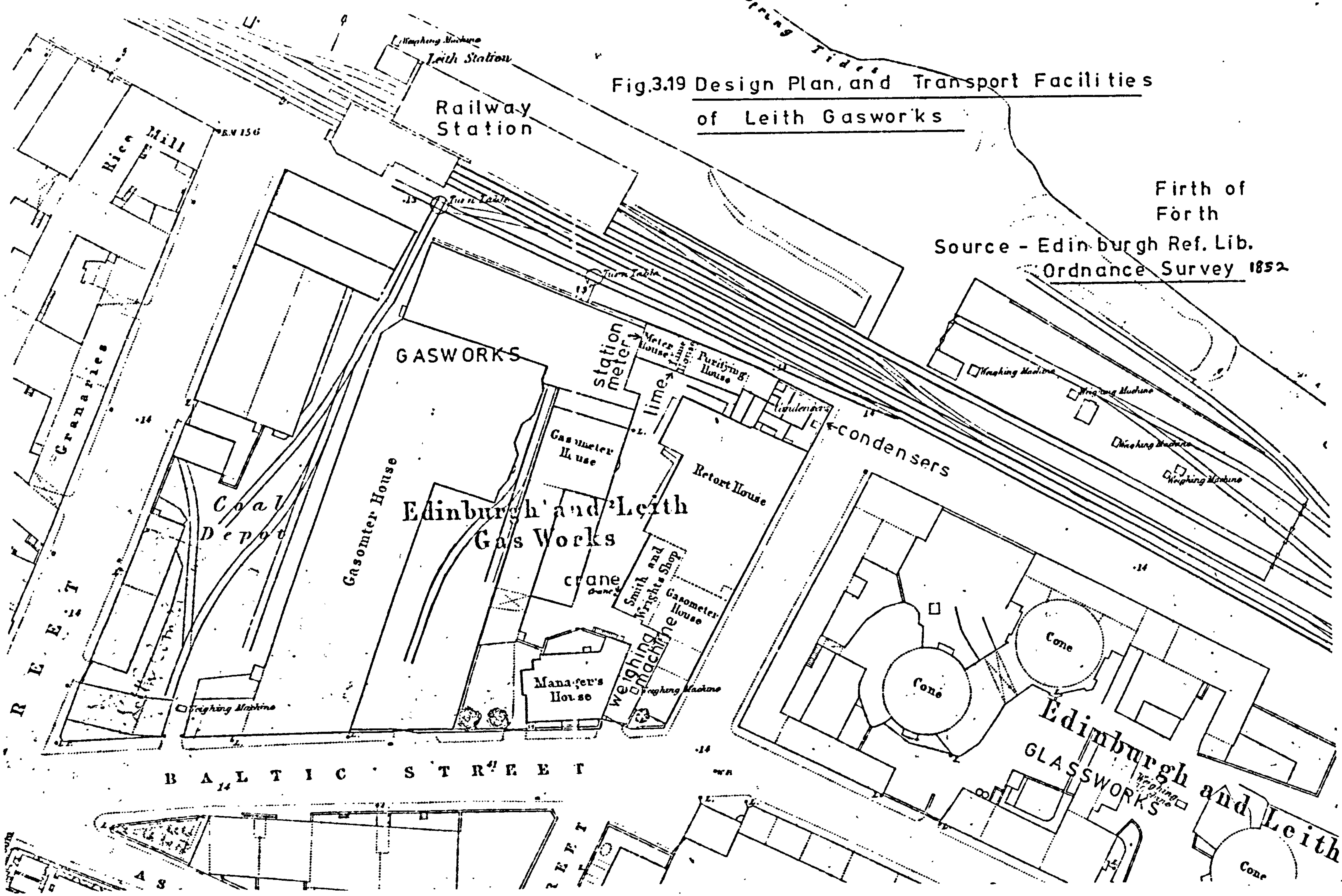

Fig.3.19 Design Plan, and Transport Facilities of Leith Gasworks

Source - Edinburgh Ref. Lib. Ordnance Survey 1852 floodplains,[1] were nevertheless often chosen for other advantages like the supply of water.[2] Scotland had few canals, and the railway network[3] was also very slow to develop, so these were not important location factors for most gasworks which were built before 1846. The factors influencing J. Neilson[4] when he advised Dundee Gas company in 1825 to build on the low Peep-O-Day site outside that town, included the provision of adequate room for expansion on flat

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occupied a slightly elevated site. J.G.L. 25/3/1884; Gas World 24/10/1882. Vide infra p. 264

1. The rusting of pipes, and flooding, were consequent hazards. Troon was flooded in 1882, Rothesay and Ayr by the sea in 1884, and Kilbarchan by a river in 1890. English works, like Darlington on R. Skene, and Fulham on R. Thames, had the same problem in 1875. J.G.L. 10/1/1882, 5/2/1884, 18/11/1890, 30/11/1875.

2. Dalkeith, Bathgate and Annan had private water-wells in the 1830s, and Selkirk prepared to sink a well when the Police in 1876 wished to raise water charges from £5 per year to 1s 6d per 1,000 gallons. Two Eyemouth gas directors were members of the local water company which provided their supplies in 1846. Bo'ness in 1849 installed a wooden water-tank to supply the wet-lime purifier, whilst Stranraer in 1852 had piped supplies. Galashiels in 1873 used 1,000 gallons of water per day, and had a 700 gallon tank to collect rain-water; in 1900 the company paid the town council 6d per 1,000 gallons. Arbroath obtained supplies in 1884 from the Nolt Loan. Water supplied under gravity from nearby surface sources was widely used for the large quantities required in maintaining the gasholder-tank, in quenching coke, and in purifiers and 'scrubbers'.
   Dalkeith Minute Book op. cit., 14/5/1831; Bathgate Minute Book op. cit. 11/5/1835; Annan Minute Book op. cit., 24/5/1838, 22/10/1838; Stranraer Minute Book op. cit., 29/6/1852; Selkirk Minute Book op. cit., 5/7/1849; Eyemouth Minute Book op. cit. 24/3/1846; Galashiels Minute Book op. cit., 2/9/1873, 6/11/1900. J.G.L., 18/11/1884.

3. In England, railways in the late 1840s greatly stimulated gasworks construction in "towns of minor importance", which took advantage of gravity-shoots from high level embankments to the retort-house. Scottish works were slow to obtain this advantage. Vide infra p. 387
   S. Hughes, Treatise on Gasworks (1853) pp. 251-5. F. Colyer, Gas Works - Their Arrangement, Construction, Plant and Machinery (1884), p. 5. J.G.L. 29/2/1876 p. 307; 27/3/1876 p. 415.

4. John Neilson /sic/, civil engineer, Glasgow "On the Manufacture of Gas Obtained from Pit Coal" Glasgow Mechanics Magazine 1825 Vol. III p. 105.

ground,[1] plus easy access for coal transport and rubbish removal, and even water-power to run the purifiers. Neilson refuted the idea that gas making or distribution demanded a low site,[2] but warned that if the works was at a very different level to the town, the public would object on aesthetic grounds to the 'district gas-holders' which would be necessary in the town to equalise gas pressure.[3] To supply the estimated 5,000 gas jets required in Dundee, Peep-O-Day would initially have handled 3½ tons of coal each day, and Neilson advised that transport savings alone would soon repay the cost of extra pipes from the distant site.[4]

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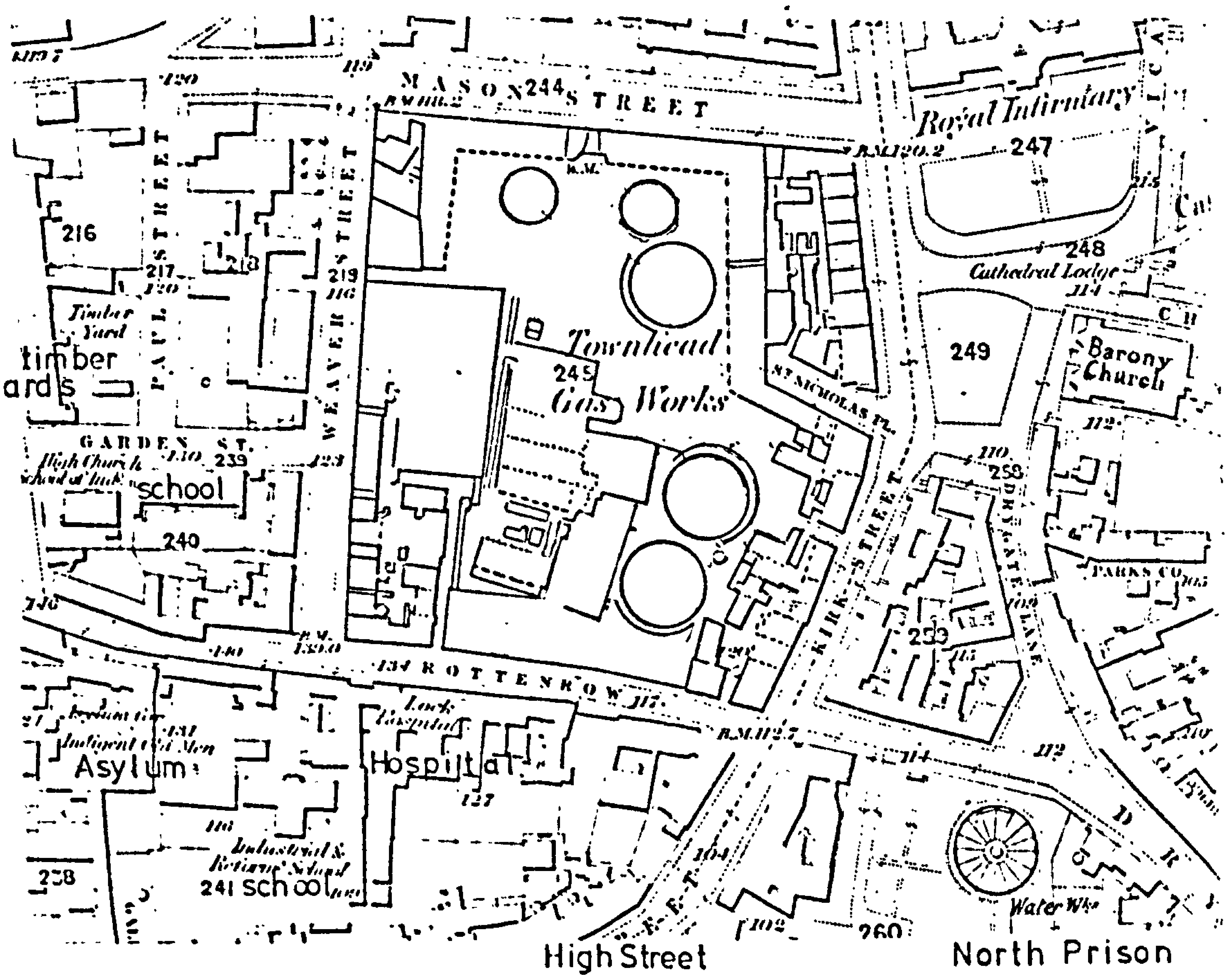
1. Neilson showed that original English sites of ½ to 2½ acres were soon overcrowded; Manchester had 55 retorts and 7 gasholders on ½ acre; Wigan had 12 retorts and 2 gas-holders on 1½ acres.

2. Directors of the Vale of Leven company personally chose the site of their gasworks, and placed it near the Alexandria Turkey-red dye works, which was expected to be a large consumer, but also "its proximity to the River, its low level, and its central situation" influenced their choice. The subsoil was not examined however, and the absence of clay subsequently caused considerable leakage from the gasholder tanks, and expenditure on repairs. Vale of Leven Minute Book op. cit., 2/6/1840.

3. Edinburgh had 'district holders' at Tanfield, vide infra 'Chartered Companies'; pp. 426, 1119
   Dunfermline in 1830 had to use a 'district holder' for the Nethertown area, at a lower altitude than the works, because insufficient gas pressure to supply it directly would have pushed the water-lutes out of gas-meters in higher parts of the town. Dalkeith also installed a 'district holder', for lower parts of the town in 1854. In 1832, half of the 8 Glasgow gasholders were 'district' holders. Paisley, with 190,000 cu ft capacity in 1842 had 5 holders at the works and 2 'district' holders at Sacell and Ferguslie. Dunfermline Minute Book op. cit., 24/12/1829; Dalkeith Minute Book op. cit., 22/6/1854.
   J. Cleland, City of Glasgow Statistics (1832, Glasgow) p. 142; New Statistical Account VII, p. 262

4. Peep-O-Day was 300 yards from the nearest consumer, Baxter's Spinning Mill, and the pipes for that distance cost £300, being 9 inches diameter and adequate to supply up to 10,000 jets with 3 inch flames, i.e. of 1½ "candlepower", (an inexplicit calibration).
   Until experiments by Andrew Fyfe, consumers believed upto the 1840s that gas either lost many of its illuminating constituents by condensation during transit, or else improved in quality because lighter, purer particles travelled furthest. Fyfe

Fig. 3.20 Plan of Townhead Gasworks, Glasgow



Source - Glasgow City Archives Ordnance Survey 1860

"The first large roof constructed entirely of iron" was designed by J.B. Neilson for extensions to Townhead (Kirk Street) Gasworks according to Chambers. Underground tunnels for materials transport were less successful, though installed by Neilson at Tradeston works (Fig. 3.21) in 1835-9 (£ 20,000) at Crawford Street south of the Clyde. By 1861, when abolished, those tunnels used 2 million cu.ft. year, one third of total consumption at the gasworks.

Townhead works commenced in 1817 with 25 retorts in one bench on the one acre (£ 625) site.

R. Chambers Biographical Dictionary of Eminent Scotsmen (1875) T. Thomson Ed. Vol. 5 p. 216

J.G.L. 12/2/1861 Gas World 25/6/1887

Gas Supply of Glasgow (1935) op cit

Most gasworks commenced on a modest scale, and expanded after taking a measurement of the market demand. Townhead [1] works in Glasgow opened in 1818 with a single 'bench' of twenty-five cast-iron retorts, a daily output capacity of 35,000 cu ft, and one 25,000 cu ft gasholder. The square site had condensers and other apparatus along one side, and coal 'shades' or stores[2] along the other three, holding 6,000 tons and divided into compartments of different quality. Expansion began almost immediately, with the construction of a second retort bench, and 'district holders'[3] at Old Wynd, Broomward Street and Hutchensontown which increased the storage capacity to 100,000 cu ft by the end of 1819. By 1832 there were 152 retorts each able to produce 5,000 cu ft per day. One hundred and five retorts were used in winter, leaving the others in reserve, but only thirty were required in summer. The size of all gasworks was determined by peak winter demand, and most of the equipment was idle throughout the summer.[4] Paisley[5], with fifty-two

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detected no appreciable change. Edinburgh New Philosophical Journal 1843-4 Vol. 36, pp. 223-31.

1. J. Cleland, City of Glasgow Statistics 1832 (1832, Glasgow) p. 142; New Statistical Account - Lanarkshire pp. 162-5; Gas Supply of Glasgow (1935, Glasgow Gas Dept.) op. cit.; J.G.L. 18/3/1913 p. 774.

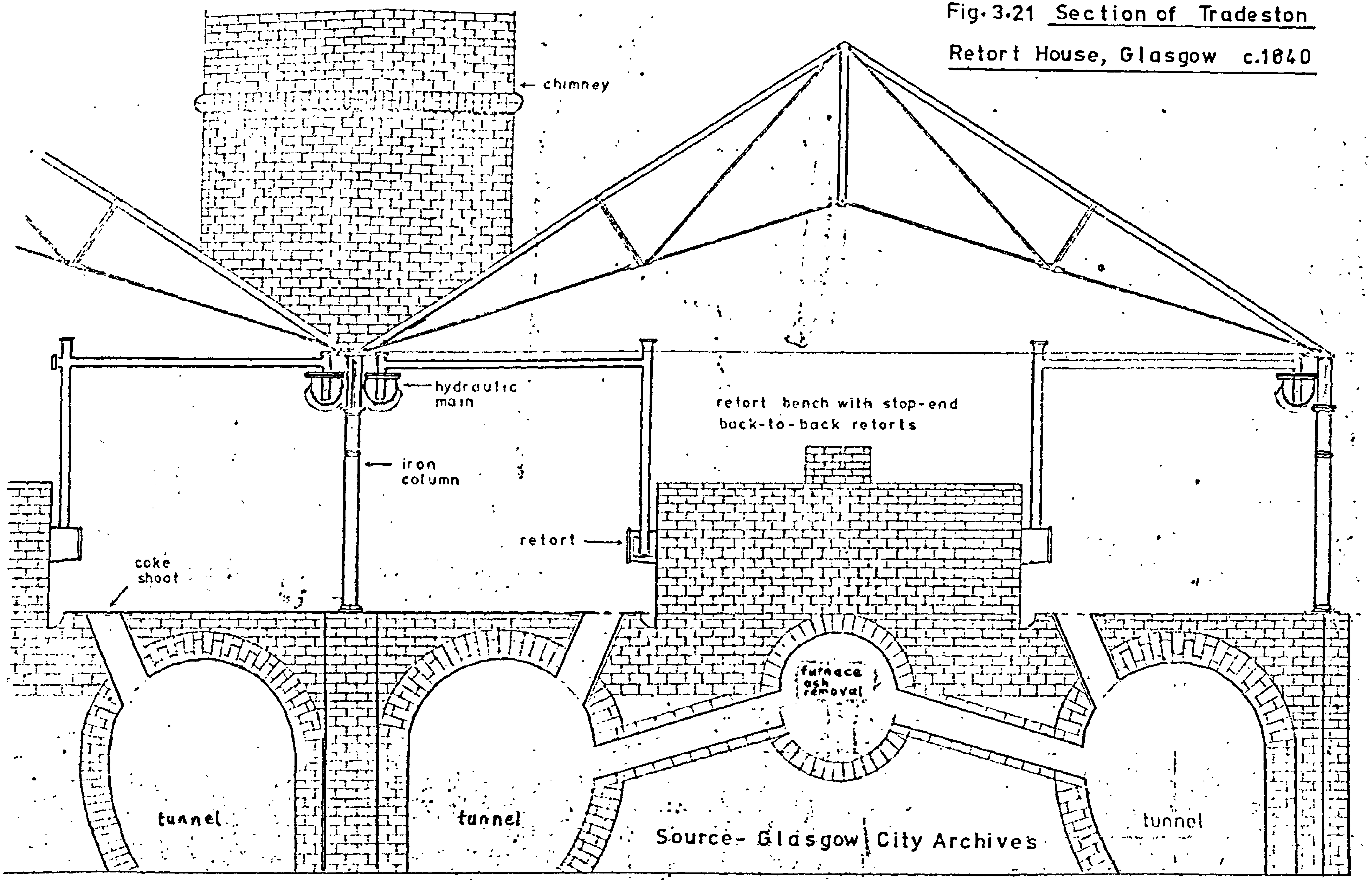
2. cf. Aberdeen in 1875 had storage for 10,000 tons coal. As in other aspects of equipment, storage space was related mainly to peak winter demand. Aberdeen consumed 100 tons coal per day in winter, but only 20 tons in summer. Dundee in 1885 also had storage for 10,000 tons which was 33 per cent of annual consumption. J.G.L. 1/6/1875; Gas World 18/7/1885 p. 76.

3. To equalise pressure vide infra p. 263

4. Vide infra, 'Finance' p. 760

5. New Statistical Account (1842) VII, p. 262.

Fig. 3.21 Section of Tradeston Retort House, Glasgow c.1840



retorts each capable of producing 6,000 cu ft per day in 1842, used forty in winter but only four in summer. Banff[1] commenced with only four retorts in 1830, Kirkintilloch[2] with six in 1839, and Stornoway[3] with three in 1848.

The gasholder[4] and its water-filled tank were among the most expensive[5] requirements of a gas company, and improved but cheaper designs introduced into Scotland in the late 1820s, were a significant stimulus to new companies. Early holders were suspended by a single chain, attached to the eye-bolt in the centre of the crown, running up to a pulley set in a stationary cast-iron framework which surrounded the gasholder, and then attached to counterpoise weights. Pressure to force gas through the mains was provided by the weight of the gasholder, which could be altered manually by reducing the counter-balancing weights.[6] A heavy wooden frame and massive iron stays were used inside the first holders, and the outer iron framework and weights were in similar proportions.[7]

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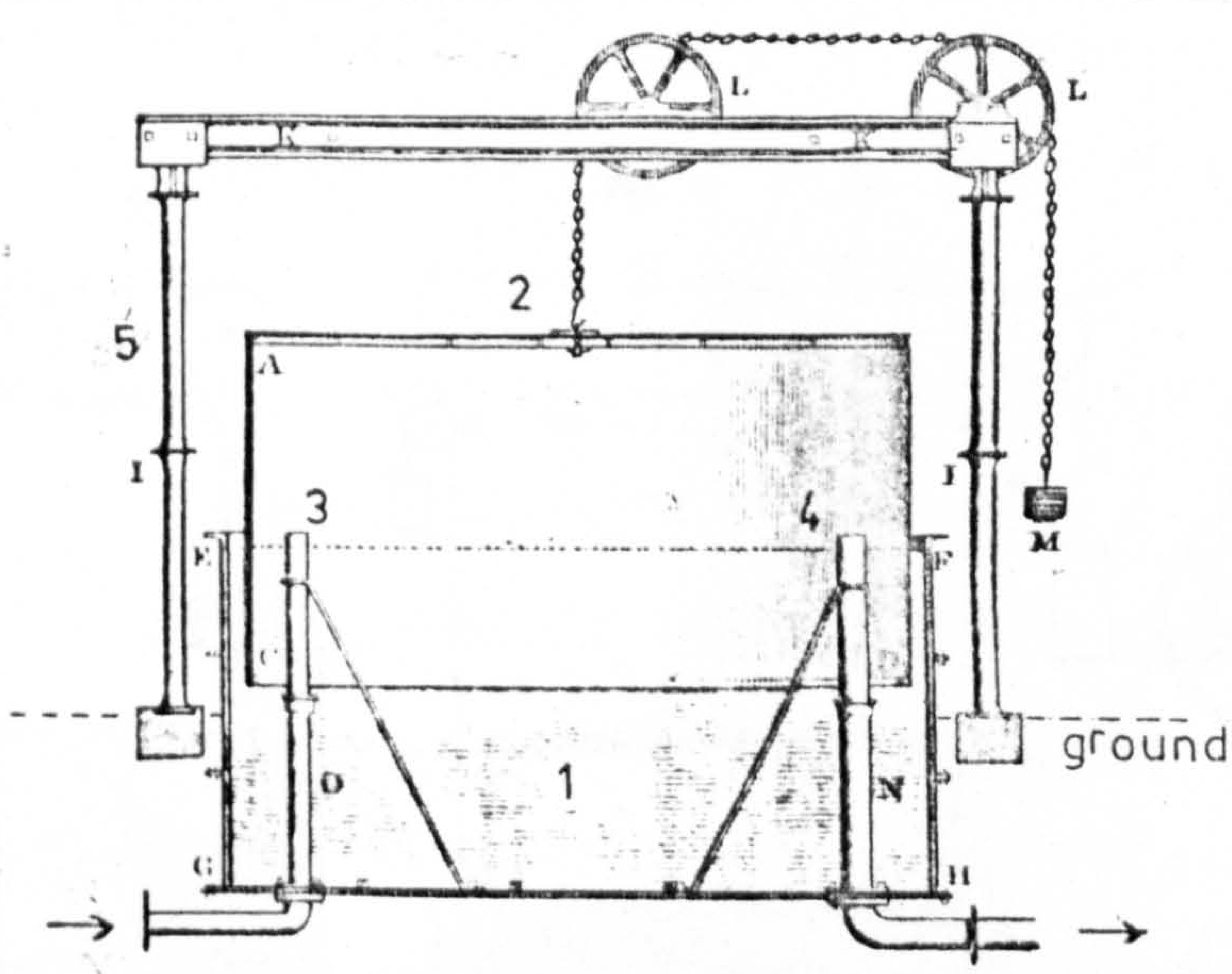
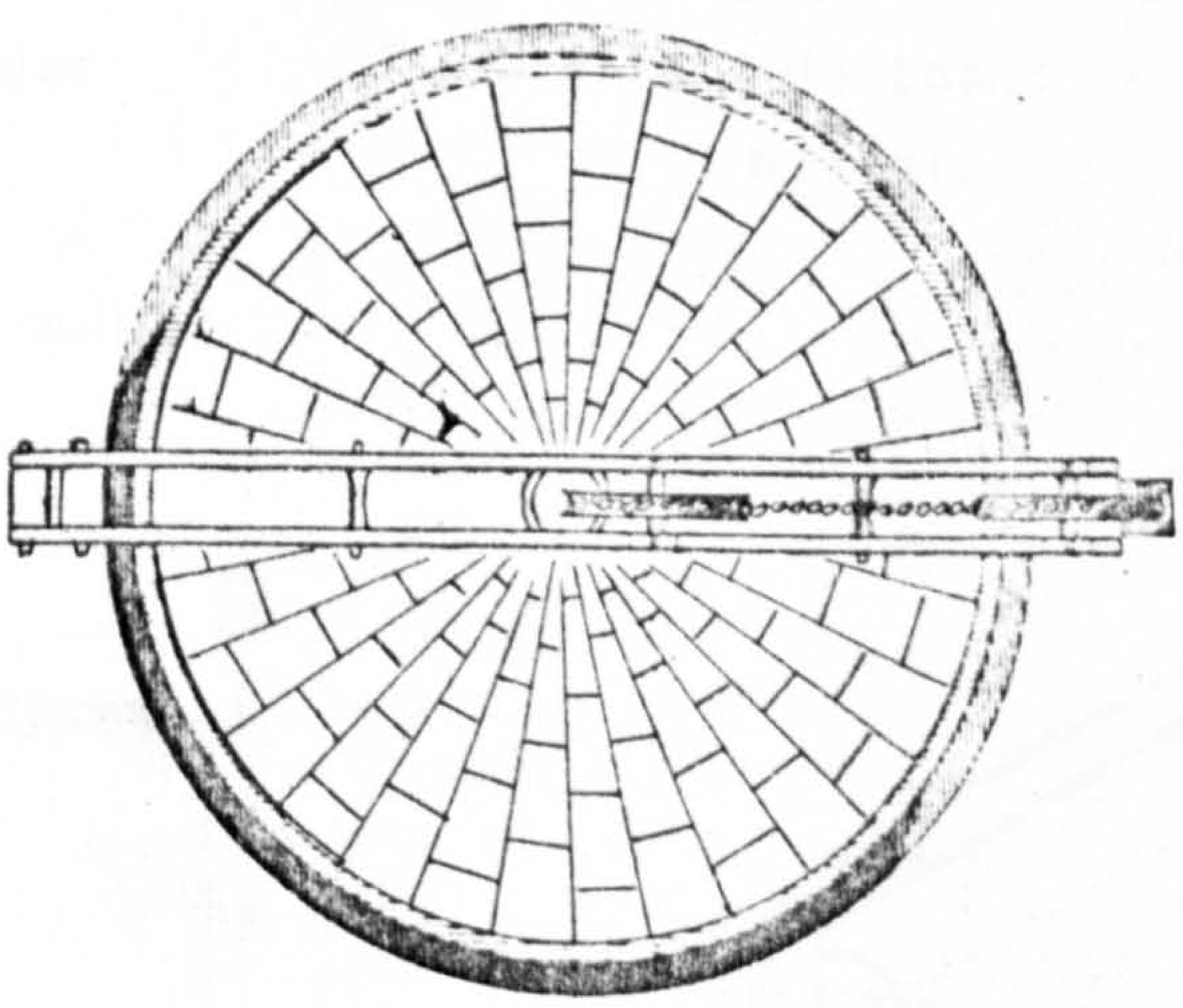
1. Banff had only 7 retorts in 1869, and held none in reserve in winter. Banff Minute Book op. cit., 5/7/1869.
2. New Statistical Account VIII p. 204
3. Stornoway Minute Book, op. cit., 15/4/1848, 16/5/1848
4. Invented by M. Levoisier in 1782 and termed a 'Gasometer' by him in Opuscules Chymiques et Physiques (1789)
5. F. Accum, Gas Works of London (1820) 2nd edn. op. cit., p.165
   W. Richards, Practical Treatise (1877) op. cit., p. 161
6. A pressure gauge could be fitted to show pressure within the holder, or a scale of feet and inches painted on the holder showed the depth and was used to calculate the cubic contents.
   T.S. Peckston, Theory and Practice (1819) op. cit., p. 221
   D. Chandler and A.D. Lacy The Rise of the Gas Industry in Britain (1949) p. 141
7. In 1820, Dorset Street gasworks, London, had counter-balances of 7 tons; B.P.P. 1823 (193) V p. 251.
   Diagrams of early gasholders vide J.G.L., 2/3/1875 p. 283; 9/3/1875 p. 319

Fig. 3.22 Gasholder 1819



Section



Plan

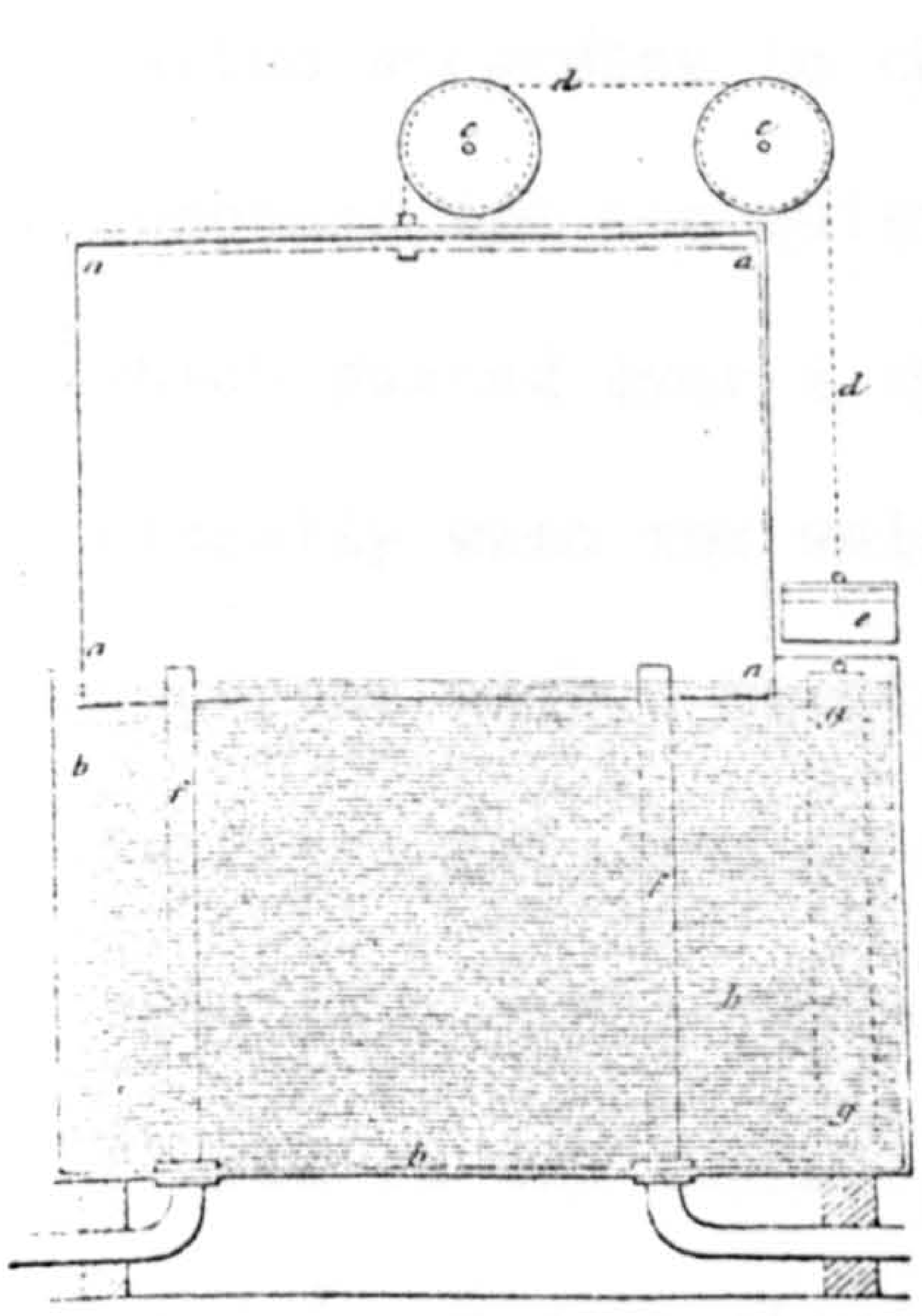
1. Water tank
2. Gas-holder suspended by chain. Capacity 15,00 to 20,000 cu. ft.
3. Gas inlet
4. Gas outlet to mains.
5. Cast-iron columns surmounted by girder.

SOURCE: T.S. Peckston, Theory and Practice of Gas Lighting (1819) p. 221

Fig. 3.23

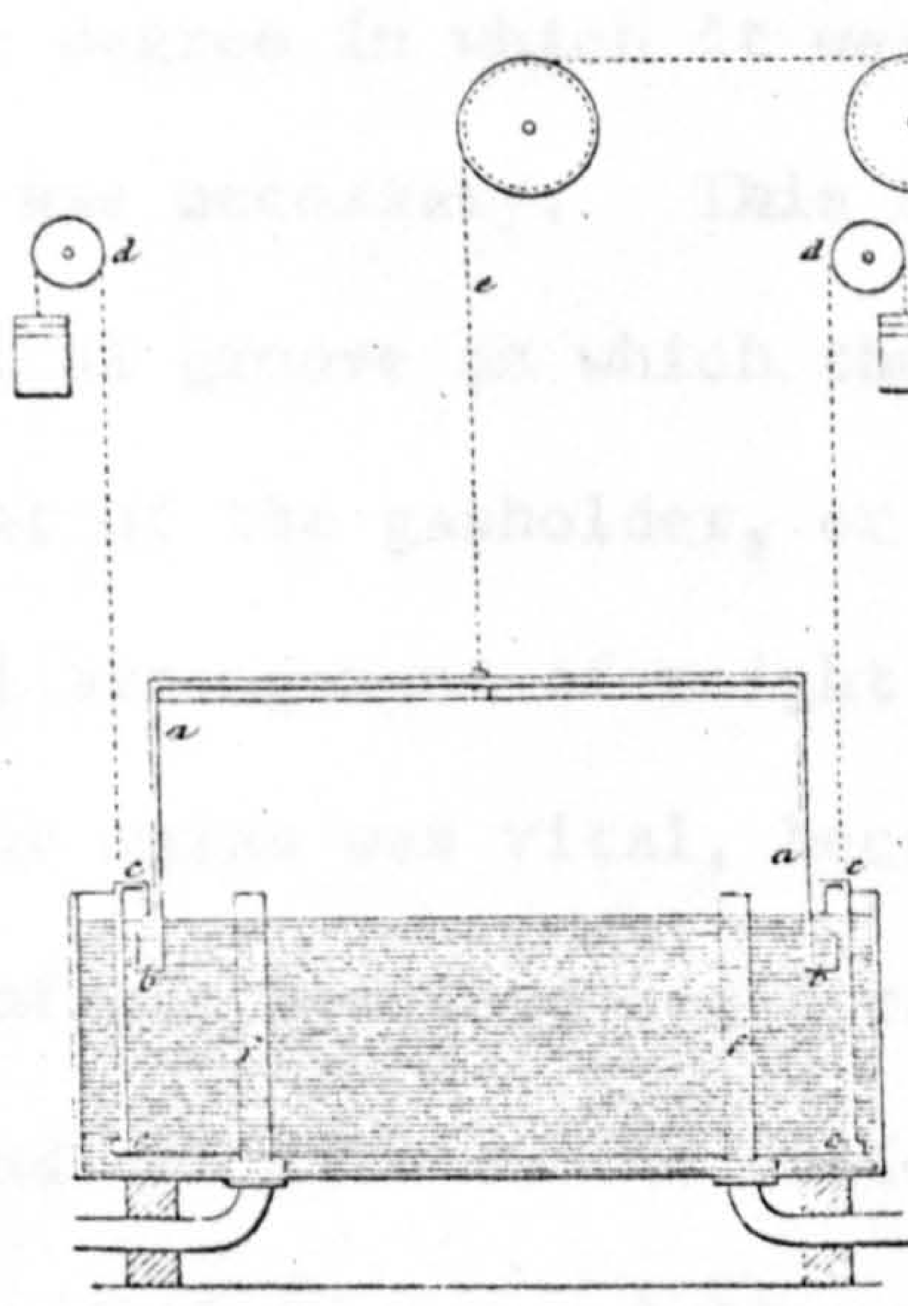
Early Gasholder Design 1824

Fig. 1.



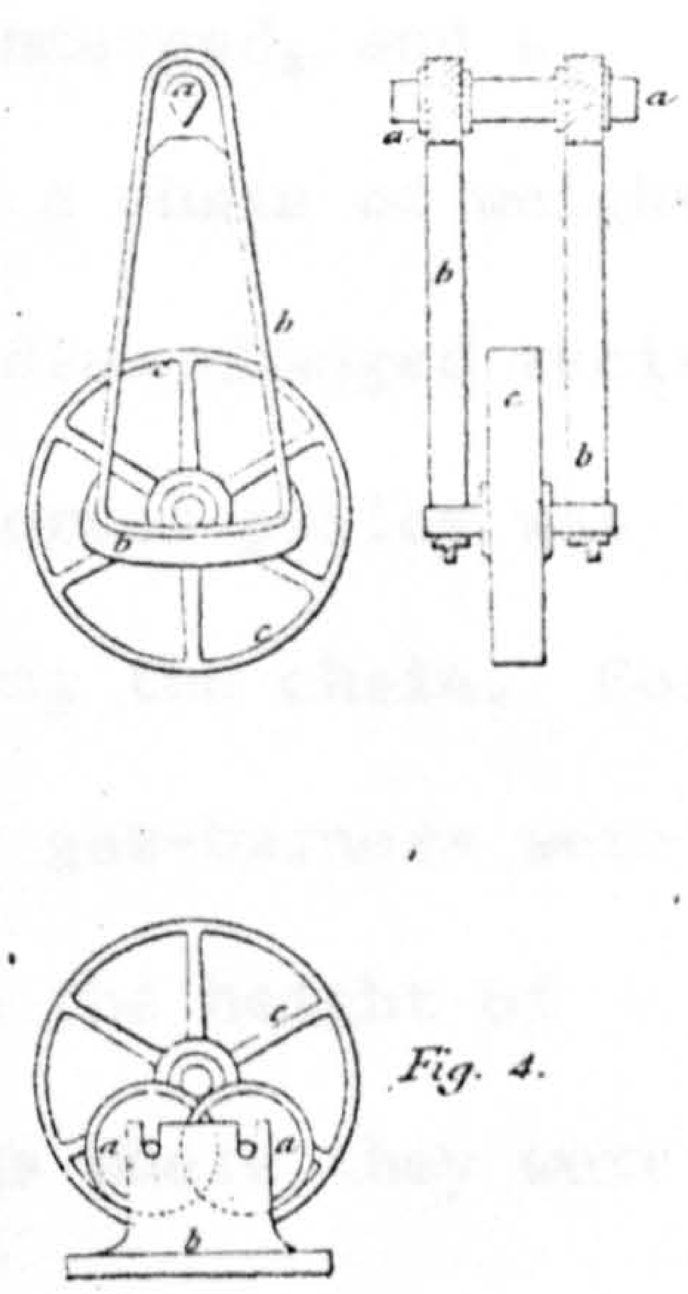
Single lift holder suspended from central eye-bolt
Basal inlet and outlet

Fig. 2.



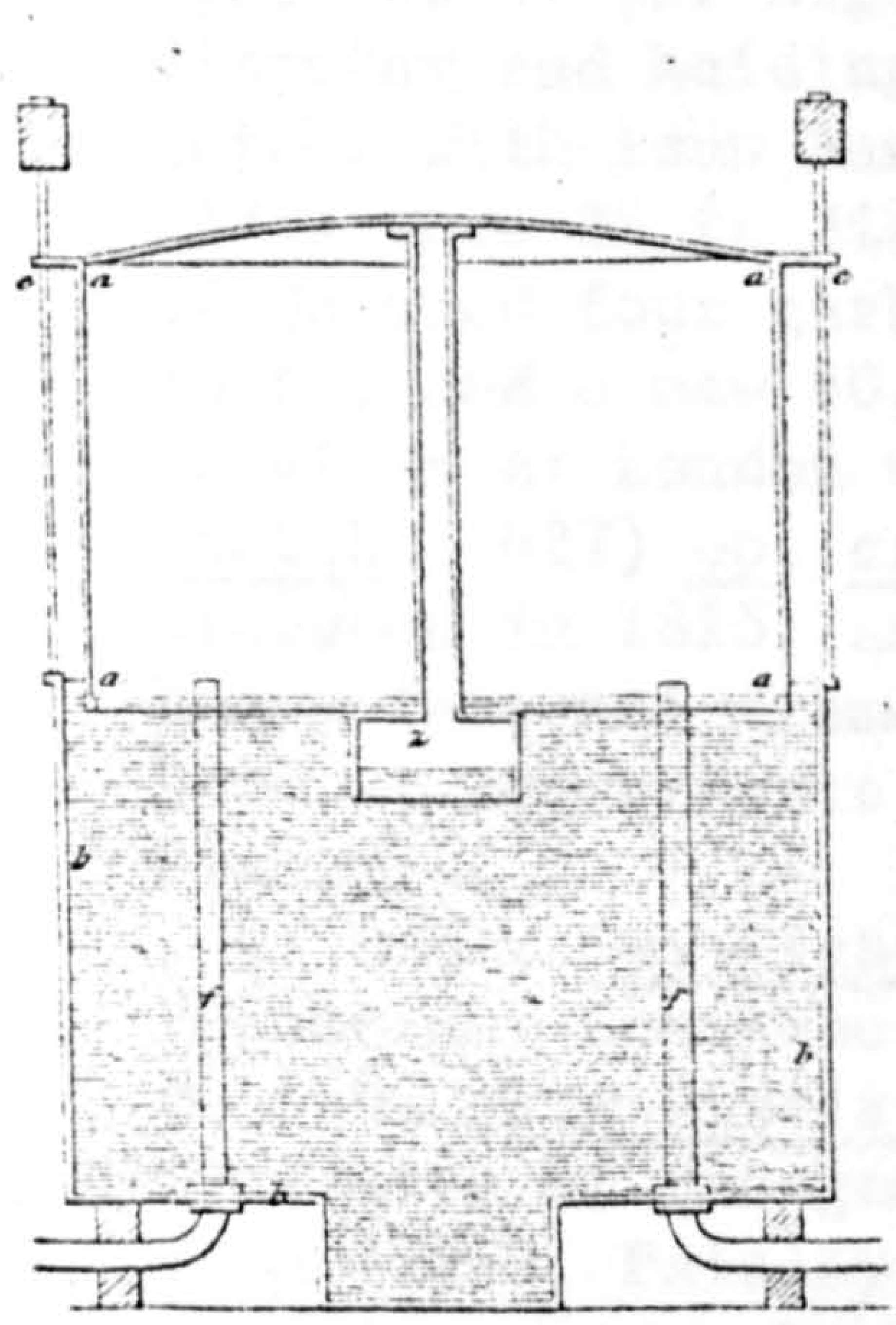
Two-lifts telescopic holder.

Fig. 3. *Fig. 4.*



Pulley system for counterpoise weights.

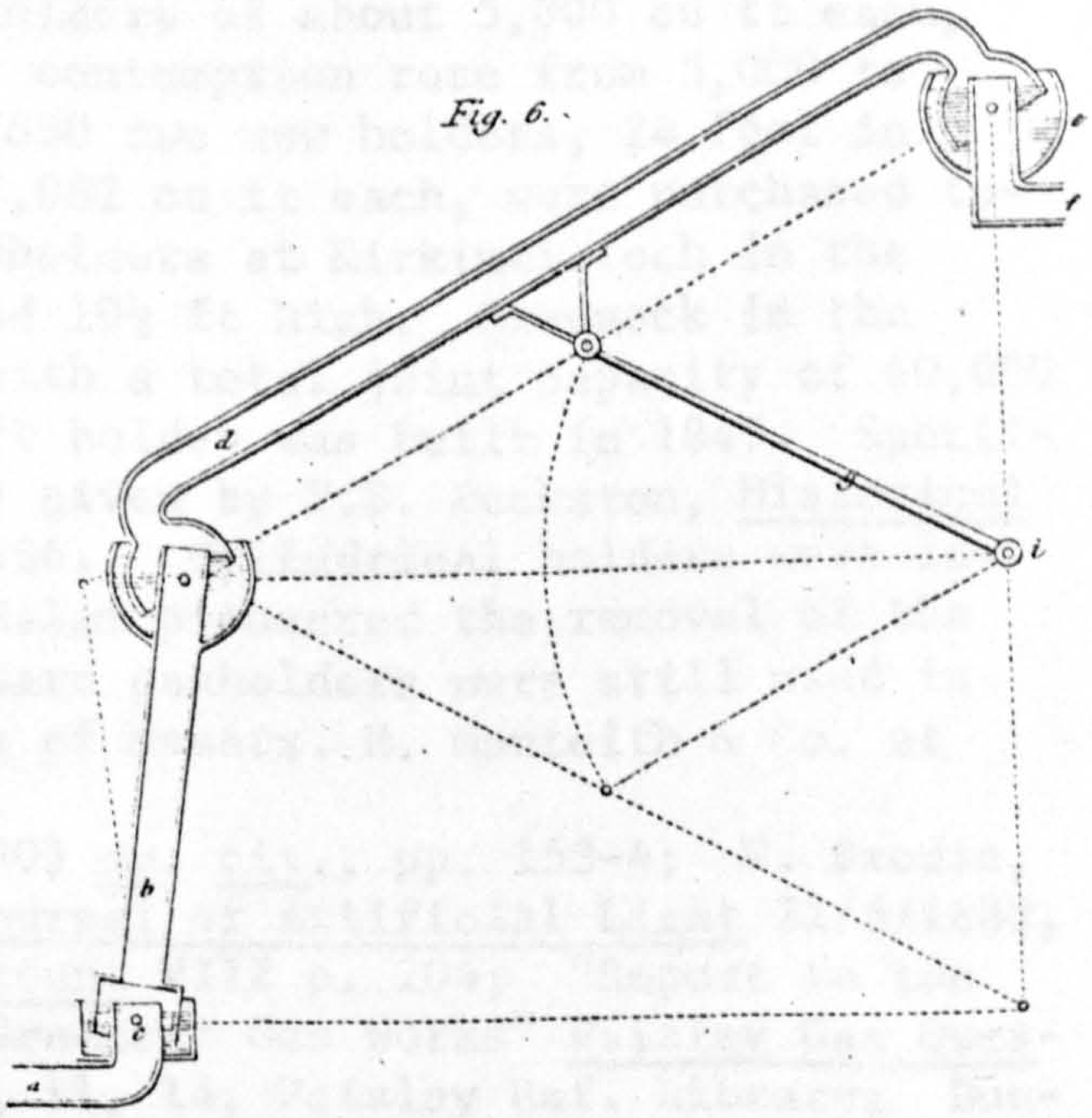
Fig. 5.



Column (slide) - guided gasholder. A mains-governor replaced counterpoise weights to control gas supply pressure.

Atmospheric air sealed in 'z' reduced weight of holder when largely submerged.

Fig. 6.



Articulated water-luted arms used for inlet and outlet pipes on side (instead of base) of gasholder, where preferred.

Source - Encyclopaedia Britannica Supplement 1824 op cit (Plate LXXXIII)

By 1819 experience showed this to be unnecessary. The typical London gasholder[1] held 15,000 cu ft gas and was built of lighter plate iron[2] with a few angle-irons at the base and top, and eight rods projecting from the eye-bolt. The weight of the gasholder varied according to the degree in which it was submerged, and a compensation mechanism was necessary. This used a chain of weights which passed over a spiral groove on which the radius changed reciprocally with the weight of the gasholder, or a normal pulley was used but with a special arrangement of weight along the chain. Correct gas pressure in the mains was vital, because gas-burners were open jets and a surge of gas pressure could raise the height of flames to ten inches and set fire to the buildings where they were used.[3] Bad weather conditions, especially snow and ice, were

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1. Few early Scottish examples are extant. Dunfermline gasworks commenced in 1829 with two holders of about 5,000 cu ft each, though during the first year consumption rose from 5,000 to 9,000 cu ft per night. In 1830 two new holders, 24 feet in diameter and holding about 7,082 cu ft each, were purchased together with iron tanks. Gasholders at Kirkintilloch in the 1830s were 28 ft diameter and 10½ ft high. Greenock in the 1820s used four gasholders with a total joint capacity of 60,000 cu ft, and a new 80,000 cu ft holder was built in 1847. Specific sizes at London works are given by T.S. Peckston, Historical Sketch (1827) op. cit., p. 136. Cylindrical holders were introduced in 1815, and John Malam pioneered the removal of the heavy internal frames. Square gasholders were still used in 1880 at the private gasworks of Messrs. H. Monteith & Co. at Blantyre.
   C. Hunt, Gas Lighting (1900) op. cit., pp. 153-4; W. Brodie, "Gasholder Construction", Journal of Artificial Light 22/5/1880, p. 668; New Statistical Account VIII p. 204; "Report to the Committee of Management of Greenock Gas Works" Paisley Gas Question (1860, Paisley) pp. 10, 11, 14, Paisley Ref. Library; Dunfermline Minute Book op. cit., 24/12/1829

2. Plates of No. 16 Wire Gauge.

3. In London, the works foreman had to check each gasometer once an hour. The main danger of pressure-surge was at times like midnight when some street-lights were turned off, and shops closed.

expected to disrupt the holder balances, and consequently gasometers in the 1820s and 1830s were often enclosed within substantial "gasometer houses".[1]

Even in 1825, J. Neilston found it necessary to tell the New Dundee gas company that the prevalent Scottish gasholders, "framed of cast-iron with wood or malleable iron" were unnecessary and thin sheet-plate was adequate.[2] He preferred the cylindrical holders, with their greater strength, to square and oblong holders still used elsewhere, and recommended for Dundee two holders, thirty to thirty-six feet in diameter, sixteen to eighteen feet deep, each of 6½ tons and costing £280 excluding the suspension gears.

Gasholder-tanks were expensive and several Scottish companies made the mistake of constructing the cheapest clay-puddle tanks[3]

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1. Dalkeith company built a gasholder-house only after severe storms threatened the works in the winter of 1837-8. Annan company in 1839 decided against a gasometer house costing £145, and instead planted trees as a windbreak and surrounded "the gasometer with two iron hoops, attached to perpendicular rollers, fixed in the coping of the tank" to steady it. Musselburgh gasometer house (demolished in 1970) was built in 1831 with a radial roof structure to suspend the gasometer from a central eye-bolt. Perth gasworks in 1824 had two gasholders, of about 5,000 cu ft capacity, enclosed in a stone building. Maximum daily winter consumption was 8 to 10,000 cu ft. Dunfermline built a gasholder house in 1829.
   J.G.L. 28/6/1887; Gas and Water 1885 p. 482; New Statistical Account Vol. X p. 86; Dalkeith Minute Book op. cit., 19/4/1838, 24/5/1838; Annan Minute Book op. cit., 12/7/1839, 24/4/1838; The National Monuments Record of Scotland (Musselburgh, ref. MLR/2/1). Vide infra p. 377
   Dunfermline Minute Book op. cit., 20/4/1830, 18/9/1829.
   Diagram of circular gasometer-house vide King's Treatise (1879) Vol. II op. cit., p. 180

2. Glasgow Mechanics Magazine 1825 Vol. III, op. cit.

3. An iron tank cost twice as much as bricks or masonry, vide J.G.L. 28/9/1875 p. 467. Bricks or even wooden staves could be used but were not popular in Scotland; T.S. Peckston, Theory and Practice (1819) op. cit., pp. 238-40; 242; S. Hughes, Treatise on Gasworks (1853) pp. 200-1.
   Although one English gasworks had nine gasholders over one

which were unsuitable for well-drained soils like glacial moraines,[1] despite taking less pressure and therefore normally requiring less clay than canal lock-basins. Cast-iron tanks, also adopted from Canals,[2] proved the most reliable. New Scottish companies began to invest initially in a small gasholder, of about 10,000 cu ft, with a cast-iron tank. When demand rose, replacement was delayed as long as possible, and eventually a holder about twice as large was built on the same site. The old gasholder and tank could then be sold as scrap iron for a high proportion of their original cost.[3]

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reservoir, the normal and most practical method was found to be one tank to each gasholder. B.P.P. 1823 (193) V p. 266; evidence of S. Clegg.

1. Pits to test subsoil foundations before construction became a responsibility of gas managers; King's Treatise (1879) Vol.II op. cit., pp. 47-50

2. First used on a large scale by Telford and Rennie -
   e.g. Long Mill aqueduct over River Tern (186 feet)
   Pont-y-Cysylte aqueduct on Ellesmere and Chester Canal (988 feet).
   S. Hughes, Treatise on Gasworks (1853) pp. 200-1
   The high cost of such tanks was the chief motive for S. Clegg's strange collapsing-gasometer, and semi-circular revolving gasometer which minimized tank-space but themselves were too expensive, vide Encyclopaedia Britannica - Supplement (1824) op. cit. p. 454. F. Accum, Gasworks in London (1819) op. cit., pp. 181-7.
   Brick tanks were first tried in 1818, followed by composite brick and concrete tanks by Mr Wyatt of the Gas Light Co. in London; J. Douglas of Portsea made the first entirely concrete tank. W. Richards, A Practical Treatise (1877) pp. 162, 182,185.
   The iron tank weighed 20 tons even at a small works like Haddington in 1836, when a storm disrupted construction work by floating the entire empty tank off its foundations. The Edinburgh Almanac (1836) - East Lothian Supplement, p. iv (Scot. Nat. Lib.).

3. W. Richards, A Practical Treatise (1877) op. cit., pp. 189-90.
   Cast-iron tanks, 18 to 20 feet deep, were still widely used in the late nineteenth century as at Rothesay (1880), Kirkintilloch (1883), Galashiels (1885) and Saltcoats (1889).
   J.G.L. 23/10/1880, 1/5/1883, 22/12/1885, 12/3/1889

Other ironware,[1] like retorts and purifier boxes, was also sold for re-cycling[2] when no longer required.

Public misapprehension over the danger of gas-light[3] centred upon the possible devastation caused by an exploding gasometer.[4] An explosion at Westminster Gasworks led Parliament to appoint a select committee on gasworks, and to request an investigation under the auspices of the Royal Society.[5] Humphrey Davy tried to persuade Parliament that anarchists could disrupt a city by exploding large gasholders,[6] and because 6,000 cu ft gas was equal to the power of two barrels of gunpowder, the legal limit held by a dealer, he advocated that urban gasworks should be forced to use small gasometers separated by mounds of earth, iron screens or brick walls, to pre-

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1. e.g. Dalkeith company in 1828 sold old iron retorts at 3s cwt. to G. Mushet's local foundry, which supplied new ones. Dunfermline in 1830 sold scrap pipes, retort doors, and retorts to Mr Campbell who supplied their retorts. Vale of Leven company in 1855 received £3 10s a ton for scrap purifiers from a local ironfounder who supplied new purifiers. Dalkeith Minute Book, op. cit. 9/8/1828; Dunfermline Minute Book op. cit. 6/6/1830, 16/8/1830; Vale of Leven Minute Book op. cit., 25/9/1855

2. Equipment which became inadequate for one expanding gasworks, whilst still in good condition, could often be sold to a smaller works. Bo'ness, for example, in 1859 purchased second-hand condensers from Great Grimsby Gas Co; Bo'ness Minute Book, op. cit 11/1/1859.

3. Aided by opposition to gas by Sir Humphrey Davy and Sir Joseph Banks.
H. Chubb, "The Supply of Gas to the Metropolis" Journal of the Statistical Society (1876) Vol. 39

4. Minor accidents did occur, as in 1814 at Peter Street works in London when an under-filled purifier produced a fire which badly burned Samuel Clegg, and received much publicity.
W. Richards, A Practical Treatise (1877) op. cit., p. 23.

5. Davy and Banks sat on the Commission of seven, together with Col. Congreve and Mr Rennie C.E., while Samuel Clegg appeared as a witness before the Select Committee. H. Lyons, The Royal Society 1660-1940 (1944, Cambridge) p. 220

6. By removing manholes, or jamming pulleys, to allow atmospheric air to enter and form an explosive mixture.

vent a chain-reaction.[1] This regulation would have led to modifications and vast expenditure at gasworks throughout Britain, and greatly retarded the growth of the industry. Fortunately the Select Committee decided the danger of gasworks was "not so great as has been supposed",[2] and showed that gasometer houses where explosive gas could accumulate were the chief problem.[3] Clegg and Congreve demonstrated that outdoor gasometers[4] were perfectly weatherproof, though many engineers like J. Millington[5] still advised the erection of a roof above each gasholder, albeit supported by an open or well-ventilated framework, to prevent snowfall and "flakes of burning matter" from nearby fires falling onto the gasholder. Millington also advocated steam-heating to prevent ice in the gasholder tank[6], a method which became particularly important in Scotland. Favourable Parliamentary comment upon the industry gave an additional boost to gas lighting and greater confidence to consumers.

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1. B.P.P. 1823 (193) V 303, Reports to Government Respecting Gas Light Establishments, pp. 221-2, 309.
   Later, sabotage was not unknown. In June 1883 Fenians, or militant railway strikers, dynamited the Tradestone gasholder in Glasgow containing 400,000 cu ft gas, and a severe fire caused extensive damage and injuries. Fenians were also suspected when a 1 lb cartridge of blasting powder was found concealed amongst coal at Dundee gasworks in 1881. J.G.L. 23/1/1883, 30/1/1883; Gas World 16/8/1881. Vide infra p.369
2. B.P.P. 1823(193) V 303 pp. 217-8. The Committee praised gas for greatly and rapidly increasing "the comfort and convenience of society", and the benefit of public gas-lights to the Police.
3. Although Davy Safety Lamps were normally used, in some gasworks the "blowers" or leaks from a gasometer were located by a man with a burning torch, a highly dangerous practice; ibid., pp.285,245.
4. Ibid., pp. 266, 215, 324.
5. Ibid., p. 23 (237). John Millington was Professor of Mechanical Philosophy at the Royal Institution.
6. B.P.P. 1823 (193) V 303 pp. 245,276.
   Vide infra pp. 234, 326, 356

The chief problems over the construction of gas-mains pipes were also solved for London before the gas industry really developed in Scotland. In 1810 the Chartered Company had to use gun-barrels, which became a normal term for gas pipes, and also used water pipes because of the shortage of metal pipes.[1] Subsequently pipes were manufactured by lap-welding, a slow process in which the edges of iron 'skelp' had to be drawn thin and then over-lapped before re-heating to weld. This process, devised originally for gun barrels, produced heavy leakage and engineers were advised to surround pipes with puddled clay[2] or thick tar.[3] Often, as in Edinburgh in 1823, water and gas pipes[4] were laid by the same contractors, and the same force-syringe used with water to test for leakage. James and John Russell who manufactured guns and gas-pipes at Wednesbury experimented with cheaper methods of butt-welding the tube without overlapping the sides, but this method was perfected and

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1. In 1807 Winsor used sheets of lead, soldered into pipes, to light Pall Mall. Paris gasworks tried paper and pitch pipes, and Cambridge tried brick-pipes.
   W. Richards, Practical Treatise (1877) op. cit., p. 251
   The Chartered Co. bought second-hand pipes from York Buildings and Middlesex Water-Companies, and in the pipe shortage the New River Water Co had to use hollow tree-trunks. S. Everard, Gas, Light and Coke Company (1949) op. cit., p. 68; H. Chubb, "The Supply of Gas to the Metropolis" Journal of the Statistical Society 1876 Vol. 39, p. 375.

2. This was so expensive, that even where carried out it was confined to the joints between different pipes. Clay bedding raised pipe costs by one-third, whereas clay joints only cost 18s over 61 yards of 2" pipe. B.P.P. 1823 (193) V 303, pp. 255, 256, 254.
   These early wrought-iron pipes only lasted 4 - 5 years, but lead pipes could not be used because with soft metal they had to be above ground and would be stolen.

3. The London Encyclopaedia or Universal Dictionary of Science, Art, Literature, and Practical Mechanics (1829, T. Tegg, London) Vol. X p. 13.

4. Edinburgh City Archives, General Minute Book of Leith Police Commissioners' Water Committee Vol III pp. 228 (16/7/1823), 232 (21/7/1823), 236 (22/7/1823).

patented independently in 1825 by Cornelius Whitehouse.[1] Messrs Russell purchased the process, whereby tubes were made and welded rapidly while pulled through a circular die and around a bell-shaped die at the same time. These tubes produced fewer leaks, and were widely used in Scotland[2] by the late 1820s where tube-manufacturers like Andrew Liddell illegally copied the process even before patent rights expired. Pipes were originally joined by bolted flanges, caulked with lead,[3] but the turned and bored joint invented in 1826 by Alfred King[4] of Liverpool was cheaper and reduced leakage. Gas

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1. Lap-welding remained more expensive than butt-welding in 1929. Original gun-barrel tubes were made under the patents of Henry Osborn (Birmingham) in 1812 (Pat. 3617) and 1813 (Pat. 3740). James Russell took a patent in 1824 (Pat. 4892), followed by Whitehouse in 1825 (Pat. 5109). Messrs. Russell opened the Crown Tube Works, Wednesbury where output rose from 3,000 feet in 1824 to 6.7 million in 1871 and 40 million feet in 1893. In 1838 the Privy Council allowed a final extension of Whitehouse's patent, for six years, when Messrs Russell complained that "combinations" of workmen had prevented its full use.
   R.T. Crane, "The Early History of Wrought Iron Gas Pipe" Gas World 28/10/1893; "Manufacture of Gas Tubes" Mechanics Magazine 1824 Vol. III, p. 281; Mechanics Magazine 1838-9 Vol 30, p.235; E.C.R. Marks, The Manufacture of Iron and Steel Tubes (1903) 2nd Edn. pp. 2-8; S.P. Marks, Pipe and Tube Bending and Jointing (1929) p. 106; King's Treatise 1878 Vol. I, op. cit., p. 47.
   Varieties of early gas pipes vide J.G.L., 28/11/1876 p. 707; 5/12/1876 p. 804.

2. Vide infra Chapter II pp. 136, 140

3. W. Richards Practical Treatise (1877) op. cit., p. 252

4. In 1819, screwed sockets between 3-foot lengths of pipe were used, but any movement of the pipe caused considerable leakage at the joints. Lead caulking of turned and bored joints was still used in 1900, to allow for some degree of subsidence. H. Bartholomew, an engineer trained by King, introduced the improved joints into Scotland for the Glasgow City and Suburban Company in 1843.
   T.S. Peckston, Theory and Practice (1819) op. cit., pp. 296, 299, 300.
   C. Hunt, Gas Lighting (1900) op. cit., p. 178
   F.W. Simms, Ed., Public Works of Great Britain 1838 Part III pp. 23-4.
   The Artizan, December 1843, p. 287.

mains were laid about eighteen inches below the streets, a safe depth in the age of horse carriages and waggons but one which caused many fractured pipes when steam-rollers were used at the end of the century.[1] A certain amount of water-vapour condensed in the pipes which, like the "service-pipes" which branched off to consumers' premises, had to be laid with a vertical slope[2] of one foot every 150 yards. At the foot of each slope a "water-trap"[3] or syphon box was placed which the gas company had periodically to pump out. The cost of mains pipes, the frictional reduction of pressure in them,[4] and the rate of leakage were the principal factors in

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1. Banchory suffered pipe damage from steam engines in 1879. A 20-ton road roller used in 1884 by Edinburgh Road Trust fractured numerous pipes, and in one case the inhabitants of a nearby house were suffocated to death. The explosion in Banff when a traction engine fractured gas pipes in 1889 produced panic and, at the request of the Town Clerk and Chief Constable, the entire supply was shut off. A.Smith, consultant engineer of Aberdeen, found the pipes to be between 9 and 17 inches below the ground. He recommended a minimum 24 inches, and stop-cocks placed outside houses to disconnect them in the event of fire or non-payment of gas rents. J.G.L. 2/9/1879, 17/6/1884, 17/9/1889; Banff Minute Book op. cit 7/9/1889, 25/9/1889

2. T.S. Peckston, Theory and Practice (1819) op. cit., p. 296

3. S. Hughes, Treatise on Gasworks (1853) op. cit., p. 255; King's Treatise (1879) Vol. II op. cit., p. 363.
The labour involved in removing water varied considerably. In 1897 Port Glasgow pumped the 'dreeps' weekly and Kirkintilloch and Dalry monthly, whereas Helensburgh had not done so for ten years. Gas World 10/4/1897 p. 578; Dalry Minute Book op. cit. 19/10/1897.

4. D'Harcourt's rough guide to loss of gas pressure was: $\frac{LQ^2}{D^5} \times 0.611$
Q = thousands cu ft per hour
L = yards of main pipe
D = pipe diameter (inches)
S. Hughes, Treatise on Gasworks (1853) p. 277

In 1855, Pole's formulae for main pipes was: $Q = 1350\, d^2\sqrt{\frac{hd}{s(1+d)}}$
Q = cu ft gas per hour
d = diameter of pipe (inches) h = gas pressure (inches water) s = specific gravity of gas (Atmosphere = 1).
E. Ronalds and T. Richardson, Chemical Technology (1855) 2nd Edn. Vol. I, Part II, p. 660.

restricting the size of market which a gas company could supply. In the early nineteenth century they effectively prevented competition between companies in towns only separated by three or four miles.

Scottish manufacturers took an early lead in the improvement of consumers' service-pipes, though a variety of metals continued to be used. James Milne, an Edinburgh brassfounder and early adept at making private gasworks,[1] travelled to London in 1817 to observe the gas fittings being used. He found that copper pipes had been most popular as service pipes, but reacted chemically with the gas to produce a 'furr' which almost completely filled pipes even of five-eighths inch diameter, and was itself a dangerous explosive which injured gas-fitters.[2] Consequently, shopkeepers were beginning to fit very expensive lead pipes. Back in Edinburgh, Milne experimented with block-tin and with a mandrel drew it into pipes one-sixteenth inch thick. These resisted crushing better than lead, and in 1817 a sample pipe one-half inch wide was uninjured by a water pressure of 1,000 feet, the maximum power of a testing machine at Glasgow Gasworks.[3] Tin was ductile, easily shaped and

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1. Vide infra, Chapter II pp. 142, 208
2. T.L. Phipson, "Explosions in Copper Gas Pipes" Engineering and Mechanics Magazine 1/11/1862, p. 213
3. J. Milne "On the Substitution of Block Tin pipes in place of Copper ones, and on the Construction of their Joints" Edinburgh Philosophical Journal, 1821 Vol. V, pp. 120-2.
The test made at Glasgow was by the "sub-engineer" there, and may have been the first time Milne met J.B. Neilson, with whom he worked closely in later years. Tin did not spread rapidly to England, and even in the late 1820s corrosion of copper and brass pipes resulted in experiments with composite pipes. Phipson in Birmingham, for example, sold pipes where a lead tube was placed within a pre-soldered copper pipe and pressed together on a mandril. Scotland continued to prefer block-tin service pipes until the 1890s, when it was increasingly replaced by wrought iron.
The London Encyclopaedia (1829) op. cit. Vol X, p. 13.
Copper and iron 'gun-barrel' service pipes were still manufactured in England in 1838 Vide F. W.

soldered, did not corrode like copper, and was easily joined by a bevel and ferrule, unlike the leaky screw-ferrules of copper pipe. It was also cheap, clean, and could be polished attractively. From 1818 Milne manufactured large quantities of the pipe, one-quarter to one and a half inches internal diameter.

J. Neilson recommended these tin pipes in 1825, but noted that most shops and factories used wrought-iron service pipes instead of copper. In 1819 Accum[1] maintained that copper and iron were far better than pewter, lead or tin service pipes because of the possibility of the pipe melting and causing a serious fire if any gas-leak was lighted. This happened on a block-tin pipe in the Royal Theatre at Glasgow[2] in 1849. The half-inch pipe melted and the entire gas-flow burst out. Although quickly extinguished by a carpenter's "blue bonnet", the bright flare caused a stampede in which seventy people died. At that date, the relative costs of "composition tube" made of old lead, block tin tube, and wrought iron tube in Glasgow were in the ratio 2 : 3 : 4. Both lead and tin were used in situations where they were not suitable. Both were manufactured in Scotland as by Messrs. T.B. Campbell and Company of Leith[3] who by the 1860s were the principal lead company, drawing supplies

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Simms, Ed. Public Works of G.B. (1838) op. cit., Part III,p.23; D. Macfie "On the Control of Gas from Meter to Burner", lecture to the Registered Plumbers in Edinburgh, Gas World 30/1/1897 p. 167; G.P. Bevan, Ed., British Manufacturing Industries (1876) 2nd edn. p. 168

1. F. Accum, Gas Works in London (1820) op. cit., pp. 260-1.

2. The Builder, 1849 Vol. III p. 97

3. D. Bremner, The Industries of Scotland (1869, Edinburgh) p. 140 For meters, vide infra 'Use of Gas' pp. 1226 et seq

from Leadhills and Wanlockhead mines. Gas companies[1] normally tested all pipes before fitting them, but were often able to hire test-equipment and thereby reduce capital expenditure.

Within the gasworks, cast-iron retorts were an expensive aspect of early working costs because they corroded rapidly at high temperatures[2] or cracked in half when cooling because of the slower rate of contraction of thick inner carbon coatings.[3] Even in the 1870s, when their cost had been reduced to £6 or £7 per ton, iron retorts lasted only eight or nine months, equivalent to 6d or 7d per 1,000 cu ft of gas sold.[4] Clay retorts were only one-sixth as expensive, and their widespread adoption was an important stimulus to the Scottish gas industry. The problems with iron retorts led John Grafton[5]

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1. e.g. Dunfermline company purchased a testing pump, and in 1830 loaned it for one year to the new Kirkcaldy gas company for £10. Stewarton gasworks paid £1 10s to Dalry in 1835 for the temporary use of their pipe-testing machine, and similar loans were probably common. Bo'ness in 1845 purchased a separate air-pump from Messrs Laidlaw to test fittings; Dunfermline Minute Book <u>op</u>. <u>cit</u>., 24/5/1830 Dalry Minute Book <u>op</u>. <u>cit</u>., 10/1/1835; Bo'ness Minute Book <u>op</u>. <u>cit</u> 24/1/1845.

2. Cast iron retorts at maximum 760°C gave 8,000 cu ft gas from one ton of best cannel coal; Grafton's fire-brick ovens in 1820s at 1000 to 1200°C gave up to 9,500 cu ft gas; fireclay horizontal retorts were slowly improved to give up to 10,500 cu ft per ton of coal. <u>Notebook for Gas Engineers and Students</u>, J. Terrance Ed. (1948) p. 43 <u>et</u> <u>seq</u>.; <u>J.G.L</u>. 4/8/1874 pp. 155-6

3. The carbon represented a loss of gas, which formed a solid deposit as a result of local overheating. Iron retorts were also liable to form an outer carbide layer of insulation which wasted furnace heat, and if made of poor metal they sagged and by dislodging the heat-shield tiles over the fire could destroy an entire bench of retorts. To replace retorts, the brick 'oven' had to be dismantled and then rebuilt.

4. W. Richards, <u>Practical Treatise</u> (1877) <u>op</u>. <u>cit</u>., p. 90

5. <u>Ibid</u>., p. 85.
John Grafton was articled to Clegg when the latter joined the Chartered Gas Company in London. After Accum resigned in 1813, Grafton took charge of the Chartered Company's gasworks in Curtain Road, and erected extensions at the Peter Street gasworks in 1814. He left the company when his articles expired, and

to experiment with fire-clay while employed on the construction of Edinburgh gasworks. In 1818 he patented a system of double inclined-retorts, one for coal gas and one for tar-gas, in which a fire-clay lining was used to prevent carbon being deposited in the retort.[1] The outer iron casing was abandoned in 1820, when Grafton built rectangular retorts entirely of clay, in sections one foot long. These joined into an eight foot retort[2] which did not crack as easily as one-piece clay retorts, and distilled a charge of ten cwts coal for twenty-four hours. Any carbon deposits were simply burned out by allowing atmospheric air into the hot retort once a week.[3]

The new Edinburgh company was unwilling to try this radical

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may originally have come from the Manchester area from which Clegg brought several workmen, presumably with experience of private gasworks, to London.
S. Everard, History of the Gas, Light and Coke Company 1812-1949 (1949), pp. 84, 128, 116.
Gas World 1886 "Retorts and Retort Houses" pp. 650, 522.
Vide infra, Chapter II pp. 104, 280

Grafton produced many technical improvements for gas manufacture:-

1818 fireclay lining of retorts (Pat. 4306);
1820 retorts entirely of fireclay (Pat. 4409);
1819 purifiers of lime and potash (Pat. 4483);
1838 wagon for mechanical charging of retorts (Pat.7788);
1841 double retorts of fire-brick in one oven (Pat.9062)

In 1823 his clay retorts obtained the influential support of Congreve.

B.P.P. 1823 (193) V 303 p. 16 (320)

1. Each retort had a separate furnace, and Grafton's method arose from his view that hot iron was causing carbon deposits by reacting chemically with the coal.

2. The interior space was 6 feet by 20 inches, by 9 inches high.

3. Grafton's ideas were one aspect of an intensive search for cheaper gas production, especially by reduction in coal consumption. During 1819-23 the first serious attempts were made to replace coal furnace-fual by coke, which Croll of the Chartered Company was first to burn while still hot from the retorts. Reduction of fuel costs was the chief inspiration for multiple-retort ovens, and the use of tar fuel in Scotland.
F. Accum Description of the Process of Manufacturing Coal Gas(1819)p.60
T.S. Peckston Theory and Practise (1823) 2nd Edn. pp. 110, 127-30
S. Clegg jn. Practical Treatise on Coal Gas (1841) p. 74

design, but Grafton persuaded several English gasworks[1] to experiment with it. Plagiarists[2] soon introduced similar clay retorts, but they were not popular, and Clegg later claimed that workmen had deliberately sabotaged Grafton's retorts.[3] They were reintroduced into Scotland about 1827, and after early successes at the gasworks of Kirkcaldy, Dunfermline and Stirling[4] were adopted by the large Edin-

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1. Grafton's retorts were tried in 1822 at Messrs Butchers in Wolverhampton; in 1824 at Cambridge, and 1825 at Wolverhampton Gasworks, followed by Halifax, and Blackfriars in London. Different designs evolved, from square retorts holding 5 cwts to D-shaped retorts holding 12 cwts. Clegg claims incorrectly the first large scale trial was not until 1839, at Cambridge.
   The 1820 retorts were D-shaped, 7 feet long, 5 feet wide and 1½ feet high, and carbonized 7 cwts in 6-hour charges, or five times the amount held in small D-shaped retorts. S. Hughes (1853) Practical Treatise, op. cit., p. 78; S. Everard, Gas, Light and Coke Company (1949) op. cit., p. 84; S. Clegg, A Practical Treatise, (1853) op. cit., pp. 141-2; W. Richards, Practical Treatise (1877) pp. 91-2.

2. In 1823 John Malam tried flattened D-shaped retorts made of clay, red lead and 'firestone', baked in situ. Mr Herst of Leeds in 1826 made the first cylindrical clay retorts, 8 feet long and 12 inches in diameter, in 4-foot sections. Alexander Gordon used bricks and Stourbridge clay for experimental retorts at Manchester in 1826, and during the following year David Gordon used clay retorts for his experiments on compressed gas.
   Vide infra 'Oil Gas' p. 428
   "On the Results of the Use of Clay in Gas Making" Institute of Civil Engineers 1857 Vol. XVL; Gas World 1886 p. 651; J.G.L. 4/8/1874 p. 155.

3. Six large Grafton ovens in London, and two at Montpelier suffered this fate, possibly because stokers objected to the higher operating temperatures. "Grafton's Earthen Gas Retorts" Mechanics Magazine 1842 Vol. 36, pp. 466-7.

4. W. Richards, Practical Treatise (1877) op. cit., pp. 90-94.
   Perth gasworks may have been the first in Scotland to use clay retorts. (Vide infra pp. 162, 413, 541). After difficulties in disposing of tar, the company tried using it in the furnace, but in the winter 1828/9 intense heat destroyed iron retorts despite fire-brick shields. On the advice of Mr McVicar of Inverkeithing, clay retorts were successfully adopted.

   J. Reid (Perth) "Gas Lighting Past and Present" Gas and Water 1885 p. 482

   In 1824 the original half-moon retort house at Perth held 12 cast-iron retorts with their mouths facing inwards. That year only two of the retorts were in use, consuming 12s6d coal per day to supply 965 lights. Evidence of A. Anderson. Digest of Evidence Taken Before a Committee of the House of Commons on the London and Westminster Oil Gas Bill (1824) Part II p. 90 Institute of Gas Engineers Lib.

Fig. 3. 24

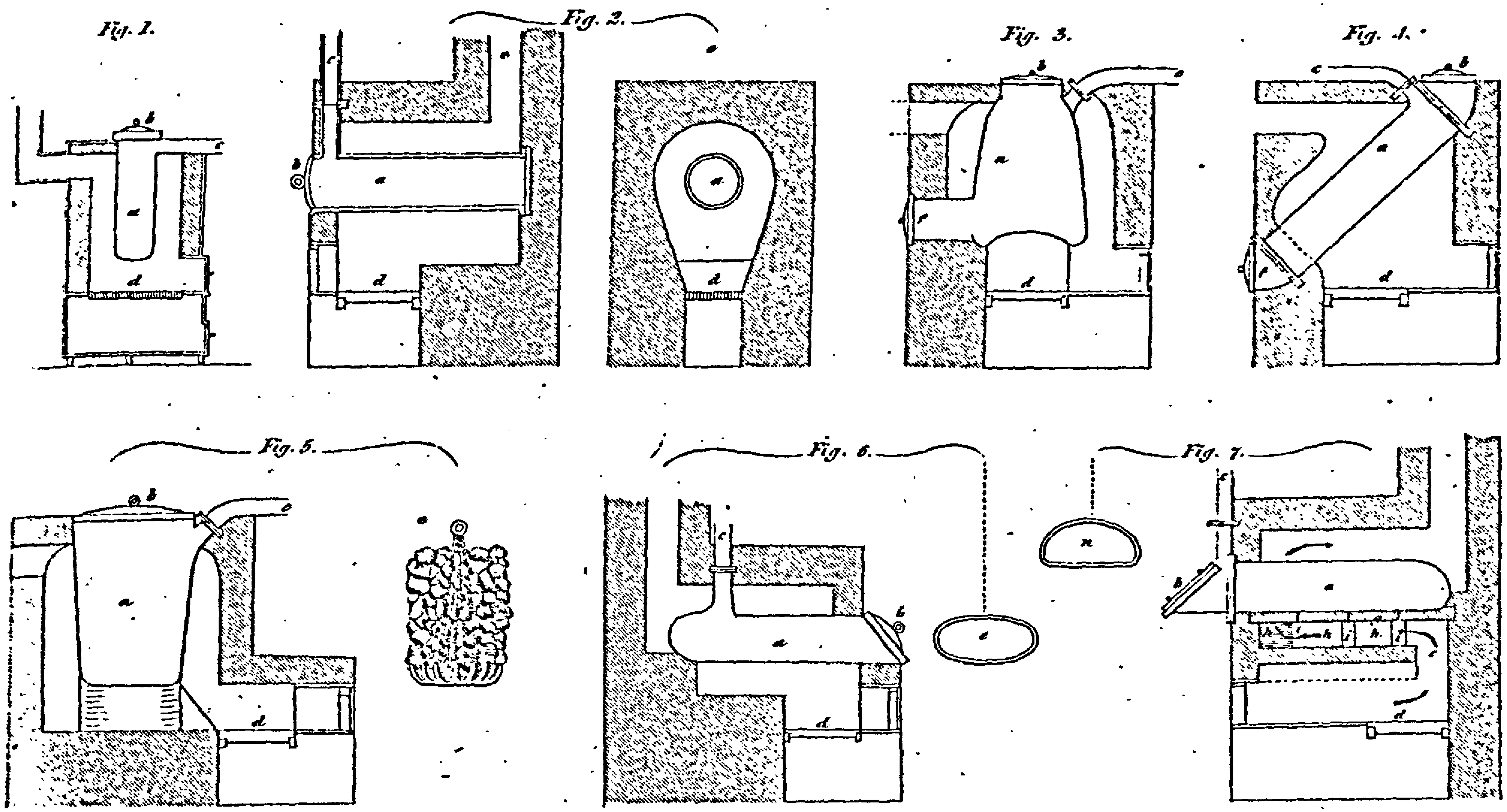
Early Retort Designs by William Murdoch at Soho

Early Retort Designs by William Murdoch at Soho

1. Earliest cylindrical cast-iron retort (a) in portable furnace (d), with a gas outlet (c) and gas-tight luted-lid (e). Filled two thirds full of coal; difficult to remove coke.
2. Improved design of 1802 - horizontal retort; fixed 'oven'; ascension pipe (C) for gas. Direct-firing from furnace (d); retorts 1 to 12 inches diameter, 3 to 7 feet long.
3. Vertical retort with gravity coal-inlet (b) and basal coke outlet (f). Used c.1804
4. Inclined retort, of similar design; used c.1805. Not commercially developed until 1880s. Used at Granton gasworks, Edinburgh.
5. Vertical retorts with iron cage (e) to hold 15 cwt. charge of coal, and to discharge coke by crane. Similar to installation for Messrs Phillip and Lee, Manchester.
6. Horizontal retort with eliptical cross-section (believed to raise yield 30 per cent), as adopted by Westminster Gas Company by 1824.
7. Horizontal iron retorts preserved from direct heat corrosion by fire-bricks along base, supported by vertical bricks (i) set on an arch over the fireplace.

Source - Encyclopaedia Britannica, Supplement to the 4th, 5th, and 6th Editions Vol 4
EDI - EDG (1824) pp. 448-462
T. Glover 'The Retorting or Carbonization of Coal'
The Institute of Gas Engineers Transactions 1906

Fig. 3.24
Early Retort Designs by William Murdoch at Soho



Source - Encyclopaedia Britannica Supplement 1824 op cit (Plate LXXXI)

Fig. 3. 25

Early Retort Designs and Gas Pressure-Governor

Early Retort Designs

8. Improved flue arrangement for heating horizontal retort. Flames from furnace (d) traversed flues (f) to reach chimney. Vertical gas 'ascension-pipe' at front of retort, outside oven, to reduce choking by tar. System "extensively used since the year 1808 in northern manufacturing districts of England, and in Scotland;" c.f. London gasworks used retorts like No.2, protected by a curved iron base-plate. Retorts 8 and 7 held 1 cwt. coal, produced 100 to 150 cu.ft. gas per hour. With 6 charges in 24 hours, retorts lasted 9 to 12 months.

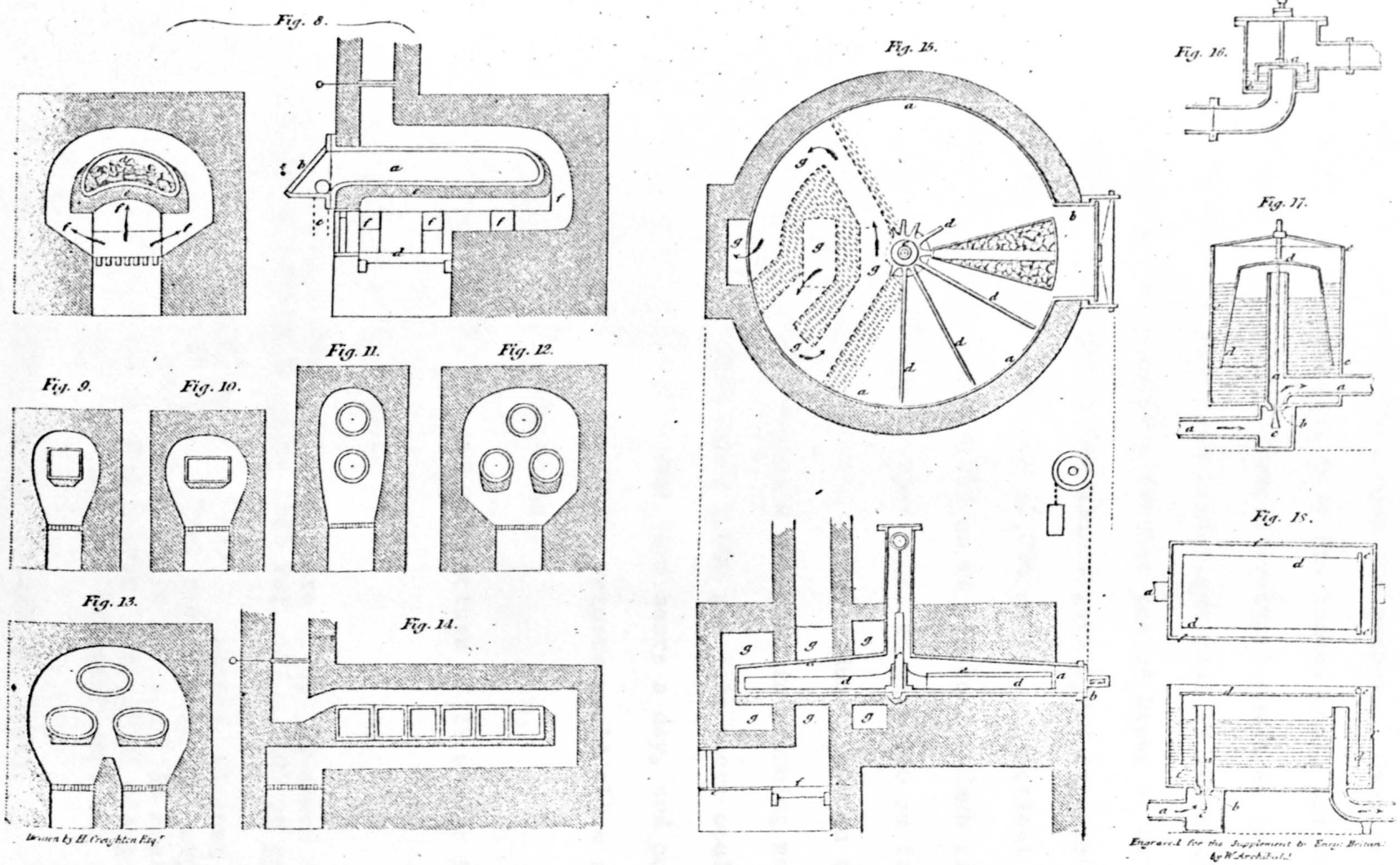
9,10, Rectangular and square cross-section of retorts used at some gasworks in 1820s.

11 - 14 Settings of multiple retorts in a single oven. Early experimental designs ; unsuccessful because one repair involved the closure of the entire oven. Two furnaces for one oven shown in No. 13.

Source - Encyclopaedia Britannica, Supplement to the 4th, 5th, and 6th Editions Vol 4 EDI - EDQ (1824) pp. 448 - 462

Fig. 3.25

Early Retort Designs and Gas Pressure Governor



Note - 15 Clegg's Rotary Retort using thin layer carbonization as devised by J. Maiben of Perth.
16 Stop-cock 17 Pressure governor

Source - Encyclopaedia Britannica Supplement 1824 op cit (Plate LXXXI) burgh and Leith Gas Company thereby achieving publicity and respectability.

Meanwhile at Glasgow, J.B. Neilson[1] believed that the shape of the iron retort had a great effect upon gas output. Oval retorts holding 'charges' of 150 lbs were best for cannel coal, but smaller round retorts were required for 'Newcastle-type' coals as sold by Lord Elgin. Glasgow in 1825 used Lesmahagow coal at 16s a ton, and each ton carbonized required a further ton of Dross at 4s to fire the furnaces. 200 lbs of Lesmahagow gave 1,080 experimentally, and one ton could produce a maximum 12,096 cu ft. Practical results were less spectacular, at about 8,960 cu ft per ton. Each 150 lbs 'charge of coal was distilled for four hours to give 600 cu ft gas, and with six charges a day one retort could produce 3,600 cu ft, or 25,200 cu ft per week. This estimate was used in planning new gasworks. Neilson advised Dundee that 5,000 gas jets there would on average consume one cu ft an hour for five hours a day, and could be supplied by seven retorts, though twelve retorts would allow some reserve capacity to meet contingencies.

"The practical application and manufacture of fire-clay retorts

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1. John /sic/ Neilson, "On the Manufacture of Gas obtained from Coal" Glasgow Mechanics Magazine 1825 Vol. III p. 105 et seq.

Glasgow retorts in 1823 were  shaped, 4½ feet long, 2 feet wide and 10 inches high. They gave double the output of retorts in London which produced 3½ cu ft gas per 1 lb coal in 8 hours, compared to 4 cu ft in a 4-hour 'charge' at Glasgow (i.e. 8,960 cu ft per ton). Superior Scottish coal was the main reason for this.

A. Ure, A Dictionary of Chemistry (1823) pp. 343-5.

Fig. 3. 26 Discharging Horizontal Retorts

Left -
Coke raked from retort into iron shoot for gravity feed into internal 'producer' with minimal heat loss. Biggar Gasworks 1972

Below -
Coke raked into iron barrow prior to quenching, at Newton Stewart Gasworks, 1974. Note mouthpiece of retorts projecting beyond brick-work of oven; iron 'staging' floor gave workmen access to underground producer and flues.

had their origin in Scotland"[1] because of special clay deposits.[2] William Fraser was the chief manufacturer to promote their use, from his Fire Clay Works[3] at Inverkeithing, and his success made this the most important centre throughout the century. Edinburgh and Leith company used his retorts exclusively from 1830-40, while his nine foot retorts built in two sections at Stirling gasworks lasted four to six years each.[4] They were also used in private

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1. Mr Lowe, of Brick Lane works in London, had to visit Scottish works to observe clay retorts in use, in 1843. During the following year, the Chartered Company of London purchased 'Newcastle retorts' of fireclay from Messrs Cowan of Blayden Burn, but experiments with them by A.A. Croll at Brick Lane proved a total failure which subsequently inhibited other English companies from experimenting. Mr Livesey (1807-1871) of the South Metropolitan Co. was the first to succeed with them in London in 1850. Two years later, Birmingham gasworks published the results of their trials with clay retorts which had reduced expenditure by 82 per cent over ten years, from £5,391 to £958. A determined campaign by Livesey and the Journal of Gas Lighting was still necessary in the 1860s, however, to persuade other English companies of the advantages.
   J.G.L. 4/8/1874, p. 155; King's Treatise (1878) Vol. I op. cit p. 47; E.A. Parnell, Applied Chemistry (1844) op. cit., Vol. I, p. 67; S. Everard, Gas, Light and Coke Company (1949) op. cit., p. 88; W. Richards, Practical Treatise (1877) op. cit., pp. 32, 93; J.E. Clift (d. 1875) (Birmingham) "On Improved Fire Brick Gas Retorts" Proc. Institute of Mechanical Engineers 1852 pp. 178-85.

2. J.G.L., 7/7/1874 p. 11

3. William Fraser of Inverkeithing (1813-1877), son of Rev. W. Fraser of Alloa. Trained as solicitor in Edinburgh and Cupar: for 38 years Town Clerk of Inverkeithing: founded local bank, a branch of Eastern Bank of Dundee: a leading partner in Halbeath Coal Co. which owned large brickworks: Agent for Kirkness gas coal in the 1850s. J.G.L. 13/3/1877 p. 390; Cupar Minute Book op. cit., 13/8/1857.

4. J.Z. Kay used Fraser's retorts in both the Dundee gas companies which he superintended. Inverkeithing retorts were also exported to England. R. Douglas first used them while Manager of Cupar gasworks, about 1837, but for ten years as manager of the Bankside and Vauxhall gasworks of the Phoenix Company in London he again installed them. Portsea Island gasworks used them in 1864-7. W. Fraser advertized that "fire-clay retorts were first made at his works". He supplied retorts to Douglas, Isle of Man, from 1864, and to Hambro Gaslight Assn. from 1866.
   Inverkeithing clay also produced a better quality of fire-bricks

gasworks, as at Auchmuty and Rothes paper-mills in 1846-66, and Prinlaws Mills 1861-6.

In 1832, A. Burgess introduced clay retorts at Edinburgh gas-light company,[1] where they entirely superseded iron by 1838. The sixty-four retorts at Aberdeen[2] in 1839 were a variety of cylindrical iron retorts, and eliptical or D- shaped "fire-brick" retorts. In 1839 Dunfermline gasworks[3] had twenty-eight iron retorts when experiments were made with clay retorts. Ten clay retorts cost

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than that of Musselburgh and Portobello, and superseded those sources for gas companies like Dalkeith in 1832. Newbigging and Fewtrell appear to be inaccurate in stating that W. Fraser made the first clay retorts in Scotland about 1816-20. They also claim that he did not produce oval or D-shaped retorts until 1834. Samuel Smiles stated that J.B. Neilson at Glasgow was the first to use clay retorts but this cannot be substantiated. King's Treatise 1878 Vol I op. cit., p. 54; Dalkeith Minute Book op. cit., 15/6/1832; J.G.L. 22/12/1868 p. 913; A. Clow, "Scotland's Contribution to Industrial Development" (1944) op. cit., p. 64; S. Smiles, Industrial Biography (1868), p. 152.

1. Gas World 10/7/1886 p. 42.
2. New Statistical Account Vol. XII, pp. 78-9.
3. Fraser and Sanderson charged £2 to £3 per retort, according to sizes and used the annual costs of retorts from Dunfermline gasworks on their advertisement:-

Date		Expenditure	Date	Expenditure
1835	Iron Retorts	£161	1840	£20
1836	"	£155	1841	£29
1837	"	£168	1842	£23
1838	Iron and Clay Retorts	£137	1843	£24
			1844	£19
1839	"	£82	1845	£15

J.G.L. 10/8/1849 p. 100; 10/9/1849 pp. 60, 68.

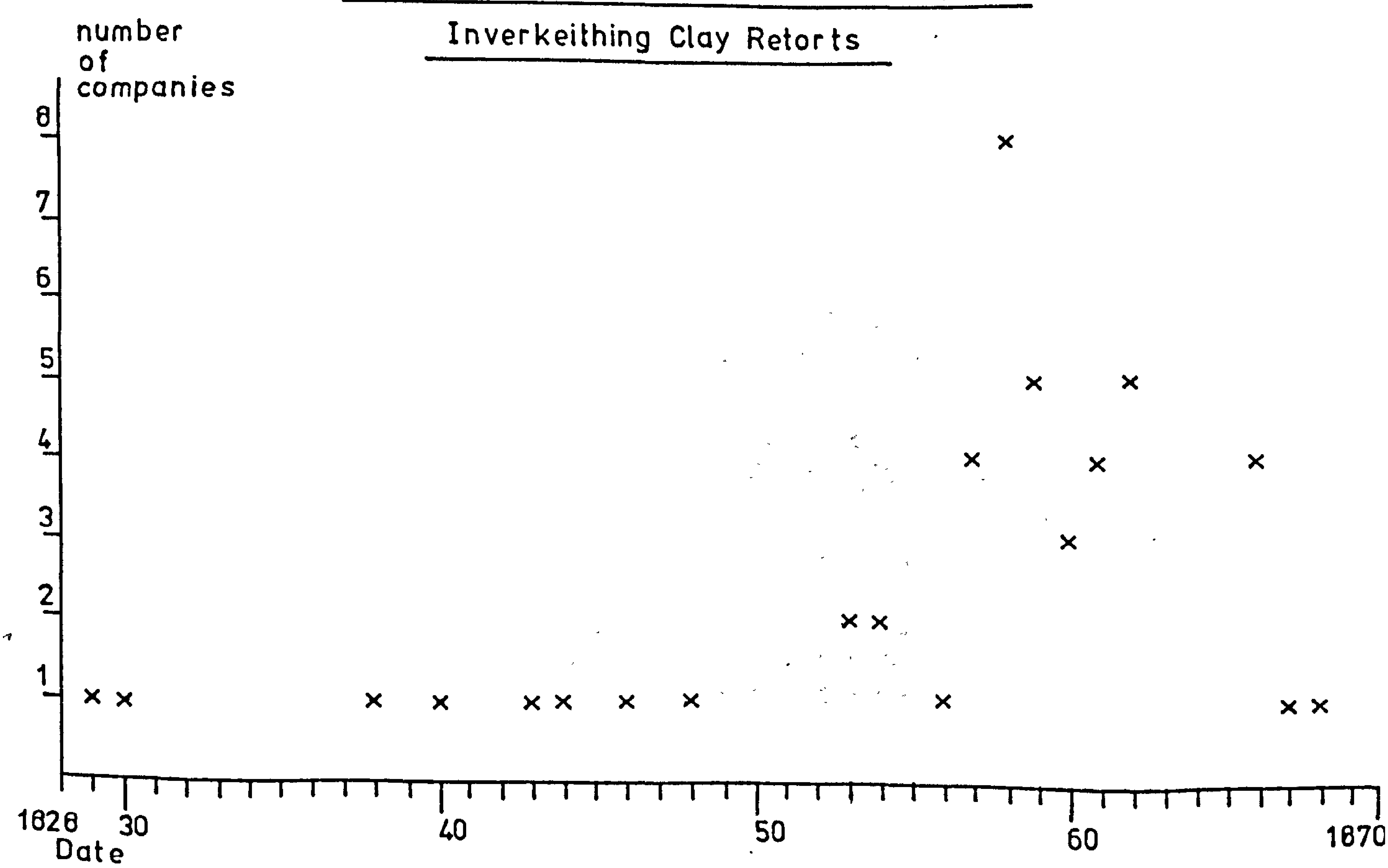
Tar-fired furnaces which stimulated the adoption of clay retorts (infra pp. 282,298,299) remained unpopular in London until the late 1830s and were probably devised by J.B. Neilson at Glasgow in 1826. Vide infra pp. 546, 597
S. Clegg jn. Practical Treatise on Coal Gas (1841) p. 74

Table 3. 27 Dates when Gas Companies adopted Inverkeithing Clay Retorts

Company	Date	Company	Date	Company	Date
Abernethy	1866	Dunfermline	1829	Kirkcaldy	1843
Alyth	1862	Dumfries	1867	Kirriemuir	1854
Auchterarder	1860	Dalkeith	1844	Linlithgow	1857
Auchtermuchty	1858	Edinburgh/Leith	1830	Leslie	1848
Anstruther	1858	Errol	1866	Leuchars	1866
Bridge of Allan	1857	Eyemouth	1862	Leven	1858
Banff	1857	Falkirk	1856	Markinch	1859
Blairgowrie	1858	Falkirk Joint Stock	1862	Montrose	1853
Bo'ness	1858			Newburgh	1862
Brechin	1858	Forfar	1854	Nairn	1866
Broughty Ferry	1861	Ferryport	1861	Perth	1840
Burntisland	1859	Falkland	1858	Perth New	1860
Cupar	1838	Inverness	1859	Stranraer	1859
Coupar Angus	1860	Kennoway	1868	Strathmiglo	1859
Crieff	1857	Kettle	1862	Stirling	1846
Deanston	1858	Kinross/Milnathort	1853	Thurso	1861
		Kincardine	1861	Tullibody	1859

SOURCE: J.G.L. 22/12/1868
Retorts by Messers Fraser and Sanderson.

Numbers of Companies which adopted Inverkeithing Clay Retorts



£19 5s 7d and produced 7.5 million cu ft gas per year. Eighteen iron retorts cost £161 5s 6d and produced 5.104 million cu ft per year. Earlier in 1836 when the annual output was only 7.244 million cu ft, all eighteen iron retorts had cost £167 17s 9d excluding the fire-clay tiles used to provide protection from the direct furnace heat. By 1844 the iron retorts were kept simply as a reserve.

Fraser[1] himself stated that most Scottish gasworks changed to clay retorts in 1830-50. He maintained that because cannel coal, especially from Torbanehill and Kirkness, produced such poor coke that it had to be mixed with coal for firing the furnaces, the profitability of many small gas companies was entirely due to the cheapness of clay retorts.

Cupar gasworks used iron retorts[2] in 1839, but in 1843 experimented with two of clay from Inverkeithing, and others from James Cowan and company of Newcastle-on-Tyne.[3] By 1845 clay retorts were in regular use. Bo'ness first ordered clay retorts from Fraser and Sanderson in 1844, but they arrived damaged and when Fraser's local agent refused to finance a trial, alternative clay retorts were

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1. Evidence of Mr Fraser following a paper by J. Church, in Institute of Civil Engineers 1857 Vol. XVL 3/3/1857.
   Larger gasworks reduced the annual cost of renewing retorts from £120 or £160 to £23 by using clay.

3. Newbigging dates J. Cowan's first retorts of Newcastle or Stourbridge clay a year later in 1844. King's Treatise (1878) Vol. I op. cit. p. 54

2. Cupar Minute Book op cit. 9/7/1839, 2/10/1843, 12/12/1843, 12/8/1845.
   The four iron retorts from Shotts in 1839 were placed in an unusual bench, "two of them to be upright and the other two to be laid on their side, according to the former practice".

ordered from the rival company established at Garnkirk.[1] Arran gasworks[2] did not adopt clay until 1858. Bathgate[3] still used iron in 1853, but Stornoway[4] in 1852 tried a clay retort from Newcastle-on-Tyne, besides an iron retort from Glasgow. Several works, like Stranraer[5] in 1845, adopted clay retorts but retained a single iron retort for the slack summer season, since it required less furnace fuel to maintain minimal output.

Because of the predominance of small gasworks, Scottish engineers, with the exception of Maiben[6] were not in the forefront of retort-bench[7] improvements. The equal heating of retorts throughout their length was important for efficient gas-production, and

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1. Bo'ness Minute Book op. cit., 7/12/1844, 12/12/1844.
   Clay retort manufacture remained concentrated in four areas of Scotland throughout the nineteenth century - around Dunfermline at Lilliehill, Inverkeithing and Townhill; around Kilmarnock at Hurlford, Dreghorn and Bonnyton; in the New Monkland area at Glenboig; and around Portobello.
   Fulton's Commercial Directory of Scotland (1887) pp. 526, 372; Worrall's Directory of the North Eastern Counties of Scotland (1877, Oldham) - supplement pp. 41, 49, 53; N.B.A.G.M., 1904 p. iii.

2. Arran Minute Book op. cit. 27/8/1847, 23/8/1858. Arran company directors suggested the use of clay retorts in 1847, when the Provost collected detailed information.

3. Bathgate Minute Book op. cit., 5/5/1852, 25/5/1853.
   Iron retorts from Hamilton Foundry Co., and Shotts Iron Co.

4. Stornoway Minute Book op. cit., 27/4/1852

5. Stranraer Minute Book 6/3/1845, 29/7/1845, 15/3/1847.
   In 1845 Stranraer purchased two clay retorts from both Garnkirk and from Fraser and Sanderson.

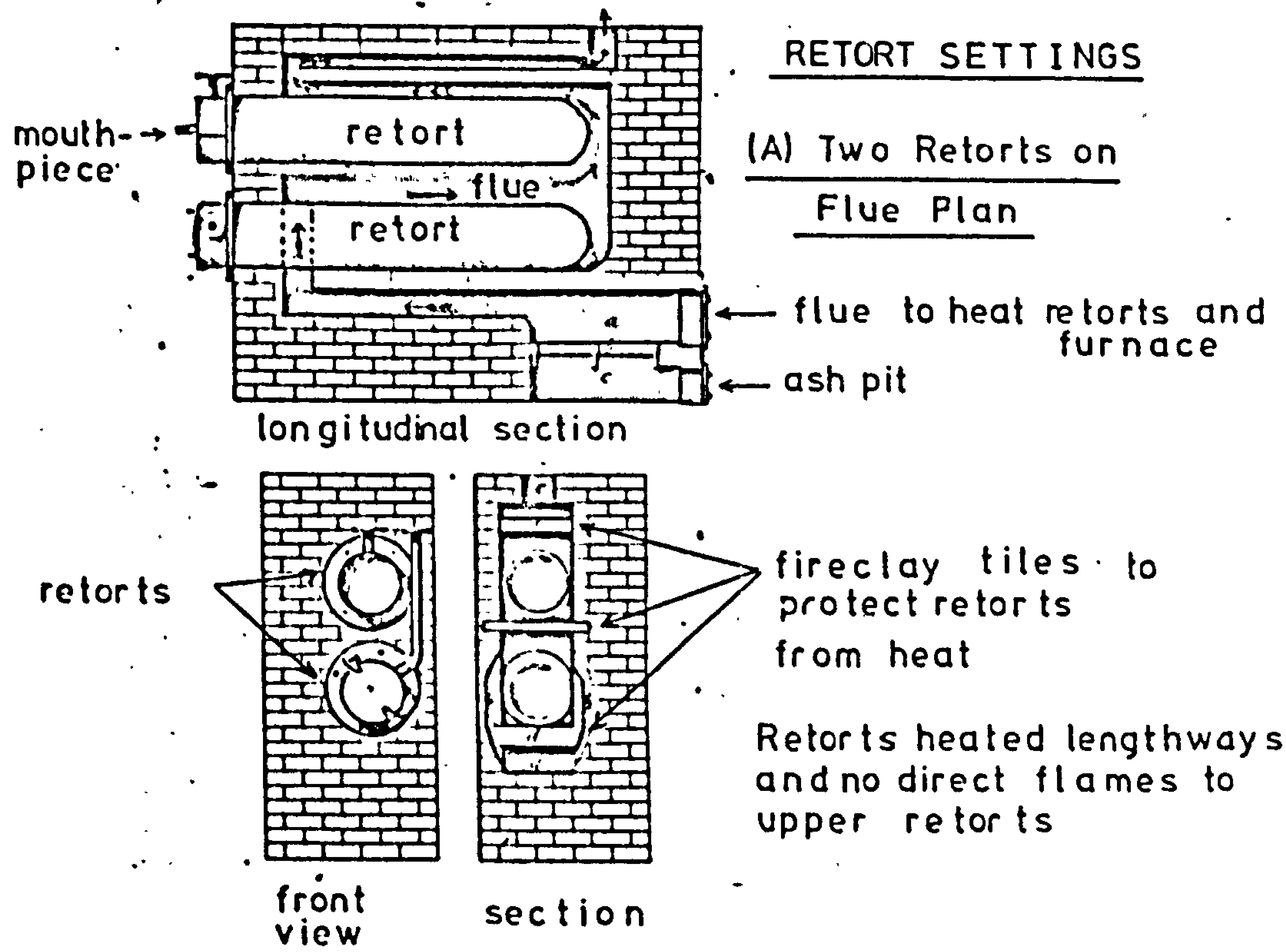
6. Vide infra Chapter I p.67 et seq

7. 'Bench' and 'setting' were alternative descriptions of the 'oven' design used to position retorts above the furnace. A 'Bench' comprised one or several adjoining 'ovens'.
   King's Treatise (1878) Vol. I p. 176.

Fig. 3.28

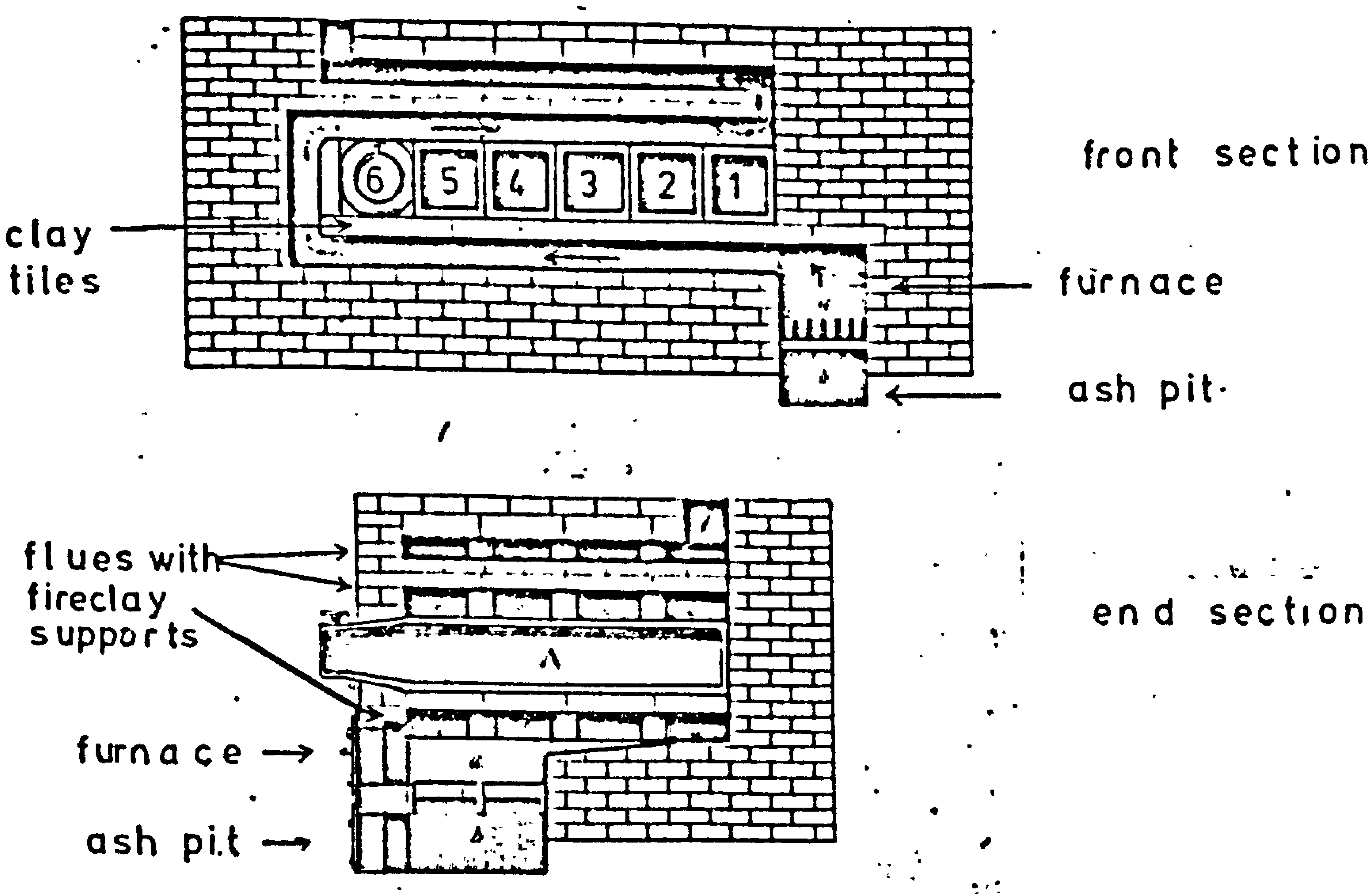
RETORT SETTINGS

(A) Two Retorts on Flue Plan



Retorts heated lengthways and no direct flames to upper retorts

(B) Six Retorts in Series - Direct Fire Plan



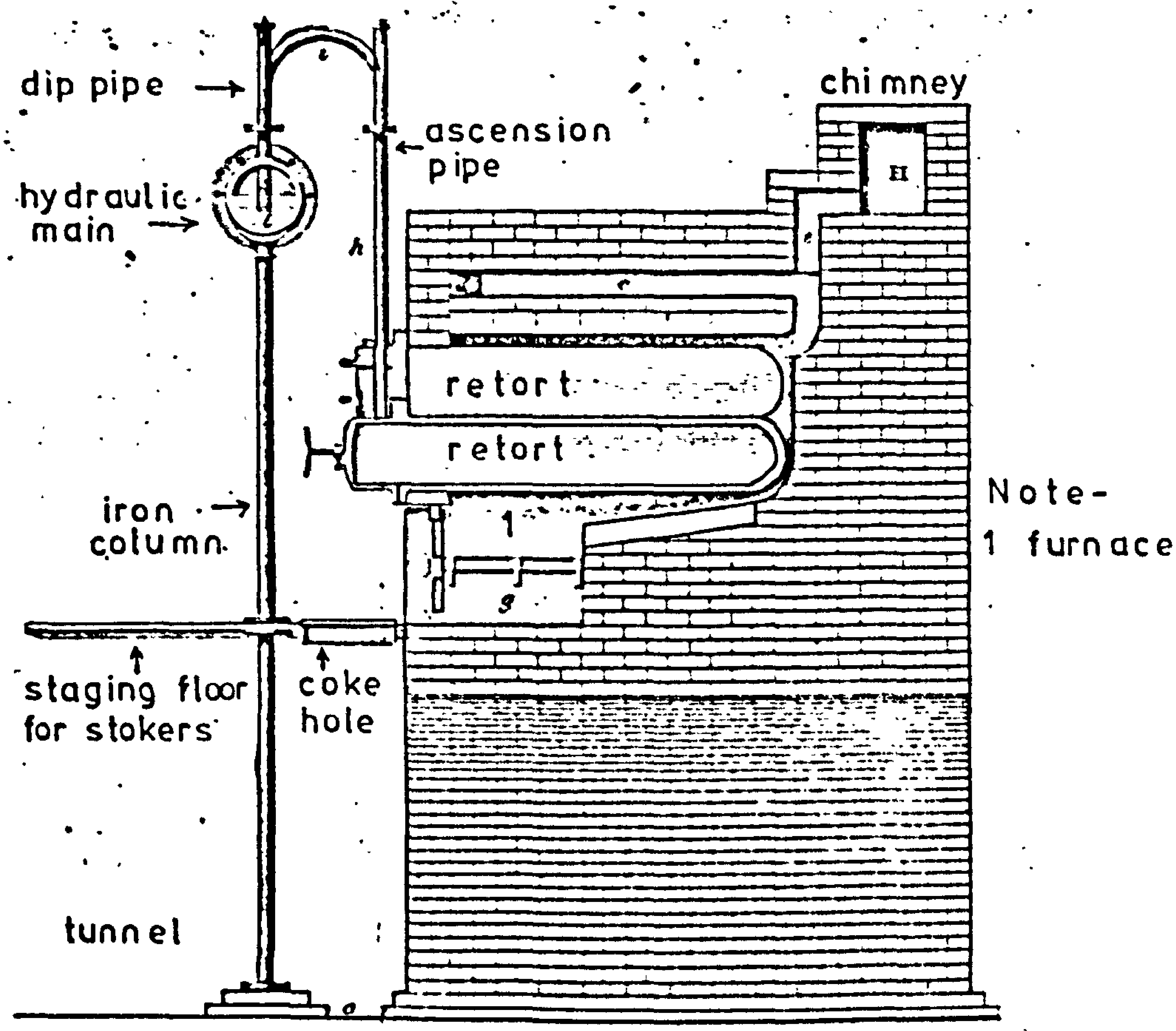
Retorts heated sideways with direct flames along base of all.
Uneven heating - (1) too hot; (6) cool

Source - T.S. Peckston <u>Theory and Practice</u> (1819)

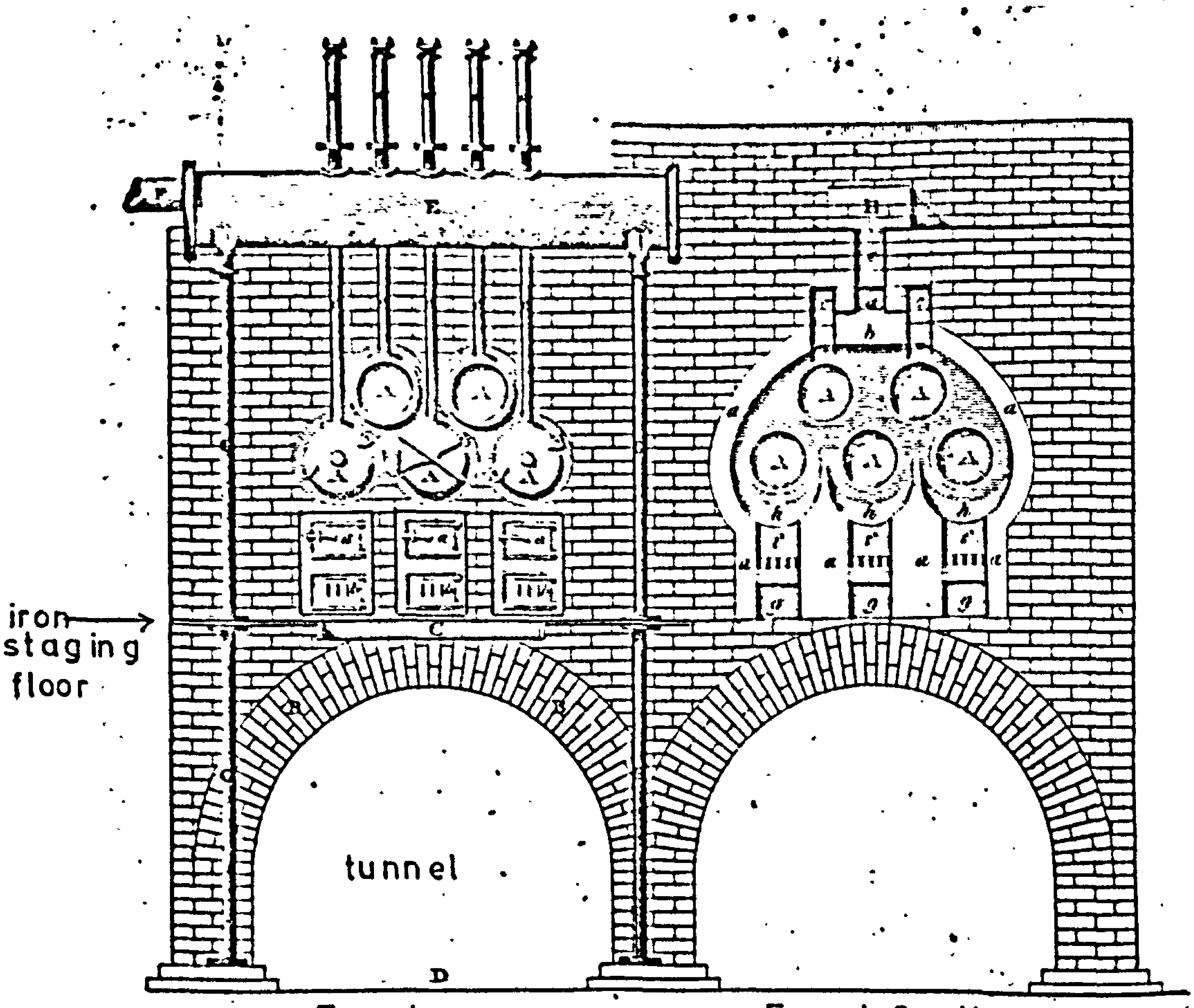
Fig. 3.29

RETORT SETTINGS

FIVE CYLINDRICAL RETORTS AND THREE FURNACES PER OVEN.



Side Section



Front   Front Section

Upper retorts supported by brick arch (b); others held by cast-iron framework.

Source- T.S.Peckston   Theory and Practice (1819) was most easily achieved by 'direct-heating' with one furnace fire beneath one retort in an 'oven'. This was the normal method in Scotland during the 1820s and 1830s, but it caused heavy fuel consumption in the furnaces. Large gas companies in London made the earliest attempts to reduce fuel by placing several retorts together in one oven. In 1819 many London furnaces consumed twenty per cent as much fuel as the coal actually being distilled, and when three retorts were first placed in one oven, the furnace heat became "insupportable to the stokers" in summer.[1] Improved designs reduced this problem, and four retorts were placed in the oven, but 'direct-firing' or the 'flue-plan' was still used in which the fire played directly against the base of all the retorts and then above them while travelling to the chimney. Heating was uneven on the different retorts, and many melted. Often an oven was kept in use with only two functional retorts, because replacement work took a week to dismantle the brick 'bench', during which time neighbouring ovens on either side could not be used.

The "oven plan" was introduced by A. Rackhouse[2] in 1817, with five retorts set above three fires in one oven, but arranged with fire-bricks so that the hot air and not the flames of the fire produced an even heating of all the retorts. By 1819 it was the normal retort arrangement in London, but Scottish gasworks were quite

1. T.S. Peckston, Theory and Practice (1819) op. cit., pp. 110-2, 116.

2. Later that year Mr. Perks, of the City of London Gas Company, arranged thirteen retorts over one fire. John Malam produced an independent but very similar design to that of Rackhouse. W. Mathews, Compendium of Gas Lighting (1832) op. cit., p. 16.

Fig. 3.30 Quenching Coke at Biggar Gasworks (1972)

Above - Burning coke brought from horizontal retorts, where it ignited as soon as atmospheric air was allowed into the retorts during discharging.

Left - Quenching with a simple water spray. Larger gasworks had automatic quenching, usually by means of gravity shoots from the retorts into water troughs from which conveyor belts transferred cold coke to a storehouse.

reluctant to adopt ovens with multiple retorts.[1] Two factors inhibited them, the poor quality of coke[2] from Scottish cannel which gave inadequate heat for several retorts, and the small size of gasworks. Hamilton[3] Old gas company, for example, had one retort per oven in 1846, because when demand for gas was reduced in Spring, one oven at a time could be taken out of service to minimize excess production. Gasholder storage facilities were inadequate for an oven of several retorts to stop or start when consumption changed very gradually.

This tradition persisted even when tar was used as furnace fuel, because of difficulties in disposing of it. Dunfermline installed equipment[4] for burning tar in 1829, whilst at Aberdeen in 1839 some

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1. English gasworks in the 1830s rarely used more than five retorts in one oven with two furnaces, and were strongly accused of conservatism and of wastage equivalent to 25 per cent of output. They had failed to reduce the price of gas, and made the 1810s machinery "more picturesque" but it was not scientifically improved. Back-pressure was excessive, and companies prevented engineers from making improvements which would outdate existing equipment. D. Macrae (Vauxhall) "On the Machinery Employed in the Manufacture of Illuminating Gas", Mechanics Magazine 1839 Vol 31 pp. 5-8; P. Pindar, "Improvements in Gas Manufacture - Retort Setting", Mechanics Magazine 1837-8 Vol. 28 pp. 99, 120, 218, 402.

2. In 1853 English gasworks carbonizing Newcastle coal, used ¼ of the resulting coke as furnace fuel, and in London the average was ⅓ of the coke. But even in the 1870s, many Scottish and northern English gasworks carbonizing cannel coal used all of the coke for furnaces plus some furnace coal. Hence the importance of 'regenerative' furnaces in the 1880s. S. Hughes, Treatise on Gasworks (1853) op. cit., p. 107; W. Richards, Practical Treatise (1877) op. cit., p. 73.

3. Evidence of G. Miller, House of Commons M.S.S. 1846 Vol. 102. Committee on Hamilton New Gas Co. Elsewhere ovens with up to three retorts were gradually accepted, as at Dalkeith in 1828, and Annan in 1839. Bo'ness in 1850 had one oven of three retorts, a second being converted from two iron to three clay retorts, and a third containing a single iron retort which was held in reserve. Dalkeith Minute Book op. cit. 24/3/1828; Bo'ness Minute Book op cit., 5/4/1849, 27/6/1850, 4/8/1853; Annan Minute Book op. cit., 8/11/1839, 29/9/1839.

4. Dunfermline Minute Book op. cit., 6/8/1829. Glasgow used a

furnaces used coke and coal but most were heated by tar.[1] Dalkeith[2] company in 1842 was advised to install two tar furnaces, for £14 10s, as they could reduce solid fuel consumption up to forty per cent. In the 1840s experiments were made at Berwick on Tweed but the white heat produced by blowing tar into the furnace with a steam jet destroyed the retorts. It did, however, give considerable saving on fuel[3] and labour costs which Scottish gas companies with more durable clay retorts were in a better position to benefit from. W. Kemp at Galashiels gasworks achieved most publicity. Until 1848 he used a force-pump[4] to inject warm tar, but clinkering and destruction of furnace bars was excessive. Kemp[5] then used exhausted bark from a tanning works, mixed with an equal quantity of coke and doused with tar. Combustion was greatly improved, and peat-moss could also be used, giving an annual saving of £126 on furnace coal at Galashiels. Elsewhere a modification of the furnace door allowed a special compartment for burning a trickle of tar in the furnace.[6]

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mixture of tar and coke in the furnaces during the 1820s and early 1830s. J. Cleland, City of Glasgow Statistics (1832, Glasgow) p. 142.

1. New Statistical Account 1939 Vol. XII p.78
2. Advised by Mark Taylor, engineer of Edinburgh gas company; Dalkeith Minute Book op. cit., 24/6/1842
3. In 1877 Richards described tar-burning furnace fed directly from the hydraulic main, for use during slumps in tar prices. W. Richards, Practical Treatise (1877) op. cit., pp. 73, 75.
4. S. Clegg, A Practical Treatise 1853 op. cit. p. 124
5. W. Kemp, "On Economizing Fuel in Gas Works" Civil Engineer and Architect's Journal May 1848, p. 155.
6. Scottish works like Portobello in 1886, readopted tar-injection firing whenever tar prices fell. Portobello used 18 to 33 gallons of tar per ton of coal carbonized, and reduced fuel expenditure by 2s 8d per day. Dumfries works in 1886 found coke fuel alone cost 9s 8d a day, but tar and coke 6s 8d. J.G.L. 18/5/1886; 10/5/1850 p. 209; N.B.A.G.M. 1887 C. Waterston (Portobello) "Notes on Tar as Fuel".

Section of Retort Bench at Glasgow c1840

Fig. 3.31

Note - 2 retorts per oven; at least 5 ovens in the 'bench'.

Source - Glasgow City Archives (D.G.E. 288)

Anonymous Scottish gas managers plied early editions of the Journal of Gas Lighting, from 1849, with praise of clay retorts. One works[1] which changed from iron to clay in 1842 was pleased with D-shaped 7½ foot clay retorts for lasting forty to forty-five or even seventy-four weeks in ovens of three. This was hardly a record, and obviously iron retorts had required replacement several times each year. The clay retorts were heated more evenly than iron, thereby reducing manual error and allowing greater use of cheap dross and coal-tar in the furnaces. They did not become covered with an insulating layer of iron oxides, and the three produced about 95,000 cu ft per week. Another, a rural town "In the Lothians",[2] in 1850 served only 341 consumers[3] out of a population of 4,000, but almost half of the total consumption, 0.86 out of 1.76 million cu ft per year, was taken by these shops and houses in the winter months. These were the most difficult operating conditions for a gas company to face, and the gas price was high at 7s 11d per 1,000 cu. ft., but the company proved able to meet the entire demand from two 5½ foot long clay retorts.[4] Using tar and coke they ran at very high temperatures and gave 8,561 cu ft gas per ton of Arniston parrot coal.

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1. J.G.L. 11/2/1850 pp. 173-4. These were fitted in ovens of three; two retorts were D-shaped 15" wide and 14" high, and the top retort circular, 15½" diameter. Built in two sections, they had a moveable endpiece to allow for heat expansion.

2. J.G.L., 10/5/1850; Dr. Fyfe (Aberdeen) "On the Use of Clay and Iron Retorts" J.G.L. 10/6/1850

3. Of these, about ninety consumers used only 100 to 900 cu ft per Quarter Year.

4. Retorts 5½ ft long, 20" wide by 13" high. Each retort gave 4,725 cu ft gas per day from 11 cwt coal. This example was also quoted by S. Hughes, A Treatise on Gasworks (1853) op. cit. pp. 79-87.

In the 1850s, when clay retorts were increasingly popular in Scotland, Joseph Cowan and Company of Newcastle-on-Tyne began to increase competition for the market. They provided the 5½ foot retorts used most successfully by J. Robb at Haddington gasworks. With dry coal and uniform heating those two retorts gave 35,000 cu ft each per week, but to meet peak demand the daily output could be raised from 5,000 to 14,000 cu ft each, and Robb achieved much publicity for clay retorts.[1] Throughout the 1850s controversy raged between the supporters of iron retorts and those of clay,[2] but no empirical measurements were made of the influence of different heating arrangements within the 'oven' upon both types of retort.

Lack of standardization also hindered accurate comparisons, and the variety of retorts[3] actually increased up to the 1890s which

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1. Retorts 5½ feet long, 20" wide, 12" high; J.G.L. 10/3/1853, 11/4/1853

2. J. Paterson, "Rival Schools of Gas Manufacture" J.G.L. 10/10/1858

3. In 1877, W. Richards observed some Scottish gasworks with brick retorts, built in situ; but most had cylindrical clay retorts from 14 to 20 inches in diameter. Retorts which were oval, square with rounded corners, or squat and 27" x 13" down to 15" x 13", were also in use. Even in the 1890s, retorts were built by hand, around a frame, with only a small roll of clay added each day. The manufacturing season was February to August, with peak demand in June-July. Fireclay-manufacturer P. Hurll in 1894 recorded in Scotland 44 different sizes of D-retort, 12 of oval retorts, and 7 of round retorts, with 140 different 'mouthpieces' having various slots and bolt-holes. In contrast, railways and textile mills developed interchangeable parts in the 1840s-50s.
   W. Richards, Practical Treatise (1877 op. cit.) pp. 93-4; P. Hurll (Glasgow) "On the Manufacture of Fire-Clay Gas Retorts, and the advantages of having Standard Sizes" Gas World 18/8/1894; King's Treatise (1878) Vol. I op. cit., pp. 151-61; A.B. Searle, Refactory Materials, Their Manufacture and Uses (1917) pp. 346-67; C. Hunt, Gas Lighting (1900) op. cit., p. 27; S.B. Saul, "The Market and Development of Mechanical Engineering Industries in Britain 1860-1914" Economic History Review 1967 II Series Vol. XX p. 111.

raised their costs and that of iron 'mouthpieces'.[1] Manufacturers could not keep a stock of spare retorts, or maintain continuous output, but had to rush to meet each individual order as soon as it was received, thereby causing mistakes and keeping the gas company waiting even in an emergency situation. D-shaped retorts of all sizes, plus square, circular and eliptical retorts were used in various Scottish gasworks[2] by 1853. S. Clegg believed that the D-shaped clay retorts eight feet long, were the most typical. At Montrose such retorts, purchased at Inverkeithing or Clackmannan, cost £2 6s and lasted two to three years with three retorts set in one arch, supported by columns costing 6s each, to be heated by a single fire in each oven.[3]

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1. The 'mouthpiece' was cemented to one end of the retort, and supported a metal door, which was originally a plug that fell to the ground when opening the retort. The door was later hinged, but had to be 'luted' with lime before each charge, until 1869 when Robert Morton's self-sealing door greatly reduced the labour of stokers. 'Ears' on each side of the mouthpiece supported a detachable horizontal bar. In 1879 Glasgow purchased 300 of Morton's retort-lids from Messrs. Tangye Bros. of Birmingham. Before Morton's lids, lime luting cost 15s to 35s per retort per year, but even in the 1870s self-sealing lids were used less in Scotland than England. However cast-iron doors were replaced by lighter wrought-iron doors resting on a hinged-bridle and requiring less luting. Ayr company adopted self-sealing lids in 1883.

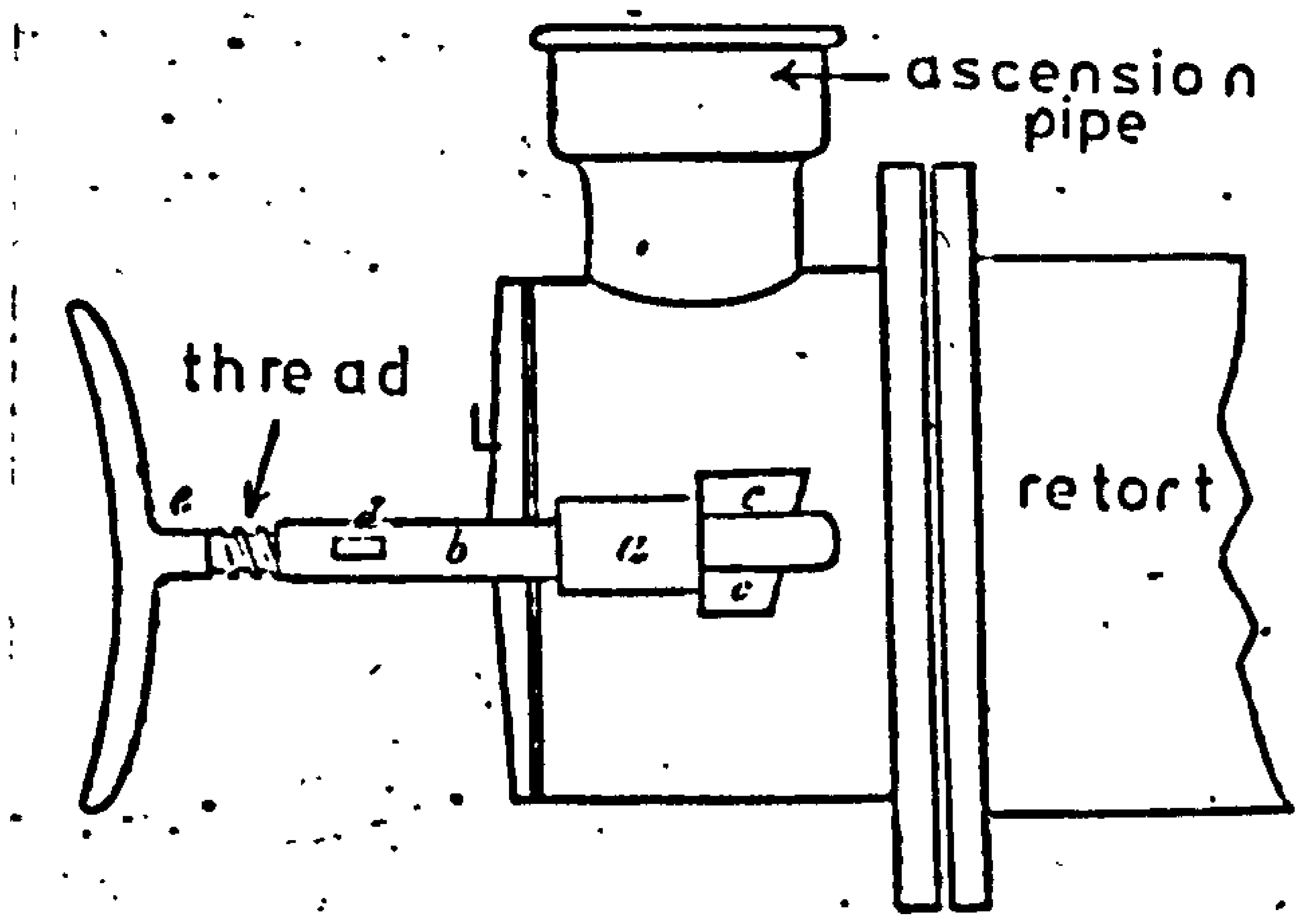
   A. Morton, "On Self-Sealing Retort Lids" J.G.L. 3/8/1869 p.634; T. Newbigging, The Gas Manager's Handbook (1883) p. 66; Evidence of J. Hall (St Andrews) N.B.A.G.M. 1878; Gas Journal Centenary 1849-1949 (1949) op. cit., p. 102; S. Hughes, A Treatise on Gasworks (1853) op. cit., pp. 52-3, 114; W. Richards, Practical Treatise (1877) op. cit., p. 77; King's Treatise 1878 Vol. I op. cit., pp. 41-5; J.G.L. 15/5/1883.

2. S. Hughes, A Treatise on Gasworks (1853) op. cit., p. 122.

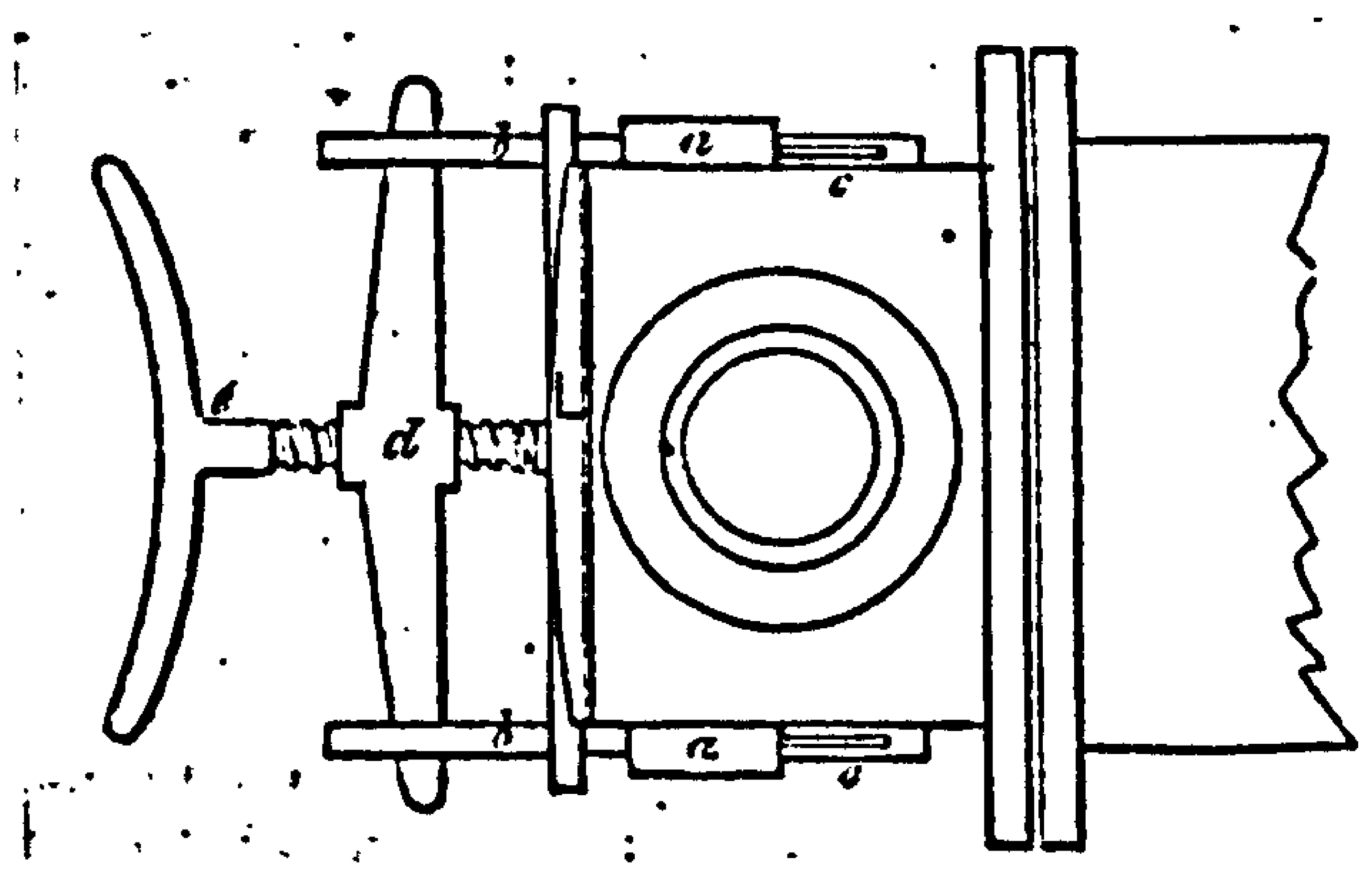
3. Retorts used by James Reid, manager of Montrose, were 8 feet by 14" by 14" high.

   S. Clegg, A Practical Treatise (1853) op. cit., p. 140.

Fig. 3.32 RETORT MOUTHPIECES (1853)



side view



plan

Note - b -'ears' of retort
d - crossbar slotted onto 'ears'
e - pressure bar holding luted lid (L) to seal retort mouth

The screw from the crossbar held a metal door against the mouthpiece in a gas-tight seal.

Source - S. Hughes A Treatise on Gasworks (1853) op cit p.49

Samuel Hughes gave similar figures, but his very detailed description of a Scottish gasworks showed two 7½ foot D-shaped retorts, and one circular retort of the same length set in the arch.[1] The D-retorts were lowest, and supported by walls rising from the furnace-floor. The upper circular retort rested on a square pillar at the end of the arch, and on fire-bricks placed upon the lower retorts. With 'direct-fire' heating these three clay retorts gave 95,000 cu ft per week,[2] which Hughes believed was equivalent to the output of five iron retorts. Each clay retort gave 1.5 million cu ft gas before requiring replacement, compared to 0.8 million from an iron retort, yet the clay installation cost about £21 compared to iron at £40.

While iron-retorts operated at cherry-red temperatures, clay retorts allowed far higher distillation temperatures[3] and consequently greater output of gas per ton of coal. Gas engineers believed that more of the tar was converted into permanent gas, but the temperature also caused heavy deposits of carbon, up to 16 lbs per retort per month. Dr Fyfe, who believed this was due to the

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1. D-retorts 7½ ft by 15 inches, by 14 inches high, built in two sections; circular retort 7½ ft by 15 inches diameter.
   Set in semi-elliptical arch 5 feet wide and 3½ feet high, above a furnace 3 feet long and 1 foot wide.
   "Clay Retorts in Scotland" S. Hughes, A Treatise on Gasworks (1853) op. cit., pp. 79-87.

2. i.e., 31,666 cu ft per retort per week.

3. At "incipient white heat" according to E. Ronalds and T. Richardson Chemical Technology (1855) 2nd Edn. Vol. I, Part II p. 591.
   White cast iron retorts melted at 1920 to 2010°F, and grey iron at 2010 to 2190°F. In the 1880s retort-temperature was still judged by colour, from faint red at 977°F, through cherry red at 1650°F, to white heat at 2370°F and brilliant white 2730°F.
   Vide T. Newbigging, The Gas Manager's Handbook (1883) 3rd Edn. pp. 5-9, 63
   The Wedgwood and Daniell pyrometers lacked sufficient accuracy, and Hughes complained in 1853 that "science has not yet furnished the practical man with any convenient method of estimating high temperatures".
   S. Hughes Practical Treatise (1853) p. 112

Table 3. 33

Capital Costs of Iron and Clay Retort Settings

Iron Retort Replacement Expenditure

	£	s	d
5 iron retorts, each 16 cwt, at £5 each	25	0	0
Taking down old retorts, 5 at 4/-	1	0	0
Bricklayers wages, resetting 5 retorts at 10/6d	2	12	6
Clay, firebricks, tiles, furnace repair	5	0	0
Connections to Hydraulic Main, 5 at 3/-	0	15	0
Bolts, cement, wear and tear on retort oven	2	10	0
Contingencies 10%	3	13	9
	40	11	3

Clay Retort Installation Expenditure

3 clay retorts at £4 4/- delivered	12	12	0
Taking down old retorts and cleaning oven	0	10	6
600 fire-bricks at 10/-	3	0	0
Fire-clay tiles, lumps, etc	1	5	0
Bricklayers wages, fitting retorts and mouthpieces	2	2	6
Connections to hydraulic main, bolts, screws	1	17	6
	20	17	6

Source: S. Hughes, Treatise on Gasworks (1853) op. cit. p. 79 et seq.

decomposition and consequent loss of olefiant constituents, the richest part of the gas, was the main sceptic of clay retorts in Scotland in 1850. A self-scurfing retort was invented in 1856 by John Young of Dalkeith[1] gasworks. The rear of the retort tapered to a six inch door, and by opening that door and the normal retort mouth, carbon deposits could periodically be burned out. By 1859 at least eight Scottish works, including Haddington,[2] used this device.

Debates on the amount of furnace fuel required to heat iron retorts compared to "insulating" clay continued fruitlessly,[3] but experiments disproved the claim by many English gasworks that clay 'leaked' badly. The pores in clay closed within six months, and although many Scottish gasworks used no 'exhauster' some operated

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1. This was, in fact, merely a revival of Grafton's original plan. J.G.L. 8/11/1859 p. 601
2. J.G.L. 25/10/1859 p. 574
3. Clay 'insulation' made initial heating slower, but reduced heat-loss and damage during re-charging. In 1855 engineers still believed a clay retort to use 3½ cwt coke per ton of coal distilled, compared to 2½ cwt with iron retorts. This was no handicap to small works which were obliged to use excessive fuel. More carbon was deposited in the high temperature clay retorts, but even 16 lbs per month was, by Dr Fyfe's calculations, equivalent to a loss of only 500 cu ft of 'olefiant gas' (ethylene).
   E. Ronalds and T. Richardson, Chemical Technology (1855) 2nd Edn. Vol. I Part II p. 591.
   Dr Fyfe (King's College, Aberdeen) "On the Use of Clay and Iron Retorts" J.G.L. 10/6/1851
   "The Composition and Manufacture of Clay Retorts" J.G.L 10/7/1855
   A. Kitt, "Remarks on the Management of Clay Retorts" J.G.L. 11/3/1862, 6/5/1862, 20/5/1862.
   E. Cathels (Shrewsbury) "Clay Retorts and Exhausters", J.G.L. 3/6/1862, 1/7/1862, 17/6/1862
   J. Taylor, (Bethesda) "Iron Versus Clay Retorts" (for iron) J.G.L. 3/6/1862.
   R. Dempster (Elland) "Iron Versus Clay Retorts (against clay) J.G.L. 28/6/1862.
   R.M. Christie (London) "Clay Versus Iron Retorts" J.G.L. 14/4/1857.

successfully with a back-pressure[1] on the retorts of twenty-eight inches in winter and twenty-two inches in summer. Hughes quoted an experiment on retorts which had been in use six months, whereby during five hours of equal temperature iron retorts gave 9,064 cu ft, and clay retorts 8,000 cu ft. At eleven inches pressure, the iron retort leaked 489 cu ft per hour, and the clay retort 1,540 cu ft. However, another experiment reported by Jabez Church (1824 - 1875)[2] showed that with higher temperature distillation clay retorts could handle larger quantities of coal.

Table 3. 34 Experiment with D-shape Retorts, 7½ feet by 15 inches by 13 inches high

Durability (Days)	365	912
Weight of Charge (coal)	1½	1½
Total (cwts) Coal Carbonized	2,190	5,472
Gas output per Ton Coal (cu. ft.)	9,000	9,000
Total Output (cu. ft. gas)	985,500	2,462,400

SOURCE: Inst. Civil Engineers 1857

A steam-powered exhauster could increase the gas output by 200 cu ft per ton of coal.

The Lanarkshire[3] fire-clay deposits at Garnkirk and Glenboig were increasingly used for gas retorts by the 1850s. By 1857 P.

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1. 'Back-pressure' was the pressure of gas, in reality the 'water-pressure equivalent of the gas, necessary for it to overcome frictional resistance and push itself out of the retort, and then through all the apparatus leading to and including the gasholder. Any item of apparatus which caused a particular 'bottleneck' for the gas, such as inadequately large purifiers, could raise the back-pressure to a level where gas pushed out the water-lutes and escaped as a dangerous leakage.

2. J. Church, "On the Results of the Use of Clay Retorts for Gas Making" Institute of Civil Engineers 1857 Vol XVL. Church reported clay retorts to be "in general use" in Scotland.

3. A. McLean, Ed. The Local Industries of Glasgow and the West of Scotland (1901, British Association)

Hurll was the principal retort manufacturer in the Glasgow region, but although in the 1850s the Tradeston, Townhead and Partick stations of Glasgow Gaslight Company changed entirely to clay retorts, the Glasgow City and Suburban Company[1] still used cast-iron at Dalmarnock in 1870. In 1858 J. Patterson of Berwick on Tweed nevertheless felt justified in stating that throughout Scotland there was "not an iron retort in any establishment where above one /retort/ is used".[2]

By the late 1840s and 1850s Scottish gas companies which had expanded as urbanization progressed, like English companies, had reached a size where rule of thumb technology was no longer adequate. The consumer agitation for more efficient service in the early 1840s was followed by a spate of technical publications on the industry in the early 1850s. The precise function of the chimney,[3] for example, was

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1. H. Bartholomew preferred iron-retorts, and in 1867 the works had 740 in settings of 5 per oven. These retorts, 8 feet long by 14 inches by 12 inches, each carbonized 140 lbs in a 4-hour charge, producing about 10,000 cu ft per hour or a maximum of 3 million cu ft in 24 hours.
   P. Hurll "On the manufacture of Fire-Clay Gas Retorts" Gas World 18/8/1894; Evidence of S. Stewart (Greenock) Glasgow City Archives, Miscellaneous Papers Vol. 15, p. 465.

2. J. Paterson "Rival Schools of Gas Manufacture" J.G.L. 10/10/1858; J. Cowan, "On the Progress and Present State of Fire-Clay Goods Manufacture" J.G.L., 22/9/1863, p. 213.

3. Hot air from the furnaces expanded in proportion to its temperature, became lighter than atmospheric air at the same level, and rose through the chimney. A 20 ft chimney, 2¼ feet square, would receive air at 550°F giving an upthrust of 4 lbs, but a 40 foot chimney could double the force, and 80 feet give 16 lbs upthrust over the 5 sq ft area of the chimney. High stacks were far more efficient, but engineers up to the 1870s gave inadequate thought to the problem.
   J.G.L. "Chimney Stacks" 8/2/1876 p. 193; 15/2/1876 p. 233; 22/2/1876 p. 271
   King's Treatise (1878) Vol. I op. cit., pp. 141-50.

most important if, like Edinburgh Gaslight Company in 1845, the works engineer had to build one 341½ feet tall.[1] The chimney was an important source of motive power, because as hot air escaped up it a draught of fresh air was drawn in to ventilate the retort house and fire the furnaces. Edinburgh found three chimneys, up to 148 feet high, quite inadequate for the sixty-eight furnaces and 178 retorts which were in service.

The first 'exhausters' were developed during the 1840s and were especially suitable for the clay retorts of Scotland. They were normally placed after the condensers, and pushed the gas forwards[2] through the purifiers and on to the gasholders. By taking the full weight of 'back-pressure' caused by the friction of gas passing through that apparatus, the exhauster reduced the pressure of gas in the retorts, thereby reducing damage to the retorts and drawing out larger volumes of gas from the coal. Simeon Broadmeadow[3] used the

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1. G. Buchanan, "An Account of the Chimney of the Edinburgh Gas Works" J.G.L. 10/12/1850; Civil Engineer and Architects Journal March 1847 p. 79; F.H. Groome, Ordnance Gazetteer of Scotland (1882) Vol. I p. 526.
An endless chain inside the chimney carried workmen to the top, and even parties of tourists during the inauguration, vide The Scotsman 11/11/1846. Difficult repairs, J.G.L. 4/3/1890.
On chimney technology vide: W. Richards, Practical Treatise (1877) pp. 342-7; D.W.F. Hardie and J. Davidson Platt, A History of the Modern British Chemical Industry (1931) p. 33.
In the 1890s the chimney became even more important for regenerative-retorts, when it was used to draw primary air into the producers to make carbonic oxide (CO) and then secondary air for combustion. Works with an inadequate chimney, like Alloa, used steam jets to boost the air entering the producer. N.B.A.G.M. 1896 A. Yuill (Alloa) "Presidential Address".

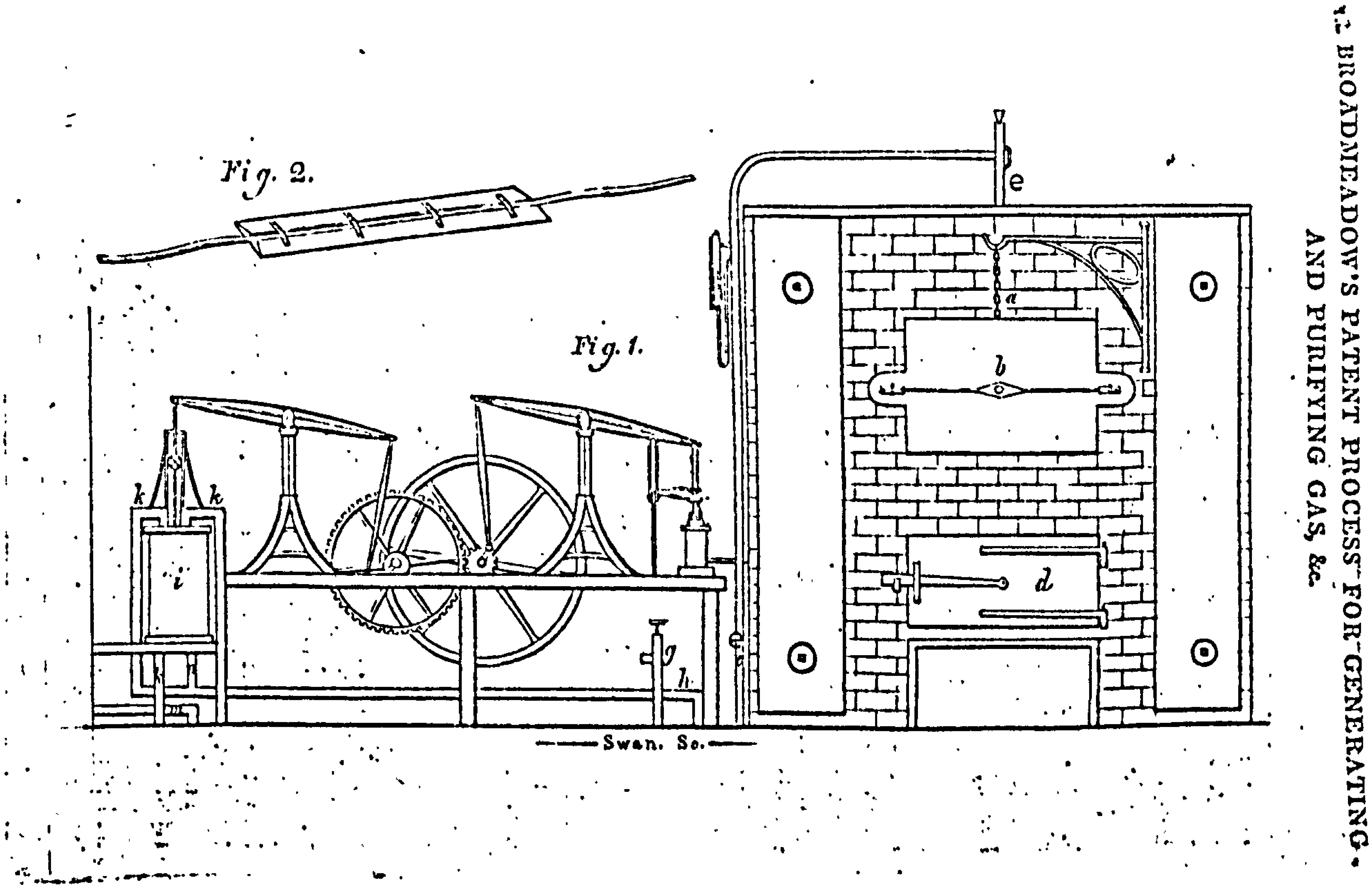
2. R.H. Patterson, Gas and Lighting (1877) op. cit., p. 160

3. At Abergavenny, Broadmeadow tried to eliminate the cost of iron-retorts by using large brick retorts holding six times as much coal. His retorts leaked badly, but he believed that an admixture of atmospheric air helped to purify the gas by removing sulphur. Therefore he built "an exhausting cylinder ... similar to the blast cylinders used in ironworks" to suck gas

Fig.3.35

Original Gas 'Exhauster' by S. Broadmeadow

1825



Note - a - oven b - retort "door"

d - furnace door below brick retort

e - ascension pipe to condensor

g - hand pump to remove tar from condensor

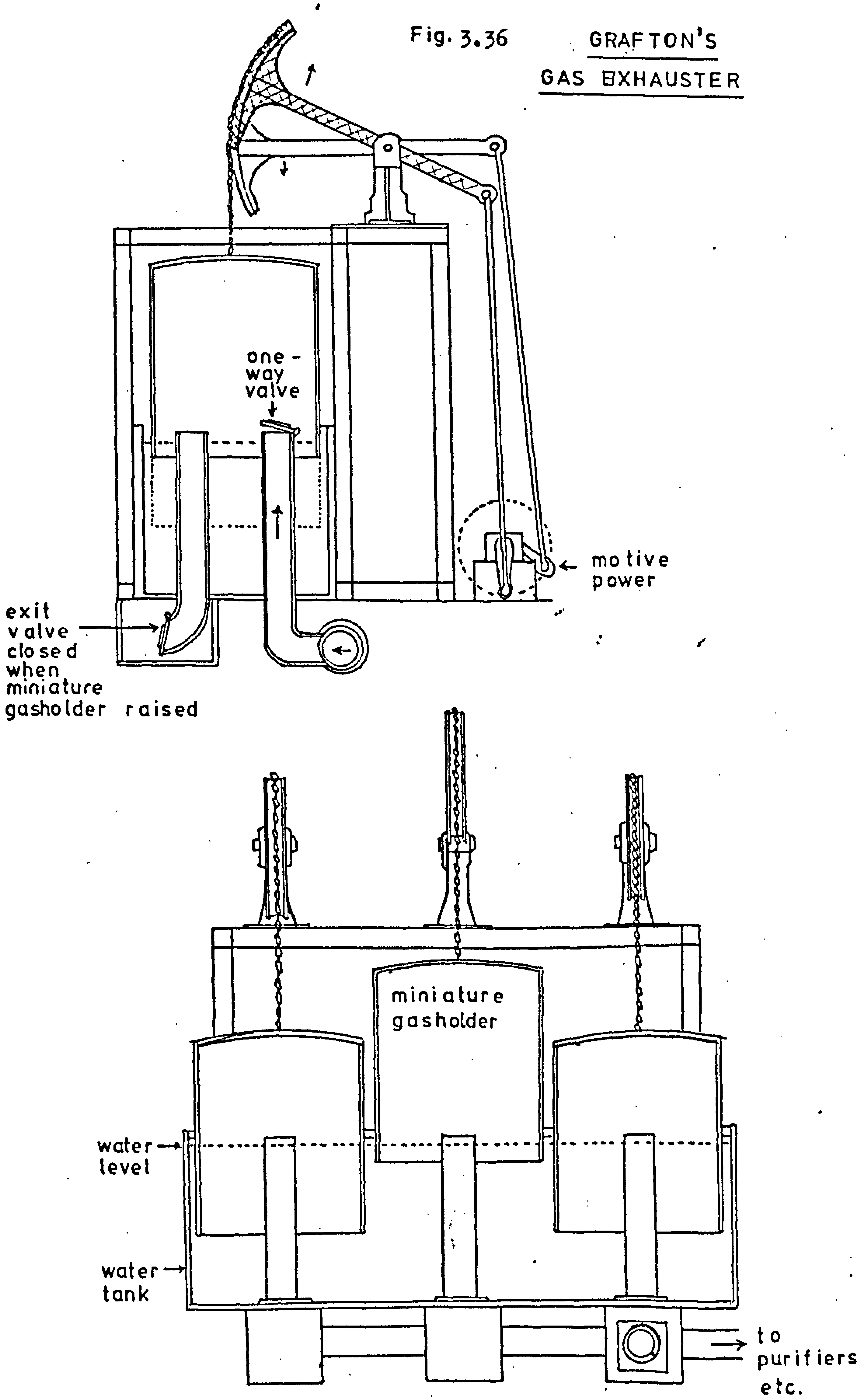
h - gas inlet to exhauster from condensor

k - gas exits from top and base of exhauster leading to purifier

i - exhauster

Source - The Glasgow Mechanics Magazine 17/12/1825 Vol. IV

Fig. 3.36 GRAFTON'S GAS EXHAUSTER



Source - C. Hunt Gas Lighting (1900)

first exhauster in 1825 while experimenting with brick-retorts in Wales, but the design was largely ignored until about 1841 when John Grafton[1] began experiments at Cambridge gasworks to reduce the back-pressure which he believed was responsible for heavy carbon deposits in the retorts, and excessive tar production. His final design could be fitted between the hydraulic main and condensers where it acted as a 'washer', or even after the purifiers, and was simply a set of three miniature gasholders fed by pipes(with a non -return one-way valve). These were mechanically raised in sequence, and sucked the gas forwards, before falling and pushing it out.

A different type of exhauster, using propellers each shaped like the figure '8' was devized by Jones,[2] and installed at Brick Lane gasworks in London in 1847. Because exhausters used motive power, usually a steam engine, they were only economical in large gasworks and were not widespread in Scotland in the 1850s. Scottish engineers were, however, not slow in attempting to use exhausters. In 1848 the manager of Johnstone gasworks, Mr Blair[3], publicised an

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out of his retorts, but the system was soon abandoned. "Mr Broadmeadow's Patent Process for Generating and Purifying Gas" Glasgow Mechanics Magazine 1825 Vol. IV p. 274. Patents 4893 (1824) and 5146 (1825).

1. With 14 inches back-pressure, retorts became almost filled with carbon after 2 months. Grafton tried various devices, like an Archimedes-screw powered by water, and a revolving under-water drum like a modified gas-meter. He also tried to combine the exhauster and purifier as one unit, using lime-water. S. Hughes, Treatise on Gasworks (1853) op. cit. pp. 152-5; C. Hunt, Gas Lighting (1900), Vol. III cf.; Chemical Technology or Chemistry in its Applications to Arts and Manufactures C.E. Groves and W. Thorp. Ed.; W. Richards Practical Treatise (1877) op. cit., p. 118; J.G.L. 20/10/1874 p. 535; King's Treatise (1878) Vol. I op. cit. p. 53.

2. W. Richards, Practical Treatise (1877) op. cit., p. 120

3. An air-vane inside a fresh-air duct to the chimney operated a miniature double gasometer at 3 strokes per minute, to exhaust 1,200 cu ft gas per hour and meet the full requirements at Johnstone. The Practical Mechanics Journal 1849-50 pp. 10-11.

exhauster similar to Grafton's but powered entirely by the chimney draught.

Technical details of some Scottish gasworks are available from the mid 1840s. Coatbridge[1] new gasworks in 1845 had four "wagon-boiler shaped" iron retorts, six feet by two feet by one foot high; a holder* built of No. 16 sheet iron and surrounded by four cast-iron pillars sixteen feet high. Both retort-house and workshops had wrought-iron fireproof roofs. Gas mains, up to only three inches diameter, had to withstand testing at 100 ft. water-pressure. Aberdeen[2] New Gas Company in 1846 installed two gasholders, sixty feet in diameter and eighteen feet deep, again of No. 16 wire-gauge metal, while the Edinburgh[3] gas company built at Tanfield a holder eighty-three feet diameter and twenty feet deep, of best Lowmoor iron, No. 15 wire gauge.[4] These gasholders were pre-coated with boiled linseed oil as protection from rusting.

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1. Gaswork designed by Neil Robson, a civil engineer of Glasgow. Detailed specification in The Artizan Sept 1845, pp. 180-2

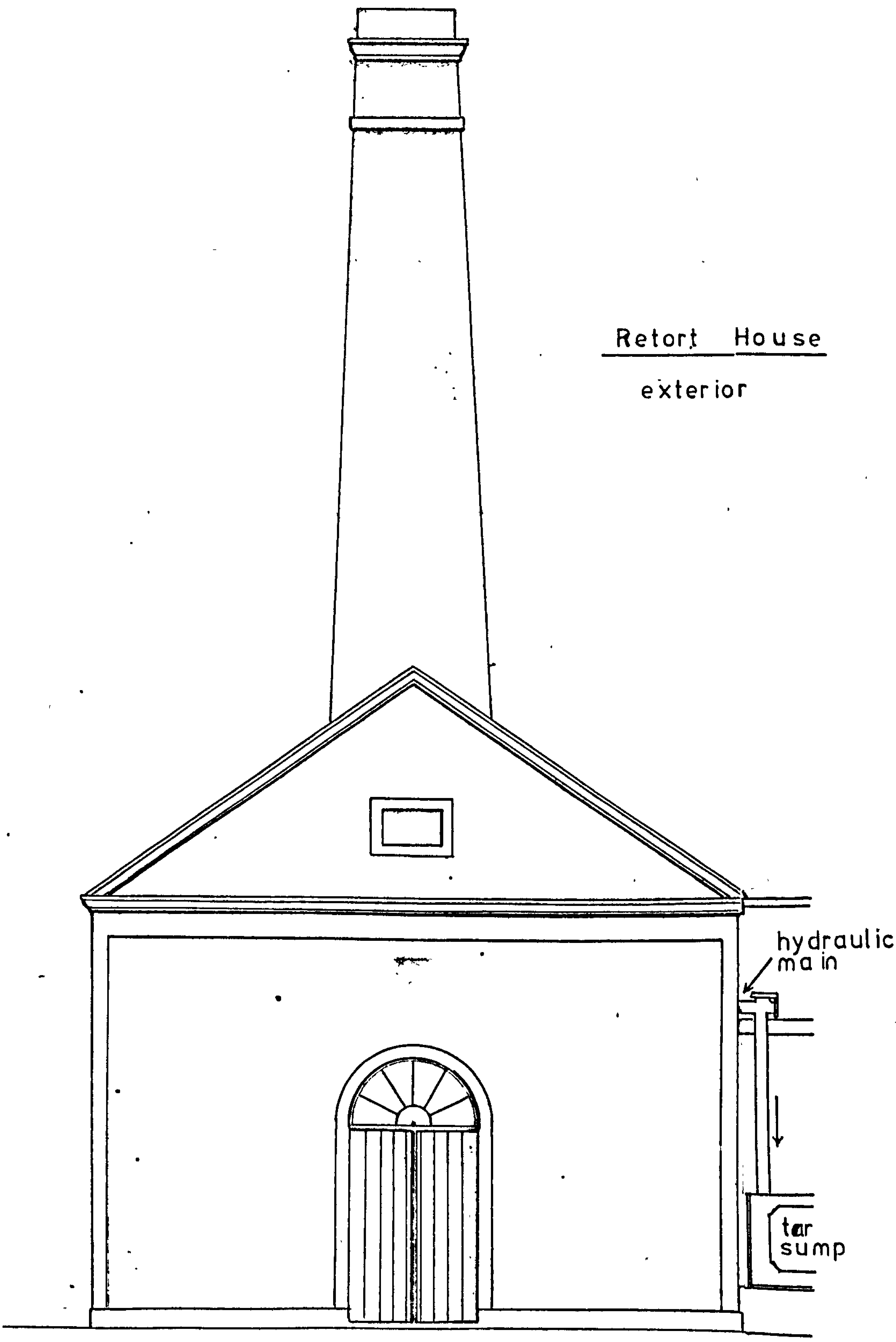
2. The Artizan, April 1846 p. 82.
   Cf. Stornoway gasholder in 1848 was 30 ft diameter, 12 feet deep, and surrounded by 4 cast-iron columns. The retort house there also had an iron roof. Stornoway Minute Book op. cit., 15/4/1848, 16/5/1848.

3. The Artizan May 1846 pp. 103-6, September 1846 pp. 196-7

4. W. Brodie later claimed that Scottish companies about 1846 began to use No. 18 iron-sheets in place of much heavier early gasholders. By 1880, when governors helped control mains pressure, he recommended No. 16 sheets for holders under 40 ft diameter; No 14 for 40 to 100 feet; and No. 12 for 100 to 160 feet diameter. In 1819 Peckston gave half the weight of gasholders in stays and trusses, but by 1877 W. Richards described only ⅛ of the weight so placed.
   W. Brodie (gas engineer, Paisley) "Gasholder Construction" Journal of Artificial Light 22/5/1880 p. 668.
   W. Richards, Practical Treatise (1877) op. cit., p. 162.

* Gasholder 30 feet diameter, 12 feet high; retorts each set over a seperate furnace.

Fig. 3.37
TROON GASWORKS c1850



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Source - S.R.O. (R.H.P. 16917)

Fig. 3.38
TROON GASWORKS c1850

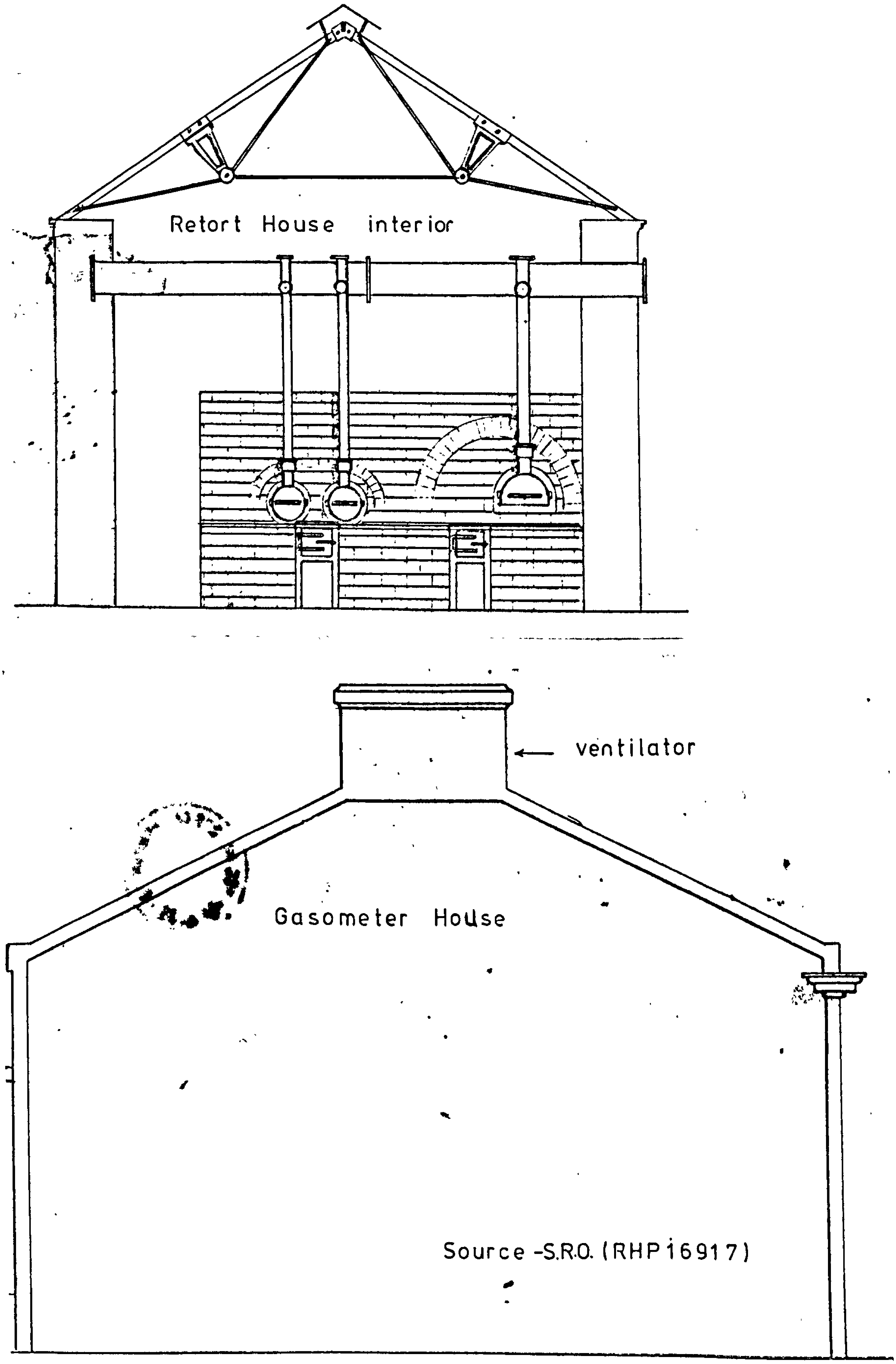

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Fig. 3.39 TROON GASWORKS c1850

Condensers and Purifiers

Note - 1 tar-sump; 2 air-cooled condenser; 3 purifier boxes with detatchable lids.

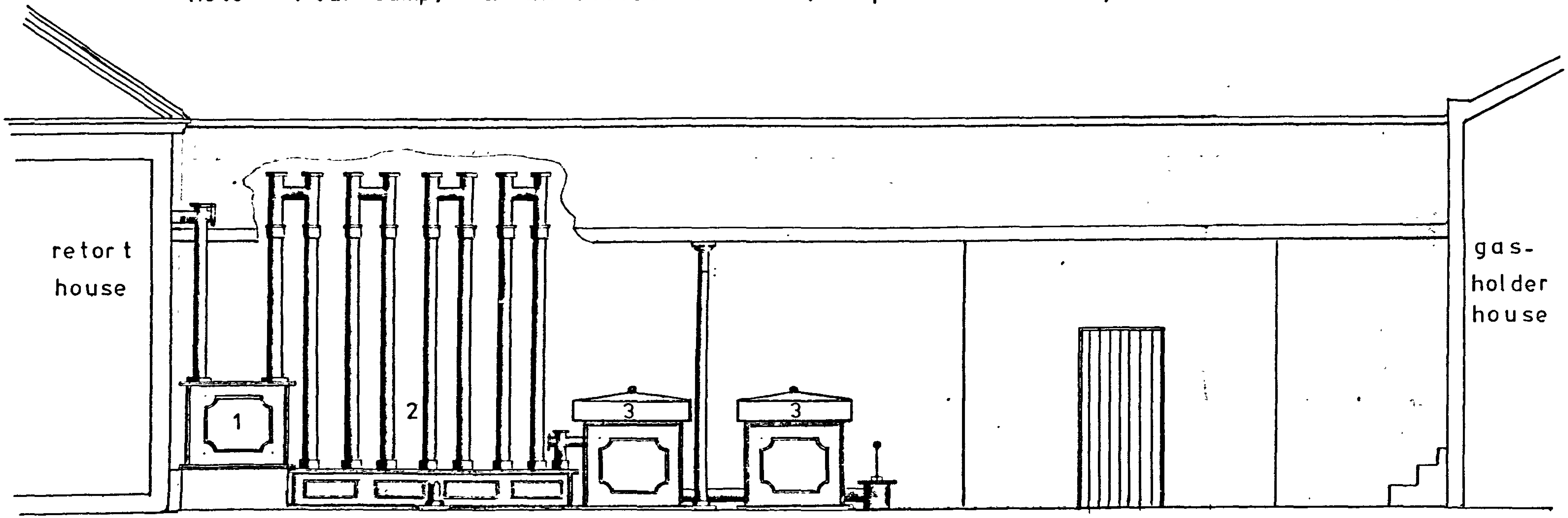

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Fig. 3.40

TROON GASWORKS c1850

Gasholder Design

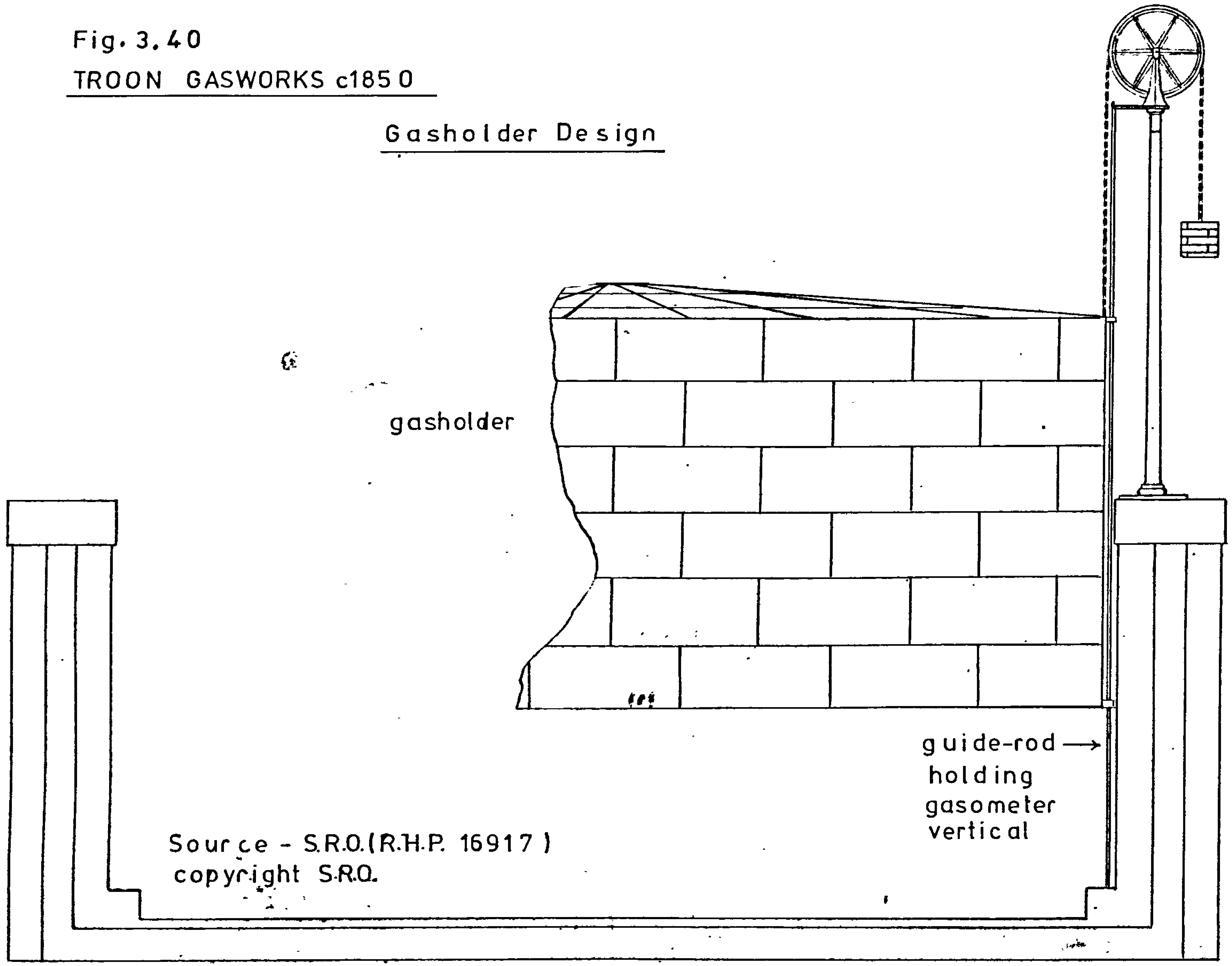

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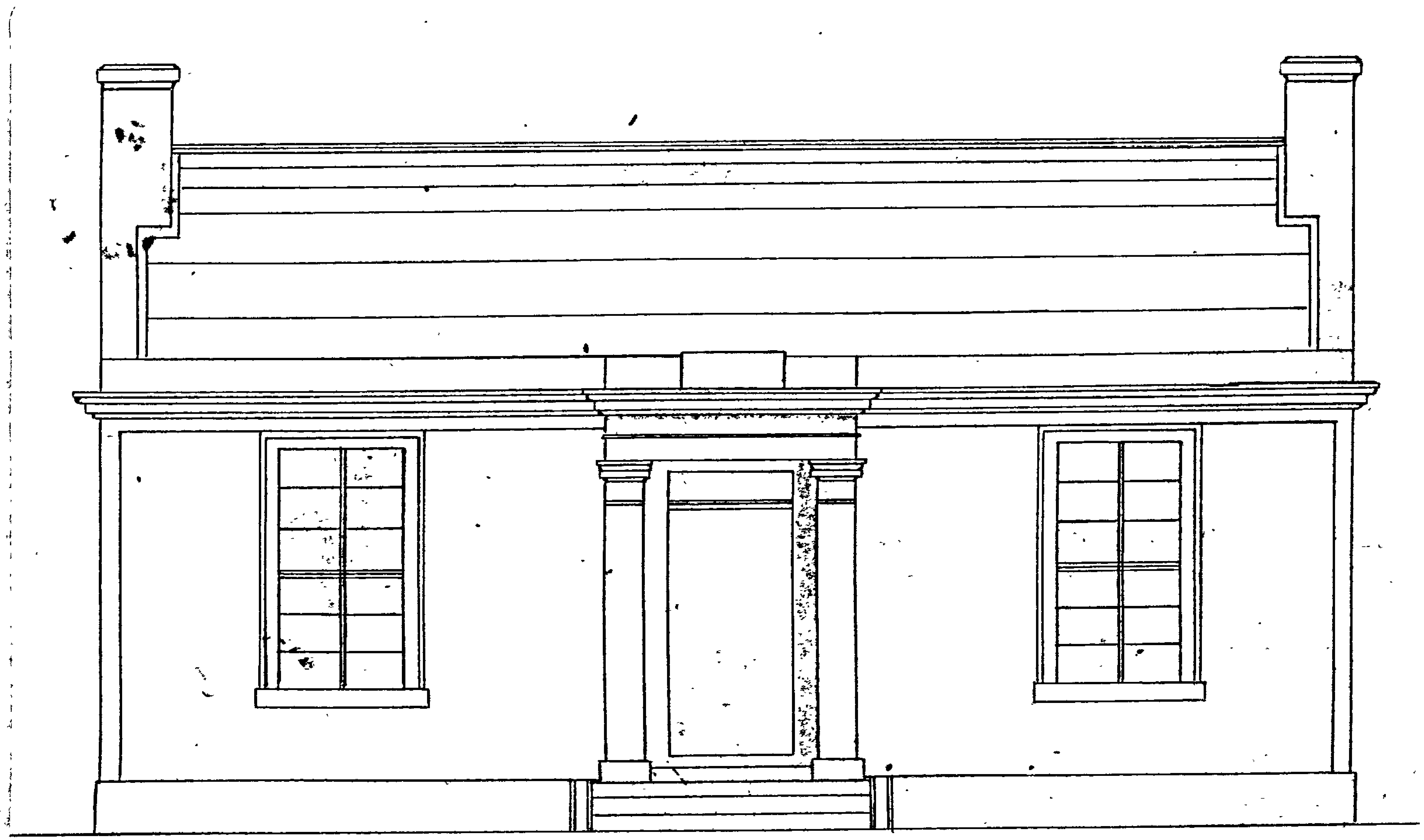
Fig. 3.41 TROON GASWORKS c1850

Manager's Dwelling House



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Ayr gasworks[1] held one of the advanced Scottish retort systems of the early 1860s. Nine foot retorts, placed back to back, were heated by three flues above and three below, and carbonized 400 lbs coal in three or four hours according to the temperature chosen. With coal yielding 10,000 cu ft per ton, each retort could give up to 12,500 cu ft per day. Two retorts were placed in each 'setting' or oven, which cost £169 to construct and about £14 per retort to renew. Most Scottish ovens contained three retorts at this time.

Three ancillary devices were gradually adopted in Scottish gasworks in the 1850s and later, on the main pipes leaving the gasometer. Where gas-pressure was controlled by a manually operated valve, a 'Tell Tale'[2] automatically recorded the pressure and hence the vigilance of workmen, whilst the more advanced 'Governor' facilitated entirely automatic pressure control.

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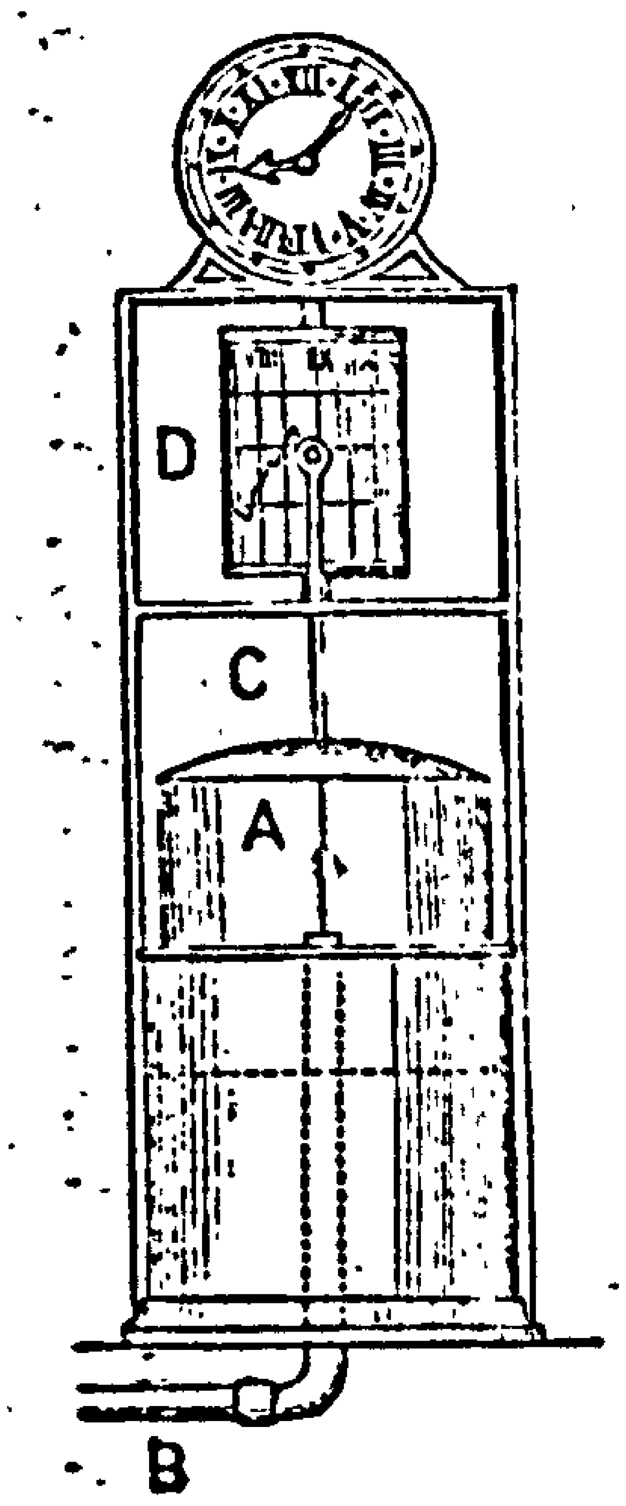
1. The eight retorts at Ayr were 9 feet long by 26 inches by 15 inches high. Later in the 1860s, the oven of 2-retorts designed by H. Walker of Saltcoats, and that of 3-retorts by T. Hall of St Andrews, were widely acclaimed as the best design for gasworks requiring small ovens. Mr Hislop (Ayr) "On Settings of Clay Retorts, and Ovens of Clay and Iron" J.G.L. 31/5/1864 p.408,14/6/64 p.431, 28/6/1864 p. 471; King's Treatise (1878) Vol. I op. cit., pp. 197-9.

2. The 'Tell Tale', devized by S. Crosley and first tried by the Chartered Company in 1824, was in use at Aberdeen in 1839, and at Glasgow in the 1830s. Even in the 1870s many small Scottish gasworks used a manually operated valve instead of a 'governor', to control mains pressure. In 1860 Greenock replaced the 'valve man' by a £120 governor.
New Statistical Account Vol. XII pp. 78-9; New Statistical Account - Lanarkshire, p. 162; The Penny Magazine of the Society for the Diffusion of Useful Knowledge 1834 p. 459; King's Treatise (1879) Vol. II op. cit., p. 37; S. Hughes, Treatise on Gasworks (1853) p. 238; S. Clegg, Practical Treatise (1853) p. 231; Chambers Encyclopaedia (1876, Edinburgh) Vol. IV p.637; J.G.L. 25/1/1876 p. 121; "Report to the Committee of Management of Greenock Gas Works" 16/10/1860 Paisley Gas Question (1860, Paisley) p. 13.

Fig. 3.42 'Tell-Tale' or 'Pressure Indicator'



SOURCE: The Useful Arts and Manufactures of Great Britain (c. 1850; Soc. For Promotion of Christian Knowledge)

Miniature gasometer A, fixed to a pen recorder, rose as gas pressure in mains rose, through subsidiary pipe B. Cylinder D rotated by clockwork and showed the time of events.

The Station Meter,[1] also devised in London, was simply a very large wet gas-meter which showed accurately the rate and total amount of gas consumption. The Vale of Leven Company[2] had no station meter until 1846, Hawick[3] until 1857, and Stranraer[4] until 1859. Dalry[5] reported them to be "in almost universal use" when first purchasing one in 1886, and saw the advantages in recording daily output, the productivity of coal samples, the annual leakage, and errors caused by the workmen during distillation. Without a station-meter, management was often guesswork based upon the consumption recorded by consumers' meters.[6] Leven[7] in 1840 used those consumer statistics, and the expectation that coal should give at least 7,000 cu ft per ton, to deduce that leakage in the distribution pipes seemed excessive.

To maintain constant gas-pressure in the mains, while consumption fluctuated, S. Clegg in 1815 designed a 'governor' which was

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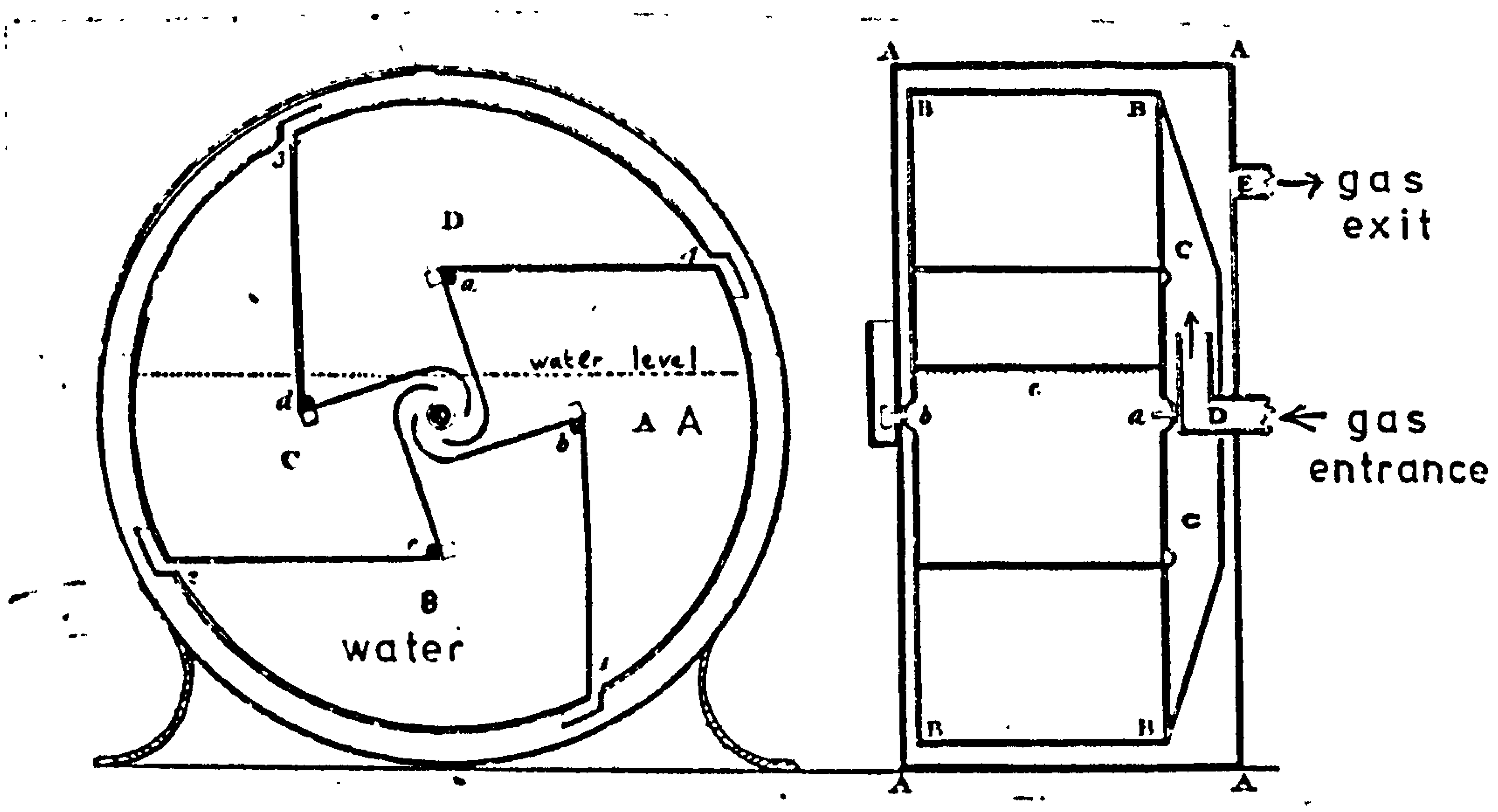
1. Samuel Clegg devized the Station Meter for the Chartered Company in 1816, but a far simpler and more accurate meter was made by Malam in 1817 and later widely adopted and improved. Glasgow gasworks used a large meter by Crosley of London, in the 1820s. T.S. Peckston, Theory and Practice (1819) pp. 315-7; King's Treatise (1879) Vol. II op. cit., p. 29; J. Cleland, City of Glasgow Statistics (1832) op. cit., p. 142.
2. Vale of Leven Minute Book op. cit., 24/5/1846
3. J.G.L., 10/7/1883
4. Stranraer Minute Book op. cit., 29/6/1858, 25/6/1860
5. Dalry Minute Book op. cit., 9/4/1886.
   Problems with heavy leakage from main pipes, which could not be assessed accurately, stimulated many small gasworks to purchase Station Meters at a late date, such as at Stevenston (Ayrshire) in 1889 and Alyth in 1891. J.G.L. 11/6/1889, 14/7/1891
6. Vide infra 'Finance' p. 792
7. Vale of Leven Minute Book op. cit., 12/3/1840

Fig. 3.43

Malam's Wet Gas Meter or 'Station Meter' (1819)



longitudinal section (1) cross section (2)

SOURCE: T.S. Peckston,[1] Theory and Practice (1819) op. cit. p. 317

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1. Gas entered at D, the pivotal position of cylinder B. (sect. 2) Outer case A was partly filled with water, and b pivot operated a recording device.
(sect. 1) Dotted line shows water-level. Gas passing into compartment D caused it to rotate and expel the gas (at E in sect. 2), while gas entered Compartment A and caused that to rotate, and the rotation continued as gas passed through successive compartments. Large gasworks gained price advantage from the economies of Station Meter size, e.g.

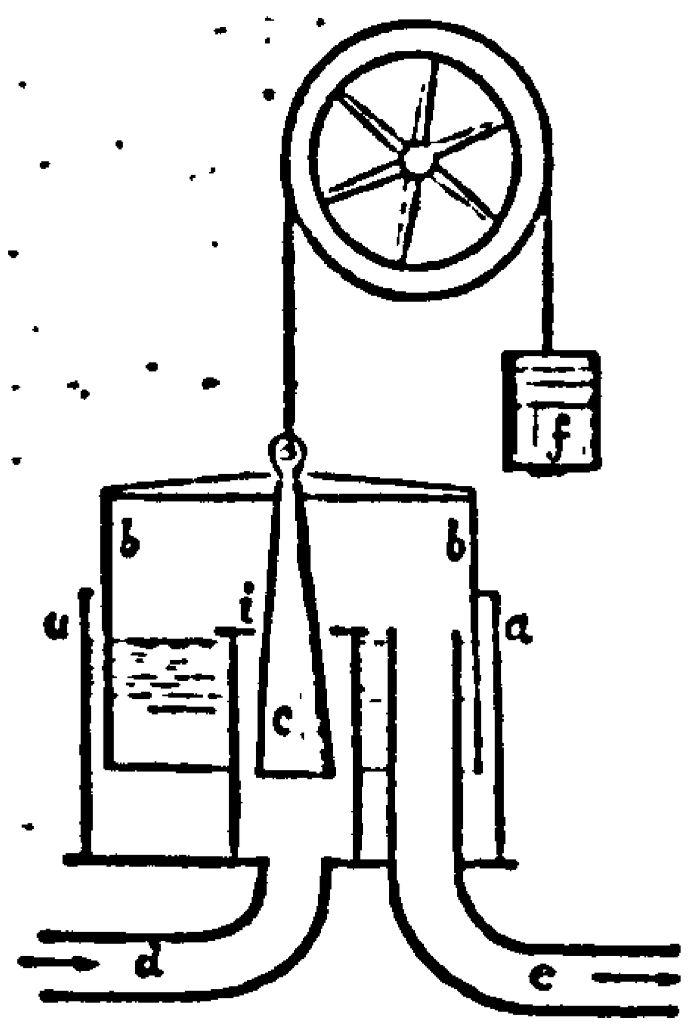
Maximum Hourly Rate (cu. ft.)	Wheel Capacity per Revolution cu. ft.	Price (£)
600	5	38
2,400	20	62
24,000	200	222

SOURCE: King's Treatise (1879) Vol. II op. cit., p. 32.

Nineteen Scottish gasworks, for example, which purchased Station Meters from J. Milne & Co. of Edinburgh, about 1903, required sizes ranging from 250,000 cu ft per hour at Glasgow to 5,000 cu ft. at Wick. J.G.L. 17/3/1903 p. 725; "History of Gas Meters" J.G.L. 10/1/1850, 10/10/1850.

adopted in Scotland in the 1850s and remained largely unchanged into the twentieth century.[1]

Fig. 3.44



GAS GOVERNOR

The entire output from the Gasholder passed (d) into a miniature gas-holder (b) attached to a cone-valve (c). As consumption demand (e) rose the miniature gasholder sank and opened the cone valve (in orifice i) to allow more gas into the mains. As consumption decreased, the valve was closed. Counter-balances (f) for the miniature gas-holder gave the gas manager the ability to manually alter mains pressure[2] if necessary.

Telescopic gasholders were probably first used in Scotland at the Glasgow City and Suburban[3] works in 1842 when four were construc-

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1. Perhaps the first station 'Governor' used in Scotland was at the Glasgow City and Suburban gasworks in 1843.
   The Artizan December 1843 p. 287; The Useful Arts (c. 1850) op. cit., p. 49; W.C. Peebles "Gas Governors - Their Action and Application" N.B.A.G.M. 1912

2. In 1852 Newton used another 'governor' between the exhauster and the hydraulic main, to prevent air being drawn in by excessive use of the exhauster. This greater control of the exhauster actually increased gas output by allowing less liquid to be used in the hydraulic main, and thus reducing back-pressure on the retort. The 'governor' directly controlled the steam power of the exhauster, by mechanical linkage.
   'Governors' on main pipes vide infra p.338

3. Contents about 271,000 cu ft. Evidence of S. Stewart (Greenock) Glasgow City Archives Miscellaneous Papers Vol. 15, p.465.
   Vide infra p. 370

ted, eighty feet in diameter and fifty-four feet high. Paisley[1] built one of 175,000 cu ft capacity in 1854, and another of 200,000 cu ft in 1862. Large gasholders reduced construction costs per cubic foot, and telescopic[2] arrangements reduced the ground-space required in city-centre sites. However they also stretched the technical abilities of engineers. Edinburgh installed the largest Scottish telescopic gasholder in 1848, 100 feet in diameter, forty feet high, with a capacity of 300,000 cu ft. The following year, however, a guide rod snapped and friction ignited the gas which destroyed the holder[3] and nearby houses. No Scottish city gasworks were so short of space they could afford such failures, and a telescopic gasholder built at Dundee in 1859 was still considered venturesome. It was designed by the Dundee manager to hold

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1. W.B. Watson, Abstract Statement of the Revenue and Expenditure of the Paisley Gas Light Commissioners 31 May 1869 to 31 May 1870 (1870, Paisley).
   Away from the large towns of central Scotland, gasholders remained relatively small. The moderately large Galashiels company in 1859 purchased a single lift holder only 60 feet in diameter from Messrs Hooper and Miller of Kelso, who had supplied "nearly every one [constructed] in the County of Roxburgh", The Builder 25/6/1859 p. 429.

2. Mechanics Magazine 1835-6 Vol. 24 p. 321.
   Telescopic holders were first designed in England where more gasworks had city-centre location problems. The first was patented in 1824, and one was used at Leeds in 1826-34. In 1833 S. Hutchinson of London Gas Co. patented a similar example, but in 1835 the Chartered Company defied the patent and employed J. Horton of Birmingham to build a 2-lift gasholder. S. Everard, Gas, Light and Coke Company (1949) op. cit., p. 156; E.A. Parnell, Applied Chemistry (1844) Vol. I op. cit., pp. 78-9.

3. The Builder Vol. III 3/2/1849 p. 59. Damage was estimated at £2,000. Previously the largest Scottish holder was 80 feet wide with 18 feet lifts at Glasgow in 1842, followed by 60 feet wide with 20 feet lifts at Paisley, both built by Messrs Hanna, Donald and Wilson of Paisley.
   Glasgow Chronicle 17/10/1842 p. 4.

400,000 cu ft, and the 100 foot wide structure with two twenty-five foot lifts, was surrounded firmly by twelve cast-iron columns fifty-two feet high.[1] Large Scottish city companies really began to use telescopic holders from the late 1860s, mainly supplied by Messrs Hanna, Donald and Wilson of Paisley who supplied their first improved version in 1866 for the Radcliffe gas company in London. In 1861-74 that company supplied ten gasholders[2] to Glasgow gasworks, but only the last five were telescopic, and 160 feet in diameter. Most Scottish gas companies[3] still had single-lift gasholders until the 1880s.

Severe weather conditions reinforced this trend. In 1866, for

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1. J.G.L. 13/10/1857, 15/2/1859; The Builder 7/3/1857 p. 138.
   The holder, like that of the London Chartered Company, was built by J. and W. Horton of Smethwick, Birmingham; only the iron columnswere made locally, by Messrs Gourlay Bros., Dundee Foundry.

2. Gas World 26/9/1885 p. 405.
   Two were supplied to Dalmarnock, and three to Dawsholm.
   From 1866-78 Hanna, Donald and Wilson also built six gasholders for the Edinburgh Gaslight Company.
   A synopsis of gas engineering improvements in 1851-61 is given in the Mechanics Magazine 1862 Vol VII pp. 405-6 "Gas Engineering".
   A 600,000 cu ft holder built by Messrs Laidlaws, Glasgow, in 1869 for Melbourne, Australia, was then the largest ever made in Scotland.
   J.G.L. 13/4/1869 p. 265.

3. Rothesay was exceptional, with a telescopic holder in 1872, but even in 1888 had only 68,000 cu ft storage until an old 10,000 cu ft holder was replaced by one of 72,000 cu ft. J.G.L. 22/11/1877, 23/10/1888, 29/5/1888.

   Many new holders, like that designed by J. McGilchrist (Dumbarton) for Kirkintilloch in 1883, were only a single-lift though capable of telescoping at a later date. Kilmarnock, for example, spent £1,600 telescoping an existing gasholder in 1887 and Campbeltown holder was telescoped in 1889.

   J.G.L. 1/5/1883, 20/12/1887, 3/12/1889.

example, Dundee Old[1] gasworks suffered a serious fire when gale damage caused a holder to leak and burst into flames. Forfar[2] in 1879 had three gasholders, the largest of 45,000 cu ft supplied by Bicket and Son, Kilmarnock. A fault in the gear system caused two supporting columns to crack, and this entire holder collapsed. At Galashiels in 1884, storm damage demolished one small gasholder[3] and damaged the retort house. In 1889 a 25,000 cu ft holder built with three guide columns[4] at Peterhead in 1874, was wrecked by a gale. Nevertheless rising consumption and the economies of scale produced an increase in size of holders throughout Scotland.[5]

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1. J.G.L. 9/1/1866, p. 19.
   In 1857, J.Z. Kay of Dundee invented a breathing-apparatus which enabled workmen to inspect inside the gasholder without emptying it. Engineering and Mechanics Magazine 1/5/1857.

2. Journal of Artificial Light, 18/10/1879

3. This gasholder of about 56,500 cu ft capacity, sixty feet diameter and twenty feet high, and supported by six cast-iron columns, was one of a pair built at Gala Foot in 1869. It held 4,600 cu ft when gales lifted it bodily out of the tank and caused irreparable damage. J.G.L., 5/2/1884; Galashiels Minute Book op. cit., 5/2/1884.

4. J.G.L., 3/12/1889.
   A small forty foot diameter holder at Wishaw was similarly wrecked in November 1881. J.G.L. 29/11/1881

5. Rising consumption often led companies to double their storage capacity in a flurry of construction which made expenditure on gasholders a major phase of capital alteration, as described elsewhere. Vide infra 'Finance'.p. 778
   In 1839 Aberdeen had a total holder-capacity of only 93,000 cu ft, when a large new holder of 61,000 cu ft was ordered. Dalkeith had 8,000 cu ft holder-capacity in 1842, but supplied 20,000 cu ft a day in winter. On the advice of M. Taylor of Edinburgh gas company, a new 18,500 cu ft holder was built, utilizing iron-plates off the old holder. Cupar company manager requested a new 10,000 cu ft holder in 1849, but on the advice of W. Foulis, manager at St Andrews, a 15,000 cu ft holder was purchased when he stated that all gasworks should hold reserves equal to two days' consumption. Broughty Ferry began with an 8,000 cu ft holder in 1847, but had only 60,000 cu ft capacity before building a new 45,000 cu ft holder in 1877. Greenock in 1860 had a storage capacity equal to only 46.6 per cent of the maximum daily winter output of 300,000 cu ft., and a Council committee reported that

Crieff[1] gas company began in 1841 with a 7,000 cu ft holder, in 1866 bought another of 15,000 cu ft, and in 1878 a third of 45,000 cu ft. Aberdeen[2] in 1875 built the second largest holder in Scotland, telescopic and 130 feet in diameter, holding 600,000 cu ft. That company also continued to use earlier holders, two of 50,000 cu ft, two of 100,000 cu ft, and one of 420,000 cu ft.

In 1875 the Journal of Gas Lighting[3] published national average prices for gasholders of various sizes which shows the price per cubic foot capacity rising as the size increased. The relative advantage of large gasholders was thus entirely related to the reduced expenditure on water-tanks and ground space. Whereas a

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most engineers favoured storage equal to the maximum daily output, and at minimum 75 per cent of that. A new holder, 100 ft in diameter, 25 ft deep and holding about 192,000 cu ft, was purchased. Inadequate storage, as at Dalry in 1886, led to the wasteful practice of "hanging" the retorts, charging an excessive number to meet any fluctuation in demand, but restraining the furnace heat.

New Statistical Account 1839 Vol. XII, pp. 78-9; Dalkeith Minute Book op. cit., 29/6/1842; Cupar Minute Book op. cit., 2/9/1847, 14/9/1849; Dalry Minute Book op. cit., 9/4/1886; J.G.L. 3/7/1877, 31/7/1877; Paisley Gas Question (1860) op. cit., pp. 10, 11, 14.

1. A.Porteous, The History of Crieff (1912, Edinburgh) pp. 186-7

2. J.G.L. 1/6/1875.
   In 1875 Aberdeen had 164 retorts. During 1883-4 Aberdeen purchased two more 600,000 cu ft holders at £11,500 from Messrs. Hanna, Donald and Wilson, in brick tanks costing £10,608 by a local firm of builders, Pringle and Slessor.

3. J.G.L. 2/11/1875 p. 646
   J.A. Combs, "On the Construction of Gasholders" J.G.L. 16/3/1875 pp. 374-6.

   From 1849 the Journal advised gas managers on which precise details to give when ordering equipment from the manufacturers. J.G.L. 10/8/1849, p. 95, "Specifications for an Iron Tank and Gasholder" normal stone or brick tank cost about £15 per 1,000 cu ft gasholder capacity, and the holder also £15, an extra lift would double the capacity for only £15 per 1,000 cu ft.

Table 3.45 Capital Cost of Gasholders Compared to Capacity (1875)

Diameter (feet)	Depth (feet)	Capacity (Cu.Ft.)	Cost Delivered (£)	Cost per cu. ft. Capacity (£)
40	15	18,000	360	50
50	15	28,000	480	58
60	16	44,000	630	70
70	16	62,000	880	70
80	20	100,000	1,300	77

SOURCE: J.G.L. 2/11/1875, 16/3/1875

The small gasholders included six cast iron columns, valves, a trussed-roof to pressurize the gas, and three counter-balances at different points. Holders above seventy feet in diameter had ten columns, but were sufficiently heavy to require no trusses or counter-balances. A seventy foot holder weighing twenty-three tons, exerted 2½ inches pressure on the gas. By the end of the century, reduced manufacturing costs greatly increased the advantage of large holders.[1]

1. E.g. Cupar (Fife) Gas company chose a 100,000 cu ft holder in 1899 on the basis of the following calculation, in each case with steel water-tanks:-

			Price	Price per 1,000 cu.ft.
50,000 cu ft holder	60 ft dia.	18 ft high	£2,370	£47 10s
80,000	72	20	2,738	34 5s
100,000	80	20	3,000	30

The large single-lift holder could also save £20 by abolishing the labour of an auxilliary fireman's labourer in winter, £50 by abolishing an old 16,000 cu ft gasholder which leaked 300,000 cu ft a year, and reduce wear and tear on retorts which would last three years instead of two.

Cupar Minute Book op. cit. 18/1/1899.

Exhausters improved in the 1860s. The efficient, reliable, and soon very popular steam-powered Rotary Exhauster by Beale,[1] was not patented until 1866. Greenock gasworks[2] meanwhile purchased its first exhauster in 1860 when the annual gas output was fifty-six million cu ft. This was one aspect of the belated change being made there from iron to clay retorts, and the exhauster[3] was expected to increase output by twenty-five per cent, a saving of 2s 9¾d per 1,000 cu ft or £1,830 per year. The exhauster and installation cost £395, and annual running costs £70. Kirkintilloch[4]

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1. Beale worked in Greenwich, and in 1870 sold the patent rights to Messrs Bryan Donkin and Co. of London who had been making their own exhausters since 1851. S. Hughes, Treatise on Gasworks (1853) op. cit., pp. 152-5; Iron - An Illustrated Weekly Journal of Science, Metals and Manufactures in Iron and Steel, 1882 Vol. 19, pp. 426-7; 1883 Vol. 21, pp. 91,93.

2. J.G.L., 23/10/1860. In 1883 Glasgow purchased two new rotary Beale exhausters from B. Donkin and Co. J.G.L. 11/12/1883.

3. 'W.D.' in 1858 claimed an exhauster could be used economically in works producing 15,000 cu ft in summer and 200,000 cu ft a day in winter, tended by the chief stokers of two daily shifts, at 1s 9d extra each per week. The steam engine used 2 cwt coke and coal dust a day. Another manager estimated that exhausters could only be used at works making over six million cu ft gas a year. Fuel and maintenance cost £10 a year, but gas output increased ten per cent. A small Scottish gasworks, like Haddington in 1853, from two retorts made only 14,000 cu ft a day in mid-winter, so the market for exhausters in Scotland was limited to large works with about twenty-eight retorts in use in winter.
   Precise financial information on exhausters is rare. The English works at Littlehampton in 1867-8 raised gas output from 8,674 cu ft to 9,744 cu ft per ton coal. Larger retort duration offset capital cost and extra labour, while the ancillary steam engine could also power tar pumps, and provide steam in winter to defrost the gasholder.
   J.G.L. 2/2/1858, p. 48; 4/7/1871 p. 516.

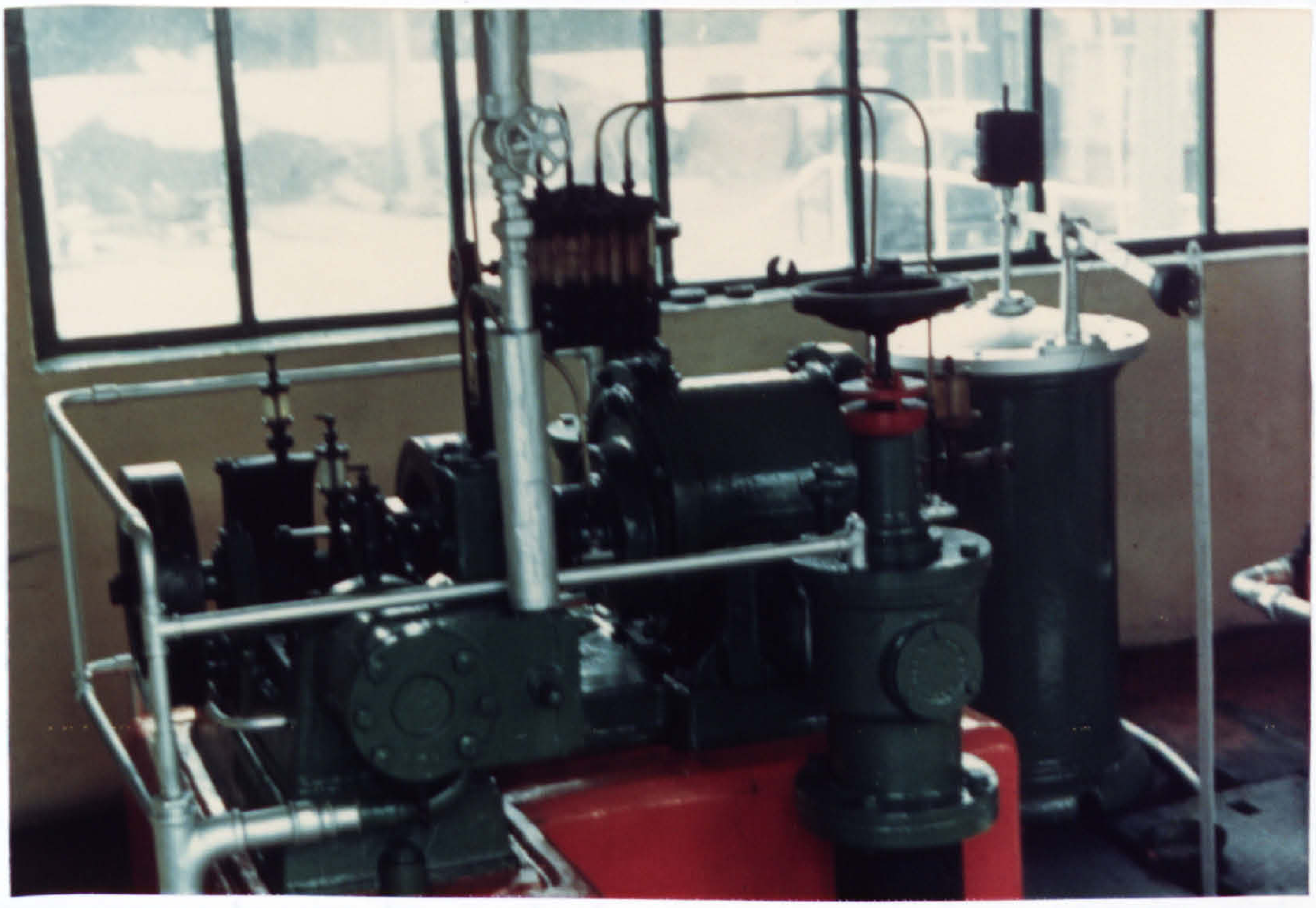
4. Two hundred Korting exhausters used by 1876, including at Glasgow gasworks.

   J.G.L. 26/12/1876 p. 930 (list of fifty places)

   S. Hughes, Practical Treatise (1880) p. 137.

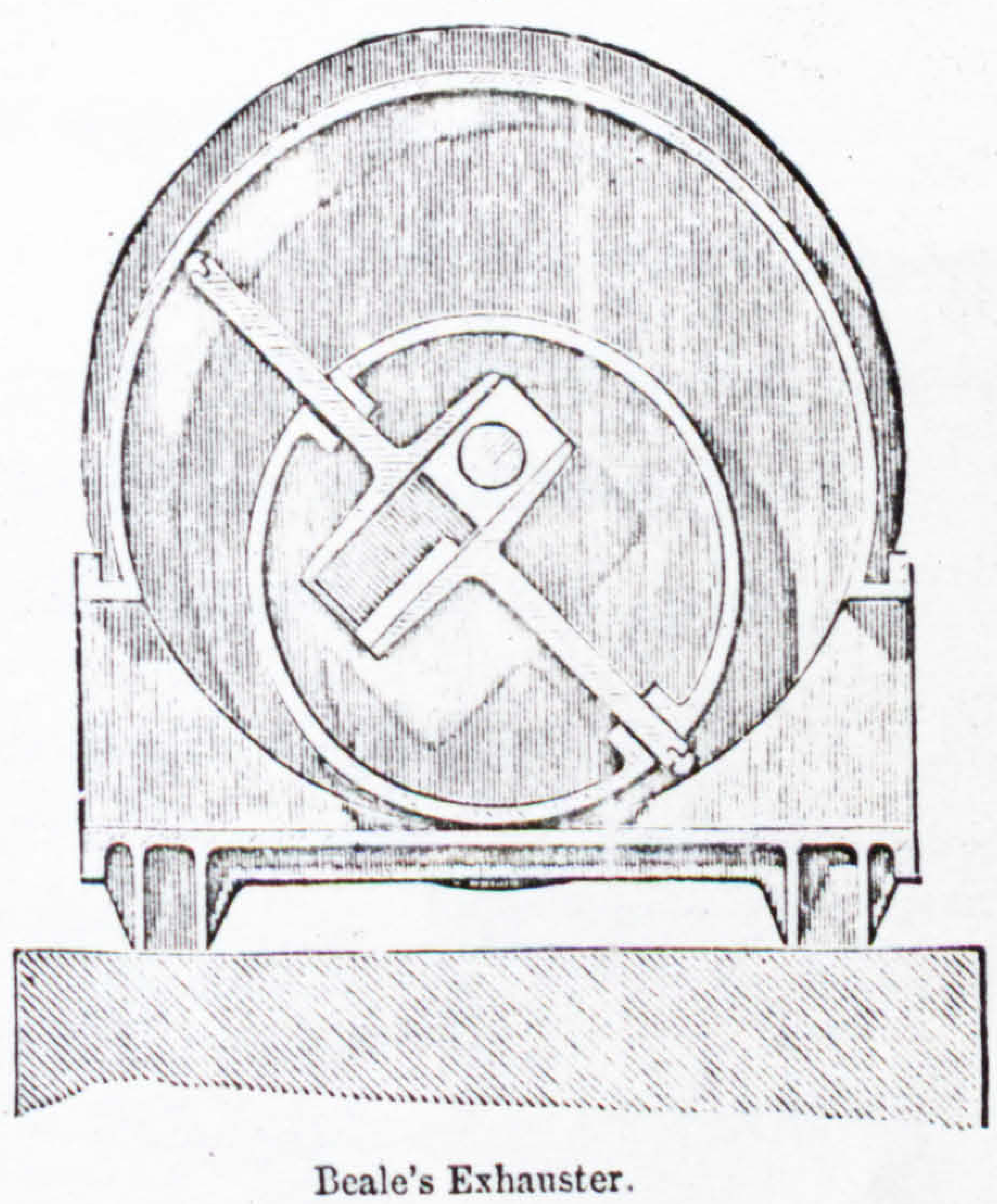
   J.G.L. 23/10/1877.

Fig. 3.46 Exhauster at Newton Stewart Gasworks (1974)



Steam powered from seperate boiler. Note 'governor' on right to reduce or increase rate of exhauster according to gas pressure in main pipes from retort house.

BEALE'S EXHAUSTER



Beale's Exhauster.

Source : Iron - An Illustrated Weekly Journal
1882 Vol. 19 pp. 426-7
1883 Vol. 21 pp. 91,93

was the first Scottish gasworks to use a Korting exhauster, which used steam to propel the gas, in 1876. These never became popular, but many Scottish gas managers tried to devize new and cheaper exhausters suitable for small works, like the popular cylindrical exhauster by T. Whimpster of Perth[1] in 1880. Mechanical innovation was the pastime of a great number of Scottish managers, and one of the reasons which, allied to the variety of different sized gasworks, produced a chaotic variety of equipment.

Other important changes in retort-houses during the 1860s included closer analysis of the coal being used, attempts to reduce retort-house labour, self-closing retort lids, and improved 'governors' to regulate gas pressure.[2] As byproducts rose in value, methods of purification and extraction of residuals improved. Scottish managers became increasingly concerned with the problems of retort-charging and the temperature-loss by retorts, caused by the high percentage of ash in coke from Scottish cannel coal and resulting in heavy labour costs for cleaning the flues and furnaces and the slag off retorts.

A continuing problem was the great winter peak in demand, so that a company had a large part of its capital equipment grossly underused for most of the year. Normally reserve capacity was kept in hand even in mid-winter to meet contingencies. In 1860 the Glasgow City and Suburban company[3] had 668 retorts, of which no more than

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1. J.G.L. 31/8/1869 p. 694; J. Anderson (Leven) "Mechanical Scrubbers" N.B.A.G.M. 1876. Many remained skeptical of the value of exhausters, vide J.G.L. 26/10/1875 p. 613; 4/1/1876, p.13; 18/1/1876 p. 85.

2. S. Stewart, N.B.A.G.M. 1876 - Presidential address and review of progress 1862-76; J.G.L. 1/8/1876.

3. New iron retorts in 1860 cost £3 12s and lasted 1 to 1½ years. Glasgow City Archives Miscellaneous Papers Vol. 18, p. 226.

450 were used together. In 1870 Glasgow Corporation used all the Tradeston station retorts in winter, but had fifty-four in reserve elsewhere.[1]

Rapidly rising coal prices in 1872-3 exaggerated the shortage of cannel coal, but were a portent of future events which required improved technology to increase by-product revenue and raise gas output from increasingly expensive coals. The first attempts, by Malam and by Aitken and Young, were only a limited success. In 1873 Malam[2] designed fourteen new retorts for Dumfries gasworks, in which water trickled down inside the ascension pipes to clean them.[3] He used twelve foot long 'through' retorts[4] with a mouthpiece at both ends, and old coke was kept incandescent in the special mouthpieces to decompose light hydrocarbons which were usually lost in the tar, and to increase the permanent gas produced. Drumpark and Auchlochan coals in 3½ hour charges thereby produced an annual saving of 986 tons of coal at Dumfries worth £1,898.

The Aberdeen gas manager observed this process to produce 9,875 cu ft per ton of coal, of 26.49 candlepower, yet refused to adopt it because ammoniacal liquor worth £1,400 a year could be lost from the ascension pipes. Dr. Wallace[5] of Glasgow also observed the contro-

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1. Viz. 30 at Dalmarnock, 12 at Townhead, and 12 at Partick.
2. J.G.L. 21/7/1874. Maxwelltown gasworks were being phased out in 1874.
   Malam was the son of a millwright, from Lincoln, and came from a family of gas engineers. His uncle John Malam invented a dry gas-meter and lime purifier, and with his brother James, John had built gasworks at Leeds, Penrith, Bradford and Hamburg. J.G.L. 18/9/1883.
3. 'Liquor' was too weak to sell, and was evaporated to dryness.
4. D-retorts, 12 ft long by 27 inches, by 16 inches high J.G.L. 13/4/1874.
5. J.G.L. 26/6/1877 pp. 1056; 15/5/1877 p. 752.

versial method, and reported quite different results. One ton of Lesmahagow coal, in ten retorts, gave 13,565 cu ft of thirty-three candle gas without an exhauster, and 15,125 cu ft at twenty-nine candlepower with an exhauster.[1] Glasgow and Dundee municipal gas-works tried the process but refused to use it because of reduced candlepower. In 1873-4 Dumfries processed 2,800 tons coal and made 31 million cu ft gas, of which twenty-eight per cent was lost by leakage.[2] Dundee normally obtained 10,000 cu ft of fourteen candle-power per ton of coal, but with Malam's process obtained 12,400 cu ft at only 10.8 candlepower. Nevertheless, the process was installed at Newton Stewart, and at several Irish gasworks,[3] and Malam later considerably improved the byproduct recovery.[4]

The Aitken and Young 'Analyser'[5] installed in 1877 at Hamilton gasworks, and later at Dalmarnock, was designed to allow cheaper cannels to be distilled, by preventing tar from absorbing illuminating constituents[6] from the gas. An iron tower, thirty-five feet high and eight feet in diameter, was heated by steam pipes at the

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1. J.G.L. 20/4/1875
2. J.G.L. 18/9/1883. This was quite excessive "condensation" loss.
3. J.G.L. 2/2/1875 e.g. Newbridge, Thurles, Mullingar, Roscrea, and Enniskillen.
4. J.G.L. 25/5/1875
5. Journal of Artificial Light 27/9/1879.
   J.G.L. 10/7/1877; 31/7/1877 p. 183.
   In 1878 Hamilton town council ordered its dismantling, vide J.G.L. 6/8/1878, 10/9/1878
   T. Newbigging, The Gas Manager's Handbook (1883) p. 84.
6. T. Newbigging, The Gas Manager's Handbook (1883) pp. 72-3.
   H. Aitken, vide infra 'By-Products' p. 441
   W. Young - vide infra 'Labour' p. 377
   Young's patent 2725 (in 1875) } Vide infra p.572
   Aitken's patent 2587 (in 1875) }

base which maintained the temperature at 212°F falling to 70°F at the top. Tar was washed out of the gas, as in a 'scrubber', but at a temperature where tar did not absorb the illuminating constituents. Although reasonably successful,[1] financial sponsors were not forthcoming.

Reducing the wastage[2] of gas from imperfect distribution systems rapidly became more important in the 1870s. Malleable iron service pipes were widely used, but several companies like Bonnyrigg and Paisley insisted upon lead pipes to resist chemical attack by saline soil[3] and sulphurous ashes. Pipes often leaked as a result of subsidence, disturbance by sewage[4] and water pipes,[5] and rat-holes,[6] to an extent equal in cost to the dividends paid by some

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1. Patented on 3/8/1875, it worked on the Coffey-still principle and was used by Young at Clippens and Causewayhead. Tar which failed to condense until gas rose to the top of the tower, dripped downwards where the temperature rose, and it relinquished any illuminating 'particles' which had been trapped. The chief problem with the 'Analyser' was the accumulation of excess light hydrocarbons and hence the need for periodical steam-cleaning.
   N.B.A.G.M. 1911; H. Aitken "The Aitken and Young Process" (West Scot. Assn. Gas Managers) J.G.L. 13/11/1877, p. 762

2. Glasgow Gaslight Company suffered leakage of 23 per cent in 1858, and 1860.
   Glasgow - Its Municipal Organization and Administration (1896, Glasgow) p. 264.

3. Stornoway reported rapid corrosion of pipes in 1854, and so forced consumers to use lead service pipes. Stornoway Minute book op. cit., 29/6/1854.

4. Sewerage operations at Annan in 1880 caused a gas loss of 300,000 cu ft. Annan Minute Book op. cit., 21/6/1880, 8/3/1881

5. W. Mackenzie (Dunfermline) "Gas Service Pipes" N.B.A.G.M.1881.

6. Gas leakage due to rats frequently caused death by suffocation. Three persons were rescued unconscious in Glasgow, for example, in 1875.
   'Compo' or 'Tripe' pipe of lead and antimony was only half as expensive as tin, but easily attacked by rats. In 1880 London and the large English towns generally used iron service pipes, Scotland and the smaller English towns used tin, and France used lead. J.G.L. 9/2/1875; W. Richards, Practical Treatise (1877)

companies. Leakage at Galashiels[1] in 1875 severely polluted some of the town's wells for drinking water.[2] Old, rusty pipes at Greenock which cost £700 to replace in 1840, had been losing gas worth £450 each year above the accepted "ordinary waste" level of 7½ per cent.

Table 3.47 Gas Leakage at Greenock under various Pressures of Supply 1840

Time	Gas Pressure	Total Hours	Leakage per hour	Leakage per Year
Sunset to 9 p.m.	1½ inches	1,055	1,100	1,160,500
9 p.m. to midnight	⅞ "	1,100	800	880,000
Midnight to Sunset	½ "	6,560	500	3,280,000
		8,715		5,320,500

SOURCE: Greenock Advertizer 19/5/1840

Ayr,[3] however, still used many main pipes in 1877 which had been laid in 1826. In 1878 Kelso[4] reported heavy leakage from mains which had been used for forty years, and Dumfries[5] spent £638 replacing mains laid fifty-three years previously. In 1888 Irvine[6]

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op. cit., p. 805; W.T. Sugg, The Domestic Use of Coal Gas (1884) pp. 44, 46.

1. J.G.L. 5/1/1875
2. Selkirk company in 1874 received similar complaints over piped water supplies tainted by gas, as did Bathgate in 1886 and the problem was quite widespread. Even well-jointed iron pipes lost gas to the extent of ten to thirty per cent in the 1850s, and even seventy-five per cent at two inches pressure. Professor Graham postulated, incorrectly, a process of 'endosmose' in which atmospheric air was drawn through the semi-permeable iron, and gas was forced out. S. Hughes, Treatise on Gas Works (1853) op. cit. pp. 259-61.
   Selkirk Minute Book op. cit., 23/11/1874
   Bathgate Minute Book op. cit., 11/5/1886
3. J.G.L. 10/7/1877
4. J.G.L., 3/9/1878
5. J.G.L., 17/9/1878
6. J.G.L., 30/10/88

reduced leakage from twenty-two per cent to nine per cent by replacing mains in use since 1842. Saltcoats gasworks made a close study to reduce gas losses and in 1903 found a 700 yard stretch of new three inch diameter mains lost 386 cu ft over four months' testing. The town[1] then had eight miles of two to six inch pipes up to sixty years old, which could therefore lose up to 60,000 cu ft a year. A well-repaired gasholder of 132,000 cu ft at five inches pressure lost 11,000 cu ft in one month. Leaking service pipes caused a further 960,000 cu ft loss each year, inaccurate public lamps 74,000, and inaccurate consumers' meters 10,000 cu ft. Many companies therefore lost their gas profits to thin air.[2]

Table 3.48 Saltcoats Gasworks - Gas 'Lost' 1883-93

Date	Gas Produced (Thou. cu.ft.)	% Loss before Sales	Date	Gas Produced (Thou. cu.ft)	% Loss before Sales
1883	5,605	11.8	1894	12,122	7.7
1884	6,456	12.8	1895	12,756	8.8
1885	7,681	15.7	1896	13,539	8.6
1886	8,041	12.7	1897	15,331	9.1
1887	7,845	12.4	1898	16,710	6.9
1888	8,908	15.4	1899	18,557	7.8
1889	9,018	10.9	1900	20,763	7.4
1890	10,013	11.1	1901	21,031	7.3
1891	11,175	9.7	1902	22,237	5.3
1892	11,849	10.3	1903	23,822	5.3
1893	12,642	9.6	1904	24,882	5.2

SOURCE: N.B.A.G.M. 1904

1. Saltcoats used mainly 3 to 4 inch gas mains; sixteen retorts in winter, four in summer. N.B.A.G.M. 1904

2. Special drainage work in Montrose in 1878 increased leakage to fifty per cent, worth £1,152 a year, and the pipes cost £200 to repair.
   In 1884 West Glasgow had severe leakage during the construction of underground railways from College Station.
   In 1889 Barrhead reduced annual leakage by 587,000 cu ft by renewal of mains and service pipes. Coatbridge in 1896 had five men employed entirely locating the leaks caused by mining subsidence and sometimes found pipe-ends 3½ feet apart.
   J.G.L. 18/6/1889; Gas World 18/4/1896; J.G.L. 23/7/1878, 1/7/1884, 18/6/1889.

Improved gas 'governors' saved the industry "hundreds of thousands of pounds",[1] by regulating the gas pressure in main pipes, public lamps, and sometimes dwelling houses. They allowed mains pressure to be reduced "to the lowest possible point compatible with a proper supply to consumers" thereby greatly reducing leakage, but were not widely applied this way in Scotland until the 1870s. D. Bruce Peebles,[2] an Edinburgh manufacturer of 'governors', showed the North

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1. D. Bruce Peebles, "On Governors for Public Lamps and Stair Lights" J.G.L. 13/8/1878

D. Bruce Peebles, "Gas Governors, with a description of Peebles' Patent Governors for Stations, Districts, Dwelling Houses and Public Lamps" N.B.A.G.M. 1876; J.G.L. 8/8/1876.

Large 'governors' for gasholder-supplies, as illustrated by F. Accum in 1819, have already been described. Vide infra p.324

Fifteen patent governors were designed in 1815-41, and 249 in 1841-66.

1825 Dry Governor invented by S. Crosley (Pat. 5089)

1854 mercurial governor by Mr Hurlett, London, for private houses.

1830s 'District Governor' devized by Mr Orlando Brothers of Blackburn, for use on gas mains to equalise pressure in different regional 'districts' of varying altitude.

1838 James Milne of Edinburgh introduced a 'governor' or 'gas regulator'(Pat. 7734) Vide infra 'Markets' p.1256

1841 John Leslie's 'Automatic Gas Economizer' was the first 'Volumetric Governor' which gave constant gas outflow, even if input gas pressure was variable.

1870 Leslie's governor, re-invented independently by H. Giroud in Paris and called a 'Rheometer'

1863 Peebles of Edinburgh began research and development of a better, gas-tight station governor to obviate another explosion like that at London. Same principles later incorporated in a 'district governor' which could be used as a 'station governor' in small gasworks.

S. Hughes, Treatise on Gasworks (1853) op. cit., p. 229

S. Clegg, Practical Treatise (1853) op. cit., p. 247

The Civil Engineer and Architects Journal, November 1840, p. 386

2. Description of Bruce Peebles governor vide King's Treatise (1879) Vol. II, op. cit., p. 317.

Biography of his successor, W. Carmichael Peebles, Gas World 30/7/1898, p. 159.

British Association of Gas Managers in 1875 how much they could gain:[1]

Table 3.49 1876 Gas Leakage at 68 Scottish Companies

Number of Companies	Percentage Leakage	Number of Companies	Percentage Leakage
11	7 - 9	3	22
15	10 - 14	2	24
21	15 - 19	1	25
14	20	1	33

SOURCE: J.G.L. 8/8/1876

Table 3.50 Pipe Leakage varying with Pressure (1876)
(1/5th diameter hole in ½ inch thick pipe, 6 to 8 inches diameter)

Water Pressure of Gas	Cu. Ft lost per Hour	Water Pressure of Gas	Cu. Ft lost per Hour
0.5 inches	42.6	2.0 inches	84.7
1.0 "	59.0	2.5 "	94.7
1.5 "	73.7	3.0 "	102.8

SOURCE: J.G.L. 8/8/1876

Table 3.51 Gas Leakage in Large Scottish Towns (1891)

Town	Percentage Leakage	Millions Cu.Ft. Annual Output	Town	Percentage Leakage	Millions Cu.Ft. Annual Output
Ayr	13.5	42	Kilmarnock	12	65
Alexandria	18	25	Kirkcaldy	13	64
Alva	20	18	Paisley	11	230
Coatbridge	17	65	Maryhill	12	290
Dumfries	20	8	Glasgow	10	2,969
Inverness	13	65	Pollokshaws	17	29

SOURCE: Ayr Minute Book op. cit., 26/10/1891

A district governor made considerable difference in reducing leakage, especially where gas travelled up-hill, because pressure rose 0.1

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1. One engineer estimated the average gas-leakage in Britain at over twenty per cent in the 1850s, and fourteen percent in 1876; seven to twelve per cent was only possible by careful management. J.G.L. 14/11/1876; 21/11/1876, p. 731.

inches every ten feet rise in altitude. From Leith gasworks, gas sent at 0.8 inches daytime pressure[1] would reach 3.1 inches by Princes Street, Edinburgh, 206 feet higher. Consumers[2] could also benefit from minimal adequate pressure, and 80,000 of Peebles house and lamp governors were in use by 1876. Glasgow Corporation[3] installed 9,000 such lamp governors in 1874 and saved £6,000; by 1876 they used 13,000.

Purification of gas by washing with water was rarely used until the method was improved in 1866 by G.T. Livesey*to supplement existing purifiers. Several less successful experiments were made earlier as at Fettercairn[4] in 1857 where sawdust and chopped wood were used to purify gas and make fertilizer. Absorption of impurities depended upon the surface-area of contact between gas and water, and Livesey[5] proved experimentally that one-quarter inch wooden boards

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1. Leith night-time pressure was 1.7 inches.
In 1879, Coatbridge used Peebles governors, both in shops, and on the mains to supply a district 200 ft lower than the gasworks. N.B.A.G.M. 1879; N.B.A.G.M., 1912. W.C. Peebles "Gas Governors - Their Action and Application". Vide infra 'Use of Gas' p.1256

2. E.g. many Dundee shops, houses and factories had governors in 1878. J.G.L. 6/8/1878

3. Glasgow gasworks used a different 'governor' designed by the gas-manager Wm. Foulis in 1877: J.G.L. 17/7/1877 p. 143; King's Treatise 1879 Vol. II op. cit., p. 319

4. By A. Ross, J. Vallentine and A. Murray at Fettercairn, Kincardineshire: The Builder 15/8/1857 p. 467.

5. The earliest 'washer' was devized by Wilson in 1817, and used ammoniacal gas to absorb sulphuretted hydrogen before 'scrubbing' the gas by passing it through a perforated plate under water. It was too complex to become popular. Livesey demonstrated that for each cubic foot of space inside the Scrubber wet coke gave 8½ sq. ft. surface area, 3 inch drain-pipe gave 17 sq.ft, 2-inch drain pipes gave 21 sq. ft, but ¼ inch wooden boards gave 31 sq. ft area.
C. Hunt, Gas Lighting (1900) op. cit., p. 89.
W. Richards Practical Treatise (1877) op. cit., p. 126.

* George Thomas Livesey (1834-1908) . Institute of Gas Engineers Transactions 1908 pp. 348-59 biography.

gave the largest feasible area per cu ft of space. Ammonia was absorbed by the water and the 'Livesey washer' was increasingly adopted in Scotland as the sale price of ammoniacal liquor increased. It comprized a cast iron box, with perforated horizontal wooden boards. Water entered through a syphon tube at the top, and dripped from board to board, leaving a ½ inch deep layer on each. Gas entered at the base, and travelled up through the perforations in the opposite direction, being washed en route. Tar was removed from the gas, and consequently 'washers' were placed between the condenser and the lime purifiers to prevent tar clogging the latter.

The 'Scrubber' which was also a water-wash, achieved increased importance in the 1870s for by-product recovery. It comprized either a tall vertical chamber,[1] or a small mechanised version of the 'Washer' and the terms were often ambivalent. In 1847 Haddington[2] used a scrubber 4½ feet in diameter, containing old bracken held in a wicker basket and fed by a water cistern. At Leith in 1865, J. Reid used a cistern with a central pivot around which were attached perforated iron-buckets. By mechanical rotation of the pivot, the buckets raised water inside the cistern to give a water-spray through which the

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1. In 1846 George Low of the Chartered Company used perforated revolving pipes to spray liquid over scrubbing material in a tower.

   D. Chandler and A.D. Lacy, <u>The Rise of the Gas Industry in Britain</u> (1949).

2. Installed by Mark Taylor, gas engineer of Edinburgh and later of Kelso, who designed the original Haddington gasworks.

   <u>N.B.A.G.M.</u> 1880 J. Anderson (Leven) Mechanical Scrubbers.

   Heather was used in the Port Glasgow scrubbers in 1879, and probably found wide application: <u>J.G.L.</u> 1879, p. 671.

gas was passed.[1] By using two cisterns, a high percentage of ammonia could be collected in the first, and cleaner water in the second used to complete the purification. T. Whimpster[2] at Perth in 1870 devized a cylindrical washer[3] eighteen feet high, divided by cast-iron plates with ¼ inch holes. Fresh water pumped in at the top produced a shower to wash the gas.

Since Perth then had an advanced design for Scotland, it is probable that most works until the 1870s had no washer or scrubber equipment though a few had a very simple design to prevent tar reaching the purifiers. In England, the tower scrubber was improved by Mann[4] who used mechanical arms to rotate a water-trickle through brushwood on top of the tower. Messrs. C. and W. Walker sold a similar version with overhead water-storage tank, and rotating horizontal sprinkler arms below which a perforated metal plate instead of brushwood revolved in the reverse direction to improve water distribution.

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1. J.G.L. 5/3/1867 p. 151 (diag.). J. Reid vide infra 'Labour' pp.631,634, 641,1730
 The device was a forerunner of Kirkham's 'Standard' scrubber, Still's revolving pan scrubber at the London Chartered Company, and George Anderson's 1874 'Brush Scrubber', all of which were sold to a wide market. The reason for Reid's failure to develop and market the scrubber is unclear. Chandler and Lacy trace the Kirkham scrubber back only to a rotary washer/scrubber by Paddon at Brighton in 1870, so Reid was well in the lead. Water can absorb up to 800 times its own volume of ammonia.
 D. Chandler and A.D. Lacy, The Rise of the Gas Industry in Britain (1949).

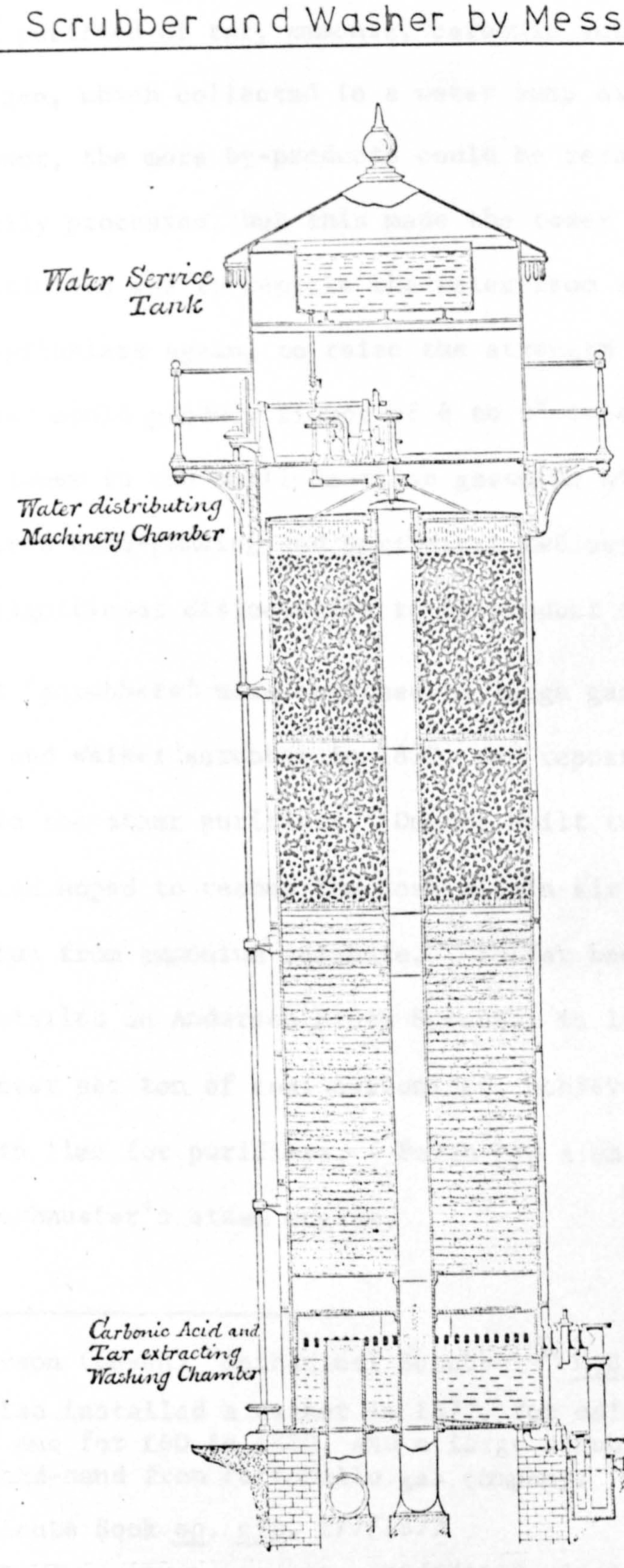
2. T. Whimpster was manager at Perth from 1845 until after 1889. Gas World 5/1/1889.

3. Montrose, for example, used a Whimpster washer and exhauster up to 1891, before substituting a Beale exhauster from Messrs Laidlaw. J.G.L. 13/10/1891; King's Treatise 1878 Vol. I op. cit. p. 350 (diag.).

4. J.G.L. 13/10/1874 p. 500; 21/7/1874 p. 91; 5/1/1875 p. 11 (diag.); 25/4/1871 p. 313; 31/3/1868 p. 228.
 C. Hunt, Gas Lighting (1900) op. cit., p. 89.

Fig. 3.52

Tower Scrubber and Washer by Messrs Walker



Source - C. Hunt Gas Lighting (1900) op cit p.89

The top of the tower contained wet coke, and the lower section used wooden boards similar to a 'Washer'. Gas ascending from the base of the tower was purified of tar, ammonia, carbonic acid, hydrogen sulphide and cyanogen, which collected in a water sump at the base. The taller the tower, the more by-products could be recovered as liquid which was easily processed, but this made the tower expensive and an alternative solution was to recycle the water from the sump, up and through the sprinklers again, to raise the strength of the 'liquor'. A tall scrubber could produce liquor of 6 to 8° Twaddle, but recycling with a small tower in the small Scottish gasworks without a steam engine, required hand-pumping and periodical tedious cleaning of the Scrubber, a significant disincentive to by-product recovery.

At first 'scrubbers' were confined to large gasworks. Stirling[1] built a Mann and Walker scrubber in 1877, and reported a great saving of lime in the other purifiers. Dundee built two the same year, for £2,000, and hoped to recoup the cost within six years by increasing the revenue from ammonium sulphate. Forfar bought one in 1881. Kirkcaldy installed an Anderson Brush Scrubber in 1878, and for ten gallons of water per ton of coal carbonized, achieved a thirty per cent saving in lime for purifiers. Perth had a smaller version powered by the exhauster's steam engine.

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1. J. Anderson (Leven) "Mechanical Scrubbers" N.B.A.G.M. 1880.

   Banff also installed a washer in 1877, for only £13. Dalkeith purchased one for £60 in 1880, and a large scrubber for £30 in 1902, second-hand from Portobello gas company.

   Banff Minute Book op. cit. 2/7/1877

   Dalkeith Minute Book op. cit., 30/6/1880, 26/9/1902.

Once the method was established,[1] Scottish gas managers produced their own versions.[2] Mr Brodie[3] of Paisley built a double-scrubber at Dumbarton in 1880, an oblong twenty-one feet high by nine feet by 4½ feet, with a cast iron partition and six trays in each section holding old road-sweepers' brooms, and a water pump. It was simple and efficient. William Young[4] developed a version of Anderson's 'Brush Scrubber' which became popular after trials at Lanark and Falkirk gasworks[5] in 1880. It was able to provide ten gallons of commercial 'liquor' per ton of coal carbonized, and was fed by a water tank with one day's supply which labourers could refill during any spare time. Whilst the advanced Kirkham-Hurlett-Chandler

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1. Rising lime prices were an important stimulus. Galashiels company, which had obtained supplies from Thomas Wilson and Company since 1856, paid 10s 4d per ton in 1868, 10s 10d in 1872, and in 1875 purchased from Wm. Taylor and Co. at 16s per ton.
   Galashiels Minute Book op. cit. 5/8/1856, 28/2/1868, 4/6/1872, 2/2/1875.

2. Washers and scrubbers were not adopted at "small, out of the way country towns and villages", because of inexperienced managers. Consequently the cost of lime purifiers was high, the by-products largely worthless, and an additional burden was added to their high coal transport costs and high wages, fuel and deterioration compared to small gas output which made the price of gas 10s or 12s compared to 3s 6d in nearby towns.
   J. Whimpster (Perth) "Equalize the Price of Gas?" N.B.A.G.M 1882.

3. Died 1896, sole partner of Wm. Brodie and Co., gas engineers of Paisley. Dalry Minute Book op. cit., 7/4/1896.

4. Vide infra 'Labour' p.377

5. A. Scott (Falkirk) "A Year's Experience with Young's Patent Washer Scrubber" N.B.A.G.M. 1882.
   Bathgate gasworks in 1881 erected a Young's Washer/Scrubber for £65 to process 5½ million cu ft per year. In one year it increased ammonia liquor yield by 10,000 gallons worth £50, and reduced expenditure on purifying lime by £2 per 4 tons. During 1881, Scott wrote personally to many Scottish gasworks, like Dalry, urging them to use the Washer-Scrubber. Dalry refused then, but in 1886 purchased a £100 scrubber to increase ammonia revenue, after making a survey of local companies which showed that Irvine, Johnstone and Paisley used "scrubbers", and Ardrossan and Saltcoats had installed "washers". Dalry Minute Book op. cit. 10/8/1881, 9/4/1886. J.G.L. 31/3/1891 p. 696: Bathgate Minute Book op. cit., 10/5/1882.

Scrubber-Washer[1] found only a very limited market in Scotland. Livesey washers and scrubbers like those of Brodie and Young were widely used from the 1880s and raised the by-produce revenue of many Scottish gas companies.

Two further developments, iron oxide purifiers and lime revivification reduced purification[2] costs in the 1870s and 1880s. Companies varied considerably in the amount of lime used, and therefore the cost involved. One in 1875 processed 120,000 cu ft a day[3] through sixteen trays with a total of seventy-two inches depth of lime. Another, with washers and scrubbers, processed 100,000 through three trays with a total six inches depth of lime. Alloa[4] used three out of four purifiers, each with three trays of lime giving a depth of fifty-four inches in total. The main disadvantage of thick lime was increased 'back-pressure' of gas, yet even in the late 1870s many

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1. This used a revolving shaft with circular discs of perforated metal, or wooden laths at ¼ inch intervals, at 5 r.p.m. to scrub the gas. K.H.C. 'Standard' Washer/Scrubbers in Scotland in 1888 included:-

Town	Cu.Ft. Capacity a Day
Burntisland	250,000
Dumfries	250,000
Inverness	250,000
Edinburgh	(1,500,000
	(2,000,000

Tradeston works, Glasgow, installed 2 sets (£17,000) in 1890 to handle 2.5 million cu ft gas per day.
J.G.L. 23/10/1888, 17/6/90; C. Hunt, Gas Lighting (1900) op cit. p. 89.

2. English gas was less pure than Scottish (vide infra Markets p.1213)
In 1860 W.R. Bowditch suggested private clay and lime purifiers to be fitted near consumers' gas meters.
W.R. Bowditch On Coal Gas (1860) pp. 15, 21-2.

3. J.G.L. 2/2/1875

4. J.G.L. 9/2/1875.

Scottish gasworks[1] were only changing from the old system with two tiers each of 24-30 inches, to three or four tiers each with ten to twelve inches of lime.

By 1860, Dalmarnock[2] gasworks in Glasgow used Anglesea iron oxide[3] in some purifiers, but that system was largely ignored[4] in Scotland until the late 1870s. At Paisley about 1879 each purifier box

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1. N.B.A.G.M. 1879 D. Terrance (Arbroath) "Working Statistics". Glasgow City and Suburban works in 1867 used five layers of lime in the purifiers. Forty purifying boxes, ten ft. long, were arranged in sets of four around hydraulic valves. Evidence of S. Stewart (Greenock) Glasgow City Archives - Miscellaneous Papers Vol. 15 p. 465.

2. Again this process was imported. Croll and Laming in London tried several metal oxides in the 1840s. In 1818 H. Palmer used a red-hot tube containing scrap iron and clay, and in 1849 F.C. Hills showed the value of hydrated iron oxide. Dalmarnock still used some lime purifiers in 1894, in boxes 3½ ft. deep and 35 sq. ft. in area. Ten men stood inside the box with shovels to clean it, and two more in the railway truck standing nearby. Each box had two seven-inch layers of lime, and in 1894 an explosion of residual gas severely injured the workmen.
   Gas World 30/3/1895; Chandler and Lacy, Rise of the Gas Industry (1949) op. cit.,: Glasgow City Archives Miscellaneous Papers Vol. 18 p. 226.

3. F. Hills showed in the 1850s that iron oxide, saturated with hydrogen sulphide, could be revivified for re-use simply by exposure to atmospheric air, when the sulphur turned to powder. After several cycles the sulphur content rose to 40 or 50 percent and the material was sent to a chemical works, which extracted the sulphur and returned the iron-oxide for re-use. Revenue from 'foul' oxide was, however, very low: R.H. Patterson, Gas and Lighting (1877) op. cit. pp. 169-71. S. Hughes, Practical Treatise (1880) op. cit., pp. 272, 255-69.

4. In 1869 J. Young of Hawick urged the retention of lime purifiers instead of iron oxide, and suggested making them small, 13 feet by 7 feet by 3 feet 3 inches, mounted on wheels and a miniature railway, so they could be run onto normal railway wagons and deposited for agricultural fertilizer in the country without causing an urban nuisance.
   Haddington in 1863 still retained 3 wet-lime purifiers, cylinders 4 feet in diameter and 2 feet high. In winter, 2 had to be refilled daily with three buckets of lime and then water.
   J.G.L. 2/2/1869 p. 78; 10/3/1863

Fig. 3.53 Purifiers at Kirkconnel (1973) and Edinburgh (1972)

Set of purifier boxes, with small overhead gantry and crane, to raise the lids for cleaning. Installation at Kirkconnel typical of small works, though frequently roofed over. Waste iron oxide purifying material in foreground.

Two storey purifier house at Granton, Edinburgh, built c.1902. Purifier boxes on ground level, with space above for the revivification of purifying materials.

had four shelves, and Hislop used iron-oxide on two to reduce back-pressure. Dundee from 1875 also tried the mixed system, in large purifier boxes 20 feet by 4½ feet deep.[1] Six inches of lime was placed on the bottom shelf, ten inches of iron oxide on the second shelf, and eight inches oxide on the top shelf. Purification costs were immediately reduced by £400 a year, because the iron could be revivified for re-use on a platform built above the purifiers.[2]

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1. By 1885 Dundee used separate boxes. Eight purifiers, 20ft. by 20 ft., held iron oxide, and the gas finally passed through four purifiers, 20ft. by 30ft, holding lime. Gas World 18/7/1885, p. 76.

2. Southern England rapidly adopted iron oxide purifiers introduced in 1868 by P. Spence of Manchester (Pat. 2959). Perth used iron oxide, with lime, from 1873. Elgin first did so in 1879, Kilmarnock in 1880, and Cupar in 1884. Greenock turned to oxide because it had difficulty selling waste lime to farmers, as did Alexandria which tried 11 tons of oxide in 1882; and Galashiels which changed in 1902. Ayr, quite a large works did not adopt iron-oxide purifiers until 1909 when they cost £110 a year including revivifying compared to fresh lime at £252 including carriage. Whilst English works used iron alone, and left much carbonic acid (CO_2) in the gas, Scottish works normally had auxilliary lime purifiers and supplied purer gas.

$$Fe_2O_3\,3H_2O + 3H_2S \longrightarrow 2FeS + 6H_2O + S$$

(natural,hydrated iron peroxide) (Hydrogen Sulphide)

$$2FeS + 3H_2O + 3/2O_2 \longrightarrow Fe_2O_3 + 2S$$ (revivified in atmospheric air)

King's Treatise (1879) Vol. II op. cit., p. 17.
G.R. Hislop (Paisley) - Presidential address to N.B.A.G.M.
J.G.L. 31/8/1869 p. 695; Galashiels Minute Book op. cit. 2/9/1902;
Dr Lethby "Spent Oxide of Iron", its utility for chemical manufacture J.G.L. 9/7/1867 p. 578
D.M. Nelson (Glasgow) "Gas Purification by means of Oxide of Iron" N.B.A.G.M. 1880; S. Black (Alexandria) "Purification by Oxide of Iron" N.B.A.G.M. 1882.
Ayr Minute Book op. cit., 15/3/1909; Cupar Minute Book op. cit., 5/9/1884, 9/12/1886.
Dr S. Macadam "The Relative Value of Purifying Agents used in the Manufacture of Coal Gas" J.G.L. 29/8/1871 p. 657.
J.G.L. 22/1/1856 p. 52; 23/12/1856 p. 704; 13/3/1860 p. 142; 12/10/1858 p. 582; 14/9/1858 p. 549; 31/8/1858 p. 501; 12/12/1856 p. 705.
F.C. Hills "Gas Purification by Hydrated Oxides of Iron" J.G.L. 13/5/1856 p. 274. Hills' patent expired in 1863, leaving gasworks free to experiment with his idea. J.G.L. 1/12/1863 p. 737.

This led Hislop to experiment with revivifying lime in 1876 at Paisley. Four calcining chambers were built over one furnace, with regenerative heat flues. Waste lime in a large upper chamber was gently heated while the lower three retorts were very strongly heated to drive out carbonic acid and impurities. When the lower chambers were emptied, they were refilled from the fourth and the process repeated. One man could attend two sets of chambers, and revivify fifty cwt spent lime per twelve hour shift, producing twenty-five cwt quick lime at the cost of ten cwts coke fuel. Lime could be re-used a hundred times, and gave great savings when good Irish lime cost 20s to 24s per ton. A set of chambers was built at Greenock gasworks in 1877, and several large Scottish works adopted the system.[1]

Purification problems at Kirkcaldy[2] gasworks in 1883-4 illustrate clearly the mechanism for diffusion of technical knowledge in Scotland. Large quantities of hydrogen sulphide appeared in the gas-

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1. Hislop's ovens, 9½ feet by 11 feet, by 9 feet high, cost about £100. Eight hundred tons of spent lime gave four hundred tons quick lime. By 1889 Paisley gasworks had purchased no fresh lime for eleven years. Revivification was previously considered by Murdoch, and promoted in 1845 by Thomas Graham.
   S. Smiles, Men of Industry and Invention (1884) pp. 136-8
   R. Smith "Thomas Graham" Proc. Royal Philosophical Society of Glasgow 1883-4 op. cit. p. 356
   G.R. Hislop and W. Young "Improvements in Revivifying Spent Lime" (1878, Pat.1591)
   Journal of Artificial Light 25/10/1879 p. 154; 16/6/1880 p.725
   J.G.L., 16/10/1877 p. 634; 23/10/1877 p. 646; 26/3/1889
   King's Treatise 1879 Vol. II op. cit., p. 21
   F. Colyer, Gas Works - Their Arrangement, Construction, Plant and Machinery (1884) p. 80.

   Unsuccessful experiments by J. Gibb of Armagh in 1874 vide J.G.L. 14/9/1875 p. 396.

2. A. MacPherson (Kirkcaldy) "Difficulties Experienced in Purification" N.B.A.G.M. 1884

holder, and the purifiers became hot. The manager, MacPherson, was unable to find the cause and sent a sample of freshly slaked purifier lime by rail to Edinburgh gasworks, but the test result was negative. He then examined the coals used, and found iron pyrites in one type. At Dunfermline gasworks where this coal was also used, he confirmed the problem, and then employed Dr S. Macadam of Edinburgh to test all his coals. Two types were rejected, the gas manager of East Wemyss was warned about the coal which he also used, and the coalmaster himself employed Macadam as well as Dr Wallace and G.R. Hislop of Paisley to test his seams. Kirkcaldy gasworks cleared the condensers and hydraulic main, but still had problems, and the managers of Perth and St Andrews gasworks joined the search for a solution, before sulphur deposits were detected in the connecting pipes and the problem resolved. The Associations of Gas Managers[1] were extremely important in promoting such co-operation.

Average retort-house practice changed very little until the improved ovens of the 1880s. S. Stewart[2] of Greenock, a leading gas engineer, advised managers in 1877 to construct works which were "old fashioned and simple /rather/ than to have untried novelties that none but the manager understands." Because production was continuous every workman had to be able to handle any of the equipment, and the best arrangement was to have all apparatus in a logical position and all pipes above ground, so no mistakes could be made. Few works retained the old 'Battery' condensers of interconnected

1. <u>Vide infra</u> 'Labour' p.648

2. S. Stewart (Greenock) "The Construction of Gas Works" <u>J.G.L.</u> 6/11/1877 pp. 718-21.

boxes,[1] many upright air-cooled pipe-condensers remained, but annular condensers had become "generally adopted".[2] Retort sizes had increased to nine feet long, two feet wide, and about fifteen inches high, and short three-hour charges were common because heavier charges wasted too much gas during the process of charging, and excessive distillation reduced the candlepower of gas.

English ovens normally had six or seven retorts, which were too confusing for the short charges in Scotland, so the North normally had three retorts per oven or four if there were four-hour charges. Many had two or three small old retort-houses, instead of one larger house, thus wasting labour. Only large Scottish works had five retorts per oven. In 1879 Kilmarnock and Dumbarton[3] had four over one furnace, Coatbridge[4] had five over one furnace, Greenock and Edinburgh & Leith five over two furnaces, Dundee[5] in 1880 three and five over one furnace and Galashiels and Perth three in a triangle over two furnaces. Maryhill had four brick-built D-retorts over one furnace.

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1. Vide supra p.241 Fig. 3.4

2. J. Hislop, the manager and designer of Partick/Maryhill/Hillhead (1871) gasworks, installed an annular condenser in 1879 for £954. It had ten stands, in each of which the gas travelled in the space between an outer tube 3½ feet in diameter and an inner tube 2½ feet in diameter. Annular condensers had larger cooling-surfaces and were more efficient than their predecessors, an important factor when heavy consumption coincided with mild winter weather. Hislop trebled the efficiency by placing a water-spray to supplement the flow of cool air in the central hole. Dundee in 1885 used steel annular condensers by Hanna, Donald and Wilson, comprising 30 sections with an inner pipe 18 inches in diameter, and an outer pipe 30 inches in diameter. Gas entered at 150°F and left at 60°F. N.B.A.G.M. 1883; Gas World 11/7/1885 p. 45; King's Treatise 1878 Vol. I op. cit., p. 295 (diag.).

3. Dumbarton retorts were 9 feet by 20 inches by 15 inches high.

4. N.B.A.G.M., 1879

5. J. McGilchrist (Dumbarton) "Retorts and Retort Settings", N.B.A.G.M. 1880.

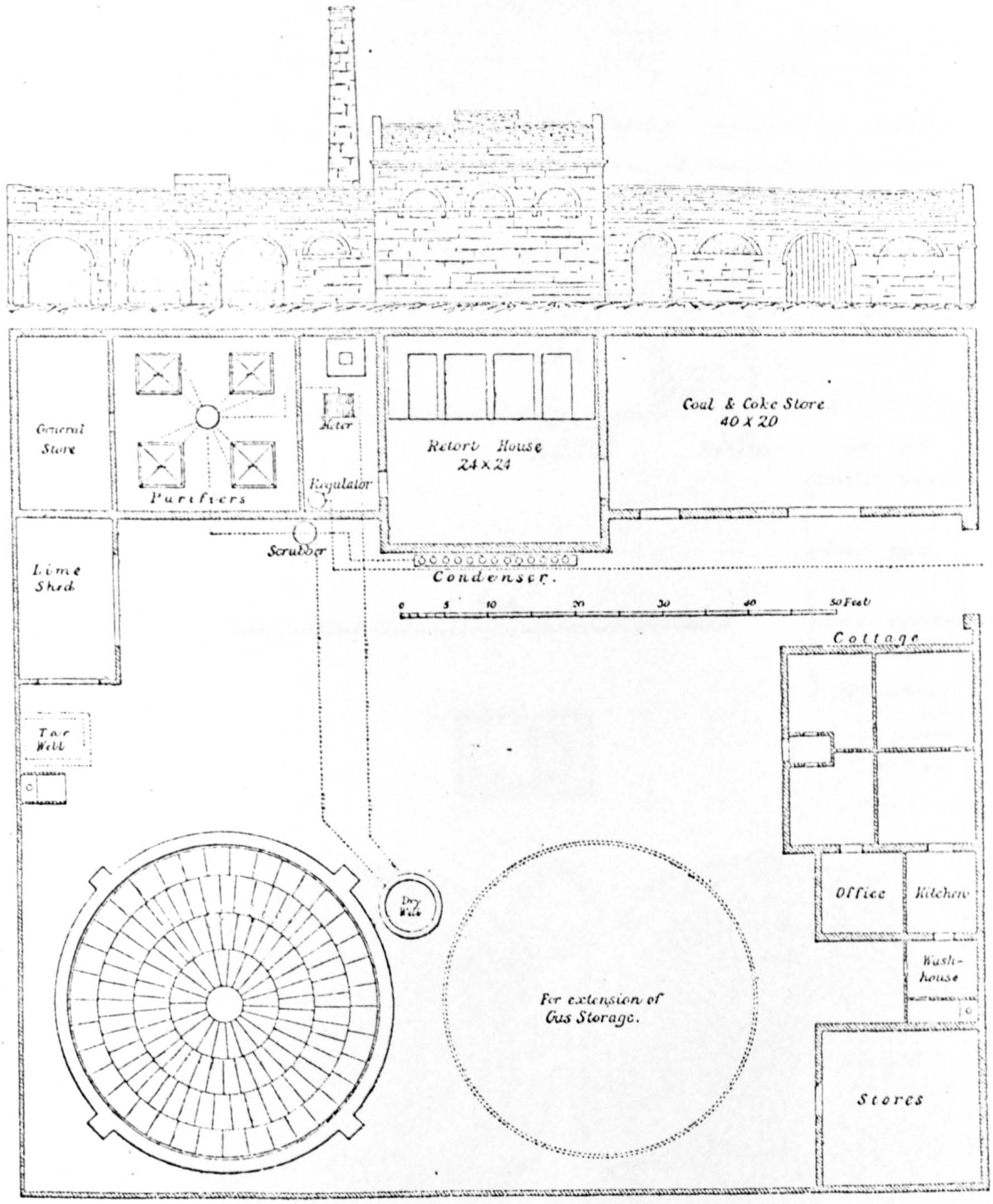
Typical gasworks of the 1870's are shown in figures 3.54 and 3.55 . A plant[1] to produce three million cu.ft. per year supplied five to twelve thousand cu.ft. per day, according to the season, at 1½ to 2 inches pressure from a gasholder with storage equal to 36 hours' winter demand. Four ovens of retorts, two with two retorts and two with three, were held in a retort house twenty four feet square and sixteen feet high. Only one retort was necessary in summer, and each retort gave about 7,000 cu.ft. per day. A thirteen inches diameter hydraulic main led to condensors, and thence gas passed through a nine foot high scrubber (2½ ft. in diameter and supplied from an overhead water cistern) and thence to a nest of four purifiers (4½ feet square) arranged around a centre-valve. Some cities retained similar small ovens holding few retorts, and even the large gasworks which supplied Paisley only

1. "Considerations Affecting the Establishment of Gasworks", J.G.L. 28/3/1876 p.455.

Fig. 3. 54

Gasworks Suitable For a Small Town or Village Requiring

Three Million Cubic Feet Per Year

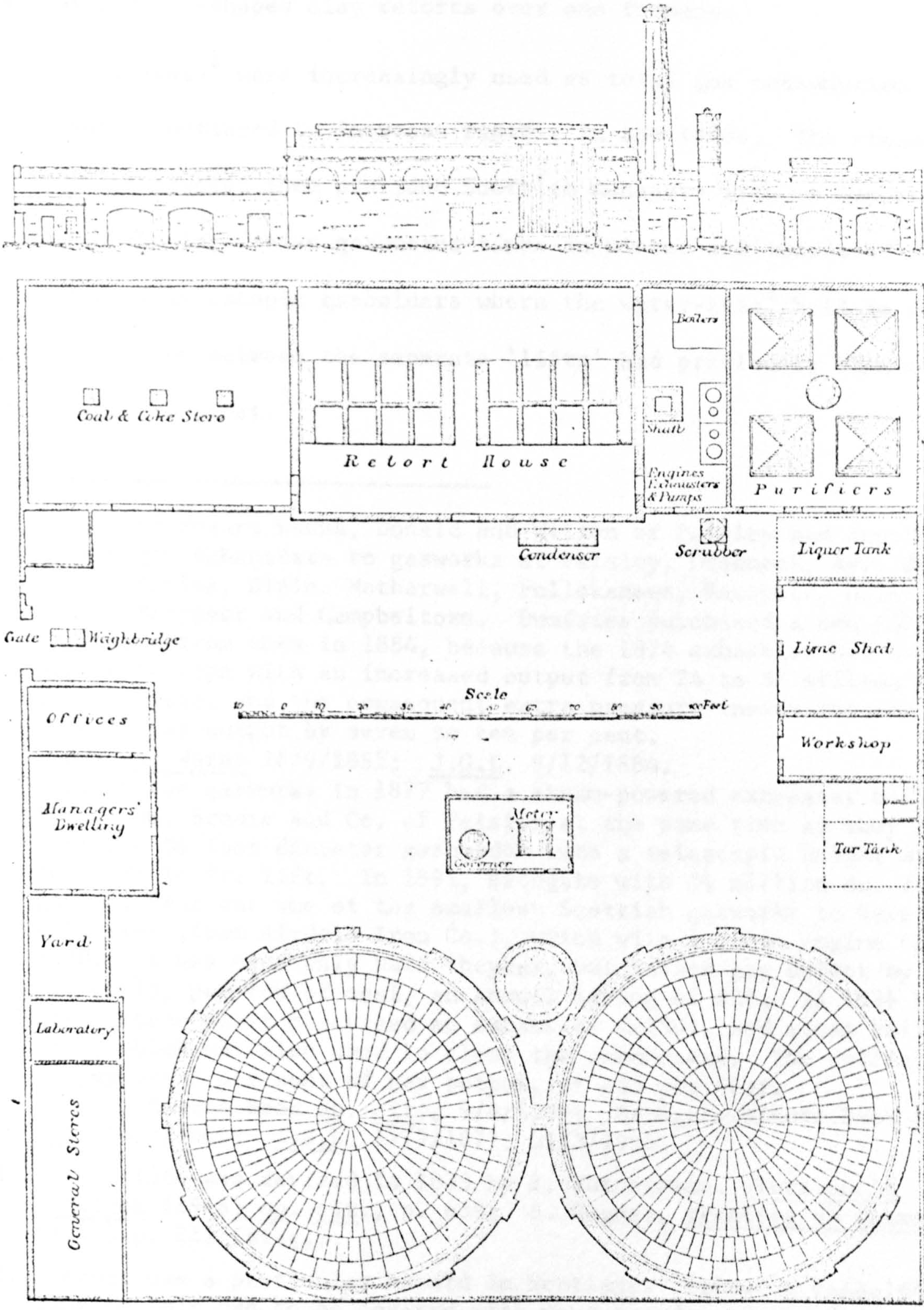


Source - T Newbigging ed. King's Treatise (1879)

Vol II op cit p. 285

Fig. 3. 55

Gas Works suitable for producing Fifty Million Feet per Annum.



Source - T. Newbigging ed. King's Treatise (1879)

Vol.II op cit p 287

had two of brick in each oven. Glasgow had the largest ovens, with six or seven D-shaped clay retorts over one furnace.

Exhausters[1] were increasingly used as total gas consumption from most works continued to increase rapidly in the 1880s. The steam-engines which powered them provided Scottish managers with an important means of thawing frozen gasometer tanks in winter and increased the adoption of telescopic gasholders where the water-lute[2] held in an exposed position between the separate 'lifts' had previously been most vulnerable to frost.[3]

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1. By 1885 Messrs Hanna, Donald and Wilson of Paisley had supplied rotary gas exhausters to gasworks at Paisley, Greenock, Ayr, Dumfries, Hawick, Elgin, Motherwell, Pollokshaws, Barrhead, Helensburgh, Maryport and Campbeltown. Dumfries purchased a new £300 exhauster from them in 1884, because the 1874 exhauster had been unable to cope with an increased output from 24 to 38 million cu. ft. per year, and the consequent extra pressure inside retorts had reduced gas output by seven to ten per cent.
   Gas and Water 26/9/1885; J.G.L. 9/12/1884.
   Dumbarton gasworks in 1877 had a steam-powered exhauster built by Messrs Wm. Brodie and Co. of Paisley at the same time as they converted a 50 foot diameter gasholder into a telescopic holder with an extra 16 ft. lift. In 1891, Bathgate with 5½ million cu. ft. gas per year was one of the smallest Scottish gasworks to have an exhauster (from Airdrie Iron Co.), which with a steam engine cost £230. It was used only half theyear, but raised gas output by 500 cu ft. per ton of coal, an annual saving of £34. In 1886 Dalry gas company first purchased an exhauster (£250), and steam boiler (£25) which was also used to clean the condensers. The estimated saving was 5 per cent of gas output, or £55 per year.
   Dalry Minute Book op. cit., 9/4/1886; Bathgate Minute Book op. cit. 16/7/1886; J.G.L. 17/7/1877, 31/3/1891.

2. This lute was devized in 1833 by S. Hutchinson. Terrance's Notebook (1948) op. cit., p. 639; S. Hughes, Treatise on Gasworks (1853) p. 212 (diag.).

3. Frost was a particular hazard in Scotland. Stirling gasholder tank in 1879 had to be covered with wood boards and straw to prevent freezing, which blocked 3 inch diameter gas pipes and could only be cleared with methylated spirits. At Perth, where the iron gasholder tanks stood above ground level, labourers were used to smash the ice, until one winter when the gasholder lurched and tangled the guide-chains; steam heating was then adopted, and for a subsequent telescopic holder. Forfar in 1881 had to telescope a 60 ft. diameter holder because of a shortage of ground space, and

Regenerative retorts[1] revolutionised the Scottish gas industry in the 1880s by reducing expenditure over a wide range of working costs and some capital costs. They were adopted under the stimulus of a shortage of high quality cannel coal, and high prices which demanded greater efficiency and reduced labour costs.

The system of re-cycling waste-heat to increase furnace efficiency was developed in the late 1850s by C.W. Siemens[2] (1823-1888)

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also placed a steam pipe along the connecting lute. Frost jambed the Kinross 'district-holder' in 1879, and in 1883 Dundee Gas Commissioners bought a £50 Keith's Hot Water Boiler for their Lochee 'district-holder' which had been damaged by frost the previous winter. Harthill company's gasholder froze solid in 1881.

J.G.L. 23/12/1879; 6/12/1881: Dundee Gas Commissioners' Reports 1882-3 (Scot. Nat. Lib) 5/11/1883: D.B. Esplin (Forfar) "A Winter's Experience with Methods of preventing Freezing of Gas Apparatus" N.B.A.G.M., 1881: P. Watson, (Stirling) "The Effects of Frost on Gas Apparatus" N.B.A.G.M., 1879: J.G.L. 12/1/1879 p. 59; 26/1/1875 p. 119.

1. The 'regenerator' principle was first used in Dr Jeffrey's respirator, and developed in 1817 by the Rev. Stirling of Dundee for a hot-air engine. Pre-heated air was also an aspect of J.B. Neilson's 'Hot Blast' process for iron. C.W. Siemens used a 'regenerator' in 1846 in experiments with a super-heated steam engine, and in 1857 his brother, Frederick Siemens, suggested its application to furnaces. The Siemens-Martin regenerative steel furnace was later developed.

   C. William Siemens "On a Regenerative Gas Furnace as Applied to Glasshouses, Puddling, Heating, &c" Proceedings of the Institution of Mechanical Engineers 1862: R.H. Parsons, A History of the Institution of Mechanical Engineers 1847-1947 (1947, London) p. 139: R.D. Corrins "The Great Hot Blast Affair" Industrial Archaeology - The Journal of the History of Industry and Technology (1970, Newton Abbot) Vol. 7 p. 252: J.D. Scott, Siemens Brothers 1858-1958, (1959, London) pp. 22, 51: Evidence of C.W. Siemens, BPP. 1871 (XVIII) pp. 214 (432) to 217.

2. Born at Lenthe, Hanover. Trained at Magdeburg Technical School, Gottingen University, and Stolberg engineering works in Magdeburg (1843). Interested in electro-plating; 1844 resident in London; 1859 naturalised Englishman; 1847 British agent for Siemens and Halske electric telegraph company, operated by his brother Werner in Berlin; 1859 married Ann Gordon, sister of the Professor of Engineering at Glasgow; 1862 Fellow of Royal Society; 1879 invented electric furnace.

   Dictionary of National Biography 1909 Vol. XVIII, p. 240

Fig. 3.56 Siemen's Regenerative Gas Producer 1862

A - inlet for "fuel" - lignite, coke dust &c

B - base of "retort" at 45 to 60° angle

C - grate, air inlet

D - water trough - produced steam for water-gas

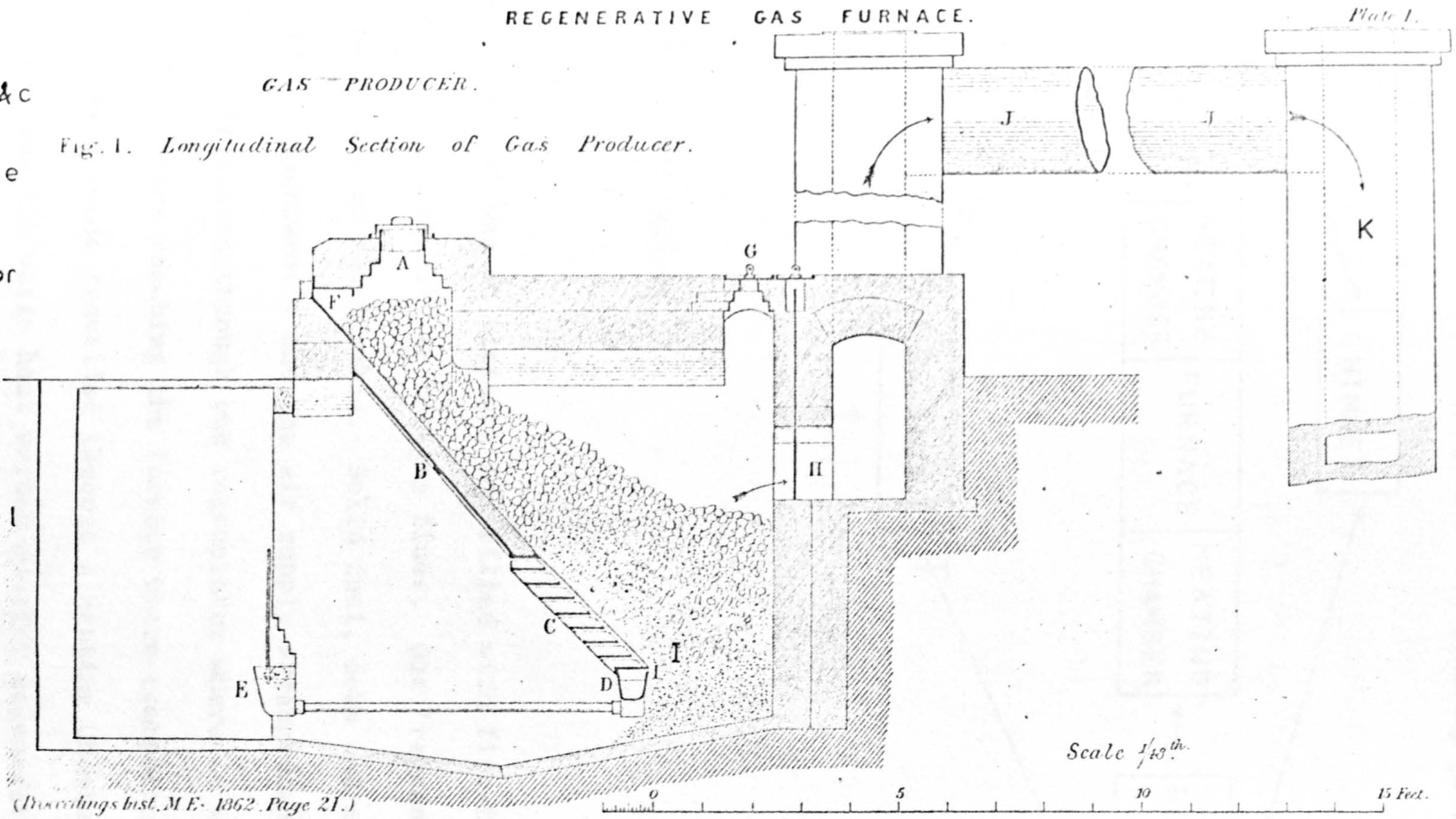
I - incandescent fuel

H - valve controlling producer gas (at 350°F) outlet

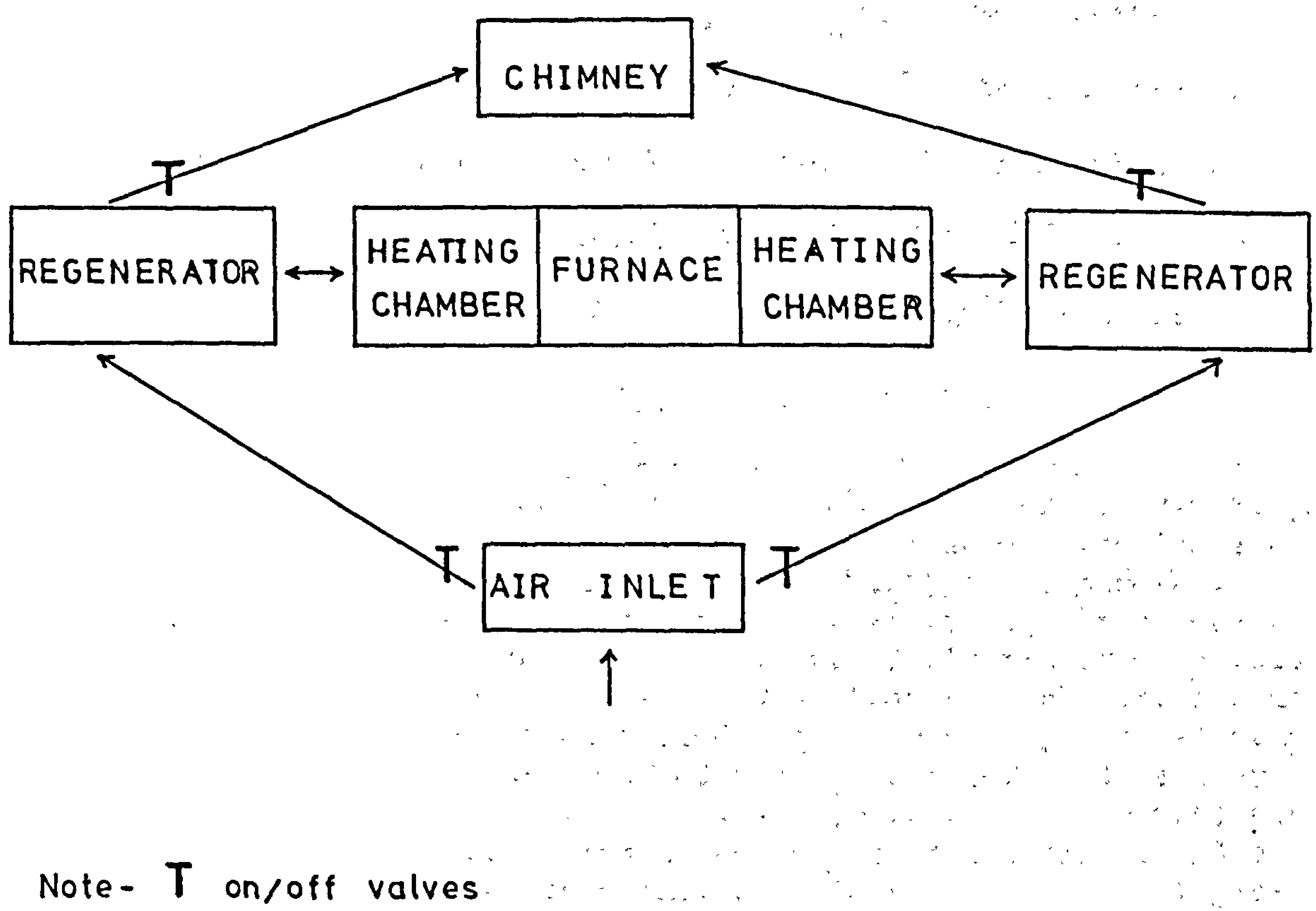
G, F - doors for pokers to de-clinker fuel

J - condensor, for cooler (150°F) gas to draw more out of the furnace

K - entrance to regenerator pre-heating gas to 2500°F before its combustion as fuel.



Source - Proceedings of the Institute of Mechanical Engineers 1962 for heavy industries like puddling iron and melting glass.



The 'regenerator' was an airtight box filled with fire-bricks to absorb heat, around the air or hot-gas flues. One 'regenerator' was placed each side of the furnace. Solid fuel, coke and coal, was used in the first experiments, and the air supply arranged so that fresh or primary air passed through one regenerator where it was heated to about 3000°F before reaching the furnace where combustion occurred. Heat from the furnace travelled through a Heating Chamber, where metals were melted, and the waste heat warmed another regenerator before escaping to the chimney at about 250°F. By altering the air flow so that primary air went to the second regenerator first, the regenerators were used alternately, one heating fresh air while the other absorbed waste heat.

The main problem with solid fuel concerned the relative positions of furnace and heating-chamber when the air-flow was reversed, and Siemens eventually used gaseous fuel, which could be directed into a single heating chamber and also be pre-heated.[1] As modified by the gas industry, a 'producer'[2] to make gaseous fuel for heating the retorts was built below ground level, and fed with incandescent coke by gravity from the retorts. Combustion, with pre-heated air,[3]

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1. By the early 1860s, such furnaces were used in several factories, including that of Messrs Russell of Wednesbury for making gas pipes. A gas 'producer' holding up to ten tons of material and converting two tons a day into gas, was built at each works. It comprised very large inclined-retorts at 45 to 60° which were fed with cheap fuel, from coal dust to peat, at eight-hour intervals. A controlled air supply kept the lowest four feet of material at incandescent heat, which distilled carbon monoxide, methane, ethylene, and many other gases out of the upper layers before they too subsided and burned. Some steam was also introduced to make water gas, and all of the hot gases ascended out of the 'producer' and onwards to the furnace where they were joined by a flow of pre-heated air and combustion occurred.

   As the hot gases left the producer, fresh air for partially burning the fuel was drawn in at the base. 72,000 cu ft. gas was produced from 1 ton of fuel. Paris General Gas Works, and the London Chartered Company experimented with the process in 1862. Several problems arose, and Birmingham gas company abandoned the Siemen's system in 1875 as too expensive.

   C. Hunt, "Gaseous Fuel Applied to the Heating of Gas Retorts" Journal of the Society of Chemical Industry 1884 Vol. III pp.89-100: "Siemens Regenerative furnaces and Vertical Ovens" J.G.L. 5/4/1864 p. 208; see also J.G.L. 15/12/1863 p. 763; 11/3/1862 p. 156; 29/7/1862 pp. 489, 493.

   Plagiarists tried producer-gas fuel at Govan Bar Iron Works in 1864 vide W. Gorman "Description of a Heat Restoring Gas Furnace, Constructed for Heating Iron" Proc. Philosophical Society of Glasgow 1865-8 Vol. VI p. 12

2. As early as 1847 Richard Laming, a gasworks engineer, experimented with pre-heating the air, very much like J.B. Neilson's 1828 Hot Blast process for ironsmelting; he also tried to restrict primary air intake so that the furnace became a 'producer' generating combustible carbonic oxide gas (CO). 'Producers' were sometimes termed 'Generators'

   C. Hunt, Jl. Society of Chemical Industry (1884) op. cit.: H. O'Connor, "Gas Manufacture and Appliances" Gas World 20/2/1897.

3. Use of waste heat, and greater control over retort heating, were the main benefits of Siemen's system. Pure carbon comprizing ninety per cent of the coke by "Direct firing" in a strong chimney draught with ample air, gave 14,500 Therms per 1lb. Pure-carbon by "regenerative firing" with restricted air supply, burned first to

occurred near the top neck of the producer and the heat was then used both for the retorts and to heat a fresh supply of air. At Dundee[1] for example, where Siemens provided the plans for heating eighty retorts in 1884, the brick-built regenerator comprized five flues 3½ inches wide on each side of each 'oven'. Three were for heating the producer gas,[2] and two for air, and they contained baffle bricks to slow down the gases and increase heat-transfers. Several teething problems arose which caused high labour costs. Slag blocked the gas-flues of the regenerator, and coke dust entered the air passages and nozzles where air and gas met, while some excessive local heating of ascension pipes baked the tar inside them. In 1886 the bench was improved, and more even heating provided by burning the pre-heated 'producer' gas and air at six places instead of at two. The regenerator was also enlarged, and the gas given five 'travels' through it instead of three. Wider flues were used to reduce blockages by dust, and carbon deposits reduced by coating bricks with "Sellars' cement".

This was so successful in raising retort temperatures that the coal charge in each eight-foot retort[3] was raised from 1½ cwt to

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Carbon Monoxide giving 4450 Therms per 1lb, and was later burned to CO_2 giving a further 4385 Therms.

W.H.Y. Webber, Gas and Gas-Making - Growth, Methods and Prospects of the Gas Industry (Pitman's Common Commodities and Industries Series) (1918) p. 21.

1. J.G.L. 14/10/1884: W. McRae (Dundee) "Improved Adaptation of Siemen's System" N.B.A.G.M. 1887; Gas World 25/7/1885, p. 114.

2. Mainly combustible carbonic oxide (CO)
C. Hunt "Gaseous Fuel applied to the Heating of Gas Retorts" Journal of the Society of Chemical Industry 1884 pp. 89-100.

3. Retorts 8 feet by 20 inches by 14 inches high. Clay retorts had to reach at least bright cherry red heat (1700°F), and this required a heating medium of about 2100°F.
King's Treatise (1882) Vol. III op. cit., p. 375.

2½ cwt. The remaining problem was one of excessive heat for the stokers, because the original underground producer was built in front of the retort bench. To clean ascension pipes or charge the retorts, workmen had to stand on the almost red-hot top of the producer. After experimenting with one "internal producer" placed underneath the retort bench, Dundee included this modification in 160 new regenerative retorts installed in 1887.

At Dalmarnock and Dawsholm gasworks,[1] where Siemens' system was installed in 1882-3 the North British Association of Gas Managers[2] made a detailed study of the method in 1883. They reported a financial saving of 1s. per ton of coal carbonized, only slightly offset by increased rebuilding costs of £5 per retort. Coke consumption by the furnace was reduced from two-thirds of all coke produced in the retorts to one-third. The 'flues' did not become choked, and more equable heating of the retorts greatly reduced carbon encrustation. Consequently the retorts required less cleaning, suffered less damage from cold air, and would last four years instead of two. The

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1. Dalmarnock had the first Siemens setting in Scotland, with 272 retorts in ovens of eight operational by March 1883. At Dalmarnock, the system required deep foundations, and underground tunnels for the 'producers', but 416 Siemens retorts were completed by November 1883. During 1884 the number was increased to 840 at Dalmarnock and 832 at Dawsholm, at a cost of £3,000 and £5,000 respectively. Carbonizing work was tripled on the same floor space as older systems, and through a saving equal to 1s per ton of coal the two Glasgow works reduced expenditure by £8,625 per year.
   Journal of the Society of Chemical Industry 1884 Vol.III, p. 94: Engineering 1883 Vol. XXXV p. 53 (diag.): Glasgow City Archives Miscellaneous Papers Vol. 19 p. 713: J.G.L. 13/2/1883, 20/3/1883, 20/11/1883, 11/3/1884.

2. J.G.L. 7/8/1883.
   The Association subsequently advised managers of small gasworks also to adopt regenerative settings.

quantity of coal carbonized by each retort rose from 14½ cwt to 18 cwt per day without increasing labour costs, as less work was necessary on the furnaces. Eight retorts were placed in each oven, instead of the previous six, thereby saving floor-space in the retort-house, while the regenerators and main-arches once built were expected to last for ten years without renewal.

Greenock gasworks adopted the continental Klönne regenerative system[1] in 1884 for four ovens of eight retorts, and in 1885 for a further eight ovens, but this was the only such installation in Scotland. With seven or eight retorts per oven, construction costs were lower than the ovens of four to five retorts which were normal in Scotland, and coke consumption as fuel was reduced about forty per cent. Each retort carbonized 2½ cwt charges, or one ton per day, and the producer used 2¼ cwt coke per ton of coal carbonized, but the retorts proved less durable than before, a factor offset by less labour for clinkering, less waste ash to remove, and more coke for sale.[2]

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1. The producer was 7 feet by 3 feet by 6 feet high and was fitted inside the oven and consequently, to charge the retorts workmen had to stand on a stage 7 feet above the retort-house floor; coal had to be hoisted up to that level. Built under the supervision of August Klönne of Dortmund, whose design was widely used in England and on the continent. Greenock installation in 1884 cost £1,800; 1885 cost £2,500. German gas engineers had made intensive study of gas-generator furnaces, like Schnuhr at Berlin in 1864, and Leigel at Stralsund in 1866 and Frankfurt in 1870. Extensive experiments were made by the German Gas Managers Association at Leipzig in 1878.
   King's Treatise (1882) Vol. III op. cit., pp. 386, 387, 406; S. Stewart, "Klönne Bench at Greenock Gasworks" Gas World, 25/7/1885; J.G.L. 22/4/1884, 4/8/1885 p. 192.

2. Greenock used 9 foot 'stop-end' retorts, placed back to back in the bench as in most Scottish gasworks. A council committee showed these allowed the best response to fluctuations in daily gas consumption, despite higher initial and running costs compared to the normal English 20 feet 'through' retorts, with one producer but two mouthpieces. The Klönne system, like Siemens saved about 1s per ton of coal carbonized; more regular heating reduced carbonizing time from six hours to four and raised coal throughput by

In 1883, copying the success of Glasgow, the Edinburgh and Leith company[1] replaced an old retort house of six ovens with five retorts each, by nine Siemens ovens of eight retorts each. They were operated on three-hour charges of eighteen cwts per retort, and produced 10,400 cu ft gas per ton of coal. Each retort gave about 9,400 cu ft per day, labour requirements were reduced, and only 37½ per cent of all coke was used for fuel, a sixty per cent reduction. The installation costs could be recouped in seven months, because 328 tons of coal would be distilled in each retort per year, saving thirty-seven tons of coke which at 5s 6d represented £10 3s 6d increase in revenue.

Table 3.57 Leith Installation Cost for One Regenerative Oven

Producer, steam tubes and valve	£22	16s	3d
Regenerator completed	27	10	3
	50	6	6
Cost per retort	6	5	10

SOURCE: J.G.L. 17/6/1884

In 1884 Kilmarnock[2] installed four Siemens ovens, with eight retorts in each, while Aberdeen[3] sent their gas manager to Paris and English

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about twenty-five per cent a day. Coke fuel for furnaces fell from 25lbs to 12 lbs per 100 lbs coal distilled: J.G.L.22/4/1884

1. J.G.L. 29/7/1884, 17/7/1883, 17/6/1884

2. J.G.L. 1/4/1884

3. Aberdeen was extending the retort house and coal sheds at this time at a cost of £5,000. The old Aberdeen ovens had five retorts set over two furnaces, and carbonized 10½ cwt coal in three hours. Siemens' ovens with eight retorts carbonized 18½ cwt in three hours. Aberdeen estimated the saving at 1s 4d per ton coal, and when all retorts were converted, would save £2,000 a year on 30,000 tons of coal.
J.G.L. 15/4/1884, 29/7/1884, 3/11/1885.

installations with Siemens system before fitting ten ovens the same year. By saving 1s per ton of coal, Aberdeen expected to save at least £1,400 per year. The Siemens system was rapidly adopted by many large Scottish gasworks.[1] Retort ovens of the size used for the Siemens and Klönne systems were, however, quite unsuitable for the majority of smaller Scottish gasworks. The number of ovens in use was regulated by the demand for gas, and it was wasteful to fire a large oven to meet a small increase in consumption.

The initiative passed to Scottish gasworks managers, who devized a great variety of regenerative settings to meet their specialised requirements. Stirling company was perhaps the first, in 1880, when a decision was taken to increase the number of retorts from thirty-six to sixty. To avoid the expense of a new retort-house, the manager P. Watson[2] designed regenerative flues to resemble those in the Journal of Gas Lighting, and increased the number of eight-foot

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1. By 1885, Kirkcaldy had forty retorts, and Dalmarnock and Dawsholm had 1672, on the Siemens system. Arbroath installed Siemens retorts in 1888 for £7,000. On 4,500 tons coal a year they could save £225, plus £75 on reduced maintenance and retort deterioration.
   By 1884 the regenerative system had increased British coke supplies by 400,000 tons a year, which could not find adequate markets and led some engineers to suggest its use for water-gas to be sold and distributed for heating separately from coal-gas for lighting.
   C. Hunt, "Gaseous Fuel" Journal of the Society for Chemical Industry 1884 Vol. III op. cit., p. 94
   J.G.L. 13/3/1888; 6/3/1888
   D. Terrance "The Adaptability of Regenerative Furnaces for Heating Retorts in Moderately sized Gasworks" N.B.A.G.M. 1885.

2. The retorts were oval, 8 feet by 18 inches by 14 inches high; the top retort round, 23 inches diameter. Watson was lucky, because his attempt to build a regenerative system for Dysart gasworks in 1883, for three D-shaped retorts 9 feet by 20 inches by 15 inches high, melted the lower retorts but left the top retort cold.
   P. Watson (Stirling) "Setting and Heating of Retorts" N.B.A.G.M. 1883.

retorts in each existing five foot wide oven from three to five. This was successful. The retorts heated well and with four-hour charges gave 8,000 cu ft per twenty-four hours. There were no problems with clinker, and coke consumption was reduced twenty-eight per cent.

Lauder gasworks was so small in 1886 that only one retort was used in the summer season, but the manager J. Turnbull[1] proved that regenerative firing was most successful even under those conditions. Originally the retorts were charged with one cwt coal four times in each sixteen-hour working day, but the furnace was so inefficient that it consumed all of the coke produced plus two cwts of coal a day. Turnbull devized a six inch pipe set along the chimney and oven floor to pre-heat the air supply, and a simple 'producer' for carbonic oxide. By this means the coke alone was sufficient to fire the furnace, and maintain heat for twenty-four hours a day so that five clay retorts costing £1 10s could be used instead of the more rapidly heated cast-iron retorts costing £5 5s. Similar experiments were also in progress by J. McNair on a one-retort oven at Holytown gasworks, with the addition of a small water-spray in the producer to make water-gas. When this succeeded, he installed a similar regenerative system of five retorts in one oven at Barrhead[2] at a cost of about £3 more than the normal renewal costs, or 12s per retort. If the more uniform heating preserved the retorts an extra two years, the cost fell to only 6d

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1. He used circular retorts, 7½ feet long and 13 inches in diameter. J. Turnbull (Lauder) "Generator Furnaces in Small Gasworks" N.B.A.G.M. 1886.

2. J. McNair (Renfrew) "Regenerative Furnaces as Adapted for Moderate Sized Gasworks" N.B.A.G.M. 1886; J.G.L. 6/10/1885

extra. This system reduced coke consumption for fuel by twenty tons per month worth £5, a very high return for the investment.

Kingskettle gasworks,[1] with three eight-foot D-retorts in one oven adopted a regenerative setting in 1887. Small works like this were run entirely by one man in the summer, when fires were banked up overnight, and in winter a second man operated the night shift. A 'producer' could be left for four or five hours with little attention, compared to a furnace where forgetfulness rapidly reduced the retort temperature. Moreover the producer could be banked up for a longer period of six to eight hours overnight. The three Kingskettle retorts previously produced only 200 cu ft gas from the first charge of coal in the morning, but with a producer gave only 20 cu ft less than normal working output. Coke consumption fell from 1½ to one cwt per four hours, and coke of lower quality could be used. Therefore lower quality coal could be distilled, giving a saving of up to 5s per ton of coal, a very great reduction of working costs.

Table 3.58 Kingskettle Installation Costs for Regenerative Retorts (1887)

	£	s	d
3 new retorts at 36s 3d	£5	8s	9d
650 fire-bricks	2	2	5
Bricks and castings for Producer	1	18	0
Total Cost	9	9	0
Cost per Retort	3	3	0½

SOURCE: J.G.L. 6/10/1885

1. This more advanced setting was designed by MacPherson, a consultant gas engineer from Kirkcaldy.
Vide infra p. 669

G.R. Hislop of Paisley gasworks[1] designed a regenerative system[2] which became one of the most popular in Scotland.[3] Paisley in 1888 had two benches of retorts, each with ten ovens, set back to back. Each oven contained only two retorts on the open-system of firing, virtually unchanged in more than sixty years. One bench was demolished that year, and replaced by eight of Hislop's ovens, each containing eight retorts, so that sixty-four retorts only required as much floor space as forty had previously. Excavations of almost six feet were required beneath each oven, since both producer and regenerator were built inside the oven. Air was pre-heated by passing five

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1. G. Love (Paisley) "The Construction and Working of Regenerative Retort Settings" N.B.A.G.M. 1891; J.G.L. 23/4/1889.
   E. Smith (Cockermouth) "Hislop's Regenerative Retorts" Gas World 15/5/1893.

2. Bathgate installed one of Hislop's earliest ovens in 1885, to hold four retorts at a cost of £56, in place of an old oven with only two retorts. In 1891 another old oven with three retorts there was converted for five retorts on Hislop's system.
   Bathgate Minute Book op. cit., 28/3/1885, 9/4/1891.

3. Dumfries installed Hislop's system in 1890, and Elgin in 1891 (£930). Ayr introduced Hislop's Regenerative Retorts in 1890, but correspondence with Dumfries gasworks which used the system in two ovens of eight, and three of six, as well as Barrhead with two ovens of five, showed that care had to be taken to prevent overheating, and in the choice of coals. Barrhead retorts gave 10,000 cu ft each in twelve hours.
   An undated pamphlet, bound at the Institute of Gas Engineers in 1945, describes Hislop's Regenerative Settings in use at Alloa, Athlone, Ayr, Barrhead, Bathgate, Bellshill, Berwick on Tweed, Bridge of Allan, Chelmsford, Cockermouth, Crieff, Dalry, Dumfries, Elgin, Gourock, Leven, Lurgan, Musselburgh, Paisley, Port Glasgow, Portobello, Stonehaven, Tain, Wishaw, Cork, Dundale, Denny and Morpeth. The distribution agents were C.M. Hamilton of Glasgow, J.E. Fisher of Stowbridge, and R.F. Hislop of Paisley, the son of G.R. Hislop.
   Institute of Gas Engineers, Miscellaneous Documents (30) 5302/29 p. 1.
   J.G.L. 11/3/1890, 14/4/1891, 14/7/1891.
   Ayr Minute Book op. cit., 15/9/1890, 29/12/1890, 23/2/1891.

times along the full length of the oven, a total thirty feet, before reaching the combustion chamber built on top of the producer and below the two lowest retorts. The steam used to make water-gas in the producer and prevent the clinkers hardening, was produced by waste combustion-gases before they reached the chimney.

This system was well designed for cleaning and maintenance. The coke from two retorts in each oven was adequate for the 'producer', and by raising the temperature of retorts gas output per ton of coal increased. Charges were run for three hours instead of four, thereby increasing the quantity of coal carbonized by twenty-five per cent a day. In 1889 two extra benches, each with eight ovens, were built at Paisley with some modifications. Each oven had two combustion chambers for the gas, instead of one, and Hislop patented a shoot to slide incandescent coke directly from the retorts to the 'producer'. The 'producer' consumed fifteen lbs coal, of 7½ per cent ash content, for every 100 lbs coal carbonized.

Gasholders with contents of over one million cu ft became more frequent in the 1890s, usually as three-lift telescopic holders. Glasgow built one of the first, at Tradeston[1] in 1870, followed by three two-lift holders of 1.25 million cu ft each at Dawsholm[2] in 1873.

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1. 160 feet diameter, 60 feet high, 2 lifts, capacity 1.5 million cu ft. Built by Messrs Laidlaw, Son and Caine of Glasgow. The City corporation held a banquet inside it when completed in 1872. Destroyed by Irish saboteurs in 1883. Replaced in 1886 by a holder from Messrs. Clayton of Leeds. <u>Gas World</u> 25/6/1887; <u>J.G.L.</u> 22/1/1883, 30/1/1883, 27/2/1883, 2/3/1886.

2. One of these holders was enlarged in 1883 when a third lift of 30 feet was added by Messrs. Clayton of Leeds, and another was given a third lift in 1889 by Hanna, Donald and Wilson of Paisley. During 1891, Irish saboteurs destroyed two of these holders by dynamite on the top 'crown'. W. Watson, <u>Report upon the Vital, Social and Economic Statistics of Glasgow for 1873</u> (1874, Glasgow): <u>J.G.L.</u> 20/1/1891 pp. 104, 192.

Dundee[1] installed a similar large holder in 1880, followed by the Edinburgh and Leith[2] company in 1885, and Paisley[3] in 1889. At Temple Farm,[4] Glasgow, a three-lift holder of 5.4 million cu ft. capacity and 240 feet in diameter was built in 1893, and another holding four million cu ft. in 1900. As the market for gas used in heating purposes was developed, not only did the quantity of gas consumed increase rapidly, but periods of frost caused a sharp rise in demand for which adequate supplies had to be held in reserve.[5]

Rising wages and trade union activity[6] were the main factors

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1. 150 ft. diameter, 60 ft. high; £8,880 holder by Messrs Clayton and Co. Leeds; £6,250 tank by Stewarton and Crebar of Barrhead. Journal of Artificial Light 7/2/1880

2. 1,152,182 cu ft. Telescopic with 2-lifts of 31 ft. height; £20,000 by Messrs. Laidlaw, Sons and Caine. In 1890 the Edinburgh and Leith Gas Commissioners had holders of 65,000 cu ft (New Street); of 410,000 2 of 350,000 and 2 of 210,000 at Tanfield; of 335,000 (Reid's Close); and at Meadowflat one of 1,020,000 and one of 1,050,000 cu ft. J.G.L. 22/9/1885, 5/5/1891

3. 1,300,000 cu ft; 2 lifts of 32 ft; 9 inches thick concrete tank by Messrs Goldie and Son, Glasgow. J.G.L. 23/4/1889, 2/6/1889.

4. Reputedly the third largest in the world (sometimes misquoted as six million cu ft.) 236 ft diameter, 3 lifts each of 45 feet. £40,000 by Messrs Laidlaw, Barrowfield Works. Steel plates instead of the usual malleable iron. Brick and masonry tank, £19,000 by Robert McAlpine, Glasgow.
   J.G.L. 29/12/1891, 6/10/1891
   Gas Supply of Glasgow (1935) op. cit.
   Glasgow City Archives Miscellaneous Papers, Vol. 27, p. 279.

5. E.g. output at Greenock in 1909-13 increased by 31 per cent to 383 million cu ft per year, and a new 1 million cu ft holder, and steel tank was found necessary. J. Macleod "Greenock's First Gas Supply" N.B.A.G.M. 1913.

6. E.g. Mr Green's mechanical stoker of 1860 was specifically designed to prevent any combination of workmen from closing a gasworks by striking. But it was too fragile, required skilled engineers, and was not widely adopted.
   W. Hamilton, Chairman's Address to the West of Scotland Association of Gas Managers J.G.L. 28/9/1875 p. 474.

   Vide infra 'Labour' p. 718

which persuaded gas managers and company directors to develop and finance mechanization at a more rapid pace from the 1880s onwards. Entrepreneurs were slow to improve the charging of coal into the retorts, and discharging coke.[1] During the interval which this manual process required the retorts were out of action, and temperature changes caused damage tothe retorts by differential contraction. Mechanical charging of the horizontal retorts was the first solution,[2] soon followed by efficient vertical retorts which could operate continuously.

Foulis's Hydraulic Stoking Machine, devized by the Glasgow gas manager was used at Dawsholm gasworks in 1874 and by 1877 also at Rochdale, Beckton,[3] and Manchester. Exhaust water from the hydraulic machine

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1. S. Clegg devized the first automatic charging, from a hopper in 1815. A belt of hinged metal plates passed through the retort like a conveyor-belt and deposited coke into a water sump, but wear-and-tear proved excessive. In 1834 John Brunton designed the first mechanised stoker, with a hopper to feed the horizontal retort and a piston, through a stuffing box on the mouthpiece, to push the coal along, thereby forcing the coke out into a sealed water-trough at the rear end. The 28 lb hopper gave one six-second charge every hour. Barnet had a similar method in 1835, and in 1838 Heginbotham devised a worm screw which charged the retort with coal and pushed coke out. It was improved by Hompesh but remained impractical. John Grafton in 1838 tried automatic charging and discharging from a miniature 'carriage' fitted inside the retort, filled by a gravity hopper at one end and then pulled through the retort while a flap-tailboard deposited coal and another flap pushed coke out in front.
   King's Treatise Vol. I (1878) op. cit. pp. 173, 263, 265-90; E. G. Stewart Town Gas (1958) op. cit., p. 14; H. Hughes, Treatise on Gasworks (1853) op. cit., pp. 55-7 (Brunton's process); W. Richards, Practical Treatise (1877) op. cit., p. 32.

2. Mechanical charging machines were only a partial answer to continuous processing which was achieved by vertical and semi-vertical retorts on the European Continent. It is one expression of the lack of entrepreneurial drive during the 'Great Depression'.

3. Built by the Patent Hydraulic Gas Stoking Machine Co., Glasgow. J.G.L. 10/10/1876, 7/11/1876 pp. 687, 725 (diag.), 10/7/1877, 18/12/1877 p. 942.
   In the Manchester area Foulis' stoker was manufactured by Messrs Woodward and Sons; and by Tangye Bros and Holman for the London area. J.G.L. 5/1/1875 p. 17, 18/1/1876 p. 76 (diag.) C. Hunt, Gas Lighting (1900) op. cit., pp. 49-51; W. Richards Practical

was used at Dawsholm to quench coke as it was discharged, and thirty retorts could be drawn and charged there in thirty minutes, giving a fifty per cent saving on labour costs.[1] A Scottish manager[2] boasted in 1878 that "skilled labour is almost a thing of the past" in large works with machinery, where unskilled labour could break any strike action by the skilled operatives.

The Foulis machine was challenged in 1881 by John West's mechanical stoker[3] which inserted one or two scoops filled with coal, inside the retort. Foulis improved his design with the help of W. Arrol[4] (1837-1913) and reintroduced it still with a hydraulic ram,[5]

Treatise (1877) op. cit., pp. 78-9 (diag.). Other engineers were also attempting mechanisation e.g. Darlington and Scott's stoking machine J.G.L. 18/8/1874 p. 274.

1. W. Watson, Report upon the Vital, Social and Economic Statistics of Glasgow for 1873 (1874, Glasgow)

2. J. Hall (St Andrews) N.B.A.G.M., 1878

3. Powered by compressed air, rope-drive or steam, and widely used by 1885. Scoop charging and rake-drawing machines were used in 1868 by Best, Holden and Mann. Some historians have ignored Foulis' early machine, and claimed that of John West (1869-1922) to be the first successfully used: vide E.G. Stewart, Town Gas (1958) op. cit. p. 14. W.T.K. Braunholtz, Institution of Gas Engineers (1963) op. cit. p. 47. Similar machines followed by Roscoe (1899) and Woodward and Crossley (1892).

4. Arrol was apprenticed to a Paisley blacksmith in 1853; then foreman of Messrs Laidlaws, a Glasgow engineering and gas apparatus works. He opened a boiler-making business in 1868; and Dalmarnock ironworks (1872) which became the largest structural steelworks in Britain. Constructed the Tay (1882-7) and Forth (1883-90) bridges. Arrol was Liberal MP for S. Ayrshire 1892-1906.
R. Purvis, Sir William Arrol - A Memoir (1913, Edinburgh) pp. 24, 30; Dictionary of National Biography 1912-21 (1927) p. 14.

5. Eight machines were installed at Dalmarnock and Tradeston, Glasgow in 1891, with ancillary coal-breaking machinery. At Tradeston each had a hopper holding five tons. In six minutes, a rake pushed six coal charges, each of 45lbs, to fill a retort at nine inch intervals from the rear. J.G.L. 3/2/1891 p. 163; Gas World 22/4/1893; 29/5/1897; 15/6/1895; Institute of Engineering and Shipbuilding in Scotland Oct. 1895 p. 331; "The Arrol Foulis Stoking Machine Installation at Edinburgh Gasworks" Gas World 2/11/1895; J. Tyso "Foulis-Arrol Machinery at East Greenwich" Gas World 19/5/1894.
Four Foulis machines were built in Glasgow for Birmingham Municipal gasworks in 1891 J.G.L. 4/8/1891: H. O'Connor "Gas Manufacture

in 1891. In 1892 a conveyor-belt charger was introduced by Green, and a projector-type charger by De Brouwer[1] in 1901 which became popular in Scotland. An accurately charged retort gave greater gas yield, and reduced carbon encrustation. Aberdeen gasworks, with particularly bad labour relations, spent £6,000 on West's rope-driven stoking and coal breaking machinery in 1890. Coal was broken for ¾d per ton instead of 5d manually.[2] The equipment gave a saving of £1,700 on working costs during the first year.[3] Manual stoking in 1889 cost 2s 8.645d per ton of coal, and machine stoking in 1891 1s 9.91d per ton, inclusive of wear and tear and all extra labour required. Coal delivered by railway was tipped into coal-breakers, each driven by a 10 h.p. steam engine which also hoisted the coal to overhead hoppers to feed the charging machine.

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and Appliances" Gas World 27/3/1897 p. 494; King's Treatise (1878) Vol. I op. cit., p. 282 (diag.).

By 1903 Arrol-Foulis machines were used also at the South Metropolitan and Commercial Companies, Liverpool, Brighton, Leeds, Bolton, Amsterdam, Vienna, Berlin, The Hague, Melbourne and Cleveland (Ohio); J.G.L. 6/1/1903 (photo.).

1. A moving wheel with a deep rim, threw coal into the retort very rapidly, though coke was discharged manually.
   M. De Brouwer was a Belgian engineer, and the technology was thus imported.
   By 1912, 'D.B. Stoking Machines' manufactured by W.J. Jenkins and Company of Retford, Nottinghamshire, were also used at Alloa, Paisley and Hamilton. J.G.L. 10/3/1908, 13/2/1912, 5/3/1912 (diag.).

2. Several old employees were dismissed. Vide infra 'Labour' p.723
   Equipment manufactured by West's Gas Improvement Company, Manchester J.G.L. 8/9/1891, 10/3/1891, 1/10/1889.
   King's Treatise (1878) Vol. I op. cit., p. 284 (diag.).

3. A. Smith (Aberdeen) "Carbonization Costs at Aberdeen", Gas World 26/3/1898.

Table 3.59
Comparison of Mechanical and Manual Retort House Operating Costs over 24 Hours - Aberdeen (1889-91)

Manual Labour - eight-hour shifts on 240 retorts, with 2½ cwt charges

	£	s	d
90 Stokers at 4s per shift	10	0	0
45 Stokers at 3s per shift	7	17	6
Breaking 240 tons coal at 5d per ton	5	0	0
12 potmen - 3 at 3s 6d, 3 at 3s 3d, 6 at 2s 7d per shift	1	15	9
3 foremen - 4s 10d per shift	0	14	6
Cost of 240 tons in 24 hours ... (2s 9.38d per ton)	33	7	9

Machine Work -

	£	s	d
12 machinemen at 4s 2d per shift	2	10	0
23 assistants at 4s per shift	6	12	0
21 barrow-men at 3s 8d per shift	3	17	0
3 coal-breaker machine men (1 at 22s, 1 at 21s., 1 at 20s., per 51 hours)	0	10	8
3 boilermen at 3s 6d per shift	0	10	6
12 potmen - 3 at 3s 6d, 3 at 3s 3d, 6 at 2s 7d per shift	1	15	9
6 coke-quencher men at 3s per shift	1	1	0
3 foremen at 4s 10d per shift	0	14	6
Cost of 232 tons in 24 hours ... (1s 6d per ton)	17	11	5

SOURCE: Gas World 26/3/1898

Repair and renewals costs were not excessive, at £484 in 1894-5, and £410 in 1896-7 when coal carbonization had increased by 1,575 tons.

Vertical retorts facilitated a great increase in mechanization and in the integration of material handling. Vertical retorts were first tried by W. Murdoch,[1] but all early experiments failed through

1. Vide infra Appendix I; also p.284
J.B. Mollerat in 1837 (Pat. 7358) tried a vertical shale-gas retort.

problems of adequately heating the retorts and discharging coke.[1] Subsequent development was made entirely by the oil-shale industry centred in Scotland.

Table 3.60 Oil Shale Retort Chronology in Scotland

Date	Innovators	Retort	Heat	Patent No.
1850	J. Young	Horizontal, iron	Red	13,292
1854	J. Young	Vertical; intermittent; revolving rod		326
1860s	Dr. Price	Vertical; continuous	Dull red	None
1867	W. Young, P. Brash	Vertical; intermittent		650
1873	Henderson	Vertical Retort	800°F	1327
1882	W. Young, G.Beilby	Vertical; 'Pentland Retort'; heated by producer gas; continuous.		(1377, (5084
1889	Henderson	Vertical; continuous; heated by producer gas	900-1300°F	6726
1897	W. Young, J. Fyfe	Vertical; multiple hoppers; increased mechanization		13,665

SOURCE: B. Redwood, Petroleum (1922) Vol. II pp. 611-22

Dr Price used 10 foot circular retorts, 2 feet diameter. Henderson in 1889 used 15 foot retorts holding 18cwt charges.

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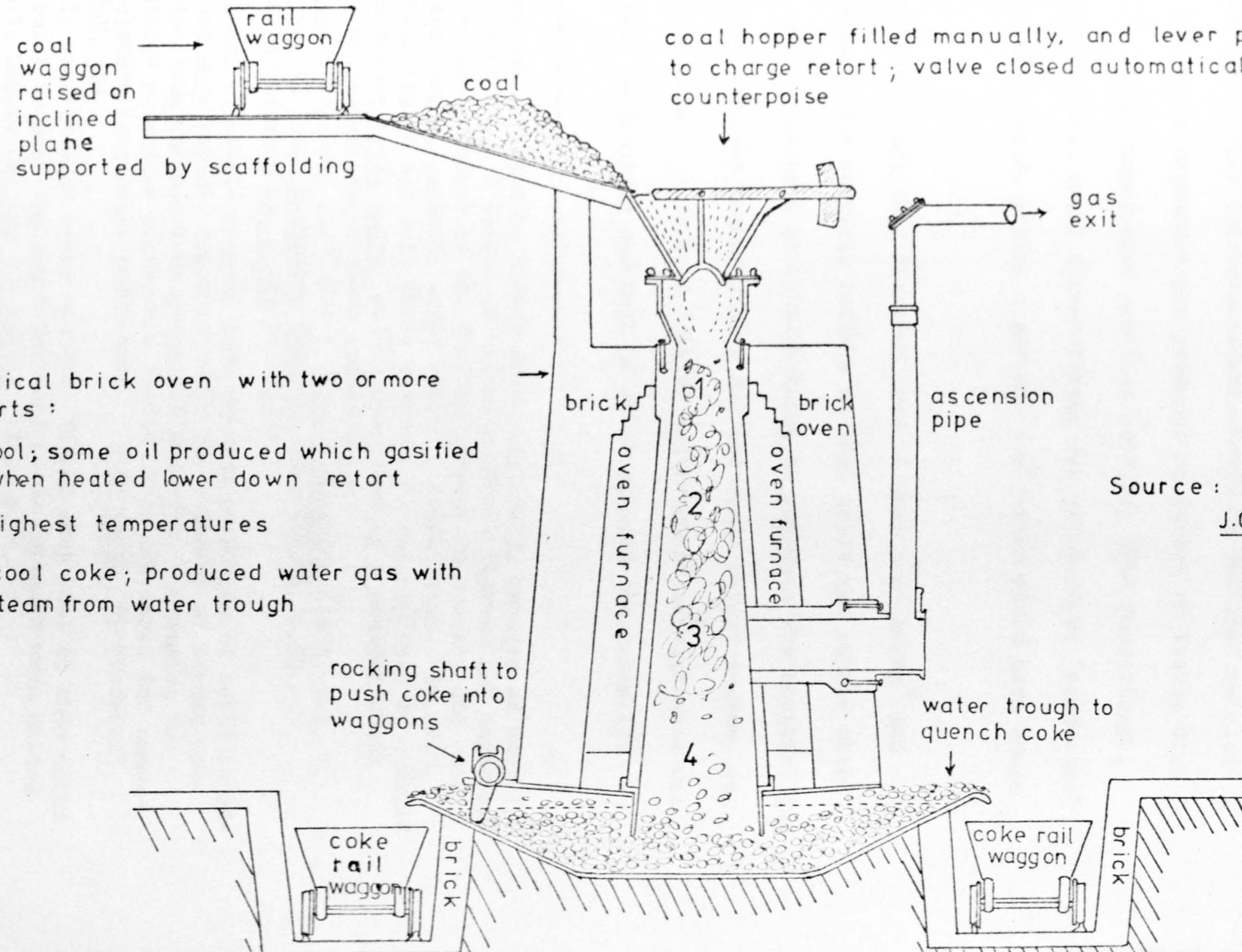
1. John Brunton, manager at West Bromwich gasworks, tried a vertical gas retort in 1828 (Pat. 5712). He was the brother of W. Brunton (1777-1851), who had progressed from colliery 'viewer' to be fitter at New Lanark Cotton Mills in 1890 and to become mechanic for Boulton and Watt (1796-1807). Their father, Robert Brunton, was a watch and clockmaker at Dalkeith. D. Brownlie, "Early History of the Coal Gas Process" Trans. Newcomen Society 1922-3 Vol. III op. cit.; Dictionary of National Biography (1908) Vol. III, p. 148.
   Later unsuccessful vertical gas retorts were by Barnet (1829), F.A. Winsor jr. of the Chartered Company (1830s) and Rowan (1855). In the early 1880s several Scottish gas engineers tried to adapt the shale-oil retorts for illuminating gas e.g. G.R. Hislop of Paisley in 1882 (Pat. 5252) and J. Hislop of Partick in 1884 (Pat. 12912). The Partick retorts in 1886 held 5cwt charges, and 4 retorts carbonized 1 ton in 5 hours, an hour faster than horizontal retorts, reducing fuel costs by 35 per cent. S. Everard, Gas, Light and Coke Company (1949) op. cit., pp. 87-8; Evidence of E.A. Harman (Huddersfield) Transactions of the Institute of Gas Engineers 1908 pp. 163-4; Gas World 3/4/1886; G. Lunge Coal Tar (1909) op. cit., p. 892.

Fig. 3.61

MUSSELBURGH VERTICAL RETORT SYSTEM 1874



Vertical brick oven with two or more retorts:

1. cool; some oil produced which gasified when heated lower down retort

2, 3. highest temperatures

4. cool coke; produced water gas with steam from water trough

Source: J.G.L 21/7/1874

In 1874 the first attempt was made at Musselburgh gasworks to adopt four vertical retorts, designed by William Young,[1] an oil-shale distillery engineer, for coal gas production. Oil shale technology was essentially low-temperature chemistry designed to minimize the amount of permanent gas produced in favour of liquid distillates.[2] High-temperature vertical retorts, like Musselburgh, remained impractical until direct-firing was replaced by 'producers' like those of Siemens, giving a gaseous fuel which could burn where required.

Despite the fact that Scottish cannels were non-caking[3] and highly suitable for vertical retorts as they would not expand while heating, and the efforts of William Young to persuade the Scottish gas industry to adopt the highly mechanized oil-shale retort system, no progress was made. A serious lack of entrepreneurial[4] vigilance was present both in Scotland and England which ignored the potential

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1. Young was assisted by Andrew Scott (d. 1885), manager at Musselburgh (1845-81). A native of Dalkeith, Scott learned gas engineering from David Hunter of the Phoenix Company in London, and constructed several gasworks under Hunter's supervision. In 1845, when Musselburgh had only three retorts, he was employed to rebuild the gasholder (vide supra p. 271) suspended by a central chain over a water-tank built above ground-level.
   J.G.L. 17/5/1881, 21/7/1874 ; King's Treatise (1878) Vol. I, op. cit., p. 235. Mechanics Magazine 1829 Vol.XI p.67.
   Scott's Obituary Gas World 27/6/1885

2. Vertical oil-shale retorts gave maximum retention of solid paraffin, and were rapidly improved under the stimulus of strong competition from the American petroleum industry. Steaming out solidified petroleum produced a liquid later developed for ammonium sulphate fertilizer production. Vide infra 'By-Products' pp. 565, 581

3. Early retorts were never entirely filled with coal or they would have burst because English bituminous coals expanded when heated.
   W.H.Y. Webber Gas and Gas Making (1918) p. 9.
   Terrance's Notebook for Gas Engineers (1948) op. cit., p. 163

4. Vide A.H.Cole's method of evaluating entrepreneurial behaviour in P.L. Payne Ed. Studies in Scottish Business History (1967) p. 253

savings until after 1885 when intermittent inclined retorts were erected at Rheims.[1] When Dr J. Bueb of Dessau, Germany, brought intermittent[2] vertical retorts to Britain in 1902, he was soon challenged by Settle and Padfield with a composite retort, vertical above and inclined below, with continuous charging and intermittent discharge.[3]

Woodall and Duckham's vertical retort[4] with continuous processing appeared in 1903, while William Young[5] took his experience to help the work of Samuel and Thomas Glover. Young and Glover in 1905 devized a vertical retort with independent charge and discharge, and their experiments on continuous carbonizing progressed at St. Helens,[6] not in Scotland.

Granton gasworks, built in 1898-1901 for Edinburgh and Leith Gas Commissioners, represented the peak of efficiency at that date. Inclined retorts were installed by W.R. Herring. Nine D-shaped fireclay retorts,[7] each twenty feet long and at an angle of 32° from the

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1. W.A. Bone Coal and Its Scientific Uses (1918) p. 284.
   At Rheims, the 32° angle of the retorts was the 'angle of rest' of coal, which could be fed under gravity to a specific thickness along the length of the retort. Murdoch's inclined retorts in the 1800s used a 45° angle and thus failed. Rice and Schilling used a 35° angle and 1-ton charges for very successful ovens at Munich in 1901.

2. i.e. charging and discharging were intermittent. Dr Bueb took a British patent in 1902 (Pat. 15,154).

3. Settle and Padfield (1902 Pat. 12,252).

4. Notebook for Gas Engineers (1948) J. Terrance Ed. p. 43 et seq.

5. N.B.A.G.M. 1908 p. 19; E.G. Stewart Town Gas (1959) op. cit. pp. 16-17.

6. J.G.L. 19/5/1908 p. 423.

7. Retorts 20 ft by 22½ inches by 15¼ inches. Walter Ralph Herring, chief engineer to the Commissioners from 1897, was the engineer leading British experiments with inclined retorts, in 1889 at Brentford Gas Co, 1890 Rochdale, 1892-4 Huddersfield. His father, Ralph Herring (1837-1911) was gas manager at Dover, where he was suceeded by Walter's brother, E.C. Herring. J.G.L. 5/9/1911; W.R. Herring "New Gas Works in Edinburgh" Gas World 1899 pp. 90-4.

horizontal, were placed in each 'setting' or oven. Each of the four retort benches held fourteen 'settings'. Machinery instead of manual labour was used wherever possible, but the process was far from automated in this, the largest retort-house in the world.[1] Railway[2] coal waggons were shunted by the work's locomotive, tipped by hydraulic rams, and the coal carried by bucket elevator[3] to overhead bunkers holding 700 tons, or sixteen hours' supply. Different quality coals were segregated and measuring chambers, for 5 to 8 cwt charges,[4] fed coal from the hopper to a portable shoot and into the upper mouthpieces of the retorts.

Distillation took four hours, and the coke was then discharged under gravity, after a manually operated rod opened the iron 'stopper' which protected the retort mouth. Coke fell through a portable shoot, either directly into a 'producer' for the furnace,[5] or into a water trough for quenching, with a chain conveyor which carried it to elevated stores and screens outside the retort house for gravity

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1. W.R. Herring, Edinburgh and Leith Corporations' Gas Commissioners Granton Works (1902, Edinburgh); J.G.L. 6/1/1903; 27/7/1902 (diag.). Retort house 386 feet long, 100 feet wide; capable of carbonizing 1,000 tons coal per day. Total works site 106 acres.

2. Branch lines to North British Railway, built by T. Sammerson and Sons, Darlington. Access also to Caledonian Railway, and private railway to Granton Harbour.

3. Automated coal and coke equipment by Messrs Graham, Morton and Co. of Leeds. Coal stores built on the site could hold 15,000 tons. The belt-conveyor was developed by G.F. Lyster of Mersey Harbour Board in 1868, but only widely adopted for mineral transport in 1885-90 by T. Robins.
Terrance's Notebook for Gas Engineers (1948) op. cit., p. 243.

4. Inside the retort coal formed a seven inches deep layer at the 'angle of repose'.

5. One producer per setting.

loading into railway waggons or carts.

Each 'setting' had a separate hydraulic main from which the gas travelled to a 'foul main' which served an entire bench. This was suspended from the ceiling and acted also as a condenser, being a 200 feet long coil of 20 inches diameter pipe. Four 'foul mains' then merged into two 30-inch pipes which carried the gas through water-tube condensers,[1] four rotary exhausters[2] in two sets which could be used separately or jointly, through more condensers,[3] followed by Washer/Scrubbers[4] 12½ feet wide and 22 feet long, a Cyanide-Recovery plant,[5] lime purifiers followed by iron-oxide purifiers,[6] two station meters,[7] and finally into a massive seven million cu ft, four-lift telescopic gasholder.[8] The gas was then sent up to 8½ miles through a 48-inch main pipe to gasholder-stations in Edinburgh, Leith and Portobello, at a pressure of 5lbs per square inch provided by Laidlaw exhausters[9] used as boosters.

Granton could produce five million cu ft. gas per day. Much of

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1. By Messrs. Clapham.
2. By Messrs. Laidlaws.
3. American designed Pelouse and Adouin condensers by W.C. Holmes and Co., Huddersfield.
4. W.C. Holmes.
   Vide infra 'By Products' p.584
5. Ibid.
6. From Barrowfield Iron Works Ltd. Water-luted, in two sections each of six boxes, 45 feet long by 30 feet broad, by 6½ feet deep. Purifier house built on two levels, allowing space for revivifying above the purifier-boxes, and storage of fresh materials. A conveyor belt set on rails above the purifier boxes assisted the manual clearing of purifiers by carrying waste to railway waggons on an adjoining low-level line. A hydraulic crane lifted the purifier lids.
7. Messrs. R. Laidlaw and Sons, Edinburgh.
8. Tank 252½ ft. diameter and 37 feet deep; by Messrs Clayton, Sons and Co. of Leeds.
9. Powered by 125h.p. gas engine by Grice and Sons, Birmingham.

the equipment was powered[1] by steam-lines from one set of boilers. A by-product works was built on the site, near the sea-shore where it could be supplied under gravity. Compressed air drove salt water pumps to supply that works, and also drove machinery in the purifying house to reduce the danger of explosions. Like other retort-house systems adapted by large Scottish gasworks at the close of the nineteenth century, Granton owed much to engineering skills and technology imported from England[2] where the number of large gasworks stimulated a greater volume of research into the problems faced by such works.

Granton demonstrated the possibility of high-pressure distribution to increase the market for gas.[3] Lochgelly was one of the first to seize this opportunity, to supply ribbon developments and the

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1. T.R. Cameron "A History of Gas Manufacture in Edinburgh" (1951, Scottish Junior Gas Association) Typescript, Edinburgh Ref. Lib.

2. Continental practice had also been closely examined by Herring, and four town councillors, who visited Amsterdam, Berlin, Budapest, Brussels, Copenhagen, Hamburg, Paris, Schoneberg, Vienna and Zurich. J.G.L. 8/10/1898.

3. Long-distance transport was an early although then impractical idea. In 1839 a scheme was made for gasworks on the coalfields piping gas to London, alongside railway lines, with pumping stations at fifteen mile intervals. In 1865 R. Ayton proposed vast gasworks on the Scottish Lochgelly and Cowdenbeath coalfields piping gas to London more cheaply than coal could be shipped. Four hundred miles of 12-inch diameter pipe plus laying costs was equal to £400,000, and theoretically could supply three million cu ft per day at 48lbs p.s.i. pressure. On the assumption that London used 73,000 tons of coal annually on which 20s rail or 15s shipping freight was paid, piped-gas could have saved £54,750 or thirteen per cent on the capital cost of the pipes.
Ten years earlier, Samuel Clegg junior (1814-56) had urged the removal of large London gasworks to the Essex shore to provide better transport facilities; from there long-distance piping was also necessary.
J.G.L. 22/8/1865 p. 657; "Suburban Gas Works" Mechanics Magazine 1838-9 Vol. 30 p. 29; Dictionary of National Biography 1908 IV p. 481.

villages of Glencraig, Crosshill and Lochore on the prosperous Fife coalfield. In 1905, 4-inch mains were laid to carry gas under the normal three inches pressure, but rising population increased consumption from 180,000 cu ft per year to two million cu ft by 1908. Instead of laying new seven-inch mains costing £1,480, rotary blowers[1] costing £423 were used to boost pressure in the existing main to seventy inches, which was reduced by friction to three inches when it reached the consumers. A high-pressure district governor[2] at Lochore and consumers' 'governors' gave equalized pressure. Also about 1908, Perth installed a booster to send gas at twelve inches pressure to Bridge of Earn, four miles away, where gas-production was discontinued. Dunfermline[3] in 1909 installed a compressor for £1,500 to supply a district four miles from the town, and 144 feet lower than the gasworks, which used 2½ million cu ft a year. In 1910 the North British Gas Managers' Association remarked on the growing importance of high-pressure supply, but the development of large 'gas-grids' and phasing out of small, less efficient gasworks, was delayed until after the First World War.[4]

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1. N.B.A.G.M., 1908. Rotary Blowers by J. Keith, Blackman and Co., driven by a 5 b.h.p. gas-engine, and giving a pressure up to 138 inches water (5lbs per sq. inch).

2. By J. Milne and Sons Ltd., Edinburgh. Lap-welded high pressure iron service pipes had to be used.

3. A. Waddell, "High Pressure Gas Plant at Dunfermline", N.B.A.G.M., 1909.

4. Third Statistical Account - Lanarkshire (1960) op. cit., p. 103. Steel mains began to replace iron. Supplies from Mannesmann Tube Co. were tried at Banff in 1910 and at Greenock in 1913. Greenock also used pipe from Stewart and Lloyds, and experimented with oxy-acetylene welding of joints, using equipment from the British Oxygen Company.
   Banff Minute Book op. cit., 2/3/1910.
   J. Macleod, "Greenock's First Gas Supply" N.B.A.G.M., (1913).
   Vide supra fig. 3.7 p.246

In the early 1900s Scottish works invested largely in the mechanization[1] of material transport, and improvements to horizontal ovens, rather than vertical retorts.[2] When Falkirk gasworks were remodelled in 1909, for example, long twenty-foot 'through retorts' with a 'mouthpiece' and ascension-pipe at each end,[3] were installed. The number of retorts per oven was increased from eight to twelve,[4] and the charges were distilled for eight hours, the coke consumption of 'producers' falling from about thirty per cent to twenty-three per cent of all coke.

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1. By 1898 elevators and miniature steam locomotives, designed by W. Foulis, carried materials around Glasgow gasworks.
   G. Little, (Smethwick) "The Automatic Manipulation of Coke", Gas World, 6/8/1898 p. 201.

2. By 1912 hand charging and direct firing were unknown in large gasworks, and retorts were heated to about 2000°F., the highest temperatures possible without fluxing the brickwork. Calorific value replaced candlepower as the criterion of gas quality, and allowed higher output per ton of coal. Regenerative firing was "almost universal". T. Brooke, Modern Retort Settings - Their Construction and Working (1912). p.1

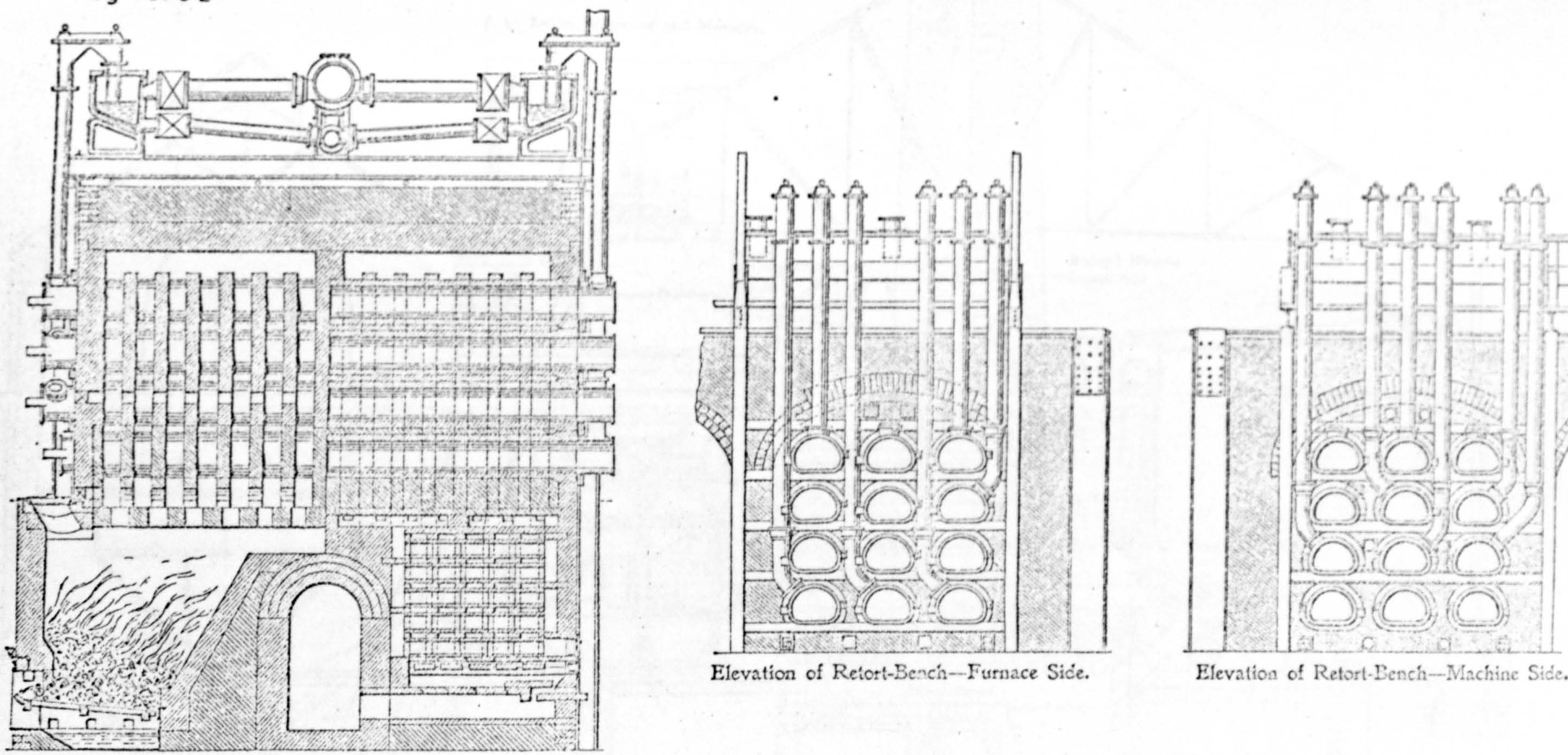
3. Also a hydraulic-main at each end. Total cost of installation £3,044. Overhead hopper holding 120 tons fed the charging machines and required one person part-time in summer and full time in winter, compared to two and three full time operatives when two small ten ton hoppers were used. Retorts 20 feet by 22 inches by 16 inches high. But Dundee and Glasgow still had 'stop-end' retorts with one 'mouthpiece' in 1909. Perth in 1902 was possibly the first Scottish gasworks to use 'through' retorts, but the experiment failed because 36cwt charges per day required furnace temperatures so high that pitch formed and blocked the pipes. Stirling in 1909 had a very similar installation to Falkirk, but with eight retorts per oven, each 20 feet by 22 inches by 16 inches high. Heavy charges of 9 cwt were distilled for six hours, and each retort gave 17,000 cu ft gas per day. Toogood's electrically powered stoking machinery was used (by R. Dempster and Sons), with overhead hoppers. A retort-house 'Governor' which prevented over-drawing by the exhauster and allowed minimal liquid in the hydraulic main, was estimated to increase gas output by 500 cu ft per ton of coal. Ammonia yield increased and long distillation reduced naphthalene problems. N.B.A.G.M., 1906.

   "The Latest Practice in Horizontal Retort Settings at Falkirk" N.B.A.G.M., 1909.

4. These retorts held 8 cwt. charges, and were charged and discharged by electric machinery from Messrs Dempster.

NEW HORIZONTAL RETORT BENCH AT FALKIRK MUNICIPAL GASWORKS 1909

Fig. 3.62



Section through Furnace. Section through Regenerator.

Retort-Bench at the Falkirk Corporation Gas Works.

Elevation of Retort-Bench—Furnace Side.

Elevation of Retort-Bench—Machine Side.

Source- N.B.A.G.M. 1909

Fig. 3.63

CROSS SECTION OF THE NEW RETORT-HOUSE AT THE STIRLING GAS WORKS. 1909

Source - N.B.A.G.M. 1909

J. D. SMITH, Engineer and Manager.

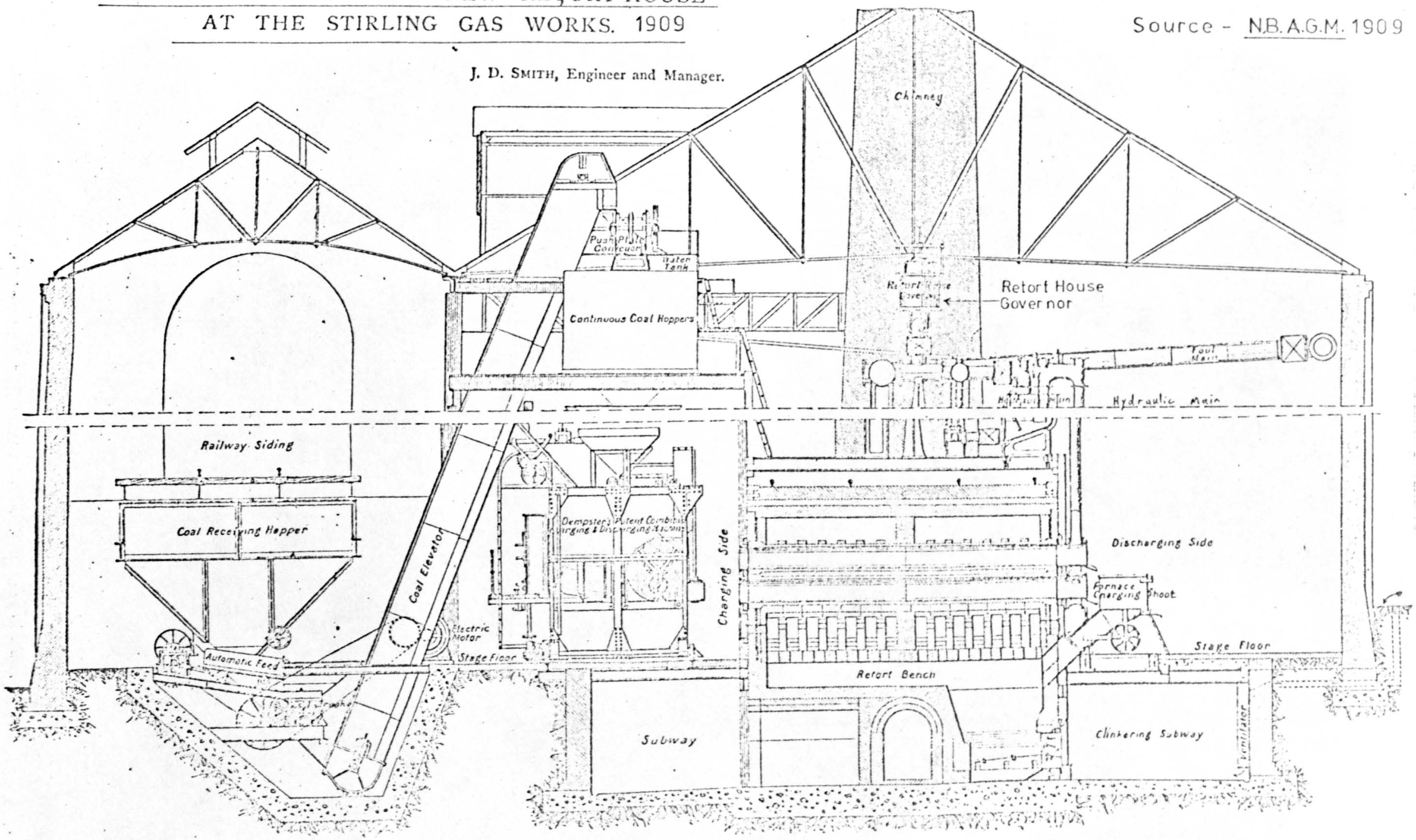
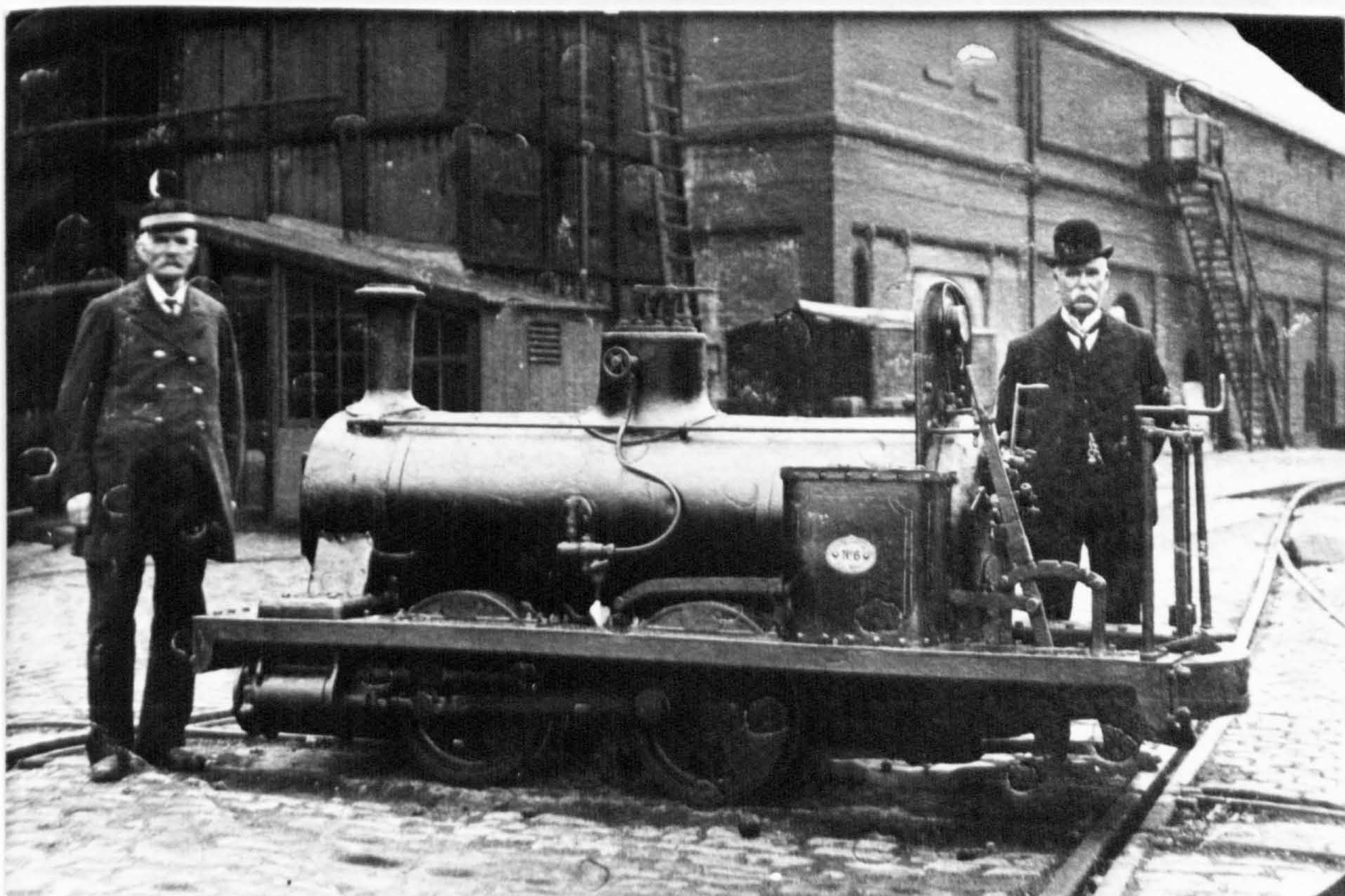


Fig.3.64 Miniature Steam Locomotives at Dawsholm Gasworks c.1906

Used for transportation of materials within Dawsholm and Tradeston works at Glasgow. Station Master (left) and gasworks Manager stand beside engine No. 6, and other employees by No. 20.



Photographs by Mr. J.R.Hume, from prints loaned by Mr D. Fulton, former gasworks engineer, of William Street, Helensburgh.

Railway branch lines were developed in the late nineteenth century to reduce material handling costs wherever possible. Paisley municipal gasworks[1] obtained a railway branch line in 1856; Galashiels[2] gasworks moved to Gala Foot along the Selkirk railway line in 1866, and Penicuik[3] opened a new gasworks in 1877. Coatbridge[4] company moved to a new works alongside the North British Railway in 1879. A large new works built at Dawsholm, Glasgow,[5] in 1871 was placed three miles north west of the city centre in order to be adjacent to the North West Railway to Stobcross and Queen's Dock, and next to a Canal. It allowed the phasing out of the 1817 Townhead works which suffered from an elevated locatinn and remoteness from railway sidings. Dawsholm had gravity feed of raw materials from high level lines, and another low level line to serve the retort house. By 1887 two small locomotives were used to haul coal from the main line and canal, and to take coke back to the main line. About half the raw material entered along the Bowling branch of the

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1. Glasgow Herald 6/10/1859. Vide infra 'Municipal Gasworks' p.1030
   Early location theories, vide supra p.262
   North Berwick gasworks (1845) moved to a new location in 1861
   Edinburgh Evening Courant 17/5/1861.

2. Galashiels Minute Book op. cit., 10/5/1862, 31/7/1866.
   Vide infra 'Finance' p. 862

3. Penicuik new works cost £11,000 J.G.L. 11/9/1877.

4. Coatbridge new works cost £22,000, and the move was upon the initiative of the company Chairman, H. McLachlan (d. 1890), an accountant J.G.L., 25/3/1879, 1/7/1890.

5. Dawsholm had 540 retorts, five per oven, and an output capacity of three million cu ft per day. Another Glasgow gasworks at Tradeston, built in 1835-9, had considerable benefit from the nearby Caledonian line to Glasgow Harbour and by 1887 held 616 retorts, seven per oven.
   Gas World 25/6/1887
   Bell and Patton, Glasgow - Its Municipal Organization (1896) op. cit., p. 264.
   Gas Supply of Glasgow (1935) op. cit.
   Vide infra pp. 1042, 1583

Forth and Clyde Canal, where it was off-loaded with a steam crane. Dalmarnock[1] gasworks in Glasgow also had two locomotives in 1887, moving 700 tons of lime and coal daily from the Caledonian railway, and returning with 100 tons of coke and waste lime. Dundee[2] obtained railway sidings in 1885, Aberdeen[3] in 1886, and Hamilton[4] in 1908. Provan[5] new gasworks in Glasgow, which commenced in 1898, were designed to handle 4,000 tons of material daily by a careful arrangement of railway lines. Elsewhere a large number of Scottish gasworks migrated[6] to new sites with rail access and room for expansion, especially during the 1880s and early 1900s.

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1. Gas and Water 23/6/1887. 2. Gas and Water 18/7/1885 p. 76.

3. Aberdeen in 1884 spent £1,158 on cartage from the railway station and docks. This was monopolised by the Great N. Scot. Rail. Co., who refused a branch line: 85 carts carried 600 tons a day through the streets. In 1886 Aberdeen gasworks built a 3-furlong railway for £6,760 which was to save £500 a year on carriage. A locomotive (£875) was purchased in 1887. J.G.L. 3/2/1885, 30/11/1886, 18/5/1887.

4. Hamilton paid £2,000 to the Caledonian Railway for a branch line. J.G.L. 10/3/1908.

5. Inside Provan works, five miles of 2ft 6 inch gauge line was designed to carry coke and waste lime.
Municipal Enterprises - Glasgow (1904, Glasgow) Handbook of the 22nd Congress of the Sanitary Institute, Mitchell Library.
Gas World 7/7/1900 p. 19 (diag.).

6. Edinburgh Gaslight Company in 1886 planned to move from Cannongate in the city centre to a site four miles away, S.E. of Portobello , on the Hawick/Edinburgh Railway, but were forestalled by municipal takeover. J.G.L. 21/9/1886, 16/11/1886.
Hawick company in 1882 moved to a new £7,000 works on the R. Teviot, alongside the North British Railway Company lines from which coal was delivered under gravity. J.G.L. 6/12/1881, 18/7/1882, 18/10/1881.
Dunfermline in 1894 opened a new gasworks alongside the Dunfermline/Queensferry railway; designed by T. Newbigging to produce 100 million cu ft per year at a total cost of £46,967 including £16,603 pipes. J.G.L. 26/8/1884; Gas World 7/7/1894; Dunfermline Press 9/11/1929 p. 5.
Carluke gasworks moved in 1897 to a new site, designed by A. Yuill of Alloa. Gas World 3/12/1898 p. 844.
Lesmahagow built a new gasworks in 1903 at £196 for buildings and £648 for equipment. Lesmahagow minute Book op. cit., 10/6/1902,

Renfrew[1] gasworks in 1903 built a coal-store alongside the 1900 Glasgow and Renfrew District Railway, so that hydraulic rams could tip coal from waggons on a siding, into an iron hopper, feeding a coal breaker, and thence an underground waggon-way. A hydraulic hoist then raised the waggons to an aerial track running to coal-stores and retort-hoppers. Discharged coke fell into iron pans to be quenched by water spray, before a trapdoor let it down into waggons which were raised hydraulically to a coke store and hoppers above railway waggons and carts. A similar arrangement operated at Alloa[2] which also had a De Brouwer stoking machine with a 7 h.p. motor and portable hopper, which could throw three cwts of coal into a nine foot retort in nine seconds. It required only one operator, who could also open and close the retort doors. Dunfermline[3] also installed a highly automated coke and coal system in 1902, and a manual charging-machine by West. Whilst the small Scottish gasworks contin-

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22/1/1903.
Ardrossan moved to a railway site in 1903, and in 1905-6 new gasworks replaced old at Peebles, Gourock, Falkirk, Newton (Ayr) and Kelty.
Ardrossan Burgh Centenary 1846-1946 (N.D.) p. 7, Nat. Lib. of Scot.; N.B.A.G.M., 1906; Third Statistical Account - Stirling (1966) op. cit., p. 328.

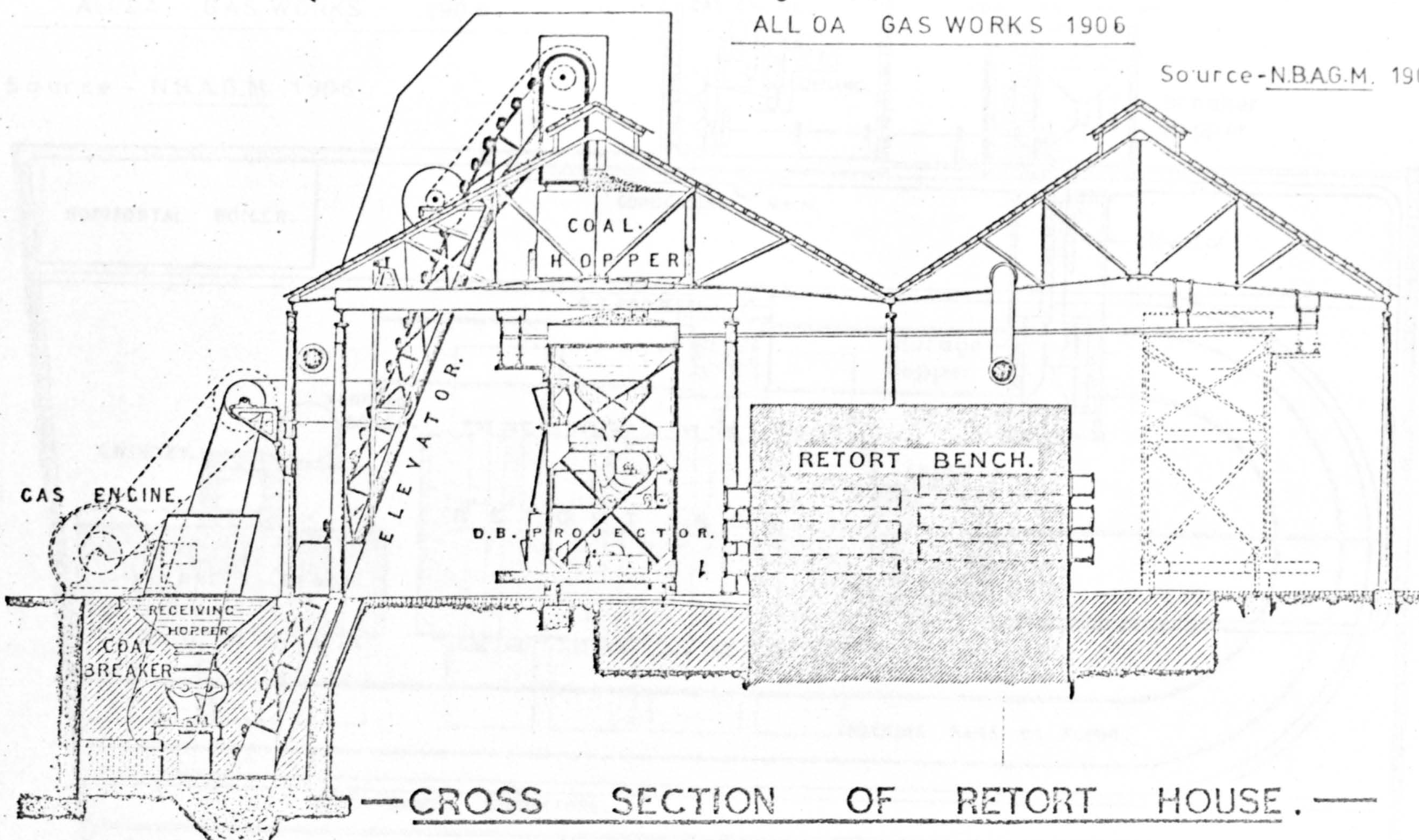
1. N.B.A.G.M. 1906. The coke and coal handling equipment cost £1,813.

2. N.B.A.G.M., 1906. 8 ovens of 8 retorts, back-to-back
3 ovens of 6 retorts held in reserve
Retorts 9¼ feet by 22 inches by 14 inches high
25½ b.h.p. gas engine driving coal-breaker and elevators.

3. N.B.A.G.M. 1906
Similar mechanical handling plant was also used at Pumpherston Oil Co.
Dunfermline installation cost £3,200, and included a 1,500 ton coal store and 1,600 ton coke store. 250 tons of coal could be handled in ten hours, and 120 tons coke in ten hours.

Fig. 3.65
ALLOA GAS WORKS 1906

Source-N.B.A.G.M. 1906

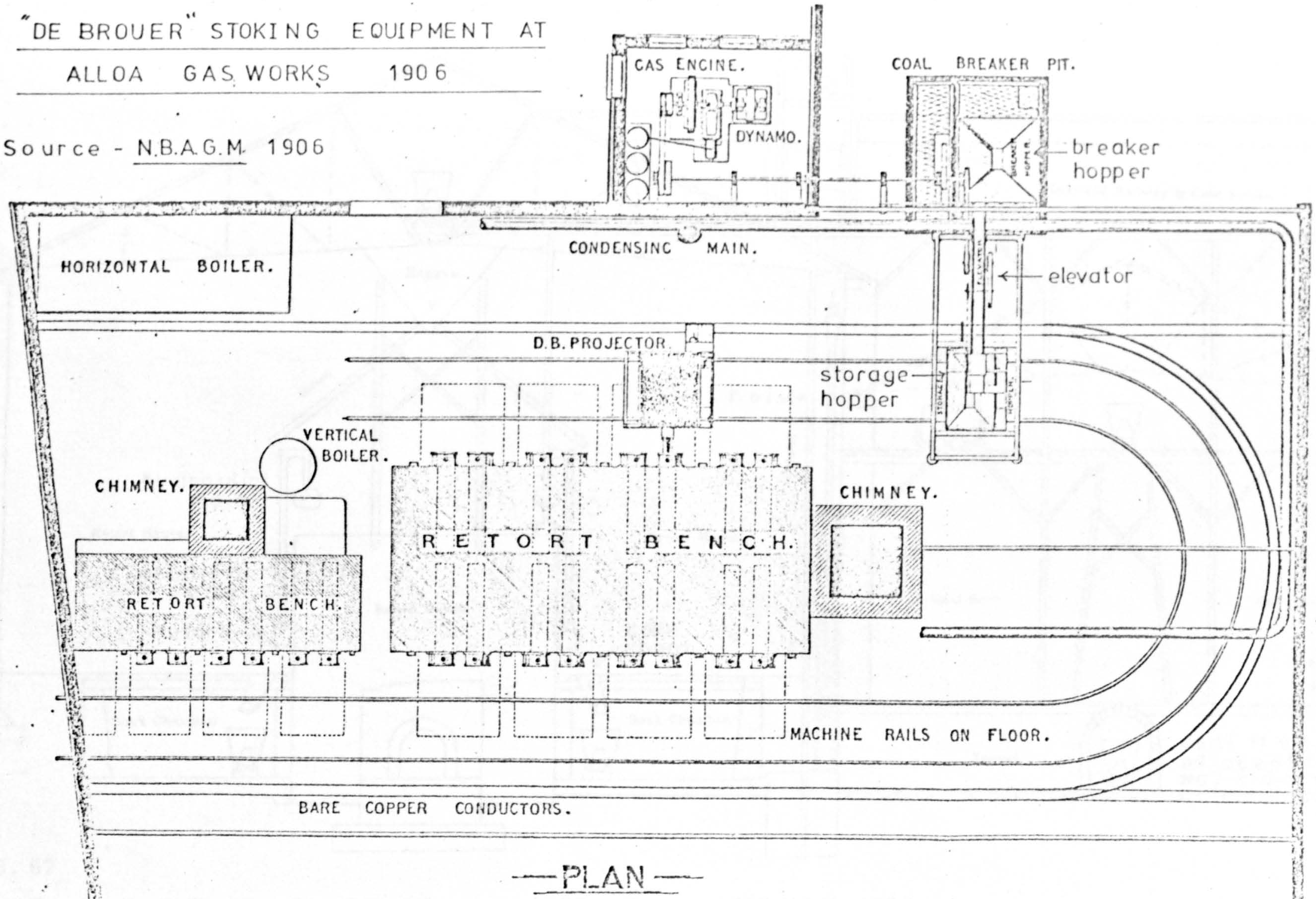


—CROSS SECTION OF RETORT HOUSE.—

"De Brouwer" Stoking-Plant at Alloa Gas Works.

Fig.3.66 "DE BROUER" STOKING EQUIPMENT AT ALLOA GAS WORKS 1906

Source - N.B.A.G.M. 1906



"De Brouwer" Stoking Plant at Alloa Gas Works.

Fig. 3. 67

Cross Section of Dunfermline Retort House 1903. Source N.B.A.G.M. 1903 ued on traditional lines, most large works invested heavily on machinery[1] in order to minimise labour costs. Improved gas-holder design, especially elevated guide-framing[2] which was slowly adopted in the 1910s, also reduced capital equipment costs.

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1. E.g. Stirling.

2. Elevated guide-framing forming a screw-like thread between two lifts of a telescopic holder, at 45 degrees from the horizontal, enabled holders to rise helically held by rollers in the guiding grooves. The absence of an external framework around the holder reduced capital expenditure by fifty per cent, but the first holder on this principle invented by W. Gadd, was not built until 1890 at Northwich, by T. Newbigging. Earlier experiments using vertical guide-rods in place of external columns, had been made in 1851 by J. and W. Horton of Etna Works, Smethwick, but had been unsuccessful. Messrs Clayton of Leeds remained the principal manufacturer of spiral-guided holders, and advertizements by Messrs. Hanna, Donald and Wilson, one of the leading Scottish manufacturers in 1904, still illustratedan external framework. J.G.L. 11/8/1851; "Gasholders Without External Framework" Gas World 25/1/1890.

   Gasholders supplied by Messrs Hanna. Donald and Wilson (1913) are illustrated in Figure 3. 68

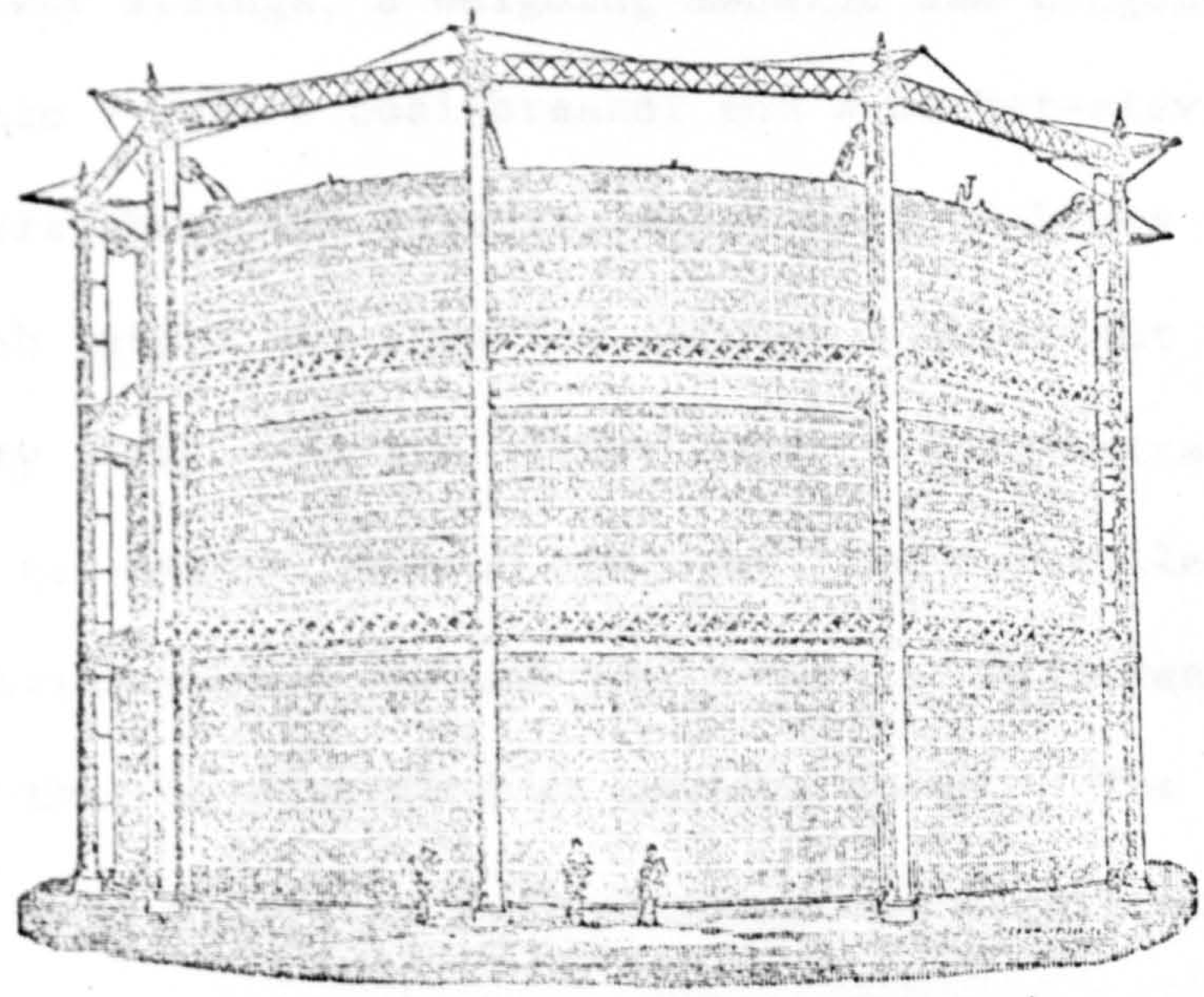
Vide N.B.A.G.M., 1913

Fig. 3.68 Gasholder Installations by Messrs Hanna, Donald and Wilson (1913)

ESTABLISHED 1851.

Hanna, Donald & Wilson, GAS ENGINEERS & CONTRACTORS.

Strasburg No. 4 Three-Lift Gas Holder.



Strasburg No. 4 Three-Lift Gas Holder.

We have supplied Gas Holders and Apparatus to the following and other Gas Works:—

Aberdeen Gas Corporation
Ailsa Craig
Albi Works
Alloa Gas Corporation
Armagh ,,
Ayr ,,
Barrhead ,,
Bathgate ,,
Beith Gas Co.
Belfast Gas Corporation
Boulogne Works
Bournemouth Gas Corporation
Bridge of Weir Gas Company
Bucharest (Roumania) Gas Co.
Brisbane (Queensland) Gas Co.
Bundaberg (Queensland) Gas Corporation
Caen Works
Campbeltown Gas Corporation
Catrine Gas Company
Cette Works
Clacton-on-Sea Gas Corporation
Coatbridge ,,
Coleraine ,,
Colombo (Ceylon)
Dalbeattie Gas Co.
Dalkeith Gas Co.
Dalmellington Gas Corporation
Dubbo (N.S.W.) Gas Co.
Dumbarton Gas Corporation
Dundee ,,
Dunoon ,,
Dutch Gas Works, Amsterdam
Eastbourne Gas Corporation
East Kilbride ,,
Edinburgh ,,
Edinburgh and Leith ,,
Fraserburgh Gas Corporation
Galashiels ,,
Genoa Works
Glasgow (Tradeston Works) Gas Corporation
Glasgow (Dawsholm Works) Gas Corporation
Glasgow (Dalmarnock Works) Gas Corporation
Gourock Gas Corporation
Greenock ,,
Hawick ,,
Helensburgh ,,
Huntly Gas Co.
Hurlet and Nitshill Gas Corporation
Innellan Gas Corporation
Innerleithen Gas Co.
Inverurie Gas Corporation
Iquique ,,
Kirkintilloch Gas Company
Kilmarnock Gas Corporation
Larkhall Gas Company
Lockerbie ,,
Marsala Works
Messina ,,
Milan ,,
Moffat Gas Company
Montargis Works
Moscow (Russian Government)
Motherwell Gas Corporation
Newmarket ,,
Paisley ,,
Parma Works
Partick, Hillhead, and Maryhill Gas Corporation
Piree (Greece) Gas Corporation
Pollokshaws Gas Corporation
Port-Glasgow ,,
Port Louis (Mauritius) Gas Corporation
Ratcliff Gas Co., London
Rhyl Gas Co.
Renfrew Gas Corporation
Rothesay ,,
Rome ,,
Rouen Works
Sampeirdarena Works
St. Andrews Gas Co.
St. Catherine's (Ontario) Gas Corporation
Stirling Gas Corporation
St. Petersburg (Russian Government)
Strasburg Works
Sydney Gas Corporation
Tamworth (Queensland) Gas Corporation
The Hague Gas Corporation
The Mint Gas Works
Toowoomba (Queensland) Gas Corporation
Townsville (Queensland) Gas Corporation
Trapani Works
Troon Gas Corporation
Uddingston Gas Company
Vienne Works
Waganui (N.S.W.) Gas Corporation
Wishaw Gas Corporation
Woolwich Royal Arsenal Gas Works and the Military College, Sandhurst

ABERCORN AND ABBEY WORKS, PAISLEY, N.B.

Note - column-guided gasholder
Source - N.B.A.G.M. 1913

Vertical retort development in large Scottish works was quite rapid in the 1910s. Some of the earliest 'Glover-West' vertical retorts[1] were installed at Helensburgh in 1911 at a cost of £14,711 including railway sidings, a weighing machine and waggon-tipper. Coal tipped into a West's coal-breaker and a bucket-elevator[2] carried it up to bunkers above the retorts, which held 24-hours supply. From the bunker each retort was supplied through a gas-tight valve by continuous gravity feed. At the retort base, a worm-extractor powered by a 4½ bh.p. gas-engine removed the coke and controlled the rate at which raw material passed through the retort. Different qualities of coal could thus be distilled at optimum speed. The twenty foot high retorts[3] were placed in two 'settings' of eight retorts each, enabling Helensburgh to produce up to 500,000 cu ft gas a day. Each setting had two 'producers' and the gaseous fuel ascended a vertical flue opening into eight separate combustion chambers which controlled the heating of the entire height.

In 1911, 3.06 tons of coal were processed each day, and produced 12,605 cu ft gas per ton with high calorific content. Coke was cool before being discharged, so water-quenching was unnecessary, and labour costs were low. Fuel consumption was reduced, as was wear and tear. Little ground-space was required, and there were no problems with dust or naphthalene deposits.

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1. Installed by Messrs West's Gas Improvement Company Ltd. W. Blair, "A Short Experience with Vertical Retorts at Helensburgh" N.B.A.G.M. 1911; J.G.L. 5/9/1911 p. 587, 12/9/1911 p. 679 (diag.).

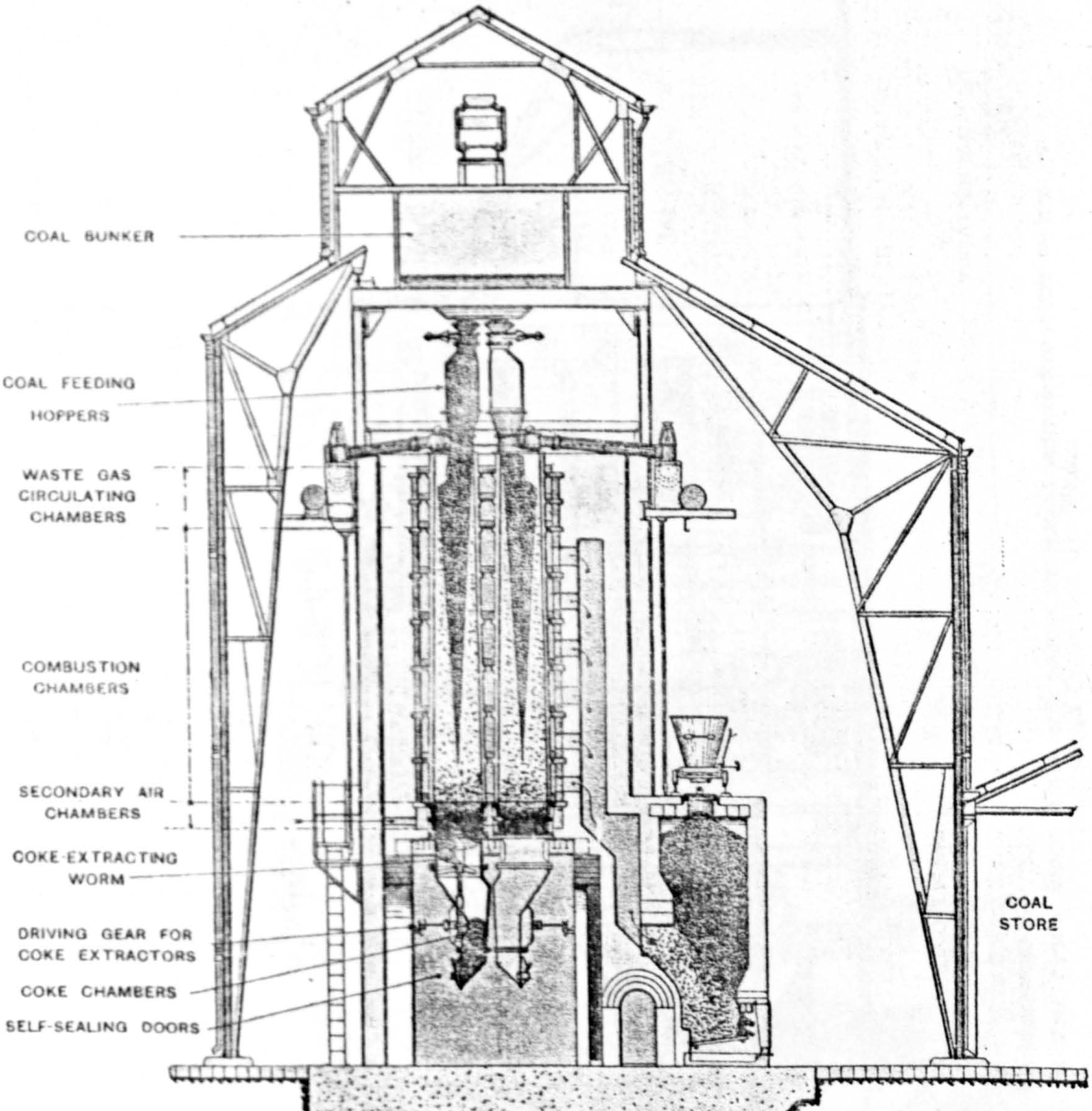
2. Driven by gas engine.

3. Retorts 20 ft high, tapered from 36" by 21", to 30" by 12", and built up in 2-feet sections.

Fig. 3.69

CONTINUOUS CARBONIZATION
IN

GLOVER-WEST VERTICAL RETORTS



TRANSVERSE SECTION OF RETORT HOUSE

Source - N.B.A.G.M 1913

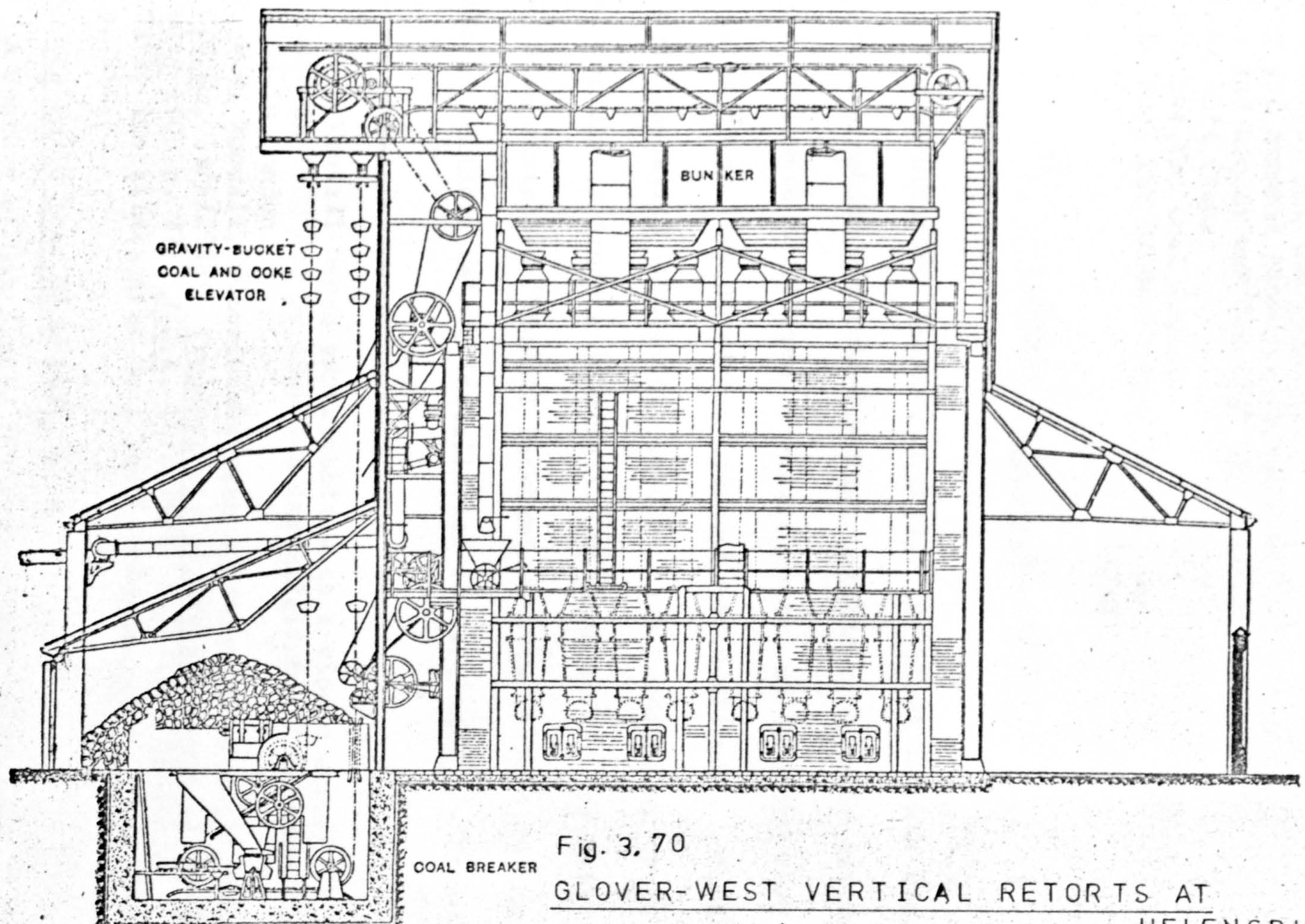


Fig. 3.70

GLOVER-WEST VERTICAL RETORTS AT HELENSBURGH 1911

Glover-West Vertical Retort House with settings arranged in units of two retorts each at the Helensburgh Corporation Gas Works.

Source - N.B.A.G.M. 1911

Table 3.71

Vertical and Horizontal Retorts Compared over 1 Year at Helensburgh

	Vertical Retorts	Horizontal Retorts
Coal carbonized (tons)	5,779	6,201
Gas output (cu. ft.)	68,755,000	59,902,000
Gas output per Ton Coal (cu. ft.)	11,897	9,498
Tar and Ammonia Liquor sold (gallons)	365,400	306,000
Tar and Liquor per Ton Coal (gallons)	63.16	49.3
Coke sold (tons)	2,621	3,304
Coke per Ton Coal (cwts)	9.08	10.65
Coke Fuel for Producer (per 100lbs coal distilled)	17%	29.5%

SOURCE: N.B.A.G.M., 1911

The alternative 'Woodall-Duckham'[1] vertical retorts with integrated coal breaking and coke-handling machinery, usually served by railway lines, were introduced at Kinlochleven[2] in 1912 and soon adopted by large towns like Aberdeen, Greenock and Hamilton.[3] Hamilton in 1913-14 installed twenty-four retorts each handling up to five tons of coal per day to produce jointly 1.5 million cu. ft. of gas. Greenock[4] also installed 'Woodall Duckham' retorts in 1913 during "an epidemic of vertical retort installation in Scotland."[5] This system,

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1. W.H. Woodall began experiments with a single retort at Bournemouth in 1903 and by 1908 had installations at Liverpool and Nine Elms in London.
   W.H. Woodall, "Continuous Carbonization in Vertical Retorts" J.G.L., 23/6/1908; Transactions of the Institute of Gas Engineers 1908 p. 97; J.G.L. 14/4/1908, 29/4/1913 (photo.). Early installations at Hull and Birmingham vide J.G.L. 9/9/1913 p. 714.
2. Gas World Year Book 1921, p. 1
3. A Century of Gas Supply 1831-1931 (1931, Hamilton).
4. J. Macleod, "Greenock's First Gas Supply" N.B.A.G.M. 1913.
5. J.G.L., 16/9/1913

Fig. 3.72 Horizontal and Vertical Retort Houses

Horizontal-retort house at Langholm (1973). Typical spacious design capable of storing coal or spare retorts if necessary; surrounded by outhouses - tool store on left, purifier sheds and governor house on right.

Small vertical-retort house at Stranraer (1974). Tall building closely tailored to internal machinery. Typical rectangular projection on left gable at summit of mechanical elevator feeding horizontal conveyors to coke hoppers. Note use of adjoining dwelling house as gas appliances showroom.

Fig. 3.73 Broughty Ferry Municipal Gasworks (1911)

THREE VIEWS OF THE BROUGHTY FERRY GAS WORKS.

Source - N.B.A.G.M. 1911

and to a lesser extent the 'Glover West', and Wilson's Retorts, dominated the Scottish market.[1]

Table 3.74 Woodall-Duckham Vertical Retorts in Scotland (1906-20)

Date of Construction	Town	Capacity (Tons per day)	Date	Town	Capacity
1912	Kinlochleven	20	1919	Brechin	11
1913	Aberdeen	100	1919	Dunfermline	110
1913	Greenock	180	1919	Lochgelly	21
1913	Ayr	40	1919	Kilsyth	24
1913	Dundee (I)	220	1919	Inverness	40
1914	Irvine	23	1919	Glasgow	1356
1914	Hamilton	132	1920	Troon	28
1914	Newton (Ayr)	60	1920	Kirkcaldy	88
1915	Forfar	40	1920	Lanark	21
1915	Cupar	22	1920	Gourock	28
1919	Dundee (II)	120			

SOURCE: Gas World Year Book 1921 p. 1

Alexander Wilson,[2] gas manager at Glasgow, installed 144 vertical retorts[3] of his own design at Dawsholm in 1912. They operated an

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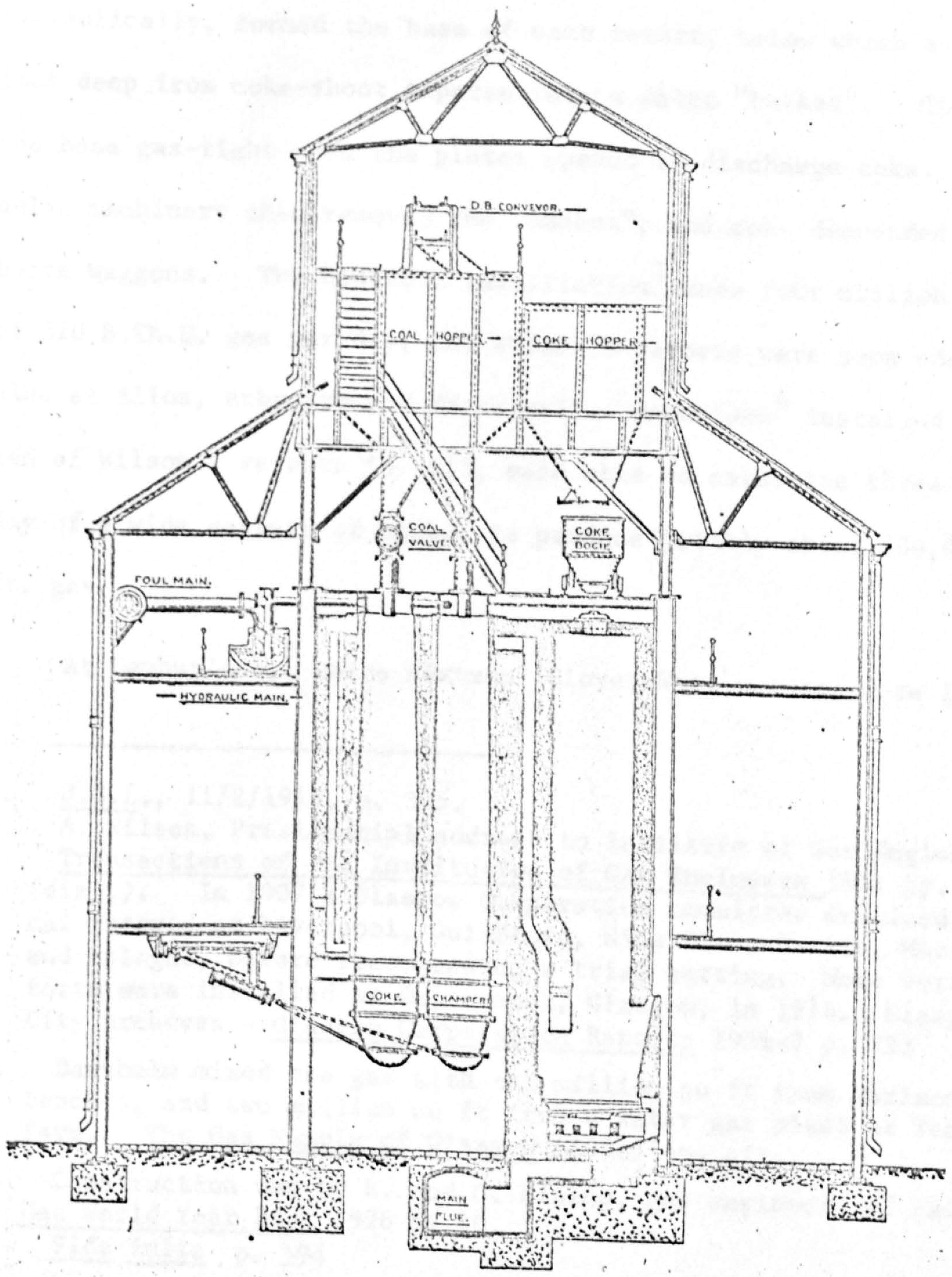
1. Keen competition was offered by Messrs Robert Dempster and Sons Ltd. of Elland, who supplied other equipment to Scottish gasworks, and began the installation of 'Dempster-Toogood' Vertical Retorts at Hebden Bridge in 1913. Robert Dempster (1828-1913), the founder, was a native of Cupar, who trained in meter-manufacture at Messrs Cochrane, Edinburgh, as meter-inspector at Dundee, and subsequently gas engineering at the Phoenix Co., London. J.G.L. 7/10/1913 p.40; Hebden Bridge installation.
J.G.L. 28/1/1913 Obituary R. Dempster. Gas World 30/5/1885 p.723.

2. Vide infra 'Labour' p. 711 c.f. p.636
Wilson stated in 1911 that mechanization had increased rapidly as a direct result of labour union disputes in the gas industry. Ayr company estimated in 1912 that vertical retorts costing about £7,000 could save £500 on stokers' wages, £500 in coal, and increase by-product revenue by £200. Ayr Minute Book op. cit., 9/12/1912.

3. Six benches, each comprizing 4 'settings' of 6 retorts. The retorts were 23 feet long tapering from an oblong 40" by 10" at the top, to 48" by 18" in the centre, and then parallel. Each setting had a separate producer and regenerator, and the producer furnace required stoking only once in twenty-four hours.

Fig. 3.75

VERTICAL RETORTS AT GLASGOW GASWORKS



Source - A Meade Modern Gasworks Practice 1916 p.115

"intermittent-continuous" system[1] with about a third of the contents being discharged and recharged at intervals of three or four hours. Cast-iron 'mouthpieces' at the top held coal-inlet valves fed by hoppers, and ascension pipes for the gas. Sliding-plates, operated hydraulically, formed the base of each retort, below which a six-foot deep iron coke-shoot tapered into a water "bucket". This made the base gas-tight when the plates opened to discharge coke. Hydraulic machinery then removed the "bucket", and coke descended into bogie waggons. The Dawsholm installation[2] made four million cu. ft. of 520 B.Th.U. gas per day, and Wilson's retorts were soon adopted[3] also at Alloa, Arbroath and Motherwell. Johnstone[4] installed eighteen of Wilson's retorts in 1913, each able to carbonize three tons per day of a wide variety of coals, to produce jointly about 600,000 cu. ft. gas.

At Cambuslang,[5] where sixteen 'Glover-West' retorts were installed

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1. J.G.L., 11/2/1913, p. 395.
   A. Wilson, Presidential address to Institute of Gas Engineers Transactions of the Institution of Gas Engineers 1911 pp. 60 - 62 (diag.). In 1907 a Glasgow Corporation committee examined vertical retorts at Liverpool, Guildford, Nine Elms, Berlin, Mariendorf and Cologne, before recommending a trial setting. More vertical retorts were installed at Dalmarnock, Glasgow, in 1914. Glasgow City Archives - Glasgow Corporation Reports 1906-7 p. 723

2. Dawsholm mixed the gas with ten million cu ft from horizontal benches, and two million cu ft from a water gas plant at Temple Farm. The Gas Supply of Glasgow (1935) op. cit.

3. Construction was by R. and G. Hislop, gas engineers of Paisley. Gas World Year Book 1926 p. 40.
   Vide infra p. 394

4. Electric-powered equipment was used. J.G.L. 21/10/1913

5. Installation cost £9,500. Produced sixteen candlepower gas, sold at 2s 9d. Consumption varied from 130,000 cu ft a day in July, from four vertical retorts, to 360,000 cu ft from twelve retorts in winter.
   J.G.L. 18/11/1913 p. 576 (photo.).

in 1913 the number of stokers employed was reduced from fourteen with horizontal retorts to three men with vertical retorts. Bothwell and Uddingston[1] works installed the same system in 1913, but at many city gasworks the 'Glover West' system had the disadvantage of requiring greater floor space than its rivals.[2] Most Scottish investment in vertical retorts falls outside the scope of this study, but by 1914 the advantages of a highly integrated carbonizing and material transport system, with minimal labour requirements, were clearly visible despite the very heavy costs of installation.

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1. Plant to handle eighty tons coal per day. J.G.L. 16/9/1913

2. At Ayr, Glover West Retorts to produce 420,000 cu. ft. per day, were estimated at £10,830, but the smaller Woodall Duckham setting was placed in the old coal store, and by eliminating some of the mechanization like screens and elevators, the cost was reduced to £6,998.
   Ayr Minute Book op. cit., 9/12/1912, 20/12/1912.

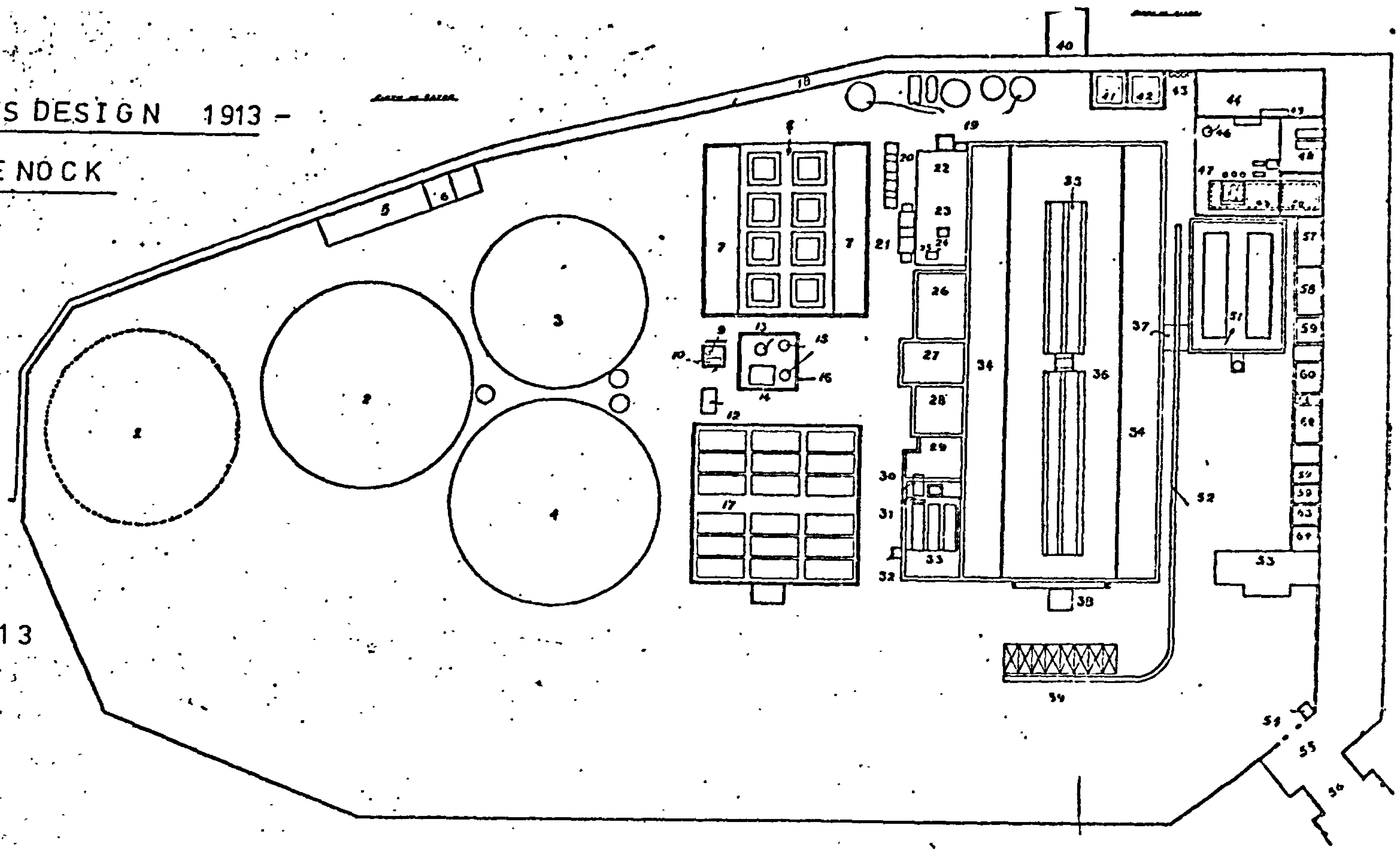
Fig. 3.76

GASWORKS DESIGN 1913 -

GREENOCK

Source -

N.B.A.G.M. 1913



—Block Plan of the Greenock Corporation (Inchgreen) Gas-Works.

1—Site of new holder—1,000,000 cub. ft.
2—No. 3 holder—500,000 cubic feet.
3—No. 1 holder—400,000 cubic feet.
4—No. 2 holder—500,000 cubic feet.
5—Shed.
6—Slaters' stores.
7—Oxide store.
8—Old purifier house.
9—Carburettor.
10—"Simplex" vaporizer.
12—Naphthalene extractor.
13—Rotary meter.
14—Station meter.
15—Governors.
16—Meter house.
17—New purifier house.
18—Boundary wall.
19—Liquor storage tanks.
20—Condensers (water-tube).
21—Rotary scrubbers.
22—Pump house
23—Tar well.
24—Liquor pump house.
25—Tar extractor.
26—Exhauster house
27—Compressor house.
28—Engineers' shop.
29—Men's mess-room.
30—Green's economizer.
31—Superheater.
32—Boiler pump-house.
33—Boiler house.
34—Coal stores.
35—Tar tower.
36—Retort house.
37—Coal hopper.
38—Engine house.
39—Coke and breeze hoppers.
40—Jetty.
41 & 42—Oxide purifiers.
43—Condensers.
44—Sulphate house.
45—Acid tank.
46—Donkey boiler.
47—Liquid ammonia plant.
48—Liquor tanks.
49—Tar well and pump.
50—Wood store.
51—Site for Woodall-Duckham vertical retorts, capacity 2,000,000 cubic feet per day.
52—Electric telpher to be erected.
53—Offices and chemical laboratory.
54—Gatehouse.
55—Works entrance.
56—Bridge.
57—Carpenters' shop.
58—Smiths' shop.
59—Stores.
60—Coal testing plant.
61—Photometer room.
62—Plumbers' shop.
63—Paint store.
64—Oil store.