

## Gasworks Profiles

- A: The History and Operation of Gasworks (Manufactured Gas Plants) in Britain
- B: Gasholders and their Tanks
- C: Water Gas Plants
- D: Producer Gas Plants

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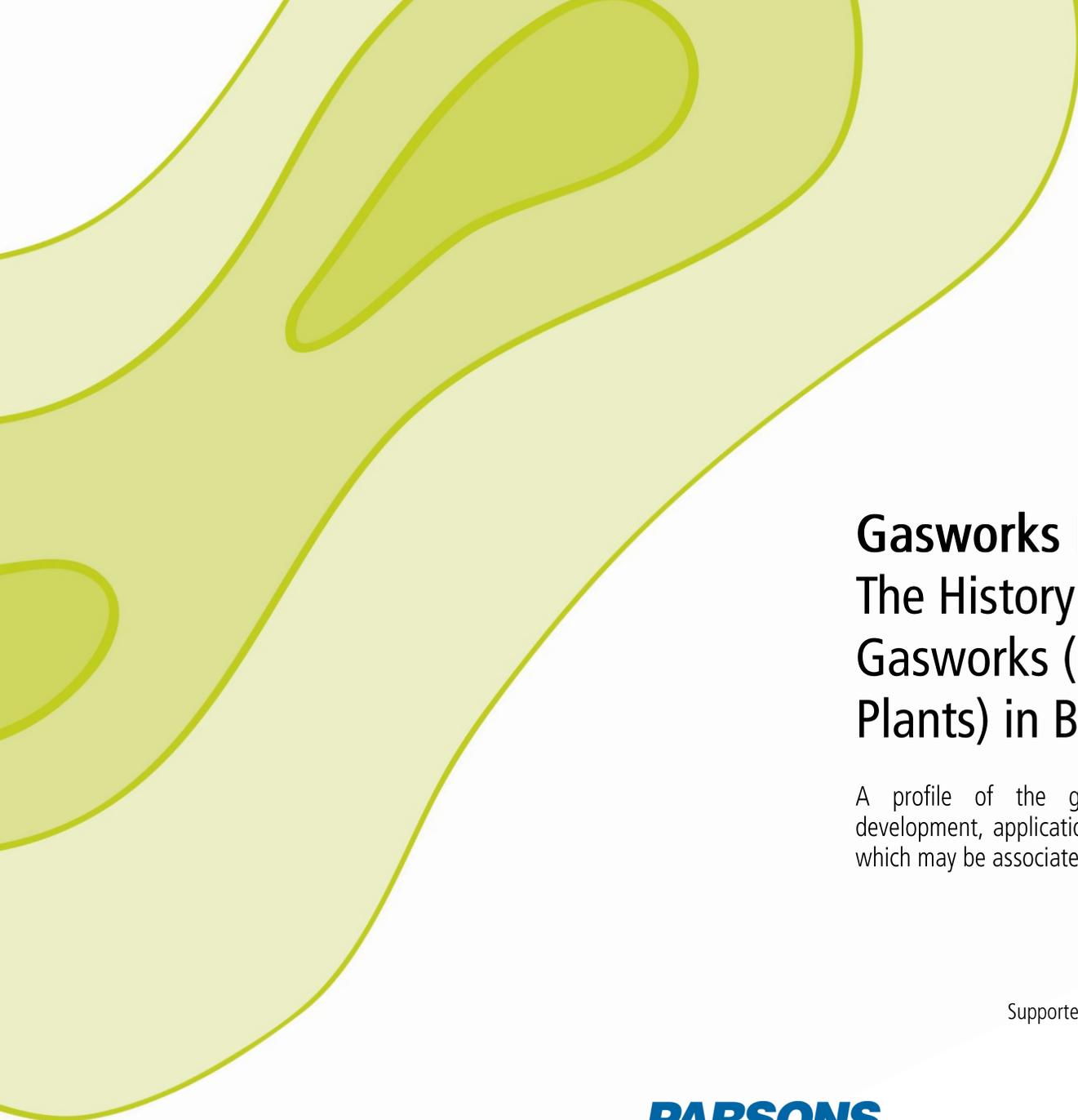
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## **Gasworks Profile A: The History and Operation of Gasworks (Manufactured Gas Plants) in Britain**

A profile of the gas manufacturing process, its design, development, application and the types of waste and by-products which may be associated with the processes used.

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## 1. Introduction

Gas was manufactured in Britain between 1792 – when William Murdock first used coal gas to light his house and office in Redruth – and 1981, when the last gasworks closed in Britain. Britain now uses natural gas, having started to convert from manufactured gas in 1967, an operation taking 10 years to complete. This profile describes the historical development of the manufactured gas industry in Britain, outlining the processes used to manufacture gas from coal and giving a brief description of other processes. It is aimed at those who have a professional or personal interest in the manufactured gas industry.

## 2. A Brief History of the Development of the Gas Industry

### Ancient Times and the Early Awareness of Gas

People were aware of the existence of flammable gas in ancient times, when 'Eternal Flames' formed the centrepiece of religious shrines. The external flames were seepages of combustible gases from sources of gas in the ground below. The Chinese were known to have captured natural gas seepages and transported them through bamboo pipes to be burnt to heat salt pans, evaporating water to produce salt. They had also worked out how to capture the gas in animal skins so it could be stored and transported.

It is, however, not until much later that the great potential of gas was realised, and a practical process to manufacture it developed. Many people from across Europe experimented with the distillation of coal, splitting it into its constituent parts of inflammable gas, ammonia rich water, tar and coke.



**Photograph 1. Former gasworks clockwise from top, Coatbridge (Lanarkshire, Scotland), Falmouth (Cornwall, England) and Pembroke Dock (Pembrokeshire, Wales).**

Jean Tardin documented in 'Histoire naturelle de la fontaine qui brusle pres de Grenoble' (1618), that he had heated crushed coal in a closed vessel producing coal gas, after identifying that the source of the fire well in Grenoble was gas escaping from burning coal beds.

Thomas Shirley made an early observation (1659) of 'carburetted hydrogen' emanating from a natural spring; when he put a candle to the surface of the water, it ignited. Shirley believed the source of the gas was coal below the ground.

Dr John Clayton, the Dean of Kildare, continued Shirley's work and, years later (1684), excavated the base of the spring to find coal 18 inches below. The gas escaping from the coal measures was inflammable and Clayton assumed that the coal was the source of the gas. Clayton's work continued with the distillation of coal in an open retort. He noted: 'At first there came over only Flegm, afterwards a black Oyle and then a spirit arose which I could no ways condense'. Clayton collected the gas in bladders which, if pricked with a pin and squeezed, emitted gas which could be ignited. Much of this work was unknown until Clayton published the work *circa* 1739.

In 1760, George Dixon (Photograph 2) of Durham undertook experiments heating coal in a kettle and igniting the gas which escaped from its spout. He established the first works for extracting tar from coal in Cockfield, Co. Durham, in 1779, the gas from which lit his house.

Carlisle Spedding, the manager at Lord Lonsdale's Saltom mine in Whitehaven (1765), lit his office with mine gas otherwise known as 'fire damp' which was vented from the mine. He had offered to supply the town with gas for street lighting, an offer they refused. This had followed earlier work (1733) by Sir James Lowther in

burning fire damp at the surface of a mine from which it was being vented.



**Photograph 2. A diorama of George Dixon demonstrating burning coal gas.**

Archibald Cochrane, otherwise known as Lord Dundonald, had spotted a market for coal tar with the Royal Navy. By tarring the wooden hulls of the Navy fleet, he proved in tests that it would prevent them from rotting and fouling. Tar distillation ovens were built at the family home, Culross Abbey in Fife, but the Royal Navy did not purchase the tar. The gas produced from the distillation of the coal was reputed to have been lit, producing a bright flame visible from many miles away.

Abroad, others were active in experimenting with coal gas. Jean Pierre Minckelers, a professor at Louvain, lit his lecture room in 1785. In 1786, Professor Pickel lit his chemistry laboratory in

Wurzburg, Bavaria. In France, Philippe Lebon obtained gas from heating sawdust in a retort and also lit a room by gas in 1791. Lebon is recognised as the father of the gas industry in France. The son of a court official of Louis XV, he was an engineer and scientist of considerable reputation and devoted great efforts to gas lighting, being awarded a patent in 1799 for this purpose. His work spurred on the development of gas lighting across mainland Europe.

Most credit for the discovery of a commercial process for coal gas manufacture goes to William Murdoch, an engineer born in 1754 at Bello Mill, near the town of Lugar in Ayrshire, Scotland. Murdoch is believed to have experimented with producing gas from coal in a kettle when he was a child. After walking to the Boulton and Watt factory at Smethwick, Birmingham, from Lugar in 1777, Murdoch found employment. Mathew Boulton was particularly taken aback by an oval-shaped wooden hat that Murdoch was wearing. He had made it himself on a lathe of his own design.

Murdoch performed well and within a few years (1779) he was given the difficult task of selling and installing steam powered water pumping equipment to the Cornish mine owners. This was, at the time, the most prosperous industry in Britain, and Boulton and Watt's most valuable market. Murdoch was so well liked in Cornwall that he married Ann Paynter, the daughter of a local mine owner.

#### A Strong and Beautiful Light

Murdoch was based in Redruth, where he experimented with the production of gas from coal in a small iron retort in his back yard. The gas was piped into the house allowing him to light his house and office in 1792 (Photograph 3). Murdoch was an engineering genius, much

overlooked when compared to some of his peers. He also built the first working model steam carriage at the same house in Redruth in 1784.



**Photograph 3. A diorama of William Murdoch demonstrating gas lighting at his home in Redruth, Cornwall.**

Between 1795 and 1796, at the Neath Abbey Iron Works, Murdoch conducted further experiments into the design of retorts. He lit the counting houses of the works, describing the light produced by the gas as 'a Strong and Beautiful Light'. At the same time, Murdoch lit a factory in Old Cumnock, Ayrshire. He did this by filling small bladders with gas from a retort outside the factory and then attaching them to light fittings within the factory and burning the gas.

Recalled to Birmingham in 1798, Murdoch continued to experiment with gas lighting, without much support from his employers – until Gregory Watt visited Paris and discovered the rival work being undertaken by Philippe Lebon.

With more encouragement, Murdoch went on to light the Soho works of Boulton and Watt in 1802. To celebrate the Peace of Amiens, the exterior of the Soho works was illuminated, the first public gas lighting exhibition. Murdoch had experimented with a vertical retort design with the coal held in baskets, but this proved impractical and he developed horizontal retorts by 1802. Murdoch operated the retorts in a way that required him to light the furnace shortly before the gas was required, an inefficient form of operation. A colleague, John Southern, pointed out that if the gas could be collected within a storage device (gasholder), then fewer retorts would be required and they could be operated continuously. Murdoch examined the process of coal gas manufacture in great detail, costing his employers an estimated £5,000. In 1805, the Boulton and Watt factory was the only supplier of gas-making plant in the world. In the same year, Murdoch also developed the world's first circular gasholder (Photograph 4).

Following on from the success at the Soho works, Murdoch looked for opportunities to install gas plants at other sites. In 1804 George Lee of Phillips and Lee in Salford was the first industrialist to employ Murdoch to build a gas plant and install gas lighting in a mill, initially George Lee's house was lit by gas. Once its safety had been proved, Murdoch lit their Salford Twist Mill, one of the biggest factories in Britain at this time. The mill was fully lit by gas in 1805; in 1806, Chapel Street in Salford was the world's first street to be lit by gas.



**Photograph 4. Murdoch's original circular gasholder at the Soho works.**

Murdoch was not alone in his interest in gas lighting, a former colleague, Samuel Clegg, had set up as a rival and was busy installing a gas plant at Henry Lodge's Mill at Sowerby Bridge in Yorkshire. Clegg is believed to have beaten Murdoch by two weeks on the installation of gas at Sowerby Bridge.

Despite this success, the ambitions of Boulton and Watt, Murdoch's employers, in the field of gas lighting, were limited. It was a small part of a large business empire focussed on manufacturing steam engines. It was this lack of interest which caused Clegg to depart and for other employees to set up as gas engineering contractors to rival their former employer. Other engineers in the Birmingham area had also seen the potential for gas lighting and engineers such as Josiah Pemberton started designing their own plant for smaller works. Boulton and Watt focussed on the owners of large factories who could afford their plant and they went on to light some of the larger establishments in Britain such as Strutt's calico

mill in Derby, Gott's woollen mill in Leeds and two flax mills in Shrewsbury.

By 1815, the Boulton and Watt Company, and Murdoch, had started to withdraw from the manufacture of gasworks plants. Other specialist gas engineers had taken the lead. Gas was adopted in many large mills and factories across Britain most notably the mills across the north of England.

Mills had predominantly been lit by tallow candles or oil lamps, using up to 1,500 candles per night in the winter. Candles and oil lamps could easily be knocked over, and were responsible for many mills burning down with considerable loss of life. George Lee was offered a greatly reduced insurance cost (one third of the previous cost) for having the Salford twist mill converted to gas lighting, a great incentive.

In 1808, Murdock presented a paper to the Royal Society entitled 'An account of the application of coal gas to economical purposes', for which he received the Rumford Gold Medal.

#### The Development of the Public Gas Supply

The philosophy of William Murdoch was to build small gasworks to provide gas to a single establishment. Other proponents, however, had greater plans. A key figure was Friedrich Albrecht Winzer (Figure 1), an impresario who had seen Lebon's early experiments in Paris. Hailing from Braunschweig (Brunswick) in Germany, to succeed in Britain he changed his name to Fredrick Albert Winsor.

Winsor proposed the concept of centralised gasworks providing gas to multiple establishments through gas mains under the street. It should be noted that Lebon had been murdered in mysterious circumstances crossing

the Champs-Élysées in 1804, after which the development of gas in Paris almost ceased until renewed interest in the 1820s. If Lebon had not been murdered then gas may have been adopted in France much sooner.



**Figure 1. Sketch portrait of Frederick Winsor.**

Lebon's work on the thermolamp cannot be underestimated. It was highly influential in continental Europe and led to significant developments in gas manufacture outside of Britain. Following Lebon's death, Germany became the main centre for interest in the thermolamp, and a number of books and articles were written on the subject between 1802 and 1812. The most important thermolamps were built by Zachaus Winzler, including a large thermolamp in Bruno. Winzler was a chemist from Unlingen, Germany, who moved to Blnsko to

run a saltpetre factory for the aristocratic Zu Salm family.

Winsor thought London a suitable place to develop a gas industry. He gained a reputation in the field, undertaking evening lectures and demonstrations at the Lyceum Theatre in London, going on to demonstrate gas lighting on Pall Mall in 1807. In the same year, Josiah Pemberton built a gasworks to light the Golden Lane Brewery and also the street outside the brewery.

Winsor had a very commercial outlook, much more so than Murdoch, and had unsuccessfully challenged Murdoch for a patent for lighting by coal gas. Winsor was intent on setting up a company to produce gas from a centralised gasworks. He first proposed the National Light and Heat Company in 1807 with the grand aim of supplying the whole country with gas. Making applications to Parliament for a charter, he found strong opposition from Murdoch and his friends. He persisted and, eventually, on 30 April 1812, the Gas Light and Coke Company (GL&C Co) received its Royal Charter. Its first gasworks was built on Cannon Row, Westminster, but the plant failed technically and the site was too small to meet future needs. What could be salvaged from Cannon Row was removed to a new site at Great Peter Street, Westminster, which was a success.

Winsor's success with the GL&C Co was short-lived. He was ousted by the ruling court and in 1813 was given an annuity of £600. This was suspended in 1815 and Winsor had to flee the country to avoid his creditors. He returned to France and floated a short-lived gas company. He died in 1830 a disappointed man, but his influence on the gas industry was significant.

## The First Gas Engineer

Born in Manchester, England, Samuel Clegg was the son of a wealthy businessman, Wheatley Clegg. Samuel Clegg was educated at New College Manchester between 1794 and 1797; in 1798 he became an apprentice engineer at the Soho foundry of Boulton and Watt. Completing his apprenticeship, he worked on steam engines. His introduction to gas came when he assisted William Murdoch in lighting the Soho works for the 'Peace of Amiens' in 1802. Clegg soon realised the potential of gas and the limitations of working at Boulton and Watt, where gas was just one of many departments. He split from the company in 1805 and established himself as a rival gas engineer, based in Manchester.

A great innovator, Clegg experimented with the purification of gas using lime, incorporating such a plant at the gasworks he installed at Stonyhurst College (Preston, England) in 1811. Clegg also invented the gas meter and self-acting governor and adapted the Argand burner for burning gas.

In 1812, Clegg went to London to establish a small gasworks for the famous publisher Rudolph Ackerman. This proved an excellent advert for Clegg's skills as an engineer. On 25 December 1812, Clegg began work for the GL&C Co. This proved vital for the company's survival as its existing technical experts (Winsor, Accum and Hargreaves) were not engineers. He maintained the GL&C Co gasworks almost singlehanded for the first few years.

Clegg even took to lighting the gas lights on Westminster Bridge, as the lamplighters originally refused to light them for fear of explosion. He left the GL&C Co in 1817, installed gas at the Royal Mint, then went on to establish gas in various towns and cities including Birmingham, Bristol and Chester.

Having developed the large circular gasholders at the GL&C Co, Clegg spent much time persuading others that they would not suddenly explode. This included instructing a gas worker to put a pick axe into the side of a holder and then lighting the resulting gas leaking from the vessel. This burnt with a strong flame but no explosion.

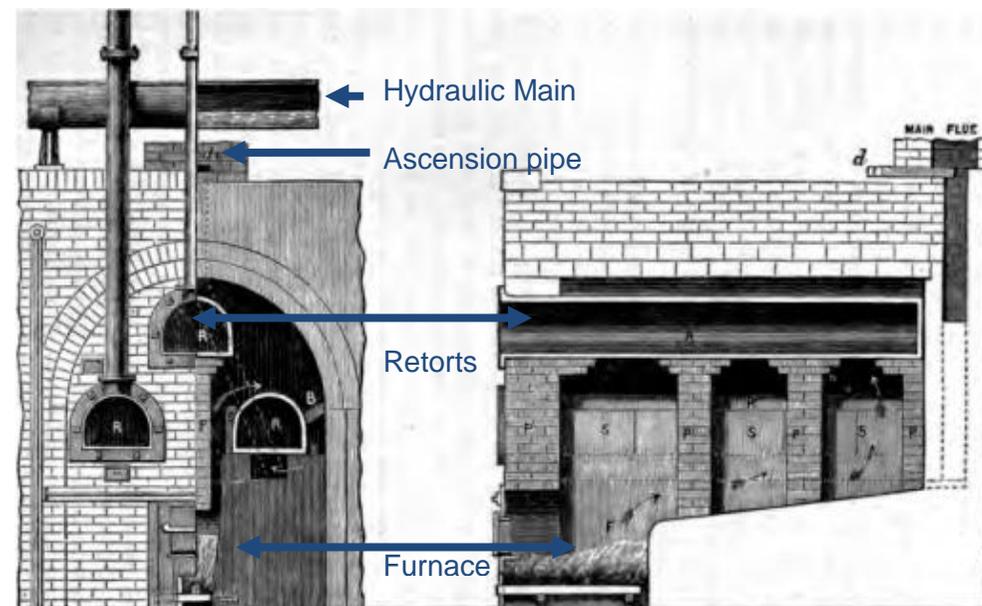
These fears over gasholder safety required many of the very early gasholders to be housed within a building. These buildings were later dispensed with in Britain.

Clegg left the GL&C Co in 1817. Prior to this, he had been undertaking consultancy work and was important in the construction of many gasworks across Britain. He left the industry in 1824, returning at various times as his fortunes fluctuated. With his son, Samuel Clegg Junior, he produced an important book 'A Treatise on Gas

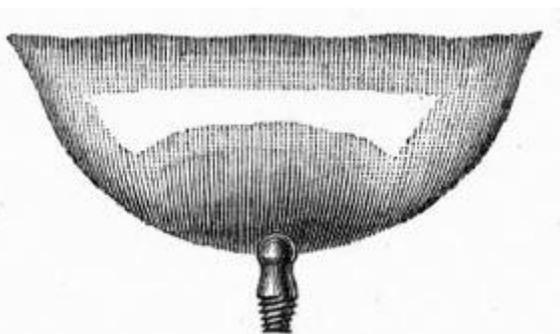
Works and the Practice of Manufacturing and Distributing Coal Gas', from which Figure 2 is taken.

## The Development of Gas Lighting

Lighting was the primary use for gas in the 19<sup>th</sup> century. The first gas burners were very simple, with names such as rat tail and cockscomb. They comprised iron caps with one or more pinprick holes through which the gas escaped and was burnt. Gradual improvements saw these simplistic burners replaced by more efficient models. Samuel Clegg converted the Argand burner for use with gas in 1809; Stone devised the batswing burner (Figure 3) in 1816; and the latter was further improved upon by Milne in 1820 to produce the union jet or fishtail.



**Figure 2. A schematic of a simple bench of three directly fired retorts which would be found in a small gasworks, attributed to Samuel Clegg Jnr. Source: Russell Thomas.**



**Figure 3. A batwing burner.**

In addition to the town and city councils that required street lighting, the early customers were mostly public houses, hotels, theatres, shops and public halls and institutions.

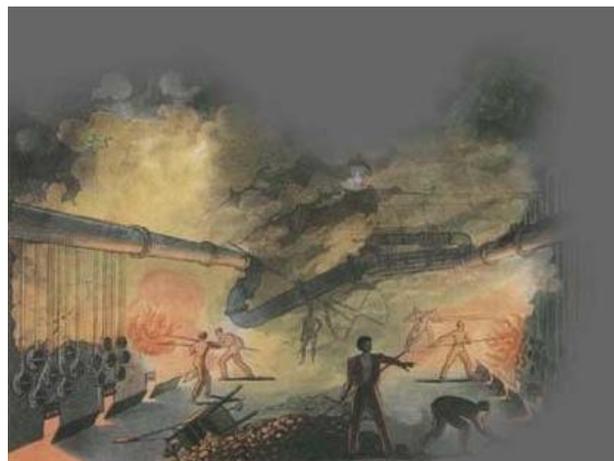
#### The Great Expansion into the Provinces

Following on the heels of the GL&C Co, many other gas companies were established in London. By 1850 these numbered 13, the most notable rival being The South Metropolitan Gas Company, formed in 1834.

Outside London, Preston became the first provincial town to have a public gas supply, securing an Act of Parliament in 1815 to 'light, watch, pave, repair, cleanse and improve the towns streets'. The Preston Gas Light Company was formed and Samuel Clegg provided his assistant John Grafton to act as engineer. On 20 February 1816, Preston became the first town outside London to be lit by gas. Exeter and Liverpool soon followed, with Acts of Parliament in 1816. In Scotland, the Glasgow Gas Light Company received an Act of Parliament giving it statutory powers in 1817, with gas lighting commencing a year later. In Wales, a public gas supply was first provided to Swansea in 1821.

Gas spread rapidly throughout the country, often through the passing of 'lighting and watching' Acts of Parliament.

Conditions for the workers in early gasworks were very harsh. This was especially true for the stokers, whose role it was to load coal and unload coke from the retorts, and tend the furnaces in hot, dirty and dangerous conditions. An example of the conditions within the Brick Lane gasworks retort house can be seen in Figure 4.



**Figure 4. An early painting depicting conditions within Brick Lane gasworks.**

#### Expansion Abroad

In order to export Britain's new-found experience in gas manufacturing, the Imperial Continental Gas Association (ICGA, emblem Figure 5) was formed in 1824 by Major-General Sir William Congreve. By this time, gas was already starting to be manufactured in some European towns. This was in part promoted by success in Britain, but also followed on from the work of Lebon and Winzler with the similar gas-producing thermolamp.

In 1825, Congreve toured Europe to establish business ventures. Success was mixed, as some places already had established local gas-lighting rivals. His first venture was a small oil gasworks in Ghent, purchased from a local company; this was later converted to use coal.

The ICGA went on to operate in the Netherlands, Belgium, Germany, Austria, Hungary and France. Given the nature of their short- to medium-term contracts, and political changes and war in Europe, the business changed considerably. Despite these changes the company continued to operate until 1987.



**Figure 5. The emblem of the Imperial Continental Gas Company.**

The ICGA was not unique and other British companies were established to target Europe, including the European Gas Company and the Continental Gas and Water Company.

British engineers also looked abroad to seek their fortune independently. Aaron Manby established Manby, Wilson and Co. otherwise known as the 'Compagnie Anglaise', to light some of the streets of Paris. George Bower exported entire gasworks as kits to be built abroad in countries from Russia to Argentina. French and German companies

were also later created to export expertise in gas manufacture.

The British Empire was also targeted by British companies such as the Colonial Gas Company, and by independent gas engineers who set up their own companies. With British support and independently, gasworks were built across the globe on all continents except Antarctica.

### Municipal Undertakings

Gas undertakings were all privately owned until the Manchester Police commissioners took an interest in gas lighting. Their first involvement came in 1807 when a gas light was installed over the door of the King Street police station. The Manchester Police commissioners were the government authority in the town and were responsible for lighting (and watching) the streets with oil lamps. They passed a resolution in 1817 to build a gasworks at Water Street to light the police stations and principal streets, and to sell any surplus to private customers. This was the first example of a municipally owned gas undertaking.

The Manchester Police commissioners built another gasworks at Rochdale Road in 1824. Manchester was incorporated in 1838 by the Municipal Corporations Act of 1835 and the gas undertaking passed to the Manchester Corporation in 1843, making it the first municipal gas undertaking.

Many other gas undertakings came under municipal ownership, in particular in the Midlands and North of England. The Birmingham Corporation purchased the two private gas undertakings operating in the Birmingham area in 1875, operating them as the Birmingham Corporation Gas Department.

The gas departments were an important source of revenue for the towns and cities which owned them, and the profits funded many important civic projects. Between 1844 and 1921, the Manchester Corporation gas department earned the council a profit of £3.4m, a considerable sum of money at the time.

### The Continued Development and Growth of Gas

By the 1840s, gas lighting had been adopted in the private homes of the wealthy, although it was often confined to certain rooms and not the entire house. A boost was given to the industry when the new House of Commons adopted gas lighting in 1852, and continued to use gas until 1900.

The increased demand for gas storage on a gasworks led to a major innovation in gasholders. The telescopic gasholder was developed by Tate in 1824, and the first example was built in Leeds. This had the added benefit of increasing gas storage without increasing the footprint required by the gasholders. Telescopic gasholders consisted of vessels (lifts) situated one inside the other; when the inner lift was fully extended the next outer lift would also start to rise

People started to look for alternative uses for gas, for example cooking (Figure 6). In 1826, James Sharp, the assistant manager of the Northampton Gas Company, experimented with the possibility of cooking with gas. He installed an experimental gas cooker in his home, and its relative success won him the patronage of Earl Spencer in 1834, after which he began to produce cookers commercially.

There was a great surge of interest in the late 1840s, probably due in part to Alexis Soyers, the celebrity chef of his day. Soyers used gas cooking extensively in the London Reform Club where he worked. The engineers Croll, Ricketts,

King, Goddard and Sharp all manufactured new cookers, but they did not become popular until the 1870s.

The first gas-heated bath was developed in 1850, although such new developments were not without their inherent safety risks.



**Figure 6. An early gas cooker of Arden Hill and Company. Source: Russell Thomas.**

### Regulation and Competition

The gas industry remained largely unregulated in its early years. No restrictions were placed on the prices charged or profits made by the gas undertakings; generally their only obligation was to provide parish gas lighting at a cheaper rate.

In 1847, the Gasworks Clauses Act was introduced to regulate the construction of

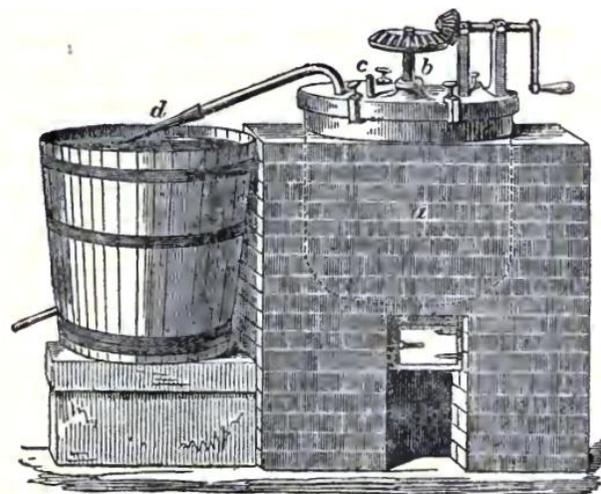
gasworks and the supply of gas to towns. The Act regulated all aspects of the industry including pipe laying, profits, annual accounts, penalties, waste produced and by-products. It was just one of a number of important acts which would regulate the gas industry in the coming century.

Parliament relied upon competition in the gas market to keep prices low. In London, almost all areas had the choice of two potential gas companies to supply them. This system was regarded as uneconomic and very inconvenient, as it led to excessive digging up of the roads. In 1853, the area south of the Thames adopted 'distracting', with specific companies responsible for supplying specified districts. This concept was later adopted throughout London via the Metropolis Gas Act of 1860.

#### New Markets Ahead

In 1856, William Perkin was an assistant of August Wilhelm von Hofmann at The Royal College of Chemistry. One summer, whilst Von Hoffman was abroad, Perkin discovered the dye known as Mauveine. Perkin had been working on a way to synthesise quinine in the fight against malaria, but instead discovered Mauvine. Perkin patented the dye and as a result founded the aniline dye industry (Figure 7). Coal tar from the gas industry was the substance from which Mauvine was extracted.

This early discovery by Perkin helped to demonstrate the important and diverse chemicals which were present within coal tar. The coal tar by-product became valuable and could be sold to the new emerging coal-tar-based chemical and dye industry. It became an important industry in its own right, particularly in Germany.

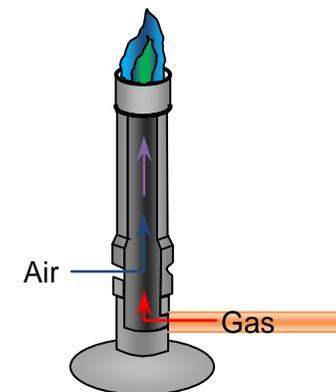


**Figure 7. An early apparatus for the production of aniline dyes, from the 'British Coal Tar Industry' by William Gardner.**

In 1855, Robert Bunsen, a famous German chemist, invented the atmospheric gas burner known to many as the 'Bunsen burner' (Figure 8). This mixed the air and gas prior to the flame allowing it to burn much hotter. It made more efficient use of the gas burnt and allowed a greater range of uses, especially in commercial and domestic heating applications. This development ultimately saved the gas industry, as heating applications became ever more important as the industry evolved.

Another significant development occurred in 1856, when Frederick Siemens developed the regenerative furnace. This furnace could operate at a high temperature by using the regenerative preheating of air. In a traditional furnace, a large part of the heat derived from combustion was lost, carried off in the hot gases which escaped up the chimney. In the regenerative furnace, the hot gases passed through a chamber (a regenerator) filled with loose bricks which absorbed the heat. Once the chamber was well

heated, the hot gases were diverted to another similar chamber. The incoming air for combustion was then heated by passing through the hot regenerator chamber, absorbing the heat which has been stored in the bricks. After a suitable interval, the air flows were again reversed through the second regenerator. The regenerator ensured that heat was recovered as efficiently as possible.



**Figure 8. A schematic of a Bunsen burner. Source: Russell Thomas.**

Other notable regenerators were developed in Germany and imported to Britain, including the continuous regenerators developed by both Schilling and Klonne, the latter being introduced in 1885. These systems did not require multiple chambers, but were arranged so hot exit gases could continually heat incoming air.

The effective use of the regenerator was dependent on another furnace developed by Siemens. This was a furnace which could produce a crude gas from the incomplete combustion of coal, known as the Siemens gas-producer (described later in the section on horizontal retorts).

Gaseous fuel passed via a flue from the producer to the regenerative furnace heating it. The combined regenerator and producer were used together at Chance's glassworks in Birmingham in 1861, and were described by Michael Faraday in his farewell lecture to the Royal Institution. This system was gradually improved and introduced to the UK through Frederick's brother, William Siemens, gaining widespread use in many industries, including the gas industry.

Producer gas plants provided the great benefit of allowing the production of heat at high and uniform temperatures. They later became used for heating all forms of gas retort. This allowed the gas-making process to proceed at higher and more efficient temperatures than previously.

Dowson developed a complete suction gas producer plant in 1878 which could be used both for industrial and domestic purposes. He demonstrated the effectiveness of gas engines in 1881 when he combined a producer gas plant with a gas engine.

Gas producers became regularly used in industry, producing a low-quality gas unsuitable for lighting but able to power gas engines and heating furnaces.

The only producer-based gas production process to use gas for distribution was the Mond Gas process. An entire gas network was built in South Staffordshire to produce Mond gas from a gasworks in Tipton. This supplied local industry with a gas for heating and powering engines. The process also produced large amounts of the chemical ammonium sulphate.

Mond gas was rich in hydrogen and carbon dioxide. It was of little use for lighting, although it could be used for industrial purposes. This is

covered by *Gasworks Profile D - Producer Gas Plants*.

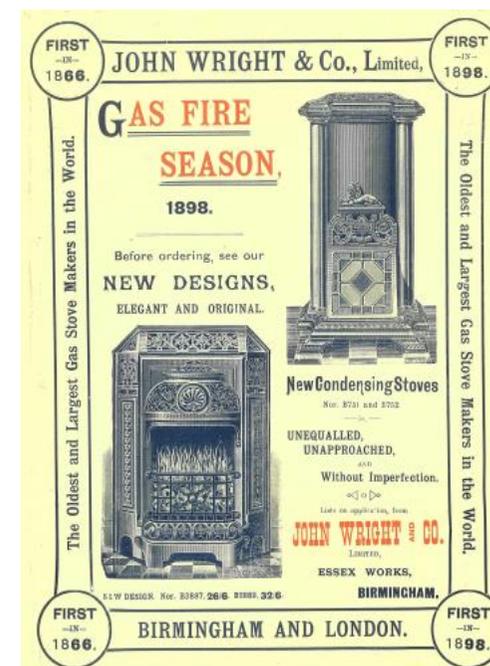
In 1863, the British Association of Gas Managers was formed, the forerunner to the current Institute of Gas Engineers and Managers, which celebrated its 50<sup>th</sup> anniversary in 2013.

Thomas Fletcher trained as a dentist but had an interest in engineering. He originally developed dental equipment, but by the early 1880s was manufacturing gas appliances. Under the name of Fletcher Russell and Co Gas Engineers, Fletcher took Bunsen's invention and developed many different applications for it, including furnaces, fires, cookers and water heaters as well as laboratory equipment. Appliances were developed by many other gas engineers, including John Wright (featured in Figure 9).

#### A Bright Future?

Baron Carl Auer von Welsbach was an Austrian chemist who made a major contribution to the gas industry with his invention of the gas mantle in 1887. He discovered that the oxides of certain rare metals had the ability to emit light when in a state of incandescence. After many years of research, the final mantle was produced by soaking a textile in a mixture of 99% thorium dioxide and 1% cerium (IV) oxide. When the mantle was heated by the Bunsen burner it produced a brilliant light.

It should be noted that, in 1826, Drummond used incandescence in the commercial application of lime-light through the oxy-hydrogen heating of calcium oxide. Platinum mantles had also been used to light the town of Narbonne, France, in 1848. They were also used by Hogg, who used an aerated flame burner with a platinum mantle.



**Figure 9. Advert circa 1898 for gas fires by John Wright and Co from the Gas Engineer's Textbook and Gas Companies Register 1898.**

None of these developments had anything like the impact of Welsbach's invention once it had been perfected (Figure 10).

Welsbach's invention was timely, with the gas industry facing a new rival: the electric light bulb. Humphrey Davy demonstrated the first electric arc lamp in 1806, but it was impractical and went no further. The more robust light bulb for everyday use was developed by Joseph Swan (UK) in 1878 and Thomas Edison (USA) in 1879. They later collaborated to form the Edison Swan Electric Company Limited otherwise known as Ediswan.

xxxiv.

**THE INCANDESCENT GAS LIGHT CO., LTD.**  
(WELSBACH PATENTS).

Pronounced by Mr. Justice Wills and confirmed by the Court of Appeal to be

**"A PIONEER INVENTION."**

FURTHER DEVELOPMENTS; ENORMOUS ECONOMY; IMMENSE SUPERIORITY;  
IMPORTANT IMPROVEMENTS.

THE NEW "GEM" BURNER, 4/6.  
THE NEW "GEM," 4/6.  
THE NEW "GEM," 4/6.



35 CANDLE POWER from 1 cubic foot of Gas!!!

The "GEM" Burner is specially suitable for Domestic Lighting.

GREATLY IMPROVED DISTRIBUTION OF LIGHT.  
IT IS THE BRIGHTEST "GEM."  
20 CANDLES PER CUBIC FOOT OF GAS!!!

The Welsbach Incandescent Gas Light is

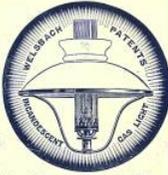
**THE MOST ECONOMICAL  
THE MOST BRILLIANT  
THE MOST HEALTHY  
THE CLEANEST GAS**

LIGHT.

THE "GEM" BURNER, 4/6.  
THE "C" BURNER, 6/6.  
THE "C" BY-PASS BURNER, 7/6.

Further Particulars and Price List can be had on application to the Company's Agents, or leading WHOLESALE HOUSES, or to

**The Incandescent Gas Light Co., Limited,**  
14, PALMER STREET, WESTMINSTER.



**Figure 10. An advert for a gas mantle from the Gas Engineer's Textbook and Gas Companies Register 1898.**

Electricity did not become a practical reality until metal filament lamps were perfected in 1911 and the Electricity (Supply) Act had been passed in 1926, leading to the establishment of the National Grid. The gas mantle had allowed the gas industry to compete with its new rival electricity for much longer than would have otherwise occurred; gas lighting was still preferred in some towns in the 1950s. Gas lighting has not completely disappeared in the UK: there are still approximately 2,000 public gas lights in the greater London area.

The Sugg family has always been associated with the gas industry. Thomas Sugg made and fitted the original gas pipes for Frederick Winsor in Pall Mall, London, in 1807 and the Sugg brand is still producing gas lighting equipment today. William Sugg & Co was a famous company specialising in gas lighting, and it made many notable developments in this field, but also in the fields of heating and cooking.

The development of new products and the gas mantle gave the gas industry greater flexibility to target new markets and produce a different type of gas, no longer dependent upon a high illuminating power.

In November 1869, work commenced on the construction of the Beckton Gasworks of the GL&C Co. Beckton (Photograph 5) was the largest gasworks ever built.



**Photograph 5. This painting of the original Beckton gasworks used to hang in the station engineer's office.**

Prepayment gas meters were invented in 1870 by T.S. Lacey. This was a major development, making gas available to those who could not have previously purchased it and could not have

afforded its installation costs. Gas was opened up as a viable alternative fuel to a whole new group of people and led to a great expansion in the gas industry in Britain. British gas companies also started to hire out cookers and other appliances to customers.

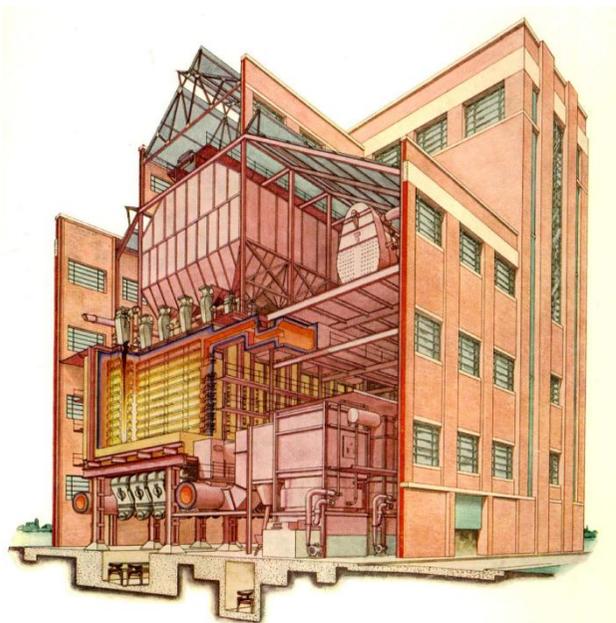
### New Technology Drives the Industry Forward

One major issue with making gas from coal was the time taken to get the gas plant operational and producing gas. This led to a heavy reliance on storage in gasholders. If sufficient storage was not possible then the continuous heating of coal gas plant was required to more readily accommodate rapid increases in gas production. This was both inefficient and uneconomic for the gas manufacturer.

Water gas provided an alternative method to meet peak demand for gas. Although discovered earlier, it was not until *circa* 1873 that a commercially viable system was developed by Lowe. Lowe devised an intermittent system which produced gas on a cyclical basis, first heating the system and then injecting steam to produce a gas comprised of hydrogen and carbon dioxide. This gas lacked illuminating power, but could be enriched by the injection of oil, a process called Carburetted Water Gas (CWG). The first major installation of a CWG plant in Britain was at the Beckton gasworks near London. This subject is covered in *Gasworks Profile C on Water Gas Plants*.

During the period from 1885 to 1905, gas engineers undertook a considerable amount of development work, producing inclined and vertical retort systems. After early work by the likes of Rowan, Coze, Rice, Schilling, Bueb, Settle and Padfield, two companies established themselves as the market leaders in vertical retorts. These companies were Woodhall

Duckham and Glover West (Photograph 6), and they constructed many of the vertical retort plants in the UK.



**Photograph 6. An artist's impression of West's vertical retort plant.**

Vertical retort plants operated with the coal being fed vertically through the retort rather than horizontally, allowing continuous operation. These are described in detail in section 4.3.

#### The Inter-War Years

The First World War had a major effect on all aspects of British life, and the gas industry was equally affected. The war had diverted funds away from the gas industry whilst driving up the price of raw materials. Price controls were enforced, and the war effort meant chemicals were required for fuels, textiles and munitions manufacture.

The war also took away skilled staff and diverted engineering materials from the gas industry, leading the industry into stagnation and decline. Many small gas companies struggled during this time; some went bankrupt and others had to amalgamate to survive. This led to many of the smaller works closing, and supplies coming from larger, more economic gasworks.

The Gas Regulation Act was introduced in 1920, and changed the basis of charging for gas. It also introduced a national basis for the testing and reporting of gas quality. From the middle of the 19<sup>th</sup> century, the quality of gas had been based on its illuminating power; the act changed the basis to the calorific value of the gas. With the invention of the gas mantle, and the move away from lighting markets, the illuminating power of gas was now largely irrelevant.

A development in the 1930s was the increasing number of holding companies formed, including the Devon Gas Association and the Severn Valley Gas Corporation. These holding companies bought up control of predominantly small gas undertakings. They allowed the undertakings to trade as the original company, but provided central control and assistance in a financial, managerial and technical capacity. Many of these small undertakings would have collapsed without the holding company's intervention.

In 1932, Eric Fraser created 'Mr Therm' (Photograph 7) as an advertising symbol for the GL&C Co. He was later adopted by the British Commercial Gas association on behalf of the wider British gas industry.

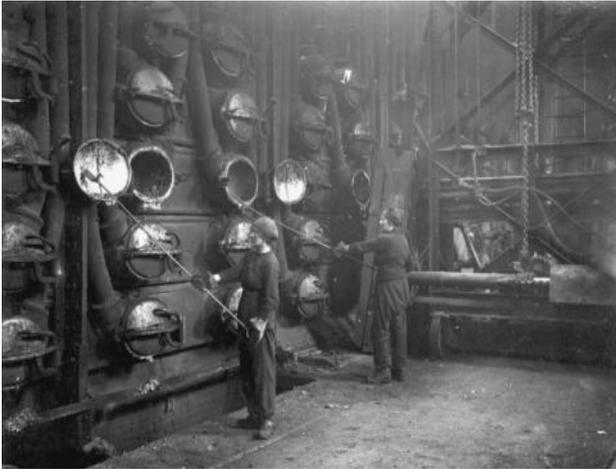


**Photograph 7. Mr Therm, the gas industry mascot, exploring the treasures of coal tar.**

As the end of the 1930s loomed, so did the prospect of another world war. The Second World War had a greater toll on gas infrastructure than the first. The industry had seen gas demand increase, with gas and its by-products (from explosives to motor fuel) essential to the war effort. The gas industry was instrumental in producing hydrogen gas for the barrage balloons which formed an important part of the British air defences.

As gas workers went off to war, many women were brought in to work in the gasworks providing a vital service in the war effort (Photograph 8).

The aerial bombing of gasworks and gas mains was hugely damaging; skilled staff were lost from the industry to the war effort and funds for new plant were hard to obtain. The damage incurred by the gas industry would require major reconstruction investment.



**Photograph 8. Women stokers during the war.**

In 1944, the minister of fuel and power appointed Geoffrey Heyworth as chairman of a review into the gas industry. The aim of the review was to consider how the industry could develop while reducing the cost of gas for all types of consumers. The Heyworth review highlighted many issues, including the need to improve the gas transmission network by amalgamating to form larger companies.

On the basis of the Heyworth review, the incoming Labour government decided that nationalisation was the best course of action for the gas industry. Nationalisation occurred through the Gas Act of 1948. The 1,064 local gas undertakings were vested in twelve area gas boards (Photograph 9). Each gas board was an autonomous body with its own chairman and board structure.

To ensure communication between the area gas boards and the Ministry of Fuel and Power, the Gas Council was established. Each area board divided its region into geographical groups or divisions.



**Photograph 9. A map showing the area boards in England and Wales in 1949; the 12<sup>th</sup> board covered all of Scotland.**

#### The Search for Alternative Sources of Gas

With the ever increasing cost of coal, the industry began to look for alternative gas feedstocks or gas supplies.

One such alternative supply was mines gas, which was rich in methane. The Point of Ayr colliery in North Wales proved to be a valuable source of this gas. The 95% pure methane gas could not be used directly, but was reformed first. Put simply, this process used steam to split the methane into a town gas of hydrogen, carbon

monoxide and carbon dioxide. It produced a lean gas which was then enriched with methane to the required British thermal unit standard. Although a useful source, mines gas could only supply a small portion of Britain's requirements.

The Gas Council had joined forces with the German Lurgi company to develop new approaches to gasifying lower grade coal. This is discussed in section 4.6 on the Lurgi Gas Process.

Early on-shore exploration for gas in Britain had found small gas fields in Heathfield (Sussex), Whitby (Yorkshire) and Cousland (Scotland), but nothing significant on a national scale.

As an alternative to coal, the gas industry started to use oil more as a feedstock for gas manufacture, which led to the construction of oil gas plants such as SEGAS plants (Photograph 10). Later, as by-products of the petroleum industry became available at economic prices, new reforming plants were built across Britain; these used butane, naphtha and Primary Flash Distillate (PFD) as feedstocks.



**Photograph 10. The Isle of Grain SEGAS plant.**

### The Demise of Gas Manufacture

The economic advantages of town gas from the reforming of petroleum feedstocks marked the beginning of the end for the production of gas from coal in Britain. The USA had already switched to natural gas after large supplies had been discovered, and pipelines were constructed to transport the gas across the country.

Without a plentiful local supply of natural gas, the British gas industry was already looking elsewhere for new sources of gas. In the 1950s, the North Thames Gas Board had been looking at the potential of importing Liquefied Natural Gas (LNG) to a special facility built at Canvey Island; this was achieved in 1959 with the first import of LNG from the Gulf of Mexico. This was the first successful LNG transportation by an ocean-going ship, the Methane Pioneer (Photograph 11).



**Photograph 11. The Methane Pioneer, one of the first LNG importation ships docked at the LNG importation facility at Canvey Island.**

From 1964, regular trips started between Algeria and Canvey Island, importing up to

700,000 tonnes of LNG per year. The Canvey Island project would have developed further if it had not been for the discovery of gas in the North and Irish Seas. Grimsby was the location of the first offshore discovery of gas in Britain.

The need for better cross-country gas transmission became apparent, and Feeder 1 was constructed in 1966. It was built to transport gas from London to Leeds, signalling the creation of the National Transmission System (NTS, Photograph 12). The NTS has since expanded significantly and is an essential part of delivering and storing gas in Britain.



**Photograph 12. Building the National Transmission System.**

Also in 1966, the Chairman of the Gas Council, Sir Henry Jones, formally announced that Britain was switching to natural gas. The first North Sea and offshore gas field was the West Sole gas field discovered in August 1965; by 1967, North

Sea gas was being brought ashore at the Easington terminal. The Bacton terminal (Norfolk) opened in 1968; Theddlethorpe (Lincolnshire) followed in 1972, and St. Fergus (Aberdeenshire) opened in 1977.

Before Britain could switch from manufactured town gas to natural gas, all of the fittings used to burn town gas had to be replaced. This required the largest engineering feat undertaken in Britain since the end of the Second World War. Known as the 'conversion programme', it required the physical conversion of every gas appliance in the country (Photograph 13).



**Photograph 13. The Conversion Programme. Flaring off town gas from the gas mains.**

Halfway through the conversion programme, the Gas Act of 1972 abolished the Gas Council and the British Gas Corporation was formed. This centralised the gas industry into a single

business, although the regional structure was retained.

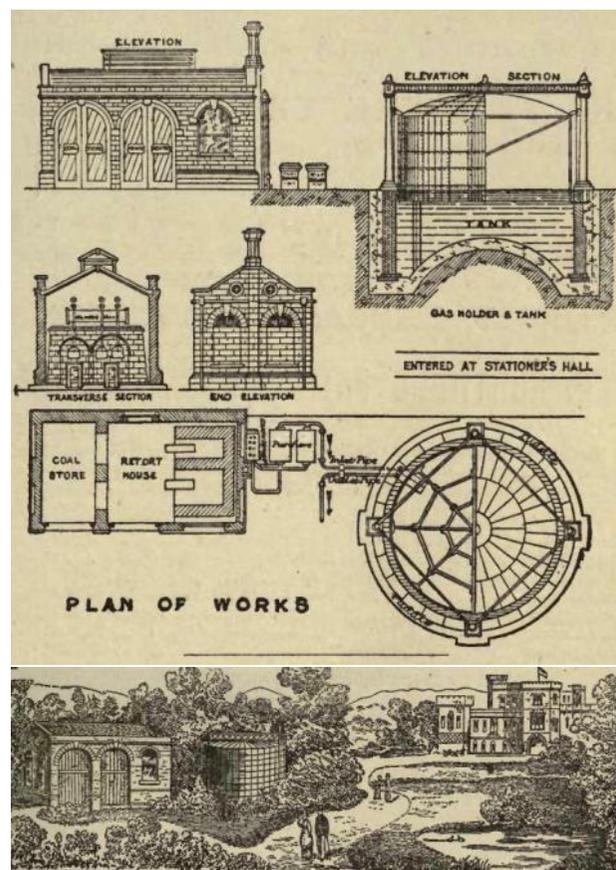
On completion, the 10-year conversion programme signalled an end to the manufacture of gas in England and Wales. Gas production at Romford Gasworks was switched off on 26 August 1976. The last gasworks making gas from coal were to be found in the remote areas of Scotland. The last gasworks to close in Britain was the small hand-charged horizontal retort gasworks in Millport on the Isle of Cumbrae, which closed in 1981. Whilst the gas industry has continued to thrive and meet new challenges, the story of gas manufacture in Britain ends here.

### 3. Different Scales of Gasworks

Gasworks were built at different scales to supply everything from large houses up to cities. As the scale increased, the type of plant used and its efficiency changed. Below is a brief description of the differences in plant at gasworks of different scales.

#### 3.1 Country House Gasworks

Country house gasworks were often the smallest-scale gasworks plant that could be purchased. Often supplied in kit form, they could be easily erected at the purchaser's home. This simple kit generally consisted of a retort house, coal store, condensers, washer, purifier and gasholder. Famous gas engineers such as Bower, Holmes, Edmundson and Porter supplied gasworks kits worldwide, at scales ranging from country houses up to towns. They would be shipped as kits and erected by local engineers. An example of a gasworks designed by the gas engineers H. Skoines and Co. is shown in Figure 11.



**Figure 11. A simple design of a country house gasworks by H. Skoines and Co.**

The gasworks could be housed in their own separate building (Photograph 14) or within the outbuildings of a farm or stables. The gasholder is often the only indication of the gasworks, being marked on the map as a 'gasometer'. Country house gasworks were popular from the early 19<sup>th</sup> century up until the start of the 20<sup>th</sup> century when they started to be phased out by alternative lighting methods such as acetylene gas, petrol air gas or electricity. Acetylene gas and petrol air gas could be produced using relatively small plants which were less costly to purchase and operate

than a coal-gas-based gasworks. The gas plants were very popular and could be easily bought and installed by the owners of smaller houses. Electricity only became a major competitor post-1910, with the development of more durable light bulbs. Electricity plants were often built to replace gas plants.



**Photograph 14. The remains of a country house gasworks retort house in Gloucestershire.**

Many hundreds of country house gasworks were built in Great Britain and Ireland. These country house gasworks also supplied outbuildings such as stables and saw mills, providing light and power. In addition, estate villages were often provided with a supply from the gasworks, although generally at a cost, subsidising the estate owner's own use. The gasworks were usually built approximately one mile away from the country house to keep the air and water pollution away from the house.

Gasworks buildings were sometimes built in an ornate design to blend in with other estate buildings, often taking the design of a small country brewery with the distinctive louvred roof.

Ancillary purification plant would be hidden so as not to be visible from the roads or bridleways.

Similar sized gasworks were also built at schools, hospitals, asylums, mills and some industrial buildings and factories. Those built at mills were the original early examples of such small gasworks. Some mill gasworks could be closer in scale to village and small town gasworks, as they were supplying large mills that required a considerable amount of lighting. Many mill gasworks did later evolve into village or town gasworks.

### 3.2 Small Town and Village Gasworks

In the mid 19<sup>th</sup> century, every town in Britain with a population of over 10,000 was lit by gas. In addition, many villages (including estate villages as mentioned above) had their own gasworks. This would provide some limited street lighting, supply municipal buildings such as churches, and supply those lucky residents wealthy enough to afford it. Such small gasworks (see Photograph 15) were often private businesses established by wealthy local businessmen.



**Photograph 15. A typical village gasworks in Somerton, Somerset. The main building is the retort house, the gasholder can be seen behind.**

### 3.3 Large Town and City Gasworks

Most large towns and cities developed large gasworks (Photograph 16) outside urban areas where there was room to accommodate the plant and it would not create too much pollution for neighbouring residents. The most famous such example being Beckton – developed into the world's largest gasworks - built by the GL&C Co in East Ham, a long way from London. The largest gasworks were also the most efficient, and could process large amounts of coal and supply gas more cheaply than the smaller works. These large gasworks could often enable their owners to purchase smaller nearby gas undertakings and close their less efficient gasworks. The gas supply would then be provided by a new gas main linking their large gasworks to the gas network of the small gas company, often retaining the gasholders of the latter.



**Photograph 16. A typical large gasworks in Blackburn, Lancashire, UK.**

## 4. Gas Manufactured from Coal

### 4.1 Overview

This section explains how a gasworks operated, listing the plant used and the way in which they operated. A general overview is shown in Figure 12 and explained briefly below.

Coal was placed within a sealed vessel called a retort and heated externally by a furnace. Without air, the heated coal did not burn; instead, moisture was driven off and the large organic molecules within the coal were thermally broken down into smaller compounds, some of which were further broken down into even smaller compounds. This process released molecules such as hydrogen, water and hydrogen sulphide into the gas as well as the organic compounds that formed the gaseous, oily and tarry phases within the by-products.

The gas leaving the retort was cooled, removing most of the tar and oil compounds trapped in the gas as coal tar. The gas would be washed to remove soluble compounds such as ammonia and phenol which formed ammoniacal liquor, and then the gas would be purified to remove sulphur and cyanide compounds. The treated gas, now called town gas, was stored in a gasholder, ready for distribution through gas mains beneath the streets to customers. Coke remained in the retort, which was removed and cooled by dousing with water. A more detailed view of a complex gasworks is shown in Figure 13.

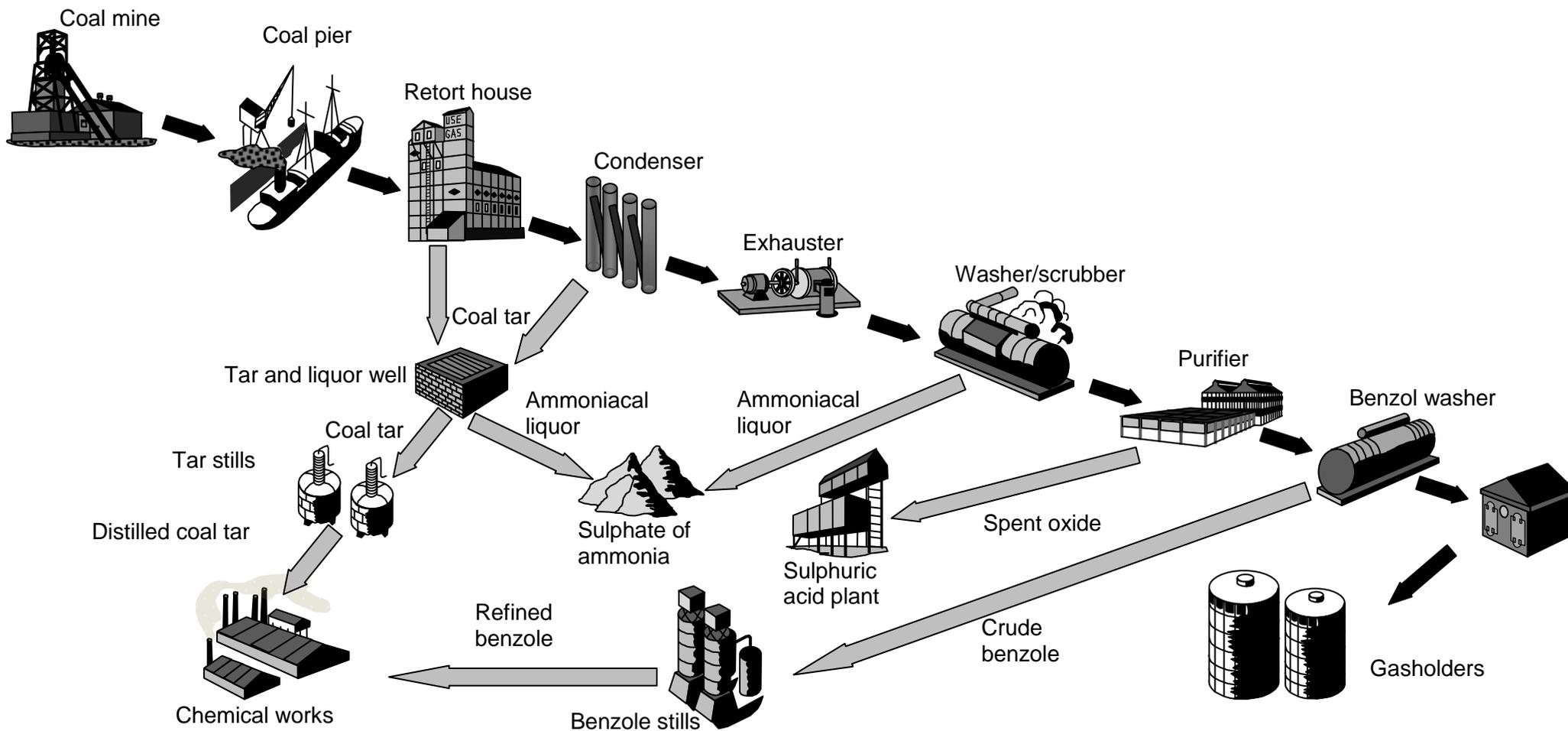


Figure 12. The production of town gas from coal. The black arrows show the progress of the gas through the plant and the grey arrows show the processing of the by-products. Source: Russell Thomas.

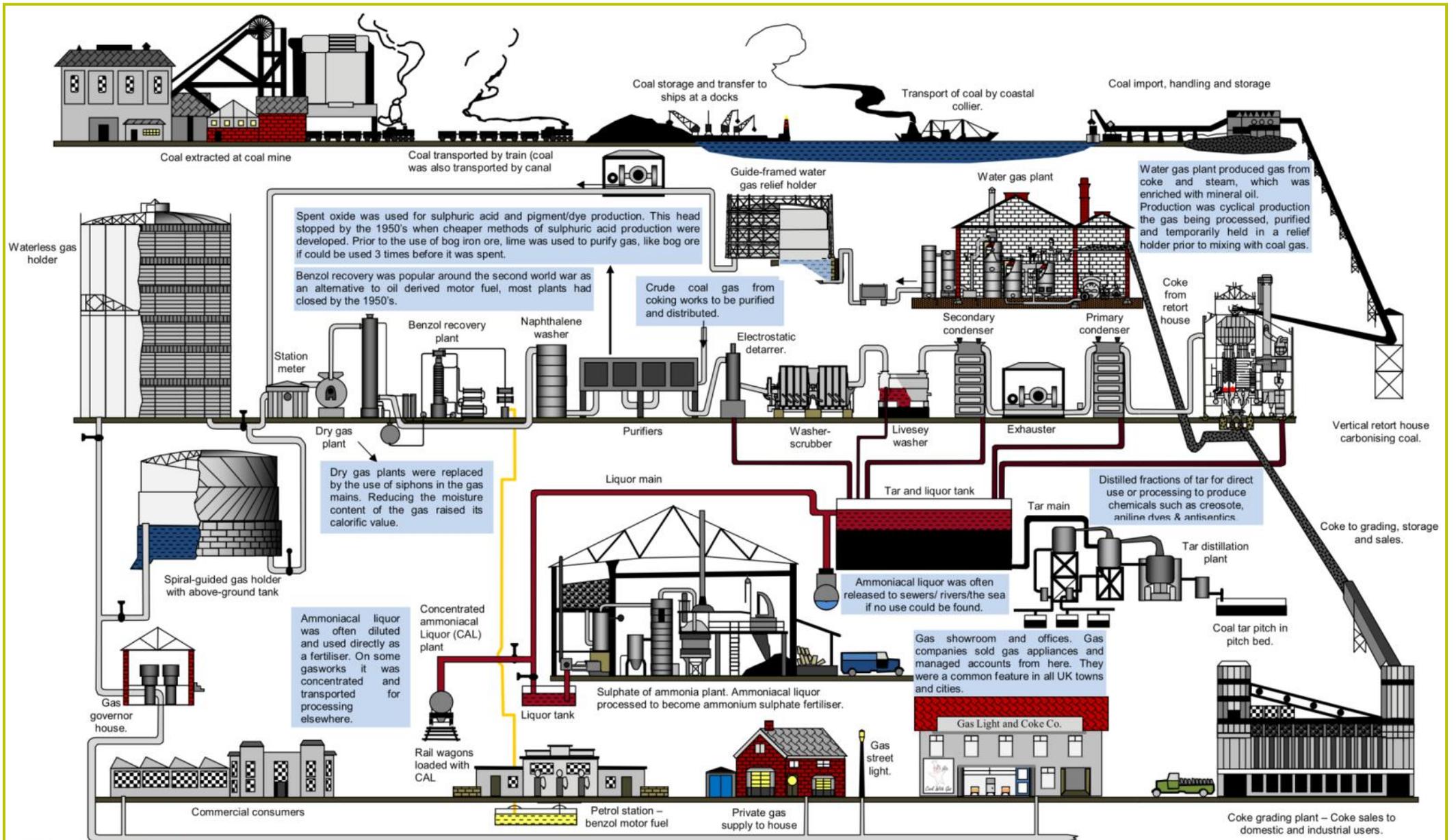


Figure 13. The production of gas from coal and the manufacture of by-products on a large gasworks, showing the process from the mining of the coal to the distribution in the gas mains. Source: Russell Thomas.

## 4.2 Types of Coal Used for Gas Making

Coal is a highly variable substance. Its incredibly complex chemistry is still not fully understood, partly because of the difficulty in analysing it. It is primarily composed of a mixture of very large complex aromatic compounds. As natural organic matter proceeds through the coalification process, the carbon content increases and the oxygen content drops. The coal becomes more ordered, forming large collections of aromatic ring structures, and eventually forming anthracite and graphite. For more information on the coalification process see reference 1 in the bibliography.

Not all coals were suitable for gas making. The preferred types have varied throughout the history of the gas industry depending on the primary purpose of the gas (lighting or heating), the type of carbonising plant used, and the coal types available.

The types of coal used are slightly confused by the different methods used to classify it. Using (Marie) Stopes classification by Maceral, the types of coal suitable for gas production included:

- bright (soft) coal: vitrain, clarain, and fusain
- dull (hard) coal: durain
- cannel coals
- bogheads and torbanites

Alternatively, the Seyler Classification (based on elementary composition and suited to British carboniferous coals) would identify suitable coal as being from the Meta bituminous to Meta lignitous, the Meta lignitous being the preferred coals used in vertical retorts *circa* 1950.

In Britain, coal used for gas making would be high volatile coals with medium to strong caking properties, although slightly caking coals could be used in vertical retorts. These coals covered

British National Coal Board coal types 401, 501, 601 and 701. The ASTM method used in the USA suggested that 'Bituminous-Common Banded Coal' was the most suitable for gas making.

Cannel coal was preferred for gas production prior to the advent of the gas mantle. This was because it produced a gas with a greater quantity of volatile organic compounds, which had better illuminating properties, making it more suitable for lighting (Figure 14). Cannel coal was however, only available in limited supply and was therefore expensive; however, it was often mixed with other coals to improve the illuminating properties of the gas. It was also the coal of preference for many country house and estate gasworks, especially in Scotland, where this type of coal was more abundant. It left little ash and made the management of a small gasworks very simple.



Figure 14. An advert for Scottish cannel coal.

The gas industry's dependence on cannel coal for enriching the illuminating properties of gas would have started to diminish as the gas mantle took over from older aerated burner design and before the Gas Regulation Act was introduced in 1920, when the switch was made from illuminating power to the calorific value of the gas. The move away from using cannel coal would have changed the composition of coal tar, decreasing the amount of paraffinic substances and light oil present in the coal tar. This was recognition of the

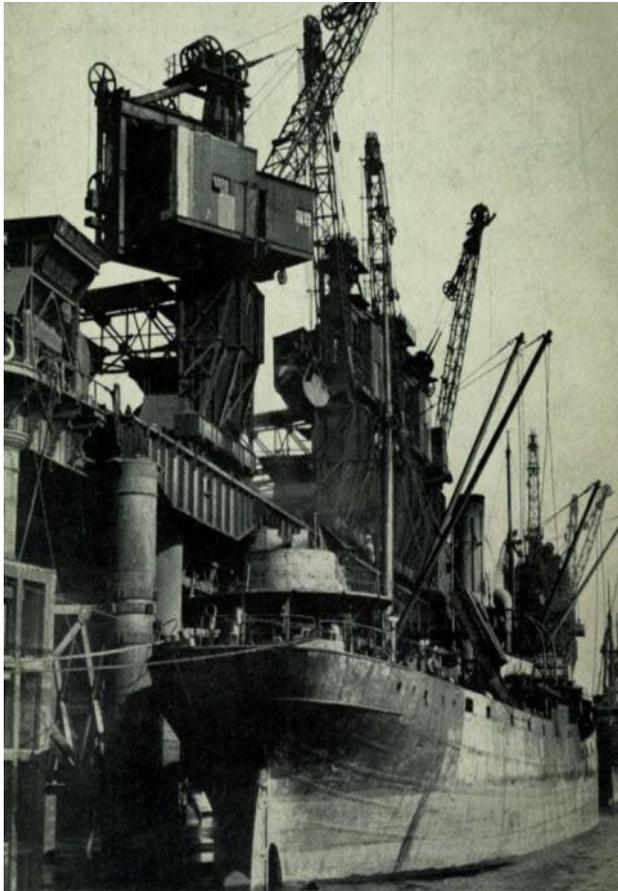
changing markets which the gas industry was serving, moving from lighting to heating.

Proximity to market, combined with coal type, had a considerable influence on the type of carbonisation process used in UK gasworks. There was a preference for the Durham and Northumberland gas coals to be used in horizontal retorts. This coal was transported along the eastern and southern coasts of England in ships called colliers (Photographs 17 and 18), and influenced gas production there. Further inland, Midland and Yorkshire coal were more easily available by rail transport and there was a preference to carbonise these in vertical retorts (when they later became available).



Photograph 17. A coastal collier taking its cargo of gas coal down the Thames to the gasworks, on its journey from the northeast.

The coals in Scotland were preferentially carbonised in vertical retort plants (when available). The South Wales coalfield contained the entire spectrum of coals, some of which would have been suitable for gas production. Other smaller coal fields would have provided locally important coals for gas production (e.g. North Somerset).



**Photograph 18. Unloading coal from a coastal collier by steam cranes at the wharf at Beckton.**

Coal was transported from the coal mines to the gasworks by collier, by canal barge, or by train.

train sidings or navigable water routes were not adjacent to the gasworks then it would be further transported to the gasworks by cart or wagon. Both methods were expensive and inefficient.

As the available quantities of suitable gas coals diminished, the gas industry eventually looked towards the gasification of low-grade coal through complete gasification (see section 4.5 on Complete Gasification) and the Lurgi process, before the later switch to oil and then natural gas.

At the gasworks, any large lumps of coal were broken up into smaller pieces in a coal-crushing plant. At larger gasworks, the coal would be taken to hoppers for loading into the retorts. If the coal was destined for a coke oven, it was first crushed to a fine powder.

### 4.3 The Retort House

The retort house was where the gas was manufactured. It housed the retorts which were grouped together into benches. Within the retorts, coal was heated in an oxygen-free environment where, instead of combusting, the volatile components were driven off, leaving a relatively pure form of carbon called coke as residue.

Retort technology changed over the years, becoming gradually more advanced. Although William Murdoch experimented with a variety of different designs, the one favoured in the early years of the industry was a horizontal retort.

#### Horizontal Retorts

A horizontal retort was primarily a D-shaped vessel, around 6.7 m (22 ft) long, 0.55 m (22 in) wide and 0.45 m (18 in) high. Originally, retorts were circular and made from cast iron, but they were not very durable and so were further improved through the use of fireclay and later silica. The retorts would suffer from wear and tear

so had to be replaced on a regular basis; the settings were designed to be taken apart and rebuilt.

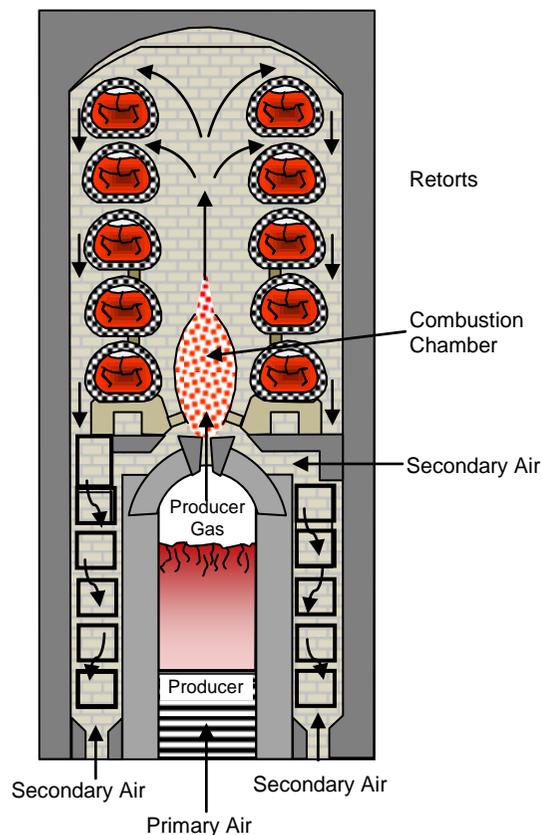
These retorts were originally designed as 'stop ended': closed at one end with an airtight iron door and ascension pipe at the other. A development by George Lowe in 1831 saw a change in design to a 'through retort' system. Doors on both sides allowed coal to be pushed into the retort at one end and, once the carbonisation process was completed, the remaining coke was pushed out through the back of the retort.

Beneath the retort bench was a furnace or producer, which was used to heat the retorts. The coal was heated for a period of between 8 and 12 hours. During this time the structure of the coal was changed significantly; the large aromatic compounds within the coal were broken down by the action of heat, releasing gas and vapour-phase compounds from the coal. These escaped up the ascension pipe, leaving behind the spongy coke (largely pure carbon).

The horizontal retorts could be heated by various methods, the earliest being the direct-fired setting (Figure 5). The more advanced semi-gaseous setting and gaseous-fired settings (Figure 15) appeared as a result of Siemens' work in 1857 to design an effective gas producer, but was not effectively introduced to the gas industry until 1881, when it was introduced in Glasgow and led to a great improvement in the efficiency of gas manufacture.

Early retorts were heated directly by a shallow fuel bed – 0.3 m (1 ft) deep – of coke lit beneath in the furnace (Figure 2). The direct radiant heat from the furnace and the hot waste gases heated the retort. This design only heated the retorts to temperatures *circa* 600°C. As a result, the

amount of gas produced was relatively low and the decomposition of the organic compounds in the tar fog produced was limited. Being simple and robust, this method of heating was used in early gasworks and later in small gasworks.



**Figure 15. Cross section of a gaseous-fired horizontal retort, showing the gas producer. Source: Russell Thomas.**

The semi-gaseous setting had a deeper fuel bed, 0.6 m (2 ft) deep, and provided some control over air supply, allowing some carbon monoxide gas to escape and burn adjacent to the retorts. It allowed greater carbonisation temperatures to be achieved with lower fuel consumption.

A later development was the gaseous-fired setting which used a gas producer to heat the retorts (Figure 15). After success in Glasgow in 1881, this system was then adopted on all future modern retort designs. The fuel bed in a producer would be *circa* 1.5 m to 1.8 m (5 to 6 ft) deep and the primary air supply was very carefully controlled to enable the correct composition of the producer gas.

The gas producers channelled gas to a combustion chamber directly around the retorts, where it was mixed with a secondary supply of air and burned. The gaseous-fired setting was the most fuel efficient and exerted the most accurate temperature control, with even heating along the retort and the highest carbonisation temperatures if required. Another important factor was whether the waste gas from the producer was used to heat incoming air, thus enabling great efficiency and higher carbonisation temperatures to be achieved. This was called a 'recuperative' or 'regenerative' gaseous-fired setting.

Loading and unloading a stop-ended retort was hot, arduous and dangerous work (Photograph 19), but it was often the only practical option in small gasworks. The increasing size of gasworks and retort houses in towns and cities allowed for further innovation. The development of the through-ended retort by Lowe (1831) made it much easier to mechanise the process by which a retort could be loaded and emptied (Photograph 20).

The most notable examples of charging machines were built by West (1886), Arrol-Foulis and Fiddes-Aldridge. The later of these used a method devised by Belgian engineer M. De Brower, which projected coal into the retort using the energy derived from the centrifugal force of spinning the coal in a large wheel.



**Photograph 19. Manually emptying hot coke from a stop-ended horizontal retort.**

At the front of the retort (above and behind the door) was the ascension pipe. Some through retorts had a second ascension pipe on the rear door. The role of the ascension pipe was to allow the gas and vapours to escape from the retort and rise up into the water-filled hydraulic main, which acted as both a water seal and primary condenser, removing a large portion of the tar and liquor from the gas. From the hydraulic main, gas would leave the retort house via the foul main.



**Photograph 20. Unloading a through-ended retort mechanically.**



**Photograph 21. Loading a retort with a mechanical charger.**

The retort house was controlled by the team of stokers under the guidance of the engineer. The stokers and engineers had very little equipment to measure the performance of the system, just a u-tube filled with water to measure gas pressure. Most judgments were made using knowledge and experience to check the colour of the flames. The retort house was subject to very harsh working

conditions and very high temperatures, and so the roof was louvred to allow heat to escape.

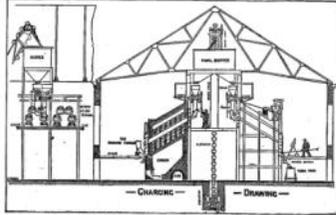
Initially, horizontal retorts were used on all sizes of gasworks. Later gasworks used ever larger horizontal retort houses with mechanical charging and emptying of the retorts employed, such as those shown in Photographs 20 and 21. In the early 20<sup>th</sup> century, new types of retort became commercially available, such as inclined and vertical retorts and chamber ovens, some of which could enable continuous operation.

### The Inclined Retort

In the late 19<sup>th</sup> century, inclined retorts were developed based on work undertaken by Coze at Rheims in France (Figure 16). Inclined retorts were designed to make loading and unloading operations easier, but unfortunately this was often not the case. The retort was placed at 32° to the horizontal, the theoretical angle of repose for coal. In theory, the system benefitted from less wear and tear and could be used without the charging machinery required on a horizontal retort. But it took skill to get an even charge within the retort and it was harder to get an even temperature. The coal was prone to creep down the retort when heated, so only certain types of coal were suitable for use in this method. The coke could be hard to remove, even with the aid of mechanical pushers. Fuel consumption for heating was higher than for horizontal retorts and they were more difficult to operate and maintain.

The inclined retorts were never very popular in Britain, although they were used in some gasworks, such as the original public gasworks in Coventry. With the development of the vertical retort they were soon superseded, although the design was still popular in some small gasworks.

**AUTOMATIC COAL GAS-RETORT Co., LTD.**  
THE SOLE PROPRIETORS OF  
**Coze's Patent System of Carbonizing Coal by**  
**INCLINED RETORTS.**



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This System effects—

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All Inquiries, &c., to be made of the

RETORT-HOUSE ON THE NEW PATENT SYSTEM.  
**SECRETARY, 111, Palace Chambers, WESTMINSTER, S.W.**

**Figure 16. Advert for an inclined retort.**

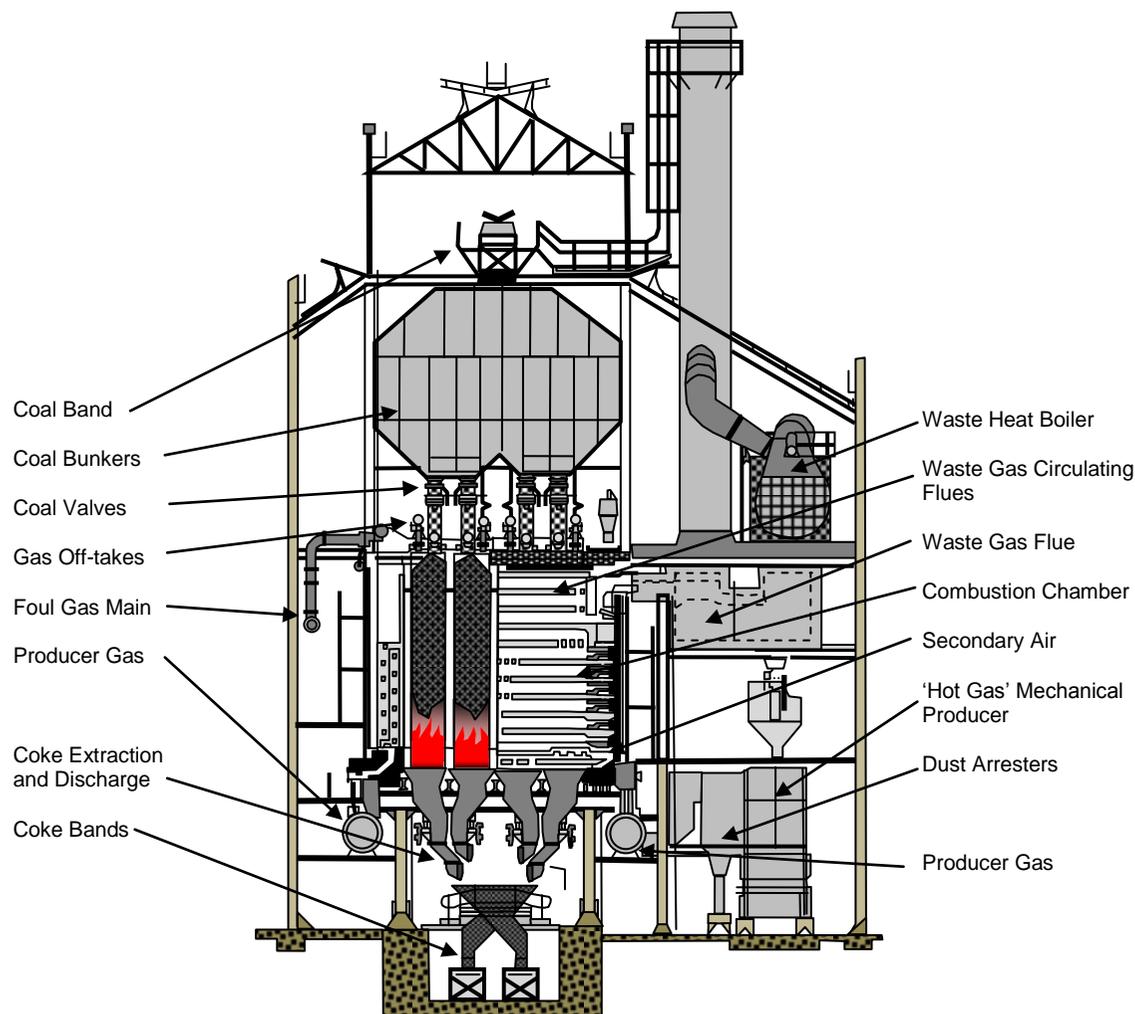
The inclined retorts were about 3.60 m (12 ft) in length and tapered from 0.60 m (24 in) by 0.38 m (15 in) at the bottom to 0.55 m (22 in) by 0.38 m (15 in) at the top. The carbonisation process within the inclined retort would take about eight hours.

### The Vertical Retort

A later development was the vertical retort; as the name suggests, the retort was rotated by 90° so that it was in the vertical plane.

Vertical retorts came in different designs. The original system – the Intermittent Vertical System – was patented in England by Bueb in 1904, after being trialled at the Dessau Gasworks in Germany. It had considerable advantages over the horizontal system. It reduced labour, as to a great extent the coal could be moved by gravity once the plant was loaded. The plant also took up much less ground space, although the retort houses were much taller than their horizontal counterparts.

A further development was the introduction of the continuous vertical retort, which could, as the name suggests, operate continuously. The first



**Figure 17. Cross section of Glover West vertical retort. Source: Russell Thomas.**

continuous vertical retorts were built at Bournemouth gasworks by the gas engineering company Woodhall Duckham. The plant entered commercial operation in 1906. The rival Glover West Company built a continuous vertical retort plant at St. Helens in 1907. An example of the Glover West vertical retort can be seen in Figure 17, which shows the customary vertical

retort stack with coal being fed vertically down the retort from the hopper. Further vertical retort plants were built at many of the medium-sized and larger gasworks across the UK, and other manufacturers also entered this market.

The process operated as follows. Coal of a suitable size was carried by conveyer to the top

of the retort house where it was fed into a hopper. The hopper would feed coal down into a coal box on top of the retort, which held enough coal for an hour. Coal would then feed down into the top of the retort (charging). The hopper and the coal box were separated by a 'coal valve', which stopped the gas escaping. The valve would be opened once an hour to refill the coal box.

The coal passed down through the producer-gas-heated retort vessel by gravity. As the coal passed down the retort, it was gradually carbonised until it was removed as coke at the base of the retort, aided by extractor gear, (effectively an Archimedes screw). The extractor gear ultimately controlled the rate at which the coal would pass through the vertical retort and therefore the extent to which the coal was carbonised.

From the base of the retort, the hot coke was discharged into a metal cart or hopper, removed and cooled by quenching it with water. Some vertical retort plants could also cool the coke in the retort. Vertical retorts were all heated using a gas producer, as described earlier.

The yield of gas in the vertical retorts could be increased by a process called 'steaming', where steam was introduced at the base of the vertical retort. The effect of the steaming process was twofold: it helped cool the coke by quenching it within the retort; and it also induced the water gas reaction, converting more of the coke to gas as carbon monoxide, carbon dioxide and hydrogen. It increased the amount of gas made but reduced its calorific value. Steaming was preferred in the winter to increase the amount of gas made at times of highest demand, and was most popular between the First World War (about the time it was discovered) and the Second World War. In some gasworks, steaming was used all year and continued until production ceased.

Vertical retorts were used at many medium and large gasworks, although some large works such as Beckton chose to keep horizontal retorts because of the more saleable tars they produced. Many small gasworks continued to operate horizontal retorts until closure, often because they could not justify the expense or did not have the demand for gas to build a vertical retort plant.

#### Intermittent Vertical Chamber Ovens

There was also another type of plant similar to an intermittent vertical retort, called an Intermittent Vertical Chamber Oven (IVCO). These were less popular than the continuous vertical retort in the UK, but included the White Lund gasworks in Morecambe, the last traditional coal gasworks to be built in England.

The IVCO operated in a batch process. The ovens within the IVCO were rectangular and constructed to hold a mass of 1 to 7 tonnes of coal. They were also heated by external gas producers. The process differed as coke breeze (fine coke) was added to the base of the vertical chamber oven prior to the coal being loaded. This kept the oven door cool and ensured the coal was fully carbonised.

Towards the end of the carbonisation process, the chamber would be steamed. This would allow the IVCO system to produce water gas. The water gas produced had a lower calorific value than the coal gas and would effectively dilute the calorific value of the coal gas.

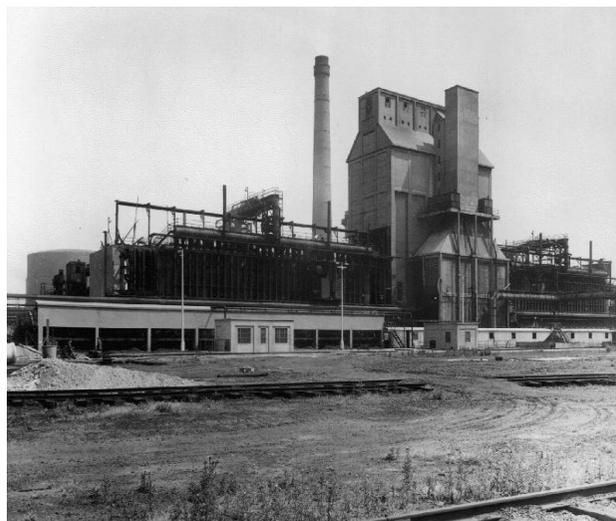
#### **4.4 Coke Ovens**

Coke ovens were not common on British gasworks, only three were built: at the gasworks at Saltley in Birmingham; and at Beckton (Photograph 22) and East Greenwich in London. Because of their large size, coke ovens could

produce large amounts of gas on a continuous basis.

Coke ovens had a big impact on the gas industry in Britain as they did in other parts of the world. Coke oven gas was taken by many gas undertakings which had coke ovens in their district. The supply of coke oven gas in some areas was so great that the gasworks stopped manufacturing gas – with the exception of Carburetted Water Gas (CWG) which was only produced at times of peak demand.

Coke ovens were not originally designed to produce either gas or by-products such as tar. It was not until the value of these by-products was realised that by-product coke ovens were constructed. Coke ovens where there was no attempt to recover the by-products were generally referred to as 'beehive coke ovens'. As the name suggests, these were in the shape of a beehive and built from brick. Any by-products formed were burnt or released into the air escaping from the top of the ovens.



**Photograph 22. Beckton coke ovens.**

The by-product coke oven had a different design from a retort, although the principles of operation were similar, especially compared to the horizontal retort. The by-product coke ovens were larger than gasworks retorts and designed to produce metallurgical coke for iron and steel manufacture rather than specifically for gas or by-product manufacture.

Coke ovens are the only remaining operational coal carbonising plant in Britain. The coke oven was effectively a long rectangular box constructed of refractory (heat resistant) material, roughly 12 m (40 ft) long and 4.5 m (15 ft) high, but only 0.3 m (12 in) to 0.5 m (20 in) wide, with large iron doors at both end. Ovens were lined up into a battery (often comprising over 100 ovens) and heated by a system of flues built into the oven walls. The combustion of gas takes place with the preheated air in a series of vertical flues adjacent to one side of the oven. The hot gases are channelled through crossover flues across the top of the oven and down the opposing side wall. The flow of gases through the flues is regularly switched to ensure even heating throughout the oven and reduce the deterioration of the refractory materials. Coke ovens are kept hot continuously; if they cooled, the refractory material would be damaged, requiring a costly replacement.

Coke ovens can be heated by one of two forms of gas. Current practice uses coke oven gas to heat the ovens; historically, it was common practice to heat the ovens with gas manufactured in a separate gas producer. Coke oven gas is now used, as its value is limited and it cannot be supplied in the gas mains as it once was. In addition, the value of the coke that would be used in producers has risen, making it uneconomical to operate gas producers now.

Coke ovens used coal in a different form to gasworks; crushed to a fine powder for the coke oven compared to solid lumps (e.g. nuts or cobbles) in a gasworks. The coal used was often a blend of various different types of coal. It was stored in a large bunker in the middle of the coke battery prior to being dispensed into the charging car in measured quantities. The charging car moved along the top of the battery charging ovens as required. Prior to charging the oven with coal, both iron doors on either end of the oven were closed. The stoppers in the top of the oven would be removed and the crushed coal would be poured in. Once sufficiently full, the coke was levelled off using a levelling arm, leaving a void at the top of the oven. The coal was then carbonised for about 16 hours.

Once the process was complete, the oven doors at the side of the oven were removed and a mechanical arm pushed the red hot coke into a hot coke car. Once full, the hot coke car was taken to the quenching machine to be cooled by spraying with water. The plant used to purify coke oven gas and recover the by-products was similar to that of a gasworks. The main plant involved is described in section 4.7 (and onwards).

Whilst most coke ovens in Britain operated at high temperatures, there were a few examples of low-temperature coke ovens, the most notable being the former Coalite works at Bolsover in Derbyshire. The composition of the by-products formed was different due to the lower carbonisation temperatures used; most notably, the coal tars were less thermally degraded.

#### 4.5 Complete Gasification

Complete gasification was a concept whereby the carbonisation and the water gas process (described in section 5.1) could be operated simultaneously; it was also referred to as a

double gas plant. Coal usually graded to the size of closely graded nuts or cobbles was used. The complete gasification plant aimed to try to combine the prior carbonisation of the coal in a retort followed by the cyclical water gas process. The coal was carbonised in a vertical retort and the resulting coke or char would move by gravity down into the water gas plant below.

These plants produced a gas which was different to a normal town gas. If the whole baseload was supplied by this plant, the gas was denser and had a higher carbon monoxide content.

The water gas phase could be operated with or without oil enrichment. The best known example in Britain was the Tully Gas Plant, of which many were built.

#### 4.6 Lurgi Gas Process

The Lurgi process was developed in 1927 in Germany to look at the complete gasification of the brown coal deposits in the East Elbe. The Lurgi process used the mixture of oxygen, steam and high pressure to achieve the effective complete gasification. The first plant was built in Hirschfelde in 1936 and further plants were built in Germany and Czechoslovakia, where a plentiful supply of low-grade brown coal was available. Plants have also been built in Australia, South Africa, the USA and more recently China.

Unlike conventional gasification, which would have produced carbon monoxide and hydrogen from the steam and oxygen, the Lurgi process formed methane, as a result of continuous high-pressure operation. The Lurgi gas generator had similarities to a conventional producer gas or water gas generator, but was surrounded by a water jacket. It had a fixed fuel bed fitted with a stirring mechanism on a rotating grate. As a pressure vessel, the coal was added and ash was

removed via a system of locks, with the ash removed in a solid state.

A Lurgi gasification plant was built for the Scottish Gas Board at Westfield, completed in 1963. It used a locally sourced low-grade coal from an adjacent Westfield open-cast coal mine. It produced gas at high pressure (20.6 bar or 300 psi) and supplied a low-toxicity gas to a high-pressure grid system in the Fife and central areas of Scotland.

A similar gas plant was built for the West Midland Gas Board at the Coleshill gasworks, near Coventry. Designed to take coal from the nearby Kingsbury Colliery, it was the first gas plant in the West Midlands to produce high-pressure gas at 24 bar (355 psi). It too entered operation in 1963.

Both plants were conventional dry-ash Lurgi gasification plants, and they were in operation for approximately 10 years. The process may have gone on to provide a greater part of Britain's gas supply, but decisions had been made to switch to natural gas, reinforced by the discovery of the North Sea gas fields.

The story did not end there. From 1974 onwards the Westfield site was used as a development site for the British Gas-Lurgi (BGL) slagging gasifier. During the development programme, two of the original Lurgi gasifiers were converted to slagging gasifier operation. The BGL technology was never used commercially in the UK, however gasifiers based on the BGL design are now being built and operated in China.

## 4.7 Ancillary Plant for Processing Coal Gas

### The Condensers

Once the gas left the retorts via the ascension pipe, hydraulic main and foul main, it entered the condensers. The hydraulic and foul mains both acted as primary condensers, helping to remove much of the tar and some of the ammonia from the gas.



**Photograph 23. A set of two atmospheric condensers, Gunnislake gasworks, Cornwall.**

The role of the condenser was to cool the gas and remove coal tar from the gas, draining it to a below-ground tar tank or well. Many different designs were employed. On small gasworks, gas

would generally be cooled using an atmospheric condenser (Photographs 23 and 24).

This relied on the temperature differential between the ambient air temperature and the hot gas to cool the gas; this process was more successful in the winter, when the outside air temperature was low.

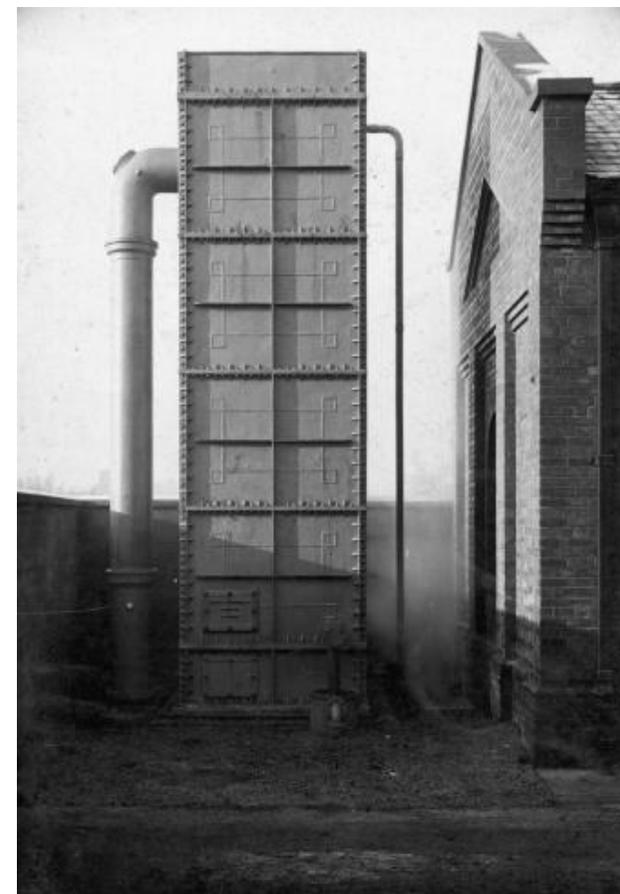


**Photograph 24. A horizontal atmospheric condenser.**

The annular condenser was a slightly more advanced design formed from two concentric cylinders. Both internal and external faces of the condenser were open to the atmosphere. The gas passed through the annular space between the two cylinders and the tar would condense over the surface of the condenser in a thin layer, draining to the well.

Another more advanced design was the water tube condenser (Photographs 25 and 26). This worked by passing the gas through a vessel containing many water-filled tubes. The cold water in the tubes flowed in a counter-current direction to the gas, cooling the gas and

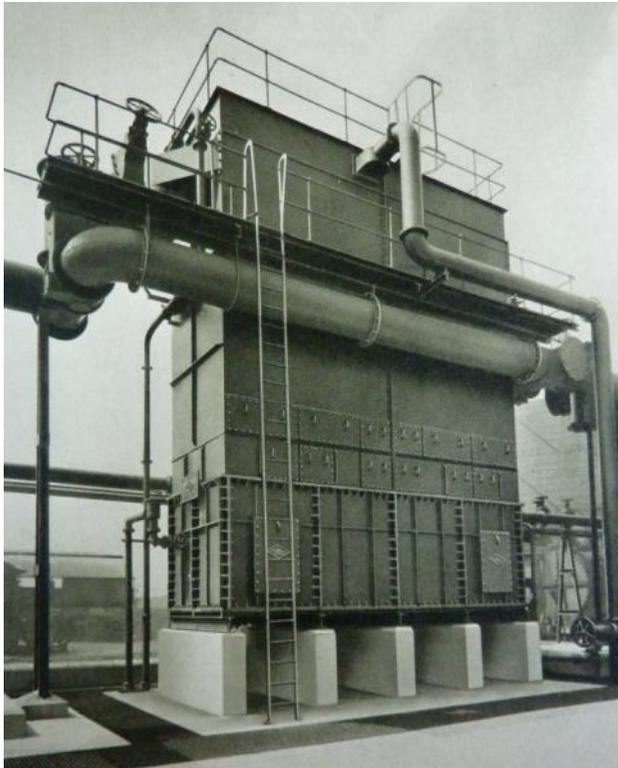
condensing out tar. The tubes could be mounted in a vertical or horizontal orientation.



**Photograph 25. A vertical water tube condenser.**

The very early gasworks built by the Neath Abbey Iron Company had a very simple design. This consisted of a long water-filled trough through which water passed and in which the gas pipes were placed. A more advanced version of this design was used at the Old Kent Road Gasworks of the South Metropolitan Gas Company.

Another form of condenser was the Pelouse and Audoin condenser, which originated from France. The purpose of this condenser was to break up the suspended tarry particles and remove them from the gas. This apparatus consisted of an outer cylindrical cast iron chamber through which the gas would enter and leave, and an outlet for the tar to drain away.



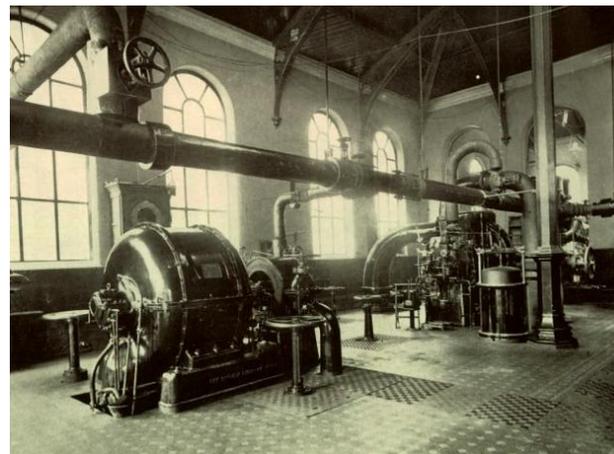
**Photograph 26.** A multipass vertical tube condenser mounted on a tar and liquor separator at the former Romford gasworks.

It contained a cylinder of perforated sheet iron which formed the condenser. The sides of the condensing chambers were two thin sheets of iron, with a concentric space between the inner sheet (which had fine perforations) and the outer sheet with larger slots. Passing through the fine

perforations, the gas was forced into jets which would strike against the solid surface, depositing the tar.

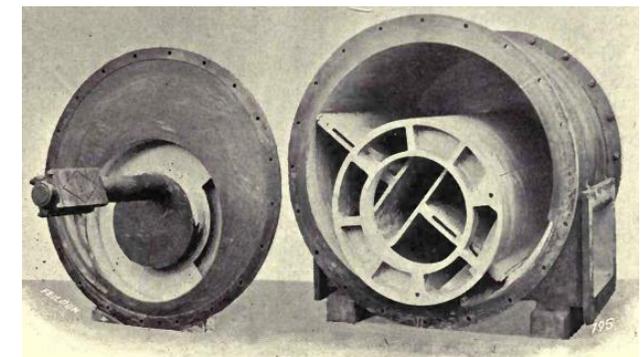
### Exhauster

The exhauster kept the gas flowing and was often referred to as the heart of the gasworks. It withdrew the gas from the retort at the rate it was produced, to prevent the build up of pressure. The gas was then pulled through the condensers. The exhauster would push the gas through the washer and scrubber and the remaining purification plant into the gasholder. If primary and secondary condensers were used, the exhauster would normally be positioned between the two. Without an exhauster, the processing plant and gasholder would push against the retorts causing significant back pressure. By swiftly removing gas from the retorts, it prevented the build-up of carbon deposits. It also prevented the loss of gas through the retort walls, caused by the slightly porous nature of the silica and fireclay.



**Photograph 27.** Gas exhausters at Windsor Street gasworks, Birmingham.

Exhausters were used on all but the smallest gasworks. They were classed as either rotary or reciprocating depending on their mode of action. The reciprocating form such as Grafton's exhauster was the earliest type, developed circa 1839. The reciprocating exhausters used a mechanism similar in appearance to a gasholder, where a vessel suspended in a tank of water was raised and lowered as it received and expelled gas in a cyclical fashion. Gas inlet and outlet pipes were connected to the inside of this vessel. When the vessel was raised, a vacuum was created and gas was pulled in through the inlet (a flap on the outlet closed to prevent back flow). When the vessel was lowered, gas was pushed through the outlet (a flap on the inlet closed to prevent back flow). By repeating this action, gas was drawn out of the retort. The vessel was raised and lowered by a simple mechanism. This consisted of a lever, one end of which was connected to the top of the vessel, the other to a shaft connected to a rotating cam.



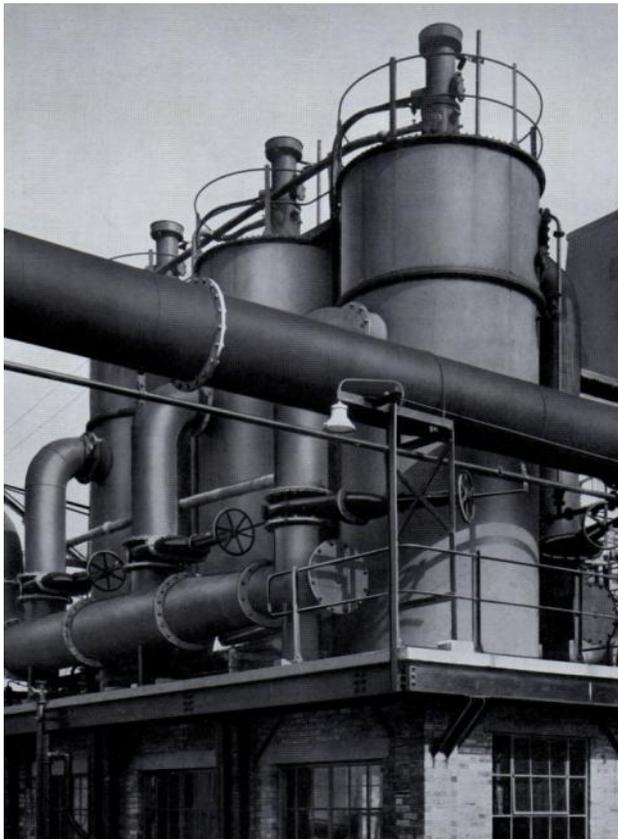
**Photograph 28.** The internal workings of an exhauster.

The rotary exhauster (Photographs 27 and 28) was a later development. It consisted of a cylindrical vessel within which was a centrally mounted rotating shaft. Attached to this shaft was a second cylinder which was concentrically mounted and had blades attached. As the internal

cylinder rotated, the blades pushed the gas through the pipes.

### Electrostatic Detarrer

After 1930, some large gasworks used a process called the electrostatic detarrer (Photograph 29). Gas passed through the cylindrical plant as it would a condenser, but an electrical current was used to remove the tar instead of cooling.



**Photograph 29. Electrostatic detarrer.**

As the gas particles passed through the electrostatic detarrer, they were exposed to a very high negative voltage, giving the tar particles a negative electrical charge. As the gas continued

through the detarrer, it was exposed to a high positive voltage. The negative charge of the tar particles would then attract them to the positive electrode where the tar would be removed. A spray of oil helped wash the tar from the positive electrode. The tar would collect at the base of the detarrer and then flow by gravity to the tar tank.

The first electrostatic detarrer was installed at the gasworks in Hinckley, Leicestershire, in 1926, and was believed to be an American design. The first British-designed electrostatic detarrer was built by Simon-Carves Ltd and Ferranti Ltd and used static electrical rectifiers. It was installed on a coke oven battery at Billingham in Teesside in 1929. The first installation on a gasworks was at Southall Gasworks in West London in 1931. This type of technology is still used today to remove particulate matter from the smoke in power station chimneys and in other processes that generate dust.

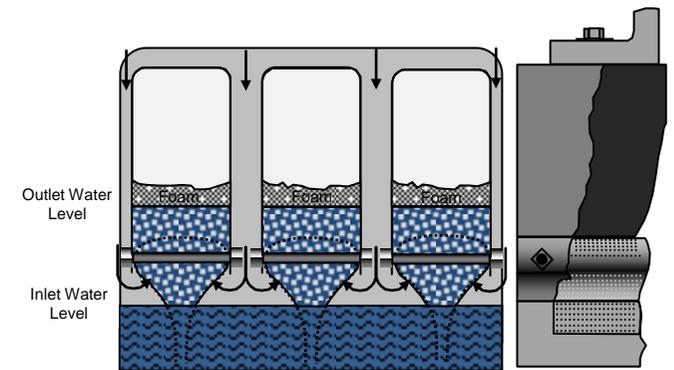
### Tar Washers

Gas washing systems were employed for two purposes: to remove remaining tar trapped in the gas, and remove soluble components such as ammonia.

Having passed through the condenser, the gas still contained small amounts of tar which needed to be removed. Prior to the introduction of electrostatic detarrers, and for a majority of gasworks which were too small to justify their purchase, another piece of plant was required to remove the trace amounts of tar: the tar washer.

The commonly used version was the Livesey washer (Figure 18 and Photograph 30), developed by the famous gas engineer George Livesey of the South Metropolitan Gas Company. The gas was bubbled through small perforated holes in gauze under water. The tar collected on

the surface of the gauze whilst the gas passed through and out of the tar washer. The tar was collected and drained to the tar well.



**Figure 18. A schematic of the inside of a Livesey washer. Source: Russell Thomas.**



**Photograph 30. A Livesey washer.**

### Ammonia Washing and Scrubbing

Having passed through the condensers and tar washer almost all of the tar would have been removed, along with around 50% of the soluble impurities of ammonium and phenolic compounds.

To remove the remaining 50%, the gas required further washing and scrubbing. For most of the 19<sup>th</sup> century, non-mechanical means were used to perform this function. From the 1880s onwards, mechanical plant started to be introduced.

The purpose of the washers and scrubbers was to achieve the most intimate contact between the gas and washing medium, to enable the greatest quantity of the soluble impurities to be removed. The medium used to wash the gas was usually a weak solution of ammoniacal liquor, although water could be used.

The washing medium dissolved the ammonium and phenol in the gas, forming ammoniacal liquor (or increasing the strength of the ammoniacal liquor solution). Once it had attained a suitable strength, the ammoniacal liquor would be drained to the tar and liquor tank by gravity, where it would float on top of the tar.

The washing of the gas would take the form of bubbling through seals or perforations, or passing through weirs of liquor. The scrubbing of the gas was the exposure of the gas to wetted surfaces. The liquor used in a washer was much stronger than that used in a scrubber.

The washer/scrubber could come in a wide range of designs, but there were three main types of plant employed to further wash the gas: the tower scrubber, the mechanical washer and the washer scrubber.

Scrubbers were normally used after the washers, although small gasworks would sometimes use just scrubbers. The most common form of the scrubber was the tall cast iron circular towers (Photograph 31) filled with coke, bricks, wooden boards or ceramic rings.



**Photograph 31. Two tower scrubbers.**

As the gas flowed slowly up the tower scrubber, it met a spray of cooled water passing down the scrubber. This would cover the filter media (e.g. coke) and provide the largest possible surface area to absorb the ammonia and phenol. It would then fall into the base of the scrubber and drain to the tar well. These tower scrubbers were relatively simple and problem-free.

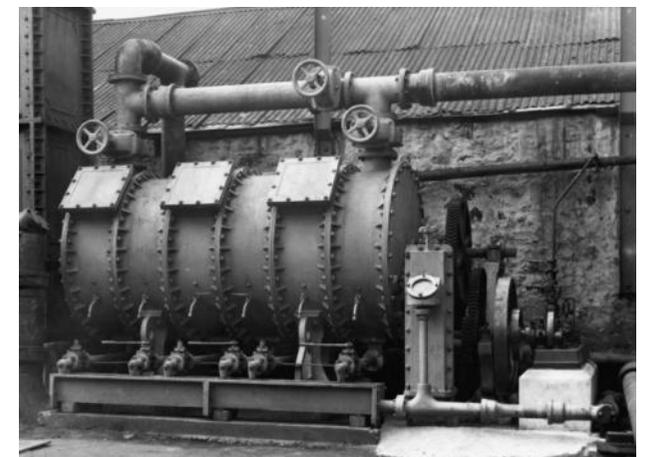
The mechanical washer-scrubber benefitted from a very large freshly wetted surface and the mechanical means to break up the gas into the fine bubbles. The mechanical washer-scrubber

could also carry out some of the tar removal function which the Livesey washer would undertake.

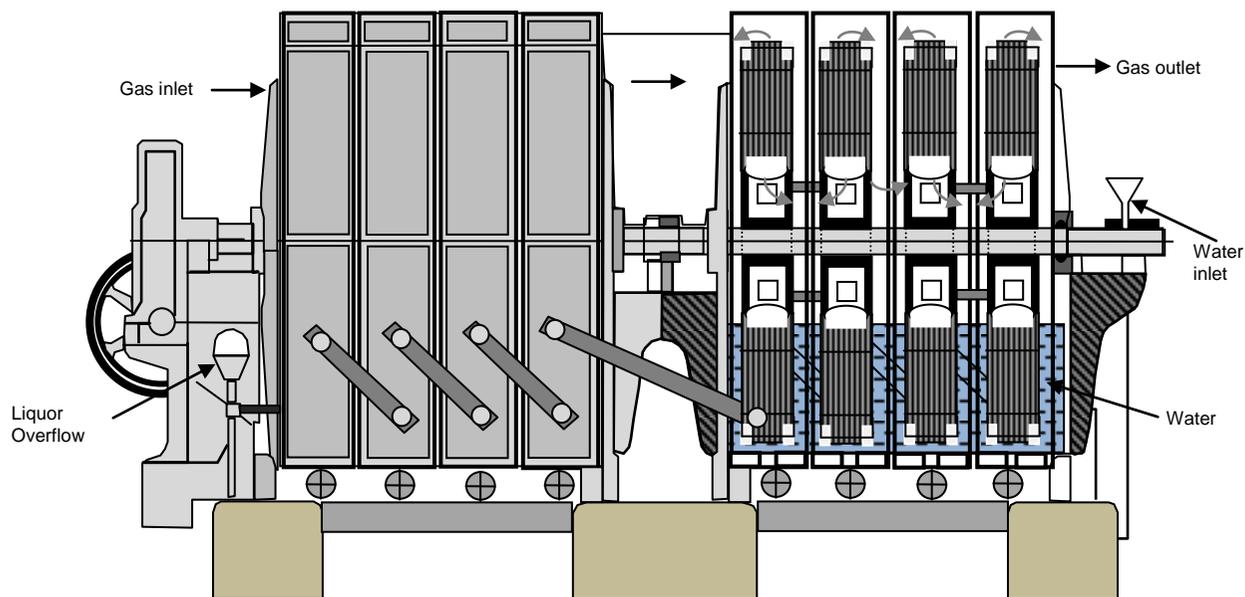
If two washing units were used then it was typical that the latter unit would be fed by clean water in order to maximise the amount of ammonia which could be removed from the gas.

In small gasworks, it was common to have only one or two tower scrubbers with no mechanical washing equipment. The most popular combination was the mechanical washer-scrubber, followed by either one or two tower scrubbers.

Later scrubbers employed rotating horizontal (Photograph 32 and Figure 19) or vertical cylinders. The gas and water ran counter current, as in the tower scrubber. The Kirkham, Hullett and Chandler's Rotary Washer-Scrubber was the best-known example of the washer scrubber. A cross section of this horizontal washer scrubber is shown in Figure 19. The rotary washer scrubber was filled with the corrugated iron filter material shown in Photograph 33.



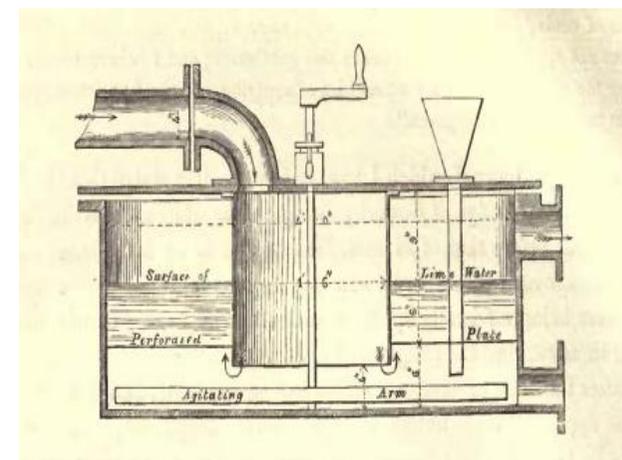
**Photograph 32. A rotary mechanical washer.**



**Figure 19. A schematic of a Kirkham, Hullett and Chandler's standard rotary washer-scrubber.**  
**Source: Russell Thomas.**

within the water in the base of a gasholder. He later developed a paddle system to agitate the lime, at a gasworks he installed in Coventry.

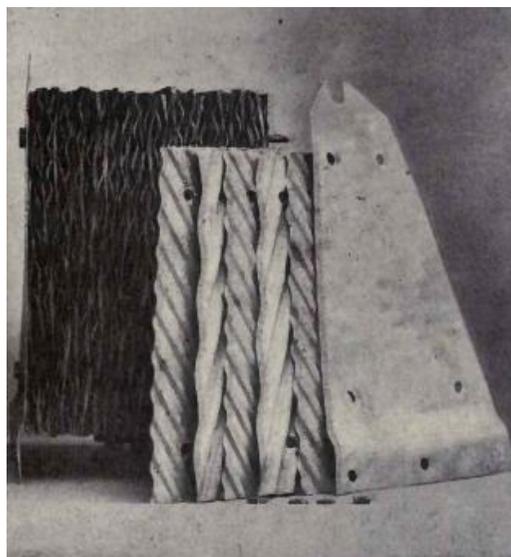
By 1812, Clegg had developed a separate tank which contained an agitated wet lime based purification system (Figure 20). This system was incorporated in the small gasworks built by Clegg for the famous Soho publisher Mr Rudolf Ackerman.



**Figure 20. The wet lime purifier developed by Samuel Clegg.** Source: Bibliography ref 3.

The wet lime purifier was further developed by Clegg, Malam and others. The better-known dry lime purifier did not appear until later. The main driver for the replacement of the wet lime system was not performance, but issues with the disposal of the waste product known as 'Blue Billy', the blue pungent wet lime waste created from the process caused problems for the gas companies with regard to transportation and disposal.

The first work on a dry lime purifier was undertaken by Reuben Phillips of Exeter (1817). Mr Phillips' purifier was in many ways similar to the system employed later in most gasworks, as it



**Photograph 33. The corrugated filter material used inside the standard washer-scrubber.**  
**Source: Modern Gasworks Practice, 1916.**

### Purifying the Gas

Once the coal tar and ammoniacal liquor were removed from the gas, two other poisonous substances were removed: hydrogen sulphide and hydrogen cyanide. Hydrogen sulphide was present in the gas at a much higher concentration than cyanide, and was the primary problem. If sulphur was not removed from the gas, it formed noxious fumes of sulphur dioxide when burnt, which would then form sulphuric acid. Sulphuric acid would cause the corrosion of gas fittings and deterioration of property within houses. It should be noted that a range of sulphur compounds were present within the gas in addition to hydrogen sulphide, including organic sulphur compounds such as carbon disulphide.

Gas purification to remove sulphuretted hydrogen (hydrogen sulphide) was first tried (unsuccessfully) when Samuel Clegg placed lime

worked on the basis of forcing the gas through layers of hydrate of lime. However, the system was flawed as it was water sealed and the purifier had no solid base. This was later rectified by adding a solid base and a removable lid (Photograph 34).



**Photograph 34. An example of box purifiers at the Fakenham Gas Museum, Norfolk.**

The lime used was actually hydrated rather than dry, as moisture was required to make the process work. The hydrated lime would react with the hydrogen sulphide forming calcium sulphide, and with hydrogen cyanide to form calcium thiocyanate and to some extent calcium ferrocyanide.

Lime was later superseded by the use of bog iron ore, although they were sometimes mixed and used together. Bog iron ore (hydrated iron oxide) was developed for use in gas purification in 1849-1850, and was the invention of Richard Laming and Frank Hills. It was adopted for use worldwide in the 1860s, with the exception of Britain.

The British Sulphur Act was enacted in 1860 to require the removal of the relatively high levels of

sulphur from gas. The net effect of this act was to make it impossible to replace lime purification with iron oxide purification, which was not quite as effective. Bog iron ore was more economical and less troublesome than lime. This was not rectified until 1905 when a new sulphur act was brought in, enabling iron oxide to completely replace lime.

When the hydrogen cyanide present in coal gas was passed over bog iron ore, it would predominantly form ferric ferrocyanide, also known as 'Prussian blue'. The hydrogen sulphide would react with the bog iron ore and form ferric sulphide, ferrous sulphide and sulphur.

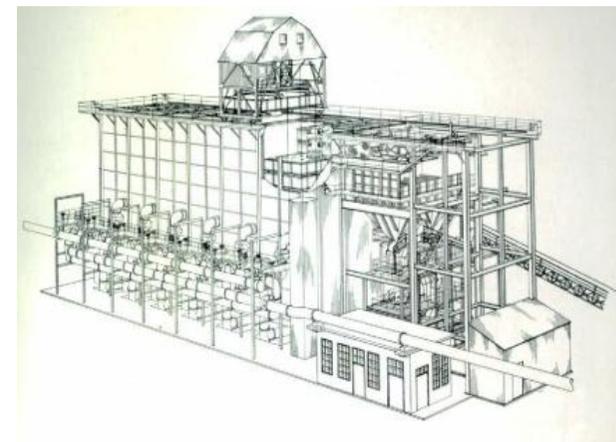
The purifiers were usually square or rectangular, made from iron (Photograph 34), and could be built on a huge scale (Photograph 35).



**Photograph 35. A large purifier house.**

Later, much larger tower purifiers (Figure 21) were used on some large gasworks and coking works. The slaked lime or hydrated iron oxide would be laid on wooden (often oak) grids inside the boxes in layers 30cm (12 inches) to 45cm (18 inches) deep, sometimes with lime mixed in with the iron oxide. The moisture content in the boxes was important and regulated by the

addition of steam. The gas was also heated prior to entry into the purifiers so the reaction could operate at the optimum conditions.



**Figure 21. A schematic of a tower purifier at the former Southall Gasworks.**

Both the lime and iron oxide could be regenerated two or three times by exposure to air within the yard (a process called revivification), before becoming either 'foul' or 'spent', respectively, containing high concentrations of cyanide (>6%) and sulphur (50-60%). Opening the purifier boxes could be hazardous, as the purifying medium would rapidly oxidise on exposure to air and could spontaneously combust, producing toxic gas. Later processes were developed which would revivify the oxide within the purifiers, removing some arduous manual handling.

Foul lime (Photograph 36) was a rock solid material of a greenish white colour and high pH (11). It was sold to farmers or allotment holders as a fertiliser. Spent oxide (Photograph 37) was a blue/green material of low pH (4) used as a by-product for the production of sulphuric acid, but also occasionally used as a weed killer.



**Photograph 36. Foul lime excavated on a former gasworks. Source: Parsons Brinckerhoff.**



**Photograph 37. Spent oxide. Source: Russell Thomas.**

#### Liquid Purification

Gas could also be purified by passing it through alkaline solutions of sodium carbonate. These methods were not adopted in Britain as they were deemed inferior to purification by iron oxide and caused more nuisance from odours.

Another method developed was the Thylox process, which washed the hydrogen sulphide from the gas using ammonium thioarsenate. The

solution was highly effective at removing hydrogen sulphide; it could be regenerated by exposure to oxygen, with the sulphur precipitating out as foam which could then be collected. The Thylox process would also remove cyanides in the gas as thiocyanates. As may be expected, there were health and environmental issues in using an arsenic-based solution so the process only achieved limited success.

The most successful of these liquid processes was the Stretford process, developed by the North Western Gas Board and the Clayton Aniline Company in England to remove hydrogen sulphide from town gas. The original process used an aqueous solution of carbonate/bicarbonate and anthraquinone disulphonic acid (ADA). The process initially suffered as the solution used had a very low capacity for dissolved sulphides, resulting in high liquid circulation rates. The sulphur formation reaction was also very slow, requiring large amounts of solution to be stored. A significant amount of thiosulphate was formed as a by-product. These problems were largely overcome by using alkali vanadates in the solution, replacing dissolved oxygen as the direct oxidant in the conversion of hydrosulphide ions to elemental sulphur. Although the vanadium additive used in the Stretford process increased the reaction rate when converting the hydrosulphide ions to sulphur, it was still a slow reaction, which limited its use. It also resulted in a significant amount of thiosulphate as a by-product.

#### Storing the Gas

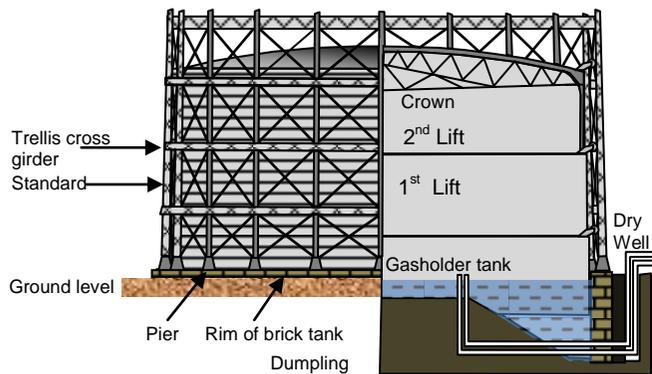
The purified and metered gas was stored in a gasholder to be distributed later. The gasholder has been an integral part of the gasworks since Murdoch's early Soho Gasworks, built in 1802.

The purpose of the gasholder was to act as a buffer. Generally containing a gas supply of 24-36 hours of production, it would afford the gasworks greater operational flexibility, meaning that it did not need to operate 24 hours a day.

The gasholder consisted of a cylindrical vessel closed at the top but open at the base, which sat in a water-filled tank. As gas entered the gasholder, it made the vessel rise up in the tank. The water-filled tank acted as a seal to prevent the gas from escaping. The pressure imparted by the weight of the tank would then pressurise the gas mains via the control provided by the governor. Booster pumps were later developed; these acted as powerful fans which could push the gas through the mains and also pressurise the gas mains.

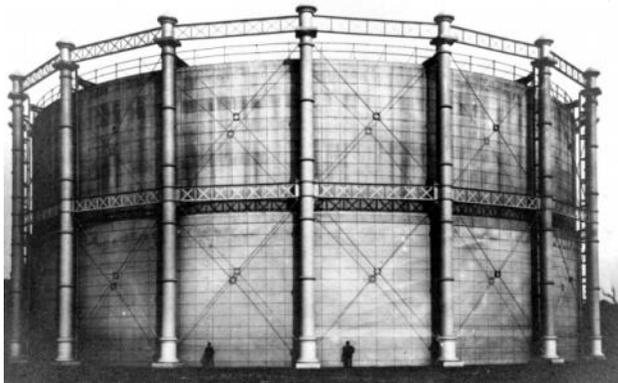
The earliest gasholders were rectangular and constructed from heavy iron with a wooden frame, holding about 14 m<sup>3</sup> (500 ft<sup>3</sup>) of gas. Rectangular gasholders continued to be built until 1815, when they were replaced by a larger cylindrical design. The tanks of these early gasholders were built above ground and normally constructed from wood. They were not robust and were prone to leaking and collapse. The gas engineer John Malam improved the cylindrical gasholder design by reducing the weight of the internal framing and using counterbalance weights and chains. Underground brick tanks were only introduced in 1818, with stone and concrete tanks following later.

The first gasholders using underground tanks were of single-lift construction. The movement of the tank up and down was aided by wheels running along guided tracks on the supporting columns.



**Figure 22. A schematic diagram of a guide-framed gasholder with a below-ground tank.**  
**Source: Russell Thomas.**

With the advent of the telescopic gasholder developed by Tate in 1824, additional storage capacity could be added without increasing the footprint. The telescopic gasholder (Photographs 38 and 39, and Figure 22) consisted of vessels situated one inside the other. When the inner vessel (otherwise known as a lift) was fully extended, it would couple to the outer lift through engagement of the cups and dips. Telescopic gasholders could have as many as six lifts, one inside the other.

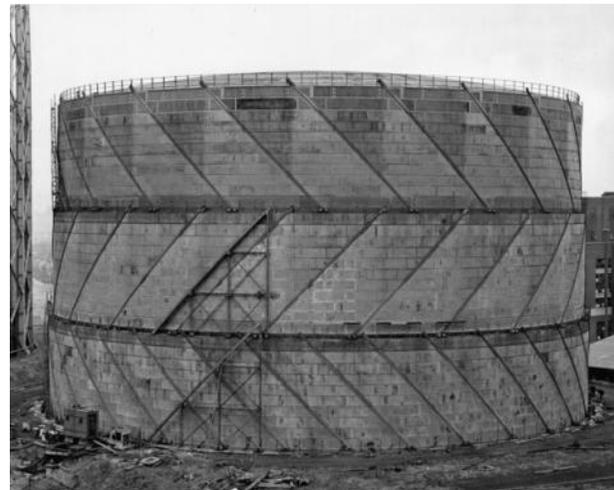


**Photograph 38. A column-guided gasholder with two sets of horizontal trusses and diagonal bracing.**

Many gasholders had underground water-filled tanks. Built from brick, stone or concrete, these tanks were generally made watertight by a layer of puddle clay on the outside face of the tank walls and beneath the base of the tank. Building the tank underground helped to reinforce the tank wall, as it was supported by the compacted ground around it.

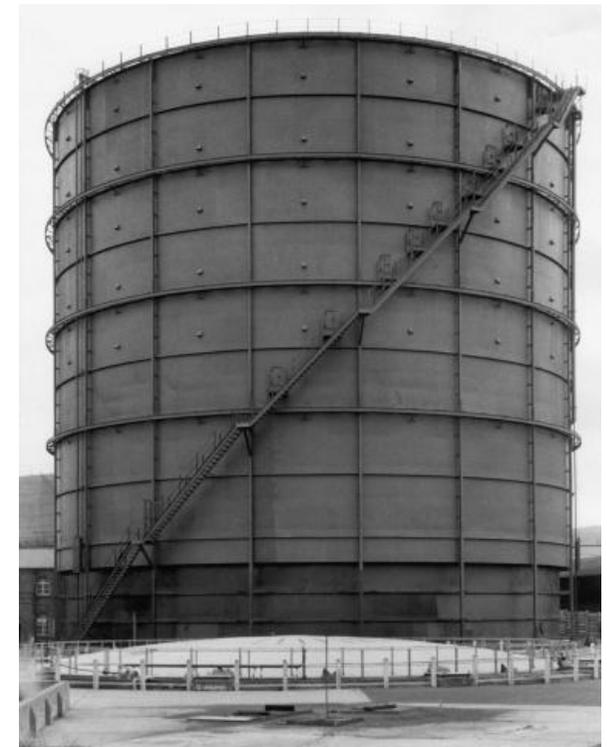
Later developments of the gasholders led to the construction of above-ground tanks made of iron, steel or reinforced concrete.

The next major invention was the development of the spiral-guided gasholder (Photograph 39), the invention of William Gadd of Manchester. The first spiral-guided gasholder in the UK was built at Northwich, Cheshire, in 1890. These gasholders saw the removal of external columns or guide frames, replacing them with spiral rails on the inside or outside of the lift. As the gasholder filled or emptied, it moved up or down in a screw-like fashion. It was cheaper to construct than the design with columns or guide frames, but more delicate to operate, especially in the winter.



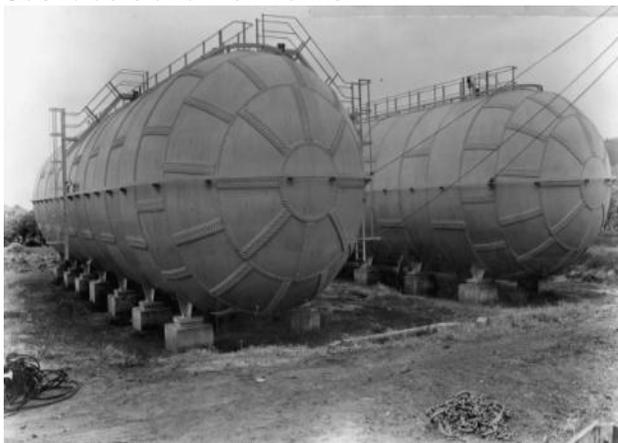
**Photograph 39. Spiral guided gasholder.**

Waterless or dry gasholders were introduced to the UK from Germany (MAN and Klonne) and the USA (Wiggins, Photograph 40). These allowed for a simplified system, where the only major moving part was the piston. The outer cylindrical shell remained static and of the same diameter, and the roof of the structure was permanently fixed. The piston was able to rise and fall inside the shell by means of guide rollers. The Wiggins holder also used a piston, but the gas was stored within a large neoprene/nylon 'bag' within the holder. A major benefit of this design was that they did not require a water tank. Many of these vessels are still used by the steel industry worldwide for the storage of coke oven and blast furnace gases.



**Photograph 40. Waterless gasholder of the Wiggins design.**

Another later form of gas storage was the high-pressure static vessel. These vessels had no tanks or moving parts, and received and stored gas at a much higher pressure than those vessels listed above. Their bullet-shaped or spherical tanks are shown in Photograph 41. In more recent years, use has been made of gas storage within high-pressure gas mains as liquefied natural gas, and within depleted gas fields or salt caverns. The subject of gasholders is discussed in more detail within *Gasworks Profile B - Gasholders and their Tanks*.



**Photograph 41. High-pressure bullet tanks.**

#### Station Meter and Governor

The station meter was generally housed within its own building or along with the station governor. As its name suggests, the purpose of the meter was to register the amount of gas produced at the gasworks. These meters were quite ornate, as can be seen from Photograph 42.

The meter was a cast iron drum approximately 1.2 m (4 ft) in diameter and 1.5 m (5 ft) long and half filled with water. Inside was a tin drum divided into compartments from which the flow of gas displaced water, making the drum rotate. The drum rotations were counted, and clock face type

dials on the front of the meter allowed a reading to be taken.



**Photograph 42. Station meters (right) in the meter house.**

The gas would also be metered at the site where it was received. This meter was essential to the early gas industry as it allowed the gas companies to provide some measure of how much gas consumers were using and how much they should be billed. Prior to the gas meter, consumers were allowed a certain number of gas lamps lit for a certain period of time, but this was not easy to enforce.

The role of the station governor was to ensure that gas delivered from the gasworks was at a uniform pressure at all times, and free from fluctuations. The governor was located between the gasholder and the district gas main. It would control the pressure exerted by the gasholders onto the gas mains, keeping it at a level that was sufficient for supply, but no more. The governor would automatically keep the gas pressure uniform despite fluctuations in production and consumption.

The station governor would consist of a small tinned iron bell floating freely in a cast iron tank containing water. As gas mains developed and became more complex, it became more difficult to regulate the gas pressure in the system. As a result, district governors were introduced; these were particularly important for districts at different altitudes.

Hanging down from below the inside of the crown was a parabolic plug. The gas entered through the gas main and was directed up through the centre of the governor through a conical seated flange which exactly fitted the parabolic plug. By adjusting the gasholder, the degree to which gas could pass through the flange was altered. Weights were placed on the gasholder to alter the gas pressure to the mains. Without any weights, the gasholder would rise and the parabolic plug would fill the conical flange, cutting off the gas supply; fully weighted, the reverse would happen.

#### Tar Tanks and Wells

The tar and ammoniacal liquor recovered from the hydraulic and foul mains, condensers, electrostatic detarrer, washers and scrubbers was usually drained by gravity (pumps could also be used) to underground tar and liquor tanks (Photographs 43 and 44, and Figure 23). These tanks had a wide range of designs, from simple cylindrical structures cut into clay to large cast iron, steel, brick or concrete structures.

Many early gasholders on former gasworks were converted to tar tanks when they became too small to be used efficiently as gasholders. Such conversions often involved the installation of brick arched roofs, as in Photograph 43. In small gasworks, tar tanks were often simply brick tanks lined with puddle clay and covered with wooden planks (Figure 22), relying on gravity to separate the tar and the liquor. Other larger tanks

incorporated a series of weirs to separate the tars from the ammoniacal liquor.

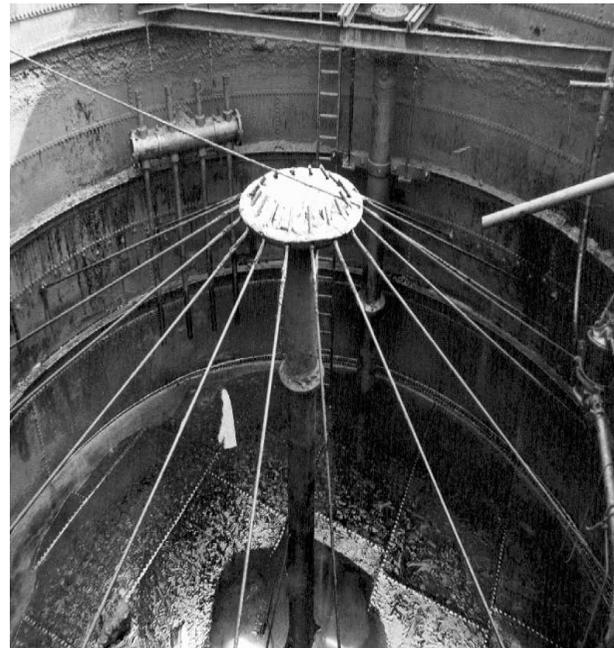


**Photograph 43. Interior of a tar tank at the former gasworks, Sydenham.**

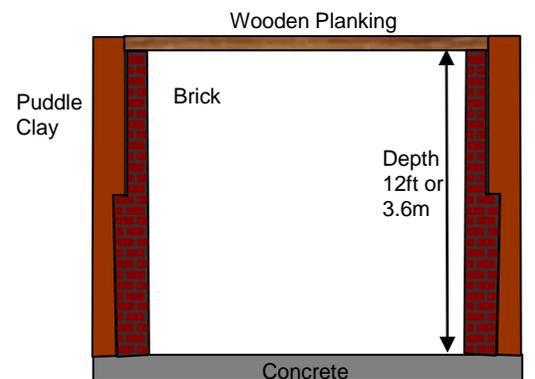
Tar tanks are poorly covered in the gas manufacturing text books and are often not marked on gasworks plans.

Tar and liquor were removed separately. Tar was often pumped by steam pumps, the heat from which would reduce the viscosity of the tar and make it easier to pump to above-ground tar tanks. It would then be transferred to road or rail tanks

and taken to a tar distillers or chemical works. Some large gasworks would have their own tar distillation plant, a topic mentioned later in the section on tar distillation.



**Photograph 44. Interior of a tar tank at the former Linacre Gasworks, Liverpool.**



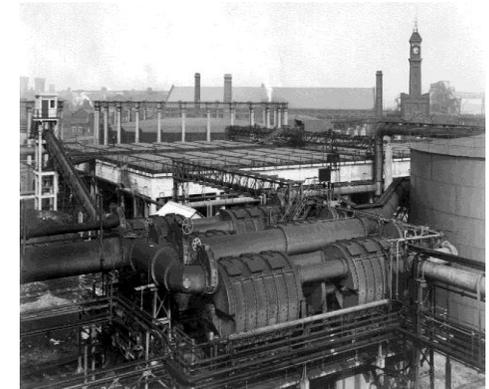
**Figure 23. A schematic of a simple tar tank on a small gasworks site. Source: Russell Thomas.**

### Naphthalene Washer

After purification, two more by-product recovery processes were used on medium to large gasworks (and by-product coke ovens); these were benzole and naphthalene recovery.

Naphthalene and associated compounds were very troublesome for the gas engineer. They could precipitate out and gum up the mains at the gasworks, and also within the gas distribution network as the gas continued to cool. Naphthalene would sublime, meaning it went straight from vapour to solid phase within the pipes or even appliances; it was therefore not captured in the moisture which collected in the syphon pots. As it separated out of the gas, it took on a very bulky crystalline form, exacerbating the problem. Similar problems could result from the presence of styrene and indene, both of which can polymerise to form a sticky gum.

Naphthalene and the other associated compounds were removed by passing the gas through a static or rotary washer through which gas oil was circulated (Photograph 45). It worked in much the same way as the ammonia washer, but using gas oil as a solvent instead of water.



**Photograph 45. Naphthalene washers at the former gasworks in Beckton.**

The gas was passed through the washer in a counter current direction to the gas. Once a high concentration of naphthalene had accumulated in the oil, it was removed and replaced with fresh oil. The naphthalene-saturated oil was then subjected to fractional distillation to remove the naphthalene and then the oil could be reused in the washer.

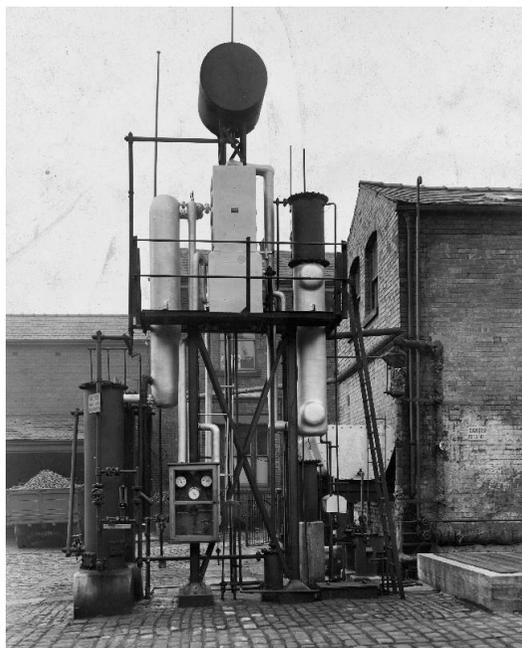
### Benzole Plant

Benzole was a light oil consisting mainly of benzene and toluene. It could be removed by washing with a solvent (as for naphthalene) or by using activated carbon. If removed by solvent washing then the process would be almost identical to that described for naphthalene. Benzole was recovered from the oil using fractional distillation, sometimes under vacuum to reduce the steam requirements.

With the activated-carbon method, the gas was passed through the activated carbon (Photographs 46 and 47). The benzole was absorbed onto the activated carbon until it became saturated, at which point the gas was diverted to another vessel filled with fresh activated carbon. The benzole was then removed from the activated carbon by steaming, often under vacuum. The activated-carbon method became the most popular form of benzole recovery, although it lost out to the petroleum industry which could produce similar products more cost effectively. Benzole plants were at their most important around the time of the Second World War, when the benzole and toluol produced were important sources of motor fuel and a base product for manufacturing explosives.

### Gas Dehydration Plant

In the 1920s, gas dehydration (dry gas) plants (Photograph 48) were developed to reduce the moisture content of the gas. Moisture in coal gas



**Photograph 46. A small benzole plant at the former gasworks in Middleton.**

had a tendency to accumulate in the distribution system and customer meters. This moisture would often contain substances which would corrode the gas mains and damage the meters.

These substances included ammonium sulphate, ammonium sulphide, ammonium thiocyanate and ammonium ferrocyanide as well as carbon dioxide. At the gasworks, the calorific value of gas would be measured under the standard conditions of 15.5°C and 101 kilopascals (60°F and 30" mercury pressure).

If moisture was lost from the gas through condensation, it effectively concentrated the gas and raised its calorific value. Dry-gas systems removed this problem.

The gas dehydration plant could be located before the station meter (if a dry meter was

used), before the gasholder, or after the gasholder (if wet meters were used).



**Photograph 47. Large benzole plant at the former Carr House gasworks in Rotherham.**



**Photograph 48. WC Holmes dri-gas plant at the former Beckton gasworks.**

Various systems were used for drying gas. The gas could be washed with a solution of calcium chloride (38-40%), which would absorb the moisture. Any excessive quantity of ammonia in the gas would waste the calcium chloride by reacting with it. The calcium chloride solution could be used in rotary washers or tower scrubbers which would resemble those described previously. A less popular method was dehydration using glycerin, which operated on similar principles as those for calcium chloride.

Another system involved the use of refrigeration: the gas was washed by chilled brine (salt water) which was recirculated and re-cooled. It was only used on sites producing more than 160,000 m<sup>3</sup> (6,000,000 ft<sup>3</sup>) of gas per day. Naphthalene and its associated compounds would precipitate from the gas using this method and had to be removed from the brine solution. The gas could also be dehydrated by compressing and cooling the gas.

#### Ammonium Sulphate Plant

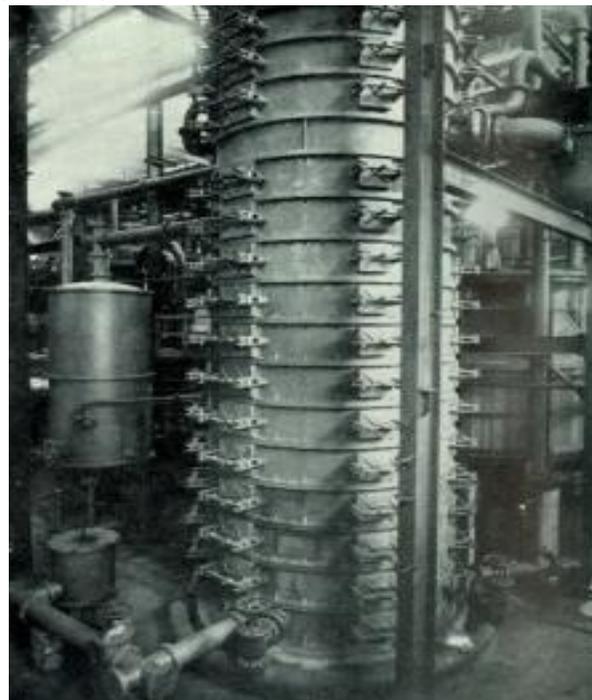
Ammoniacal liquor was processed to manufacture ammonium sulphate fertiliser (Photograph 49). The process was quite simple and involved driving off the gaseous ammonia (NH<sub>3</sub>) and reacting it with sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) in line with the following reaction:



A small gasworks that did not have access to steam would use an under-fired still or boiler to drive the ammonia from the liquor. This process was not ideal and was not used in large works. When the liquor reached near-boiling point, a great number of odorous gases such as hydrogen sulphide would be suddenly released. Dealing effectively with these gases without causing a great deal of nuisance was extremely difficult. Larger gasworks had continuously operated stills

into which liquor would continuously run. These continuous plants would operate using steam produced for various purposes in the gasworks' boilers.

The liquor would be pumped into an overhead tank and flow through into a superheater; there, the liquor would be heated to boiling point by gases from the saturator. From the superheater, the liquor passed into the top of the still; the latter contained a series of perforated trays which would contain the liquor to a depth of 6.3 cm (2.5 in). The liquor flowed down through these trays, being continuously vibrated. Steam was admitted through the base of the still; as it ascended, it boiled the liquor and released the ammonia.



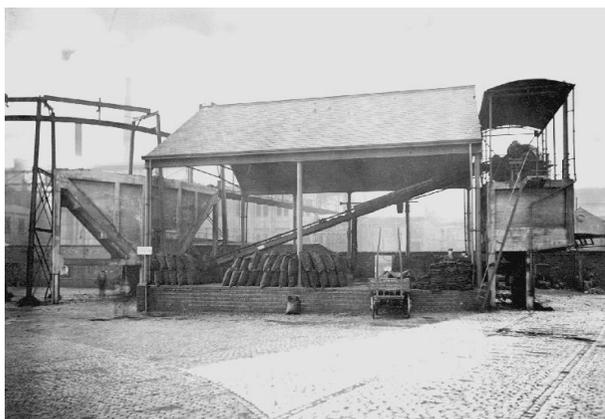
**Photograph 49. Sulphate of ammonia plant, showing liquor tower (still, centre), liming unit (left) and saturator (right).**

Cream of lime (a suspension of calcium hydroxide (Ca(OH)<sub>2</sub>) in water) was pumped into the bottom compartment of the still. Once thoroughly mixed with the liquor, it flowed through a secondary still where the same process was repeated, releasing all the ammonia. Ammonia gas coming off the stills was mixed with sulphuric acid in the saturator to form ammonium sulphate. The ammonium sulphate was removed using a ladle and left to dry. Once dry, it was placed in the sulphate store where it was put in sacks for distribution (Photograph 61).

#### Coke Screening Plant

Coke screening plant would receive coke from the retort houses into hoppers. The coke would then be fed into a grading and cleaning plant, where it was separated into breeze, (boiler) nuts, broken coke and large coke by passing over a series of vibrating mesh screens. The coke nuts were separated from unwanted shale by passing it over a perforated table through which air was blown. The air displaced the coke, leaving the shale behind.

Early grading plants were relatively simple and used basic screens for grading. They were similar to that shown in Photograph 50. At larger more modern gasworks, the coke was graded in large concrete bunkers which looked similar to retort houses. Using screens and conveyors, the coke would again be sorted into different sizes and stored in bunkers prior to weighing and dispatch into wagons.



**Photograph 50. Early coke screening and bagging plant, Adderley Street, Birmingham.**

#### Butane Air Plant

Butane air (Photograph 51) was an alternative form of gas supply used in some remote parts of the country to replace coal gas systems. As the butane had a low vapour pressure, it needed to be vaporised using a specialised piece of plant before being mixed with air and distributed.

The butane air gas produced would have a calorific value no lower than  $18.6 \text{ MJ/m}^3$  ( $500 \text{ Btu/ft}^3$ ), the same as coal gas. The small town of Whitland (Wales) was the first town in Britain to use this process alone to supply a town. It was used elsewhere to supplement gas supplies when demand required, especially at times of extreme seasonal demand, such as in a cold winter.

#### Boosters

Gas boosters were used to raise the pressure of gas in pipelines to provide sufficient gas pressure for specific purposes. On a gasworks, this was usually to transport gas at higher pressures to nearby holder stations. However on larger works, such as Beckton, booster pumps were required to enable the gasholders to be filled (Photograph 52).



**Photograph 51. A small butane air plant.**

The use of boosters to help transport gas became more common as smaller gasworks were closed for production, but retained as holder stations; they were also needed when more remote locations were added to the gas network.

The gas was pumped using booster pumps to increase the pressure of the gas in the pipeline. This compressed the gas, allowing more gas to be transported from the remaining larger gasworks to these smaller satellite holder stations. Booster pumps were either rotary fans or blowers operating at between 7-27 kPa (1-4 psi) or reciprocating compressors operating at between 138-207 kPa (20-30 psi).

Booster pumps replaced gasholders as the way to provide pressure in the local gas network. Boosters are still used to ensure the correct pressure in the low-, medium- and high-pressure gas pipelines as well as the National Transmission System (NTS). Within the NTS, rotary machines driven by gas turbines are used. Governors were used to regulate the change in gas pressure between the different pressure rated pipelines.



**Photograph 52. Four high-pressure turbine-driven boosters at the former Beckton gasworks.**

#### Tar Distillation

Coal tar had many uses, both direct and indirect. Coal tar could be distilled into fractions then used as wood preservatives, fuels, disinfectants and various pitches for roads, roofing tar, and as a binder for electrodes and insulation (Figure 24). The first tar distillery was built in Leith, Edinburgh, in 1822; it produced a spirit used for dissolving rubber in the manufacture of waterproofs. Use of middle and heavy oils as timber preservatives was one of the earliest uses of coal tar and led to its adoption as a valuable product.

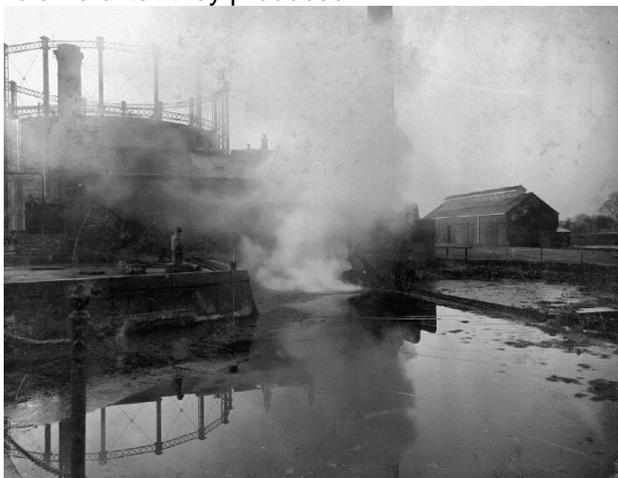
As coal tar became the base feedstock for the production of chemicals *circa* 1870 until the availability of petroleum-based oils, it was further processed to produce chemicals used in the manufacture of dyes, flavours, aromas, explosives, sweeteners and drugs, amongst other items.

This wide variety of uses and products is shown in Figure 24. The distillation of coal tars was more common at larger gasworks although a few small and medium-sized gasworks would also distil tar.



The best examples of tar distillation plants on gasworks would be the by-products plants at the former gasworks at Beckton and Southall.

Gas companies would generally work together to form cooperative tar distilleries). The cooperatives would take tars from all the gasworks in a specific region which did not have their own tar-distilling capacity or found it more economical for the tar distillery to distil the tar. Private tar distillers would also buy tar from the gas companies. By-product coking works often operated their own tar distilleries, given the high volume of tar they produced.



**Photograph 53. Running off pitch into pitch beds.**

Fractional distillation was used to separate fractions of the coal tar into oils and compounds of similar boiling points. The fractions generally referred to are light oils, middle or carbolic oils, heavy or creosote oils, and anthracene oils and pitch (Figure 24), the residue which remained. The pitch was the greater portion of the tar and the hot pitch was allowed to run into large open pits, called pitch beds (Photograph 53), where it would cool and harden before being broken into lumps and sold.

In 1939, Great Britain produced about 2 million tonnes of coal tar. Most was used as road tar (750,000 tonnes) and pitch (750,000 tonnes). Creosote accounted for 450,000 tonnes, and other sundry uses for 50,000 tonnes.

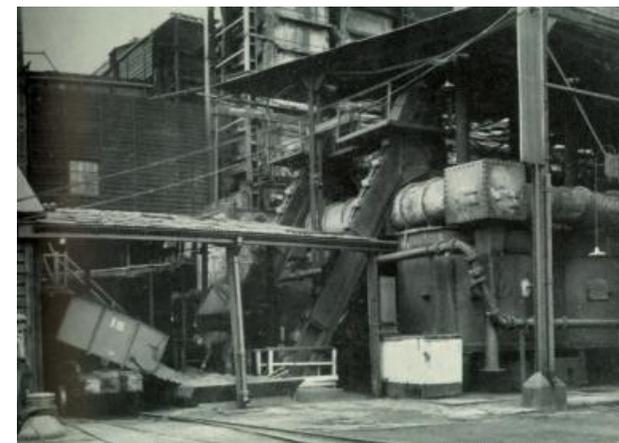
#### Sulphuric Acid Plant

Sulphuric acid was one of the most important industrial acids and its production was always in high demand. The main source of sulphur for the production of sulphuric acid was the spent oxide (or other spent purifying material) which would typically consist of about 50% sulphur. Gasworks were the source of most of Britain's raw material for sulphuric acid production *circa* 1910. A number of large gasworks such as Beckton manufactured sulphuric acid (Photographs 54 and 55).



**Photograph 54. The sulphuric acid plant at the Beckton gasworks.**

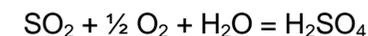
A few different methods were used to produce sulphuric acid, the most common method using a burner, chamber plant and Glover and Gay-Lussac towers. The sulphur-containing material was burnt within a Herreshoff-type furnace, resulting in the formation of sulphur dioxide.



**Photograph 55. Spent oxide being unloaded from rail wagons into buckets en-route to burning in the furnaces of the sulphuric acid plant.**

The chamber was constructed of lead, as other construction materials would have suffered corrosion from the sulphuric acid. These chambers were often supported on a wooden or iron frame above ground to allow leaks to be detected. These chambers were 30.5 m (100 ft) to 61.0 m (200 ft) long, 6.1 m (20 ft) to 9.1 m (30 ft) wide, and 4.5 m (15 ft) to 7.6 m (25 ft) high.

The overall reaction for the process was:



However, this reaction was very slow and required the presence of nitric acid or oxides of nitrogen to proceed efficiently. The overall chemistry of the process, including the chemical reactions with nitrogenous intermediates, is much more complex. The burner gas from the furnace was pulled through the system into the base of the Glover tower, either from a draught produced by a chimney or by mechanical means. In the tower it was washed with a mixture of sulphuric

acid with nitric oxide and nitrogen dioxide dissolved within it.

The Glover tower served two functions: it concentrated the acid by evaporating water using the hot gases; and it stripped nitrogen oxides from the liquid to the gas phase.

From the Glover tower, the mixture of sulphur dioxide, sulphur trioxide, nitrogen oxides, nitrogen, oxygen and steam entered the large lead-lined chambers where it reacted with more water. Sulphuric acid was then formed by a complex series of reactions, condensed on the walls, and then collected on the floor of the chamber. The acid produced in the chambers contained between 62% and 68%  $H_2SO_4$ .

From the chambers, the gases passed into a reactor called the Gay-Lussac tower where they were washed with cooled concentrated acid (from the Glover tower). This was another lead-lined tower, filled with coke. Any vapours of nitrogen oxides or sulphur dioxide were dissolved in the acid. The waste gases exiting the Guy-Lussac tower were usually discharged into the atmosphere via a chimney.

Sulphuric acid was removed from the system at a concentration of about 78%. Nitrogen losses were made up with nitric acid which was added to the Glover tower. The sulphuric acid was then stored on site and sold to merchants or direct to companies requiring this reagent. It was also used on-site for the manufacture of ammonium sulphate.

#### Other Buildings and Plant

Other buildings were found on former gasworks. These included: the boiler house, where steam was raised in boilers, using coke as a fuel; generating or power houses, where electricity

was produced by generators driven by gas or steam engines; pump houses, where water would be pumped from boreholes or rivers to supply the heavy water demand of a gasworks; a variety of stores for items including fireclay, meters and stoves; ancillary buildings such as stables, workshops, toilets, laboratories, blacksmiths, mess facilities, offices and accommodation.

## **5. Gas Manufactured from Coke and Oil**

### **5.1 Water Gas**

One of the major issues with coal gas was the time needed to get the plant operating and producing gas, making it unsuitable in periods of high demand when a quick response was required. To handle peak demands for gas, gas plant would have to be operated inefficiently or additional gas storage would be required.

Another process was developed, one that could produce gas much more quickly and cope with periods of peak demand. Known as 'water gas', its use was particularly widespread in the USA. The process worked by steaming coke to produce a gas consisting of hydrogen and carbon dioxide. The operation was split into two phases, the blow and the run phases. The purpose of the blow was to store as much heat in the generator fuel bed as possible. Hot gases from the generator heated the carburettor and superheater. During the run, steam was injected into the generator and reacted with the carbon, forming carbon monoxide and hydrogen. The run phase would gradually cool the fuel bed, increasing the proportion of inert substances (carbon dioxide) in the gas. A regular switching between the blow and run was required, making it an intermittent process. Water gas was a relatively poor quality gas, but it could be enriched by injecting oil into the carburettor. Called Carburetted Water Gas

(CWG), it was used at many medium- to large-scale gasworks in Britain and across the world, becoming a vital gas manufacturing process. In parts of the USA, this became the primary form of gas manufacture. A photograph of water gas plant at the former East Greenwich Gasworks can be seen in Photograph 56. This subject is discussed in much greater detail in *Gasworks Profile C - Water Gas Plants*.



**Photograph 56. The interior of the water gas plant building at the former East Greenwich Gasworks.**

### **5.2 Producer Gas**

Producer gas plants were used on former gasworks primarily to heat retorts and occasionally to supplement gas supplies at times of peak demand. A brief summary of gas producers is given below.

Producer gas plants started to become popular in the early 1880s and were in widespread use by 1910. Many varied types evolved from the time that the first plant was built by Bischof and their demise in the mid 20<sup>th</sup> century. In 1857, Frederick Siemens developed Bischof's gas producer into a combined gas producer and regenerative

furnace. This system was gradually improved and introduced to the UK through William Siemens. Producer gas plants provided a great benefit to those industries which required high and uniform temperatures. It was of great assistance to those industrial processes which were unable to use directly fired solid fuel furnaces, or found it very difficult to do so, and could not obtain a suitably priced gas supply. It saved fuel by enabling the gas to be at the exact point required, achieving higher temperatures, rather than relying directly on radiant heat. Gasworks were one of the major users of gas producers, using them to heat the retorts, with the by-product coke used in the generator. They were also used to heat coke ovens in the same way. This subject is discussed in more detail in *Gasworks Profile D - Producer Gas Plants*.

### 5.3 Oil Gas

The production of oil gas dates back to the start of the gas industry. In its earliest years, the coal gas industry faced competition from gas made from oil, primarily whale oil, although other fish and vegetable oils and resins (rosin) were used. These gasworks were built in places such as Bristol and Edinburgh. They were short-lived and faced closure after a few years because of oil shortages and being uneconomic to run. Some converted to coal gas production. Oil gas was more successful on the European continent.

Oil gas was also the gas of choice on the railways, and was used for lighting carriages. This method of lighting was developed by Julius Pintsch, a German engineer. The gas, a form of vaporised naphtha oil, was produced at Pintsch gas plants located at stations or works. It was stored in mobile gasholders, which would provide gas to the carriages for burning in special lamps.

As the available coal resources for gas making became more expensive and of lower quality, the gas industry looked at alternative feedstocks. Liquid feedstocks such as crude petroleum oils and derived distillate fractions were present in abundant amounts from oil refineries, providing a cheaper viable alternative. Early types of oil gas plant which had seen popularity on the west coast of the USA (Jones process) were never popular in Britain.

Oils could range from being highly paraffinic to highly aromatic. The greatest difference in gas-making efficiencies of liquid feedstocks was the relative size of the constituent molecules. The light distillate fractions had the highest efficiency and the heavy fuel oil the lowest.

An advantage of oil gas over coal gas was the lack of ammonium and cyanide; this reduced capital costs as well as the amount of land required to undertake the process. If oils were used which were rich in unsaturated, naphthenic or aromatic compounds, then there would be a much lower gas yield, especially methane and ethylene, and an increase in tar and/or carbon produced. To reduce tar formation, it was possible to introduce oxygen and hydrogen in the form of steam, enabling combustion, hydrocarbon hydrolysis or water gas reactions to occur. This could also be achieved by increased pressure.

The combustible components of a typical oil gas may be composed of 48.6% hydrogen, 26.3% methane, 12.7% carbon monoxide, and 3.8% illuminants.

#### Non-Catalytic Cyclic Method of Gas Production

The first major use of petroleum-based oils for the manufacture of town gas occurred on the Pacific coast of the USA. Referred to as the 'Pacific

Coast Oil Gas Processes', the main method was the Jones process.

Severe cracking conditions were used to produce a gas with a calorific value (CV) of 18.6 MegaJoules per cubic metre ( $\text{MJ/m}^3$ ), equivalent to 500 British Thermal Units per cubic foot ( $\text{Btu/ft}^3$ ). It gave a gas composed of approximately 40% water gas, but the efficiency was poor, with only 50% of the oil converted to gas. The rest of the oil was converted to carbon black (otherwise known as lampblack) and small amounts of viscous tar, which was rich in naphthalene and carbon black content.

This process was later extended to a wider range of oil feedstocks and also adapted to enable increased carbon black, a useful by-product which could be sold. In this case, a gas with a lower energy density of  $13 \text{ MJ/m}^3$  ( $350 \text{ Btu/ft}^3$ ) was produced, forming little or no tar. Carbon black could be sold at a price which made such a lower calorific value viable.

#### Jones Process

The only known Jones process plant in Britain was at the Gloucester Hempsted gasworks (Photograph 57). The economics of the process were based on the price received from the sale of the carbon black, the primary product; the gas produced had a energy density of  $13.4 \text{ MJ/m}^3$  ( $360 \text{ Btu/ft}^3$ ).

The system consisted of four vessels, but the two outer vessels contained chequer bricks and were only used as heat exchangers. Gasification took place in the two main generator units. These larger vessels contained oil sprays and vaporiser spaces at the top. The generators were heated and oil was injected into them for five minutes; air was then blown into them, allowing them to reach between  $870\text{-}925^\circ\text{C}$ . Steam would then be added

into the first generator for one minute, then oil injected with steam into both main generators for roughly seven minutes. Steam alone would then be injected into the generators for two minutes.

Air was blown into the generator to burn off the carbon, cleaning the unit and reheating it at the same time. This process produced about 28 m<sup>3</sup> (1,000 ft<sup>3</sup>) of gas from about 32 litres (7 gallons) of oil.

A method called the straight shot was a similar process carried out within a single generator unit; the latter was divided into sections, with heating undertaken at the base of the unit. This method produced about 28 m<sup>3</sup> (1,000 ft<sup>3</sup>) of gas from about 39 litres (8.6 gallons) of oil.

In both manufacturing processes, the oil gas would exit the generators through the carbon recovery unit and gas washing unit. The manufacture of oil gas produced a significant amount of naphthalene, requiring the gas to be passed through a naphthalene scrubber. The remaining purification process was similar to that of CWG except for the removal of carbon black. The water from the scrubbers and the wash box was passed to the lampblack separator. The carbon black was removed from the separator and dewatered, or else it was filtered, dried and briquetted. It could then be used as either boiler or CWG fuel or sold for other industrial purposes including the production of tyres, paint and ink.

#### Hall Process

The Hall process was also used at the Hempsted gasworks in Gloucester (Photograph 40). It produced a high CV gas of 37.2 MJ/m<sup>3</sup> (1,000 Btu/ft<sup>3</sup>) which was equivalent to natural gas.



**Photograph 57. The Hempsted gasworks Gloucester, where a range of oil gasification processes were constructed, including the Hall, Jones and Gas Integrale processes.**

The process was originally undertaken using adapted water gas plants; later, plants were specifically designed for this purpose.

Distillates, crude oil or residual oil could be gasified, although efficiency would decline with heavier oils and could fail because of the deposition of carbon and pitch within the generators. The efficiency of the Hall process varied from 82% of the thermal value of the feedstock on light distillate, to 50% on heavy fuel oil. The tar produced would range from less than 5% for light distillate to 20-30% for heavy fuel oil.

Other types of non-catalytic oil gas plant were also developed.

#### Cyclic Catalytic Processes

Catalytic gas manufacturing processes were more common on former gasworks sites in Britain. These plants would operate at a low pressure and their design was influenced by the type of feedstock being processed into gas.

The process used a catalyst to convert the oil to gas and this was dependent on the feedstock being used. Lime catalysts were used for the

range gas oil to medium fuel oil; nickel catalysts were best suited to light distillate.

If oil had a high content of naphthenes and aromatic compounds, then provision would have to be made to remove the naphthalene and tars using a naphthalene washer and electrostatic detarrer.

### SEGAS Process

The SEGAS (South East Gas) plant produced a gas similar to town gas. The plant had a regenerative design, using a catalyst in the form of cylindrical pellets. These contained magnesia and free lime as the active agent, which would last for three years.

A gasification efficiency of 70% was achieved, giving a CV of  $18.6 \text{ MJ/m}^3$  ( $500 \text{ Btu/ft}^3$ ), compared to the catalyst-free Jones process which only achieved 50%. If higher throughput, gasification efficiencies and a cleaner gas were required, then a nickel catalyst could be used instead of lime. The gas exiting the SEGAS plant would pass through a wash box, a direct contact cooler known as a Lymn washer, and an electrostatic detarrer before entering a relief holder.

The SEGAS process was robust, could gasify a range of oil feedstocks, and could start producing gas quickly. It was one of the most economical processes for gasifying residual oils and a number of such plants were built across the UK, a notable example being on the Isle of Grain.

### Onia-Gegi Oil Gas Process

The Onia-Gegi process was developed by the French 'Office National Industriel de l'Azote' in co-operation with the 'Gaz à l'Eau et Gaz Industriels', hence the name Onia-Gegi. Originally developed for the production of synthesis gas, it

was later used to produce town gas. (Synthesis gas consists primarily of hydrogen and carbon monoxide, and is used to produce ammonia and methanol.) The Onia-Gegi plant was designed to produce a gas similar to town gas with a CV of  $18.6 \text{ MJ/m}^3$  ( $500 \text{ Btu/ft}^3$ ), using a nickel catalyst. The system operated at atmospheric pressure and at  $900^\circ\text{C}$  to promote reaction by the nickel catalyst with steam, carbon and hydrocarbons. This produced a higher gas content and a lower tar/carbon yield than the Jones system. The Onia-Gegi system produced similar amounts of tar to the SEGAS process under the same conditions.

### Micro-Simplex Process

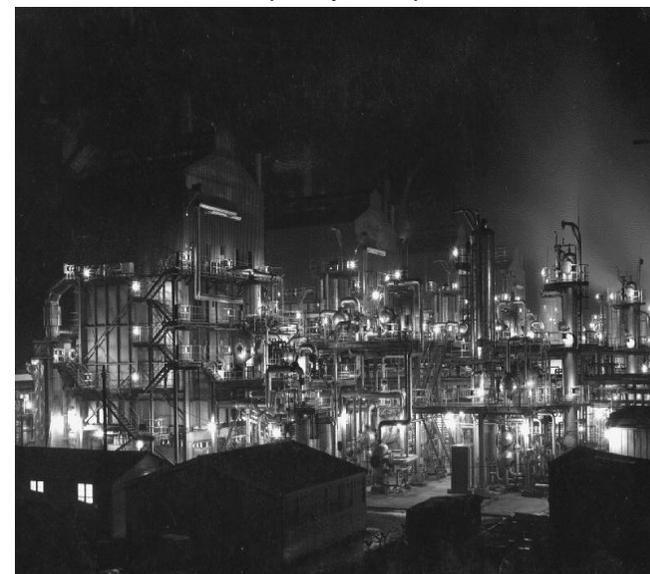
The Micro-Simplex (MS) process was developed jointly by Gaz de France and Messrs Stein and Roubaix to reform hydrocarbon and liquefied petroleum gases. The process used a nickel catalyst. Later MS plants were developed to operate on light distillates including naphtha and primary flash distillate. It produced a gas with a low CV of  $11.9 \text{ MJ/m}^3$  ( $320 \text{ Btu/ft}^3$ ), producing small amounts of tar which could be removed by electrostatic precipitators or deposited in dry purifiers.

### UGI/CCR Process

The Cyclic Catalytic Reforming Process (CCR) was developed by United Engineers and Constructors and the United Gas Improvement Company (UGI) of America. One of the earliest cyclic reforming processes developed using a nickel catalyst, it was used to produce a lean gas with a CV of  $11.1\text{-}13.0 \text{ MJ/m}^3$  ( $300\text{-}350 \text{ Btu/ft}^3$ ). It was later developed to use light distillate and kerosene as a feedstock and would be enriched by natural gas or liquid petroleum gas. The gas yields and by-products produced were similar to those plants mentioned above. A wide range of other oil gas processes were developed.

### Continuous Catalytic Reforming of Petroleum Gases and Light Distillate

A range of continuous catalytic reforming processes (Photograph 58) were developed. These processes continuously reformed hydrocarbon feedstocks with a low sulphur content at pressures ranging from atmospheric to 40 atmospheres and at temperatures between  $700\text{-}950^\circ\text{C}$ . The gases produced usually consisted of hydrogen, carbon monoxide, carbon dioxide, some methane and undecomposed steam. These processes did not produce tar, however some (Power Gas/ICI continuous reformer with enrichment by the gas recycle hydrogenator) did produce small amounts of benzole which were recovered and could be burnt to heat the reformer. If leakage occurred, the main potential contaminant from these processes would be the light distillates feedstock, although volatilisation would quickly take place.



**Photograph 58. Reforming plant at Ambergate, Derbyshire.**

## 6. The Composition of By-Products and Wastes Produced During the Manufacture of Gas

A number of by-products and wastes were produced from the processes used to manufacture gas. Most of the by-products from the gas-manufacturing industry were used elsewhere. During the history of the gas industry, there were times when the by-products had limited markets and required disposal. Sometimes these were disposed of on site or in tips. Some further information on the by-products and wastes produced are discussed in more detail below.

### 6.1 Coal Tars

In the early years of the gas industry, coal tar was regarded as a nuisance. Its main use was as a fuel. It could not always be sold, so would have been dumped on site or in available tips. Later, in the course of the history of the industry, the market for coal tar would disappear and it needed to be disposed of. In these situations, the coal tar was sometimes dumped on site and allowed to drain in the ground in areas of wasteland on or near the gasworks. Such areas are characterised by a thick layer of tarry pitch at or just below the original ground level. The thickness of the tar can be mistaken for tarmac.

Coal tars are a complex mixture of organic compounds. The exact composition of the coal tar was dependent on many factors, the most important being the type of retort, temperature of retort, and type of coal used.

In terms of elemental composition, coal tar is approximately 86% carbon, 6.2% hydrogen, 1.8% nitrogen, 1% sulphur with the remaining 5% being composed of oxygen and metallic and inorganic components of ash. In terms of the types of

compounds present, the composition is given below.

Saturates	15%
Aromatics	37%
Resins	42%
Asphaltenes	5%

The US EPA 16 Polycyclic Aromatic Hydrocarbons (PAH) are thought to compose approximately 17% of the coal tar. There is also entrained free carbon within the tar, which can be as much as 22%.

The main contaminants of concern within coal tar are:

- PAH
- Phenolic compounds (e.g. phenol, cresol, xylenol etc)
- Benzene, toluene, ethyl benzene and xylene (BTEX) compounds
- Aromatic and aliphatic petroleum hydrocarbons
- Oxygen, nitrogen and sulphur heterocyclic compounds, e.g. carbazole, dibenzofuran, azobenzene, carbon disulphide
- Inorganic components, ammonium, cyanide and sulphur-based compounds

The most predominant fraction of coal tar (approximately 67% on average) is, however, 'medium pitch'. This is solid at room temperature and relatively inert chemically and toxicologically. Therefore, these contaminants of concern do not form the majority of the composition of crude coal tar.

Coal tar was distilled on some gasworks, either in relatively crude stills or much more advanced fractionating plant which would split the coal tar into specified fractions according to temperature range, an example is shown below:

- 2-8% light oils (mainly benzene, toluene, xylene)
- 8-10% middle oils (mainly phenols, cresols, and naphthalene)
- 8-10% heavy oils (naphthalene and derivatives)
- 16-20% anthracene oils (mostly anthracene)
- 40-70% pitch

Once distilled, the resulting fractions had quite different properties, the lightest being Light Non Aqueous Phase Liquid (LNAPL) oils and the heaviest being pitch, which would set solid at room temperature. These fractions were sold for further processing into tarmac or products such as tar oil wash for fruit trees (Photograph 59) or a host of other uses as shown in Figure 24.



**Photograph 59. Spraying apple trees with tar-oil.**

Should these fractions be present in the ground on gasworks, then their fate and transport would vary significantly from crude coal tar.

On small gasworks, coal tar was sometimes mixed directly with clinker/aggregate to produce a rudimentary form of tarmac. Such tarmac would take a long time to set as it still contained volatile and semi-volatile components, which were liquid at standard air temperature and pressure. This problem could be avoided by using a tar dehydration plant, where the coal tar would be heated to drive off the volatile and semi-volatile components, making the tar more solid at standard air temperature and pressure.

Coal tar may be found in the ground around buildings, condensers, scrubbers/washers, tar wells/tanks and the pipes connecting the aforementioned. Coal tar may also be found in the base of tar tanks and gasholders. Coal tars are predominantly Dense Non Aqueous Phase Liquids (DNAPLs), although LNAPLs were also produced.

As mentioned in section 4.4 on coke ovens, a few low-temperature coke ovens operated in Britain, and these would have produced coal tars of a different composition. The most notable issue would have been the formation of polychlorinated dibenzodioxin congeners, compounds which would not normally be found in the by-products of higher temperature gas-making or coke-making processes.

## 6.2 Ammoniacal Liquors

Ammoniacal liquors were removed in the hydraulic main, foul main and condensers and also produced by spraying the gas with water in the washers and scrubbers. This dissolved the soluble ammonia and phenolic compounds in water. The ammoniacal liquor consisted of up to 1% ammonium and a lower concentration of sulphate, phenol, ferrocyanide and thiocyanate.



**Photograph 60. A tanker used for spraying ammoniacal liquor on agricultural land.**

Ammoniacal liquor could be used directly or diluted as a liquid fertiliser (Photograph 60) if there was an immediate local need, although this was often not practical.

As there was a low concentration of recoverable products in the liquor, it was often heated in a concentrated ammoniacal liquor plant. The

concentrated liquor was then sent to a chemical works for processing to make ammonium sulphate fertiliser (Photograph 61).

Ammoniacal liquors may be found in the ground around scrubbers/washers, tar wells/tanks, pipes connecting the aforementioned and also in the base of tar tanks and gasholders



**Photograph 61. Bagging sulphate of ammonia fertiliser.**

### **6.3 Blue Billy, Foul Lime and Spent Oxide**

Blue Billy, foul lime and spent oxide were all wastes of the gas purification process which would remove sulphur, cyanide and organic sulphur compounds from the gas. Blue Billy was the waste produced from reacting the gas with wet lime; foul lime was the waste produced from reacting the gas with hydrated lime; and spent oxide was the waste produced from reacting the gas with iron ore. Both foul lime and spent oxide are likely to be encountered on former gasworks sites, but Blue Billy is less likely. These processes were discussed earlier in the section on purifying the gas.

The cyanide present in spent oxide (Photograph 62) formed up to 6% of the total

weight and is predominantly in the form of thiocyanate and complex metal cyanides. Spent oxide also consists of approximately 3-9% iron, 0.08-0.36% manganese, 2-3% sulphate and 36-60% free sulphur. Spent oxide was often used as a weed killer. The amount of cyanide, sulphur and sulphate within foul lime was similar to that for spent oxide.



**Photograph 62. Spent oxide in soils at a former gasworks. Source: Russell Thomas.**

Foul lime and spent oxide may be found in the ground near the purifiers and land used to revivify the spent material. They may also be found in any location where ground levels have been raised. Their presence may be detected by blue staining on walls and paving and stunted growth in vegetation.

### **6.4 Ash/Coal Dust**

Ash was the waste material remaining after the coal or coke had been burnt in the furnace; it contained heavy metals (e.g. As, Pb, Cu, Cd, Ni, Zn) though generally only at low concentrations.

Ashes were often used for raising ground levels or for use on cinder paths. Coal dust, although not a significant contaminant from a gasworks, would have elevated concentrations of PAH including benzo(a)pyrene.



**Photograph 63. Disposal of waste ash in a former canal basin.**

Ash/coal dust may be found in the ground close to the retort house/coal store and anywhere that ground levels have been raised (Photograph 63).

### **6.5 Coke**

Coke was the useful solid remaining after gasification. It was sold for domestic and industrial use (Photograph 64). It was almost a pure form of carbon, although it would also contain metalliferous and inorganic components, depending on the original composition of the coal. The amount of these additional substances, which would not combust, would be called the ash content.

The substances would include metals such as arsenic and lead, which would concentrate in the ash once burnt. The ash was used for burning in fires to heat domestic properties. Hard coke was

produced in horizontal retorts and was most suitable for use on blacksmith's hearths and enclosed stoves.



**Photograph 64. Loading coke onto a wagon.**

## **7. The Environmental Legacy of the Gas Industry**

Over 4,000 gasworks were built in Great Britain, which have left a considerable environmental legacy. The manufactured gas industry is now largely a footnote in Britain's history, with little visible evidence of its past on the landscape. The last remaining gasholders are gradually being decommissioned, removing the final traces. It should be noted that coal carbonisation does still continue at the few remaining British coking works.

Most of the former gasworks land is now subject to different ownership and uses, from supermarkets to residential properties. Some sites have been remediated, others have not, and some have been partially remediated. The main route for remediating former gasworks has been redevelopment through the planning system; this

requires them to be investigated and, if required, remediated to make them suitable for their intended use.

The local authority has a duty to investigate contaminated land. It may inspect former gasworks sites using its powers under Part 2A of the Environment Act 1990 to ensure they do not pose a Significant Possibility of Significant Harm (SPOSH) to those living on, working on or visiting the sites.

There is also a requirement to ensure against Significant Pollution of Controlled Waters (SPoCW) or Significant Possibility of Significant Pollution of Controlled Waters (SPoSPoCW), possibly involving the Environment Agency or Scottish Environmental Protection in investigating the site. Controlled waters include important ground or surface water resources.

If a desk-based preliminary risk assessment gives the local authority sufficient concern that the site could be contaminated, an intrusive investigation would be required. This would involve the excavation of hand-dug trial pits into the shallow soil, machine excavated trial pits (where suitable), and the excavation of boreholes into deeper strata. Hand-dug pits are used to assess the immediate risk from potential contamination in the top 500mm of soil. The machine-excavated trial pits and boreholes are used to investigate deeper structures such as underground tar or gasholder tanks. Boreholes are installed to assess the pollution of groundwater, or the risk of gases or volatile substances escaping from the soils.

Tar tanks are often the major concern on former gasworks and dealing with these to remove any remaining coal tar can be a key part of most gasworks remediation jobs.

Where an intrusive investigation of a former gasworks has identified SPOSH or (SPo)SPoCW, remediation would be required to break the pollutant linkage(s), often by removal or treatment of the pollutant source. A number of former gasworks sites have been inspected and remediated through this route.

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change of chemical composition and physical phase, and is irreversible. In general, pyrolysis of organic substances produces gas and liquid products to leave char, a solid residue richer in carbon content. Extreme pyrolysis, which leaves mostly carbon as the residue, is analogous to carbonisation.

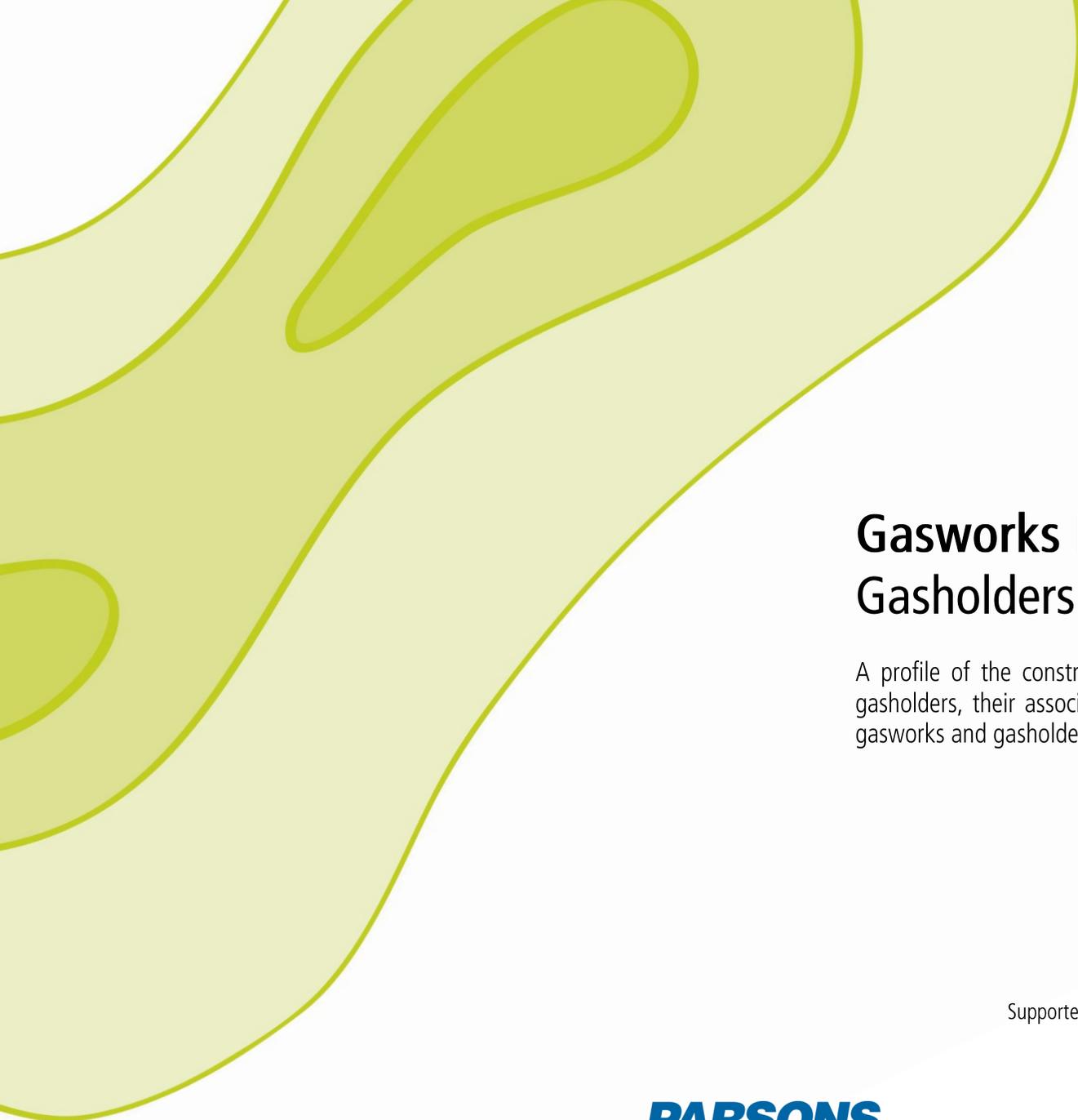
### **Appendix 1: Description of Carbonisation, Gasification and Pyrolysis**

In the manufacture of gas, three words are often used in describing the process, sometimes interchangeably: carbonisation, gasification and pyrolysis. These are described below.

Carbonisation is the destructive distillation of a substance (e.g. coal) by heating it in a closed container (e.g. retort) in the absence of oxygen and collecting the volatile products (e.g. coal tar). The carbon content of the material being carbonised increases in the final product. The solid residue of coal carbonisation is coke, which is largely composed of carbon and mineral ash residue.

Gasification is the process of changing a substance into gas form from solid or liquid form. It is a process that converts organic or fossil-based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures ( $>700^{\circ}\text{C}$ ), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas is called syngas or producer gas. Coke is gasified during the water gas process.

Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. It involves the simultaneous



## Gasworks Profile B: Gasholders and their Tanks

A profile of the construction and operation of different types of gasholders, their associated tanks and their occurrence on former gasworks and gasholder station sites.

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## Gasworks Profile B: Gasholders and their Tanks

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### Gasworks Profiles

Gasworks Profile A: The History and Operation of Gasworks (Manufactured Gas Plants) in Britain

Gasworks Profile B: Gasholders and their Tanks

Gasworks Profile C: Water Gas Plants

Gasworks Profile D: Producer Gas Plants

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## 1. Introduction

Although gasholders seem simple, the complexity and ingenuity of these structures should not be underestimated; they are the result of complex engineering design which was gradually refined and improved. This profile is limited to a brief description of the different designs of gasholders, their operation and, importantly, their tanks.

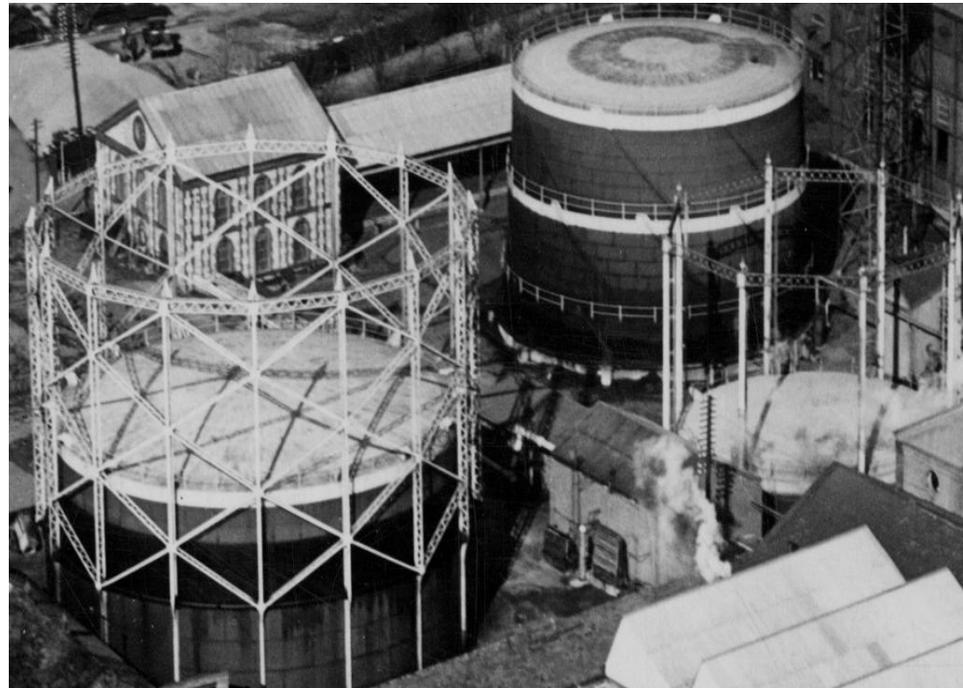
Gasholders are the only remaining distinctive feature of a gasworks to still be visible. These structures are characterised by a series of large interconnected (telescopic) cylindrical vessels (lifts) which would rise and fall, depending on the volume of gas stored. The number of operational gasholders has gradually decreased over the past 10 years, and now no gasholders remain in active service within the gas industry. This is because low-pressure gas storage is no longer required, as improved storage capacity has been created elsewhere in the gas network.

A few hundred gasholders still remain today. These are mothballed and awaiting demolition, unless protected by listed status. The gasholder shown in Photograph 1, situated in Fulham, London, is a listed structure and the world's oldest surviving gasholder.

The tanks of former gasholders are often still present on many former gasworks sites, infilled and hidden beneath the ground. During demolition, the tank void formed a ready-made repository for rubble and waste; as such, it can be a potential source of pollution, posing a risk to human health and the water environment.



**Photograph 1.**  
The world's oldest remaining gasholder at Fulham, attributed to Samuel Clegg.



**Photograph 2.**  
Evolution of gasholders on a former gasworks. Bottom right: cast iron column guided. Bottom left: steel guide framed. Top: spiral guided. Source: IGEM PHI

## 2. Gasholders in a Historical Context

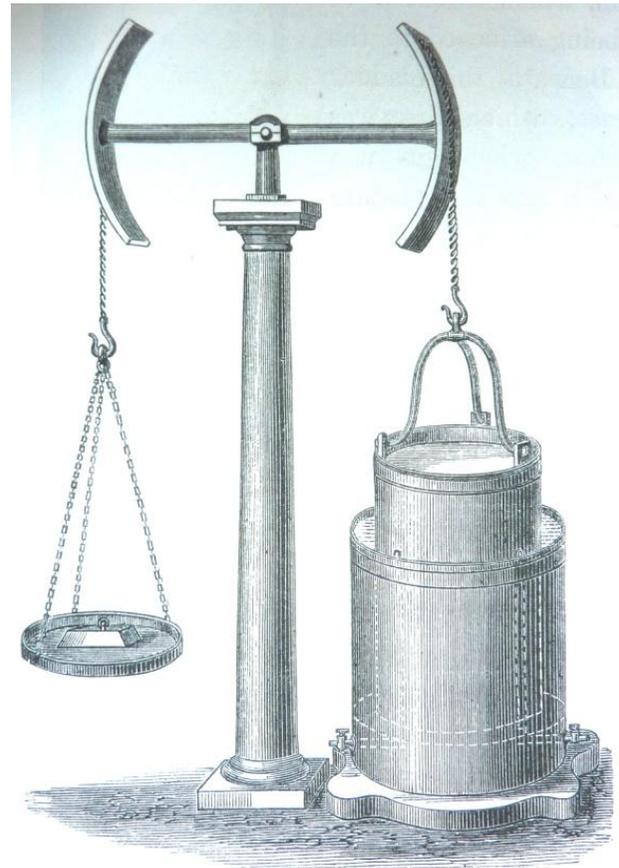
The word 'gasometer' is commonly found on historical Ordnance Survey maps dating back to their first editions. The term can even be found on older tithe maps. It was a term used by the lay person, never the gas engineer. It originated from the instrument that Antoine Lavoisier developed to store and supply a uniform stream of oxygen for his experiments and is shown in Figure 1. This had many of the later features of a gasholder for storing coal gas.

In terms of coal gas storage and supply, gasometer was an incorrect term. They were not used to measure gas, as that was the role of the gas meter, although they did give a crude visual indication. They were designed to fulfil the role of a gas storage vessel (gasholder). The term gasometer was used in early gas texts, such as Samuel Clegg Junior's *A Practical Treatise on the Manufacture and Distribution of Coal Gas*, but not in later gas engineering texts.

Many old structures marked as gasometers on maps were adjacent to mills, factories, hospitals and country houses and were associated with small gasworks (Figure 2). The gasworks themselves were often not specifically marked on maps. Where a gasometer site is shown, it is likely to be a small gasworks, with the production plant located in a nearby building or complex of outbuildings. A detailed review of the history and operation of gasworks can be found in *Gasworks Profile A - The History and Operation of Gasworks (Manufactured Gas Plants) in Britain*.

Many of the factory and mill gasworks date back to 1805-1830 when the gas industry was in its infancy. At this time, William Murdoch, Samuel Clegg and their gas engineer contemporaries were overseeing the construction of small

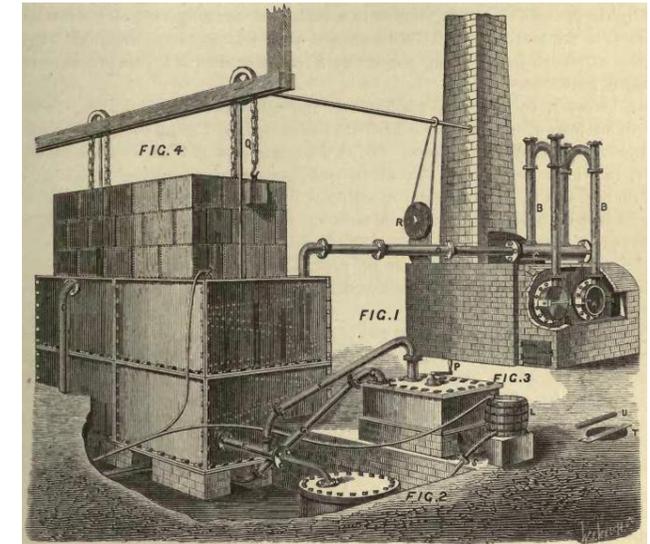
gasworks for factory owners. These followed the success of gas installations at the mills of Phillips and Lee (Salford, by Murdoch) and Henry Lodge (Sowerby Bridge, by Clegg) in 1805.



**Figure 1. A drawing of the gasholder developed by Antoine Lavoisier, which appeared in his work 'Opuscules physiques et chimiques'. From King's Treatise Vol. II, 1879.**

The philosophy of building small gasworks for a single establishment was initially successful, but these small gasworks gradually lost favour to the concept of centralised gasworks with distribution mains supplying a larger number of customers. This idea was principally promoted by the

German Friedrich Winzer who, to gain acceptance in Britain, anglicised his name to Frederick Winsor. In 1812, Winsor helped establish the first gas company to provide a public supply, the Gas Light and Coke Company.



**Figure 2. The gasworks built by Clegg for Ackerman, a famous London printer, indicating the retort setting (Fig.1), tar receiver (Fig.2), lime purifier (Fig.3) and gasholder (Fig.4). From the Journal of Gas Lighting.**

Whilst many of the factory and mill gasworks appeared small, they often produced more gas than many of the village and town gasworks, given the number of lights they needed to supply. This was because an adequately lit mill using the simple burners available at the time could have required many hundreds of burners throughout the mill and associated properties, compared to a village gasworks with 20-30 street lamps and 30-40 customers.

These mill and factory gasworks disappeared for economic rather than technical reasons. The larger gasworks established in industrial towns could supply many mills at a much lower price than the mill owners could achieve within their own gasworks. The isolated mills, hospitals and country houses (away from a mains supply) kept their gasworks (and gasholders) much longer, but would later transfer to mains gas when it reached them, or move to an alternative form of gas (e.g. acetylene) or electricity. A few mill gasworks did evolve into the main town gasworks for their area, and many others provided a limited public supply through a limited local gas mains, which was often absorbed later by the local gas company.

Gasholders have been a feature of gasworks ever since they were first constructed; examples of such early gasholders can be seen in Figures 2 and 3 and Photographs 1 and 3. The rectangular gasholder design shown in Figure 2 was used by Murdoch and Clegg in early gas installations.

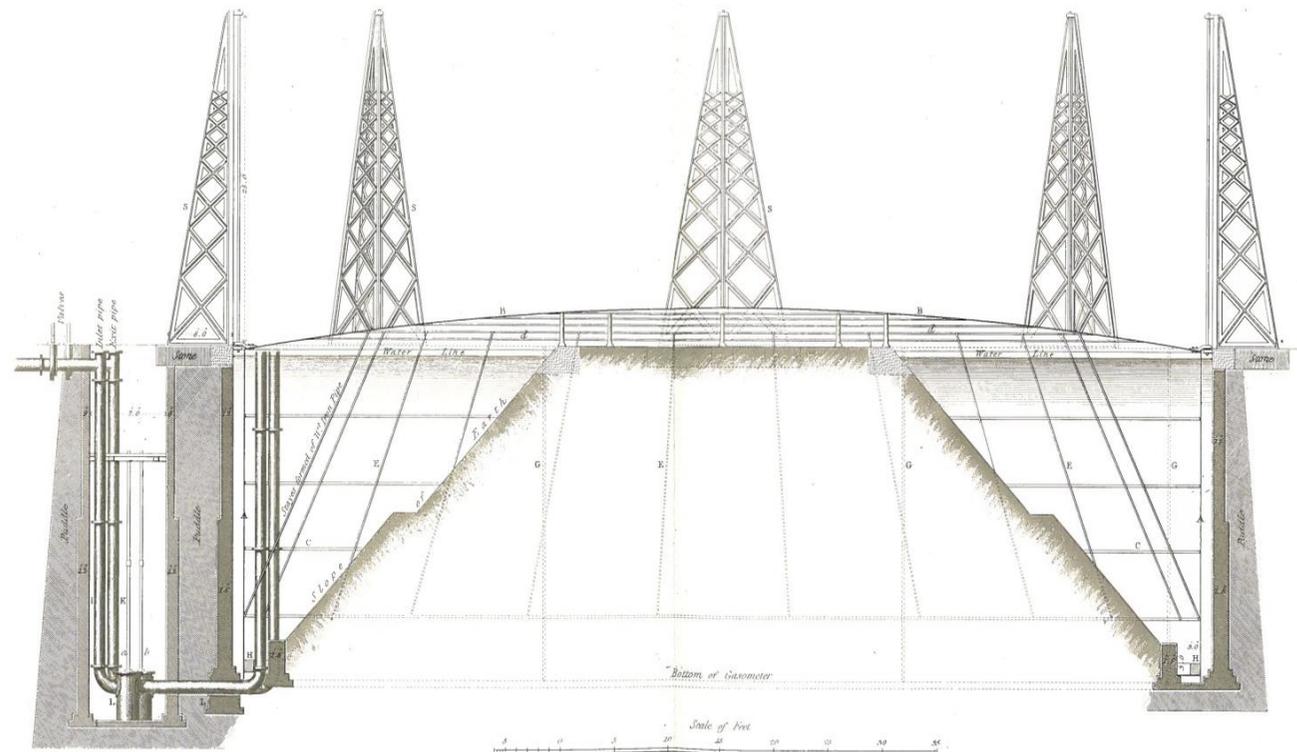
The gasholder consisted primarily of two parts: a tank which contained water, and a vessel or lift which would contain the gas. The purpose of the gasholder was more than just to store the purified gas; it acted as a crude visible 'meter', a buffer between production rates and the more erratic consumption rates and, until boosters were introduced, it provided the pressure in the gas mains for the distribution of the gas. The gasholder operated on the basic principle of a gas-filled floating vessel, rising and falling in a seal of water.

The main function of the water was to provide an elastic gas-tight seal in which the vessel could rise or fall. The water also received the whole of the pressure exerted by the weight of the vessel and, in this way, the water formed the necessary resistance to raise the vessel or expel the gas.

It was very important that the weight of the gasholder vessel was correctly calculated so that it would provide sufficient pressure to the gas in the mains with which it was connected.

It was not unusual for weights to be placed on the top of a gasholder to increase pressure. There are even stories of the gas manager and his family sitting on top of the gasholder at a small gasworks in order to provide the extra pressure at times of very high demand.

If the weight of the gasholder was too great, it would put increased back-pressure on the exhaustor. If an exhaustor was not used, the weight thrown by the gasholder would restrict the flow of the gas leaving the retorts, and the tar released from the coal would be degraded to carbon black in the retort.



**Figure 3. Design of an early gas holder taken from 'A Practical Treatise on the Manufacture and Distribution of Coal Gas' by Samuel Clegg Junior. This simple design shows many of the features common in later gasholders. Note the basic guiding of the gasholder vessel by metal brackets with eyelets running on cylindrical metal bars; these were later replaced by guided rollers.**



**Photograph 3. The primitive gasholder at the first small gasworks at the Soho factory of Bolton and Watt.**

The first gasholders were rectangular and over-engineered, being constructed of iron with a heavy wooden frame, and holding about  $14 \text{ m}^3$  ( $500 \text{ ft}^3$ ) of gas. At this time, the gasholder tank was used to condense the tar from the gas, and to purify sulphur from the gas by adding lime to water in the tank. This early use of lime was ineffective due to the settlement of the lime. Rectangular gas holders continued to be built until 1815 when they were replaced by the

cylindrical design. These cylindrical gasholders were bigger and had a greater capacity than the rectangular tanks they replaced. The biggest problem with the new gasholders was the building of suitable tanks. At this time, the tanks were usually built above ground and constructed from wood. However, they were not particularly robust and were prone to leaking and collapse. The last of these wooden tanks was removed from the Gas Light and Coke Company's Brick Lane

gasworks in 1843. The great gas engineer Samuel Clegg developed some alternative forms of gasholder but none of these were an effective replacement.

By 1819, gasholders had reached capacities of about  $566 \text{ m}^3$  ( $20,000 \text{ ft}^3$ ) using iron or wooden tanks. John Malam, a gas engineer of the famous Malam gas-engineering dynasty, did much to improve cylindrical gasholder design by reducing the weight of the internal framing and using counterbalance weights and chains. Malam also developed a system where the gasholder was guided by a central rod and tube. This rod and tube system was used extensively on small gasholders, many such examples surviving until at least the 1870s. Brick tanks were introduced in 1818, with stone and concrete tanks coming later.

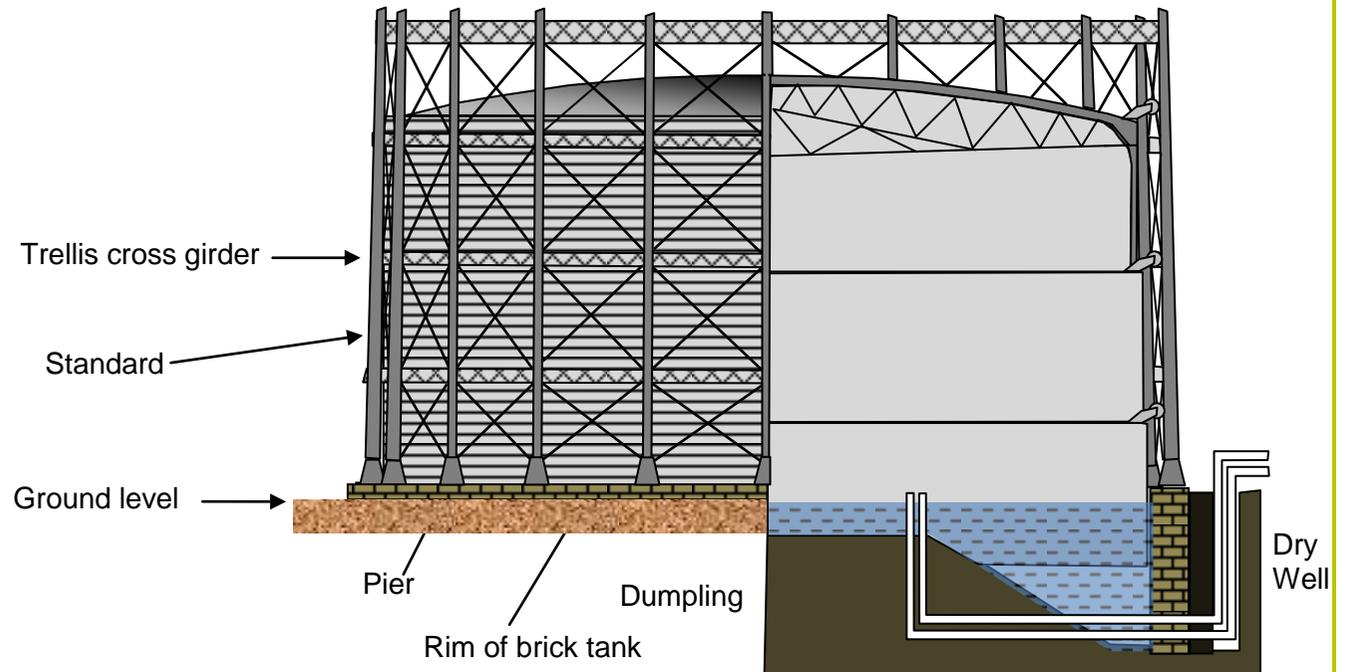
Their simple design and reliability saw the gasholder concept remain in use for over 200 years. Almost all gasholders worked on the same principle. The vessels or piston would rise and fall depending on the quantity of gas stored. It was the method employed to guide the movement of the vessel or piston that differed as the gasholder technology developed.

Originally, gasholders contained only a single vessel (lift) suspended within the tank; later, multiple-lift (telescopic) gasholders were developed. Telescopic gasholders allowed a much greater volume of gas to be stored in roughly the same footprint of land, making them more cost effective. When Samuel Clegg Junior wrote his treatise in 1841, he commented that telescopic gasholders were an expensive exception to be used only in highly constrained sites. They eventually became commonplace, with many earlier single-lift gasholders being extended to multiple-lift.

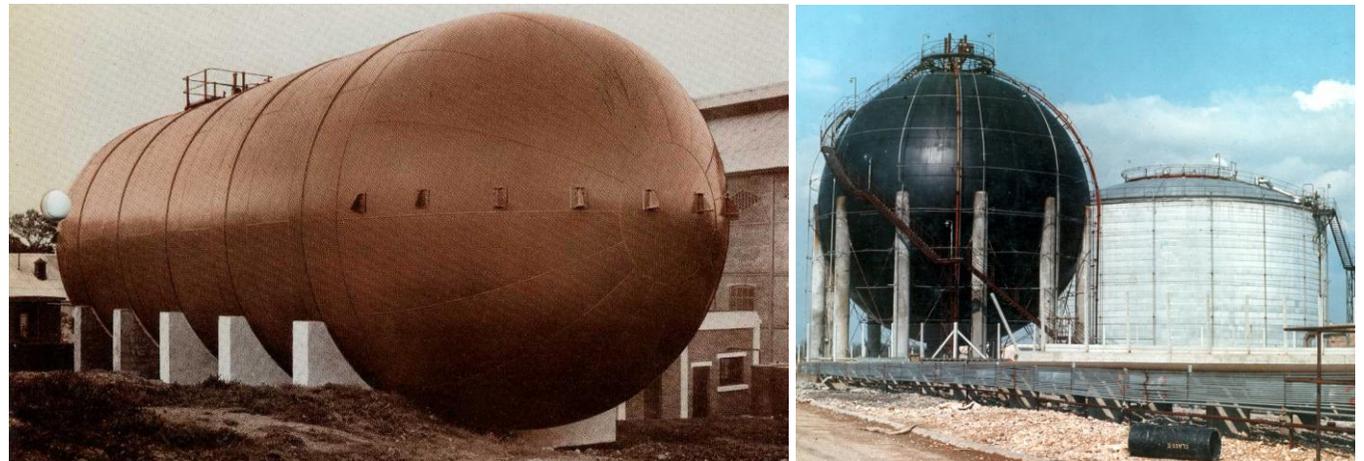
Gasholders could generally be classified under four main headings, namely:

- gasholders with vertical columns or guide-framing (Figure 4), which could be single-lift or telescopic, with or without 'flying lifts'
- gasholders guided by wire ropes or cables (rope-based systems appeared *circa* 1885 and were short lived)
- spiral-guided holders (single- or multiple-lift); the guide rails could be left-hand, right-hand or both, and either internal or external and attached to the lifts
- waterless or 'dry' gasholders which stored gas beneath a floating piston

Another later form of gas storage were high-pressure static vessels, which had no tanks or moving parts, and received and stored gas at much higher pressure than those listed above. These bullet-shaped or spherical tanks are shown in Photograph 4. In addition, in more recent years, gas has been stored within high-pressure gas mains, as liquified natural gas (e.g., Dynevor Arms, Wales) and within depleted gas fields (e.g., rough gas storage) or salt caverns (e.g., Holford, Cheshire).



**Figure 4. A schematic diagram of a guide-framed gasholder with a below-ground tank. Source: Russell Thomas.**



**Photograph 4. A high-pressure bullet-type gasholder (left, courtesy of the IGEM PHI) and high pressure sphere gasholder (right), behind which is a small LPG tank.**

### 3. The Housing of Gasholders

Early safety concerns over gasholders expressed by Sir Joseph Banks and members of the Royal Society, led to gasholders being limited in size and constructed in strengthened buildings. Known as a gasometer house, this was a separate superstructure built around the gasholder to protect it from explosions and the weather, especially lightning. The logic behind this was not entirely sound, as gas could leak from the gasholder into the air within the gasometer house, forming a potentially explosive atmosphere. They were phased out in the UK, but in Europe and North America, where cold weather brought the risk of freezing and high snowfall, ornate brick-built gasometer houses (Figure 5) were constructed. Examples in Copenhagen, Leipzig, Vienna and Warsaw are preserved.

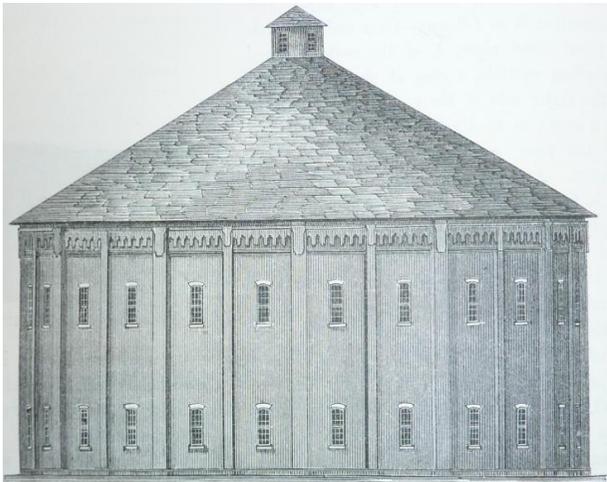


Figure 5. A gasometer house. From King's Treatise Vol. II, 1879.

### 4. Column-Guided Gasholders

Column-guided gasholders (Figures 6 and 7) were simple and generally reliable systems. As the name suggests, the weight and movement of the vessel lifts were supported by columns attached to the top of the gasholder tank. On the inside of these columns (facing the lift), guide rails were attached to ensure the rigid guiding of the lift. Guide wheels were attached to arms extending from the rim of the top of the lifts. The wheels would run up and down within the guide rail set in the columns.

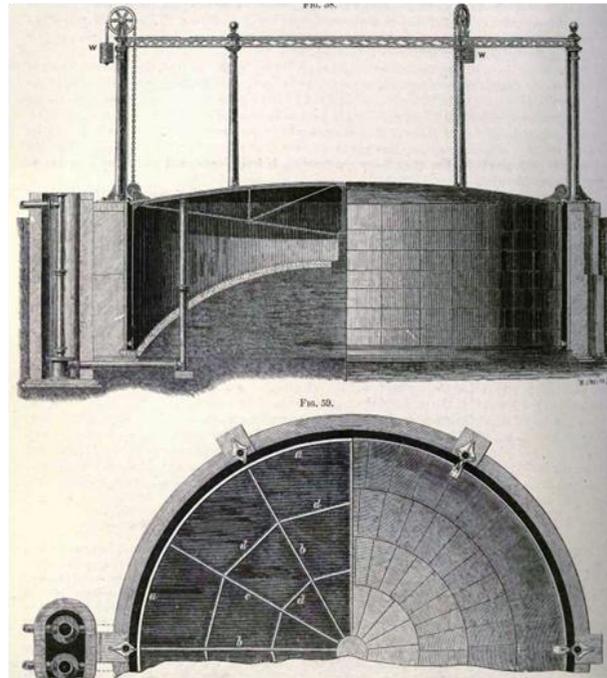


Figure 6. Drawing of an early single-lift gasholder with counterweights and a brick below-ground tank. From 'A Practical Treatise on the Manufacture and Distribution of Coal Gas' by William Richards, 1877.

The column-guided method proved the most successful, until advancements in the later 19<sup>th</sup> century.

Some very simple early gasholders were guided by a single central rod and tube as devised by Malam.

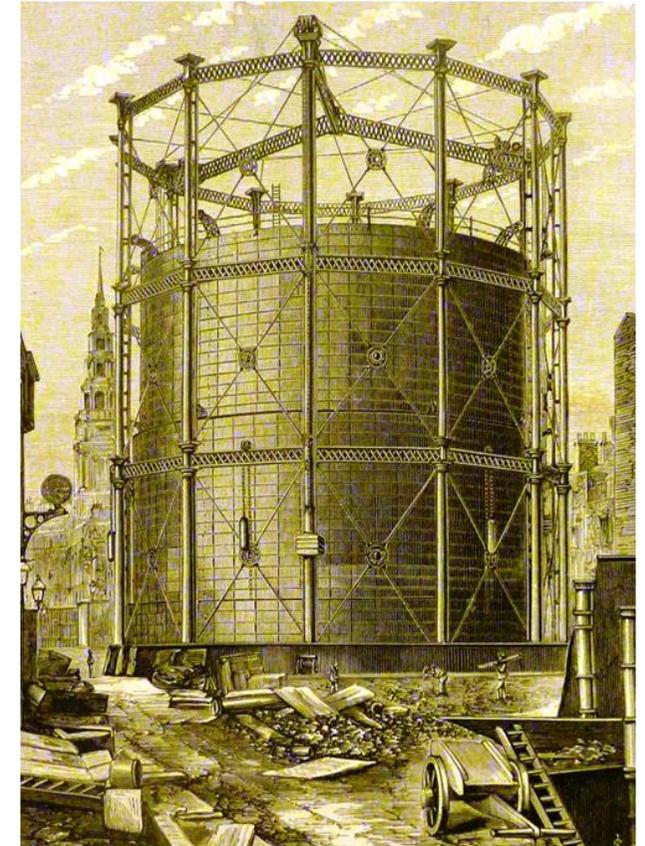


Figure 7. A three-lift column-guided gasholder at the City of London Gas Company's works at Blackfriars, London. From King's Treatise, Vol II, 1879.

Early examples of guided gasholders used cast-iron tripods as seen in Photograph 1 and Figure 3. These tripods were isolated from each other and used for small holders of 12-15 m

(40-50 ft) diameter by gas engineers such as John Kirkham. When larger gasholders were required, Kirkham connected the tripods using iron girders. The gasholder vessel moved up and down on brackets with a pierced eyelet which ran on cylindrical metal bars (Figure 3).

These columns would be attached to each other with heavy cast-iron or wrought-iron trellis cross girders, and bolted onto the piers of the gasholder tank. Given the considerable weight of the cast-iron columns, they were not suitable for very high gasholder frames (30 m/100 ft) as the piers required were large and costly. These cast-iron constructions were later superseded by structures composed of comparatively light rolled mild steel.

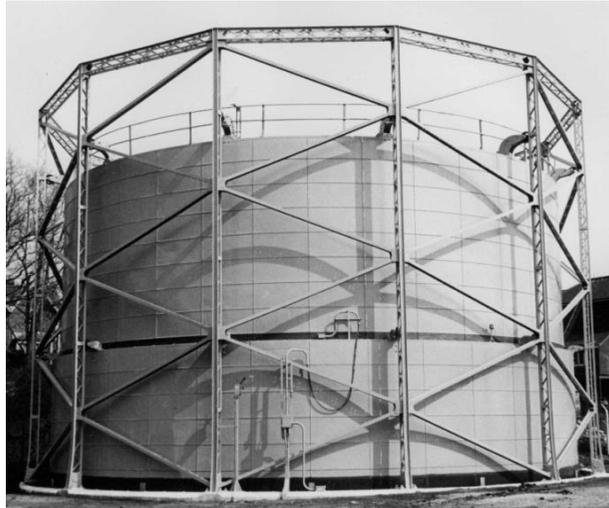
Early gasholders used counterweights (Figures 6 and 7 and Photograph 3) but these were largely phased out (apart from specialist situations). Whilst the counterbalances reduced the resistance to gas entering the gasholder, they also reduced the pressure of gas leaving the gasholder.

## 5. Guide-Framed Gasholders

Guide-framed gasholders were similar to the column-guided design (the two terms were often interchanged), except that a lighter and more extensive framework was built around the gasholder, forming an outer cylinder of structural steel or ironwork. The guide frame was attached to the outside of the above-ground tank or to the top of a below-ground tank by bolts onto the piers.

Vertical girders (known as standards) were intersected by horizontal girders and braced diagonally for extra strength (Figure 7).

An important development was Cutler's patented guide framing, which consisted of vertical standards braced by diagonal triangulated framing rather than horizontal girders (Photograph 5).



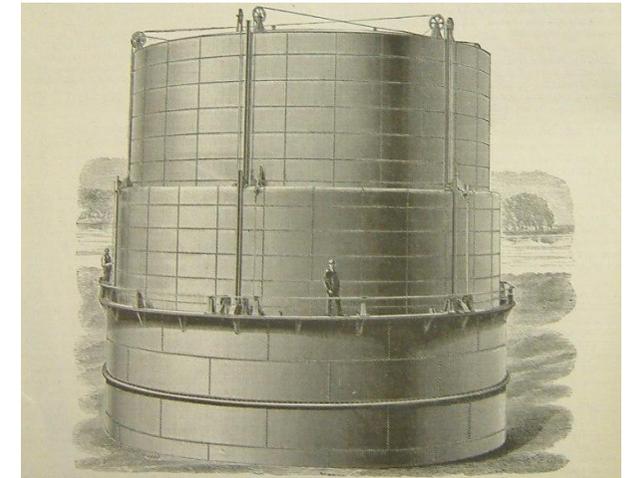
**Photograph 5.** A two-lift frame-guided gasholder with below-ground tank, using Cutler's patented system, Southern England. Source: IGEM PHI.

In general, the more modern the gasholder, the lighter the material used to construct the guide framing. The gasholders moved up and down the guide rails on wheels in a similar fashion to the column-guided gasholders, with the guide rails on the standards rather than on the columns. Some early examples were known to have been constructed using wooden frames.

## 6. Cable-Guided Gasholders

Wire-rope or cable-guided gasholders used a complex arrangement of at least three separate cables for a single-lift gasholder which stretched via a series of pulleys from the top of the

gasholder tank to the top of the gasholder vessel and back. This kept the cables taut and the floating vessel in position. They were invented in the 1880s by the Darlington engineer, Edward Pease. Figure 8 shows a two-lift example of a cable-guided gasholder.



**PEASE'S PATENT WIRE ROPE GUIDING**  
**Figure 8.** A cable-guided gasholder in an above-ground steel tank. From an old advert circa 1880.

Their use was short-lived (*circa* 1890-1910) as alternative designs proved more effective and reliable. They were retrofitted on some column-guided tanks where ground instability had caused the columns and tanks to move, and the gasholder to jam.

## 7. Flying Lifts

Both column-guided and guide-framed gasholders could be extended by inserting a flying lift, often, but not always (as in the case of Photograph 6) by adding a spiral-guided lift.

A flying lift was an additional inner lift retrofitted into the gasholder; instead of running within the

set columns or rails, the flying lift could extend above the columns or standards without being directly attached to them.

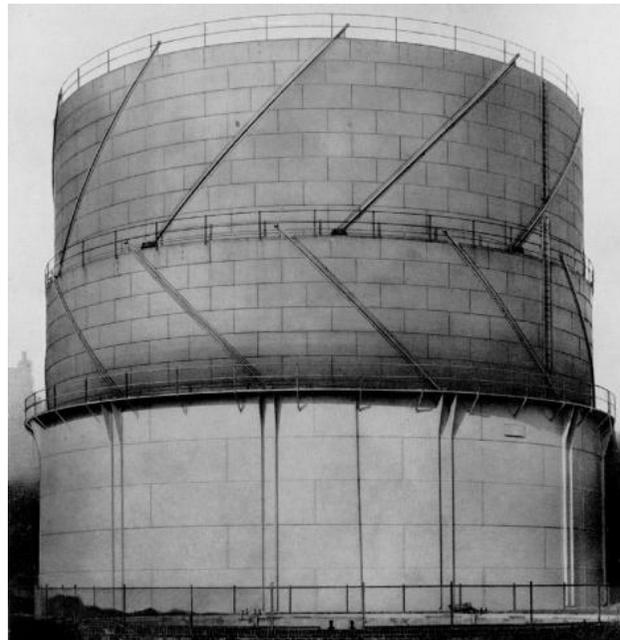


**Photograph 6. A gasholder fitted with a flying lift.**

This was a common practice for many years to quickly increase capacity on gasworks, but was later phased out. This method benefited from being relatively easy and cheap to retrofit without interfering with the existing guide frame or columns. The gas engineer would need to ensure the gasholder structure could withstand the additional weight and shear forces exerted by strong side winds.

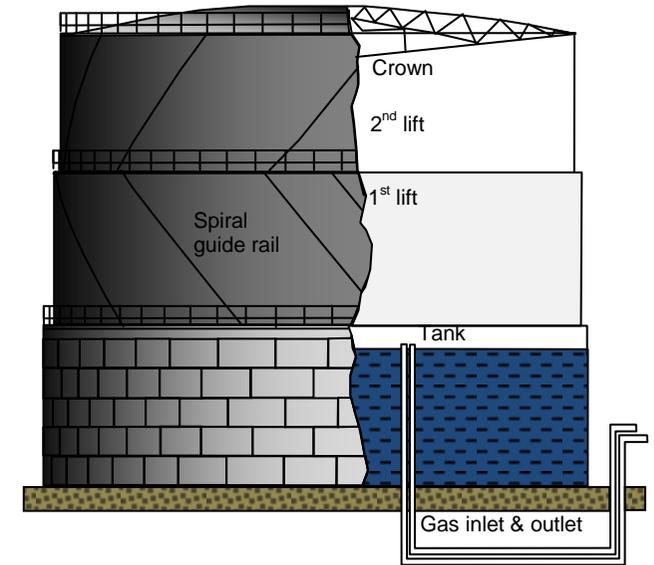
## 8. Spiral-Guided Gasholders

The spiral-guided gasholder concept was proposed by Mr W. Webber and invented by Mr William Gadd of Manchester. They were introduced into the UK in 1888. The UK's first spiral-guided gasholder was built in 1890 in Northwich, Cheshire, by Clayton, Son and Co Ltd. of Leeds. The spiral-guided gasholder dispensed with the external frame above the tank, with the lifts supported instead by spiral guiding rails fixed to the lifts (Photograph 7 and Figure 9).



**Photograph 7. Spiral-guided gasholder with two lifts in a steel above-ground tank.**  
**Source: IGEM PHI.**

The spiral guide rails engaged with rollers (two above and two below the rail) on the edge of the tank in such a manner that the bell moved up and down in a screw-like fashion (Photograph 8). The guide rails could be all left-handed, all right-handed, or successive combinations of both.



**Figure 9. Schematic of a spiral-guided gasholder with an above-ground tank, showing the internal detail and water level.**  
**Source: Russell Thomas.**

The rails on the outer lift were always fixed to the exterior of the lift, but those on succeeding lifts could be either interior or exterior, although the latter were used in preference.

Spiral-guided gasholders required more precise engineering and, as a result, the rollers were at greater risk of jamming than the other types of gasholders, if damaged. They were particularly at risk from the wheels freezing, which could lead to the catastrophic collapse of the lifts.



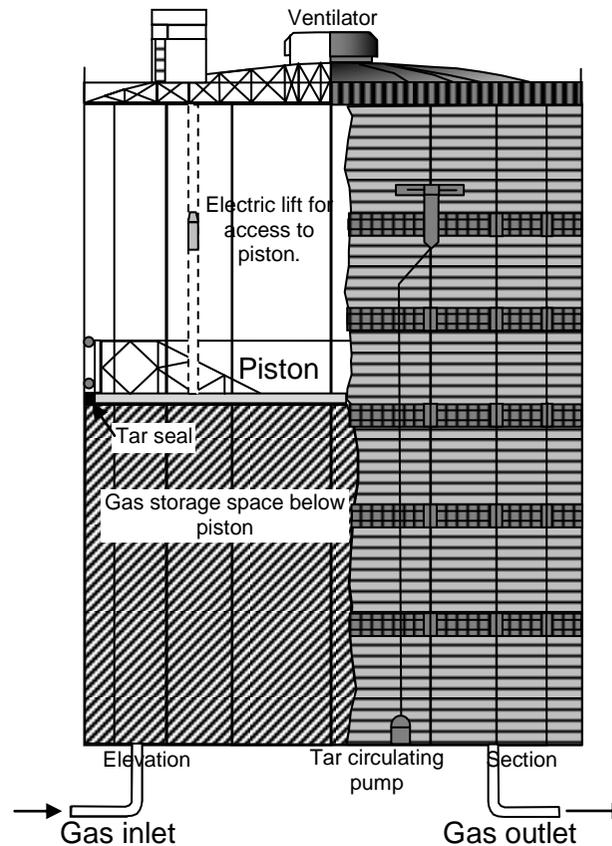
**Photograph 8. Multiple Roller Carriage which guides the upwards and downwards movement of the spiral gasholder. From *Modern Gasworks Practice* by Alwyn Meade.**

## 9. Waterless or Dry Gasholders

This design allowed for a simplified system, where the major moving part was the piston, dispensing with the need for the water seal and associated water-filled tank. The piston was able to rise and fall via the guide rollers. The outer cylindrical shell was dissimilar in appearance to other gasholders. The outer shell remained static, had the same diameter throughout, and the roof of the structure was permanently fixed.

The MAN (Maschinenfabrik Augsburg-Nürnberg AG) gasholder (Figure 10) was the first of the dry gasholders and was developed in Germany in 1915. The Klonne was another German dry gasholder design. The MAN and Klonne waterless gasholders had tar and oil/grease seals

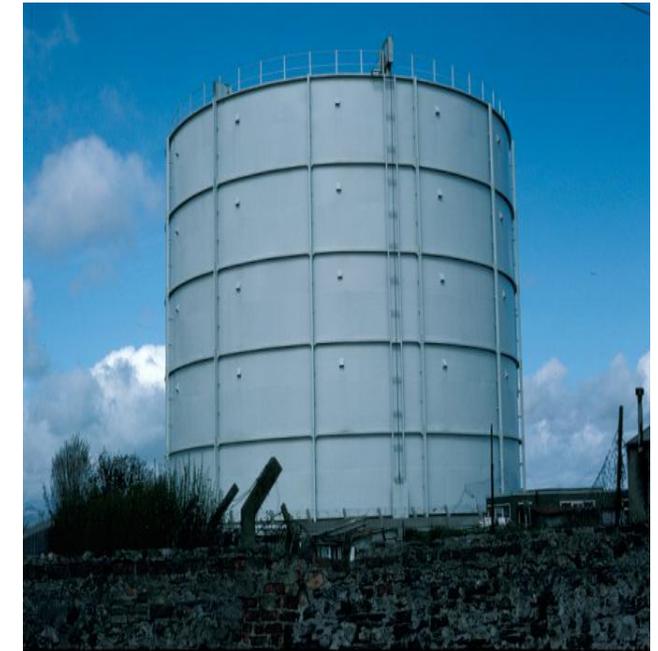
respectively; only the MAN required recirculation of the seal fluid.



**Figure 10. A MAN waterless gas holder. Source: Russell Thomas.**

These gasholders allowed the heavy water tanks used on water-sealed gasholders to be dispensed with, requiring less expenditure on foundations. Another benefit was that the gas remained dry. The MAN was polygonal in plan, and the Klonne was circular. There was a third equally important but different design: the Wiggins dry gasholder (Photograph 9). This American design is still popular and is used for gas storage for the steel, iron, and coke-making industries. The largest low pressure gasholders ever built were the Klonne

gasholder built in 1938 in Gelsenkirchen (Germany) which was 80 m (262 ft) in diameter and 136 m (446 ft) high and had a capacity of 594,000 m<sup>3</sup> (21,000,000 ft<sup>3</sup>) and the MAN gasholder built in 1934 in Chicago (USA) which had a capacity of 566,000 m<sup>3</sup> (20,000,000 ft<sup>3</sup>).



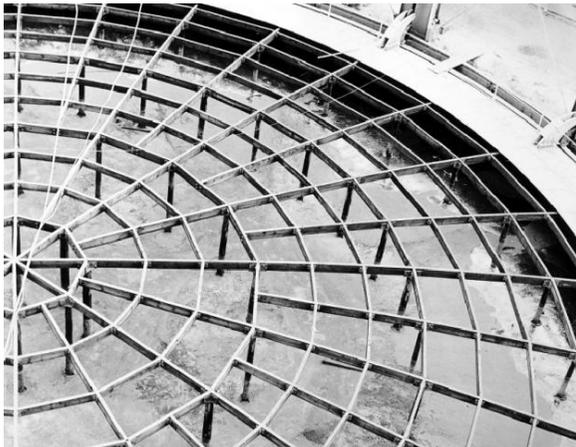
**Photograph 9. Wiggins type gasholder at Millom, England. Source: Mr Syd Bennet.**

## 10. Crowns, Cups and Dips

Due to the relative weakness of the dome (crown) of the gasholder vessel, support was required to prevent it from buckling when all the lifts were down and there was no gas pressure within the gasholder. In these cases, the crown required either its own internal frame (akin to the supports in an umbrella) to provide strength, or support from underneath to maintain its shape (a crown rest). Where an internal frame was used, this was still supported on a central column or pier. Trussing was generally limited to gasholders with

a diameter of 52 m (170 ft) or less, due to the technical limitations of the method.

The crown rest consisted of a series of radiating rafters carried on columns erected in the tank and connected by purlins to form a skeleton framework with the same shape as the crown. Earlier gasholders, especially very large examples, used a fixed timber framework (standing in the water tank) upon which the crown could be seated (Photograph10).

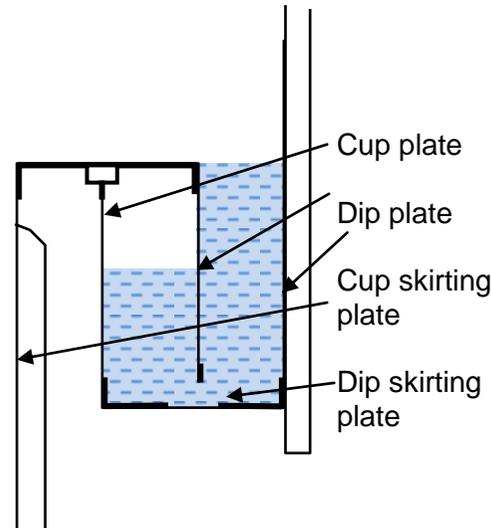


**Photograph 10. A gasholder with the sheeting removed from the crown, exposing the crown rest and water-filled tank.**

The cups and the dips (otherwise known as grips) were the semi-circular or square features which interlocked to form the seals at the edges of each lift (Figure 11). As the inner lift rose to its maximum, the cups and grips interlocked. The cup was sufficiently deep to form a gas-tight seal when filled with water.

The cups and dips were of similar size and ranged from 20-30 cm (8-12 in) wide and 40-60 cm (16-24 in) deep, depending on the size of the gasholder. They were in use prior to 1833, but it was in 1833 that the cup and dip system

was patented by Stephen Hutchinson. Originally they were built of wrought iron but were later replaced by mild steel, when it became available.



**Figure 11. A cups and dips (grips) arrangement. Source: Russell Thomas.**

The outer lift of a column or frame-guided gasholder had a different arrangement, having a bottom curb carriage at its base. This was originally referred to as a 'wooden curb', and its role was both simple and clever. It was constructed of Memel timber (pine), measured 30 cm x 30 cm, and extended around the base of the outer lift. Whilst submerged in the gasholder tank, the timber would add buoyancy to the lift. Once partially out of the water, it would act as a weight to stop the lift leaving the water tank and blowing the seal, diverting gas to flow to other gasholders not yet filled with gas. The lifts grounded on rest blocks of stone or concrete set in the annulus of the gasholder tank.

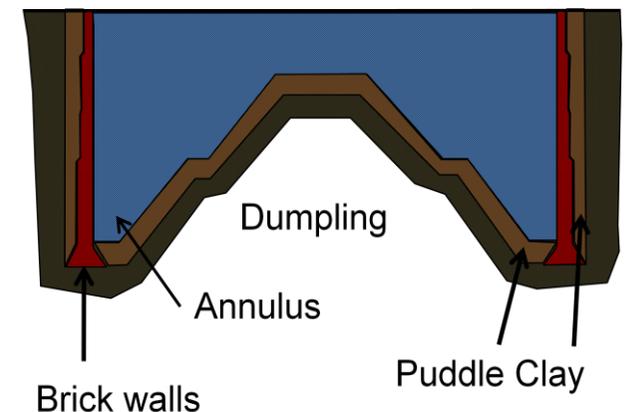
## 11. Gasholder Tanks

The gasholder tank was the part of the gasholder which would house the lifts when down (empty of

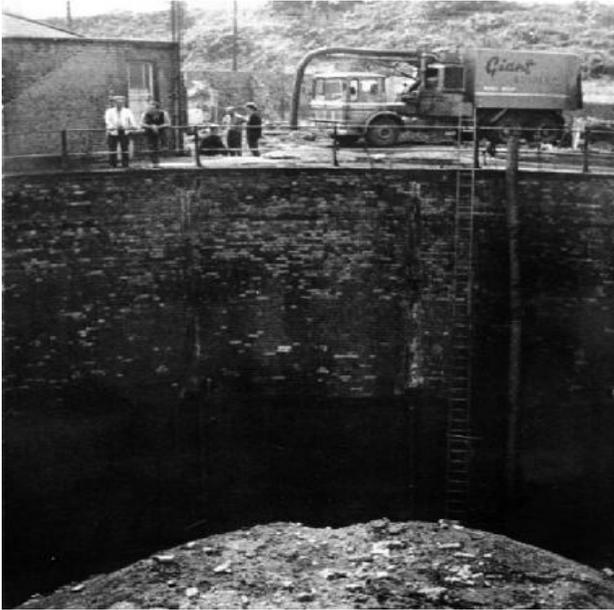
gas) and contain the water in which the lifts would rise and fall, depending on gas flow. The water functioned primarily as an elastic gas-tight seal. The tank was waterproofed to prevent water leakage. The gasholder tank could be below ground level (Figure 12), partially below ground level, or entirely above ground level, depending on the type of gasholder employed and the ground conditions.

The material from which a gasholder tank was constructed was dependent on the available local building materials and the ground conditions at the gasworks. Where a local source of good quality building stone was available, then this would have been used to build the tank. The most commonly used material for building below-ground gasholder tanks was brick (preferably low-porosity hard-burnt bricks). The full range of building materials for gasholder tanks comprised:

- stone
- brick
- mass or reinforced concrete
- cast or wrought Iron
- steel
- bedrock
- combination of the above (composite)



**Figure 12. Schematic of a gasholder tank with a dumpling and annulus. Source: Russell Thomas.**



**Photograph 11. A brick gasholder tank with dumpling visible at the base.**

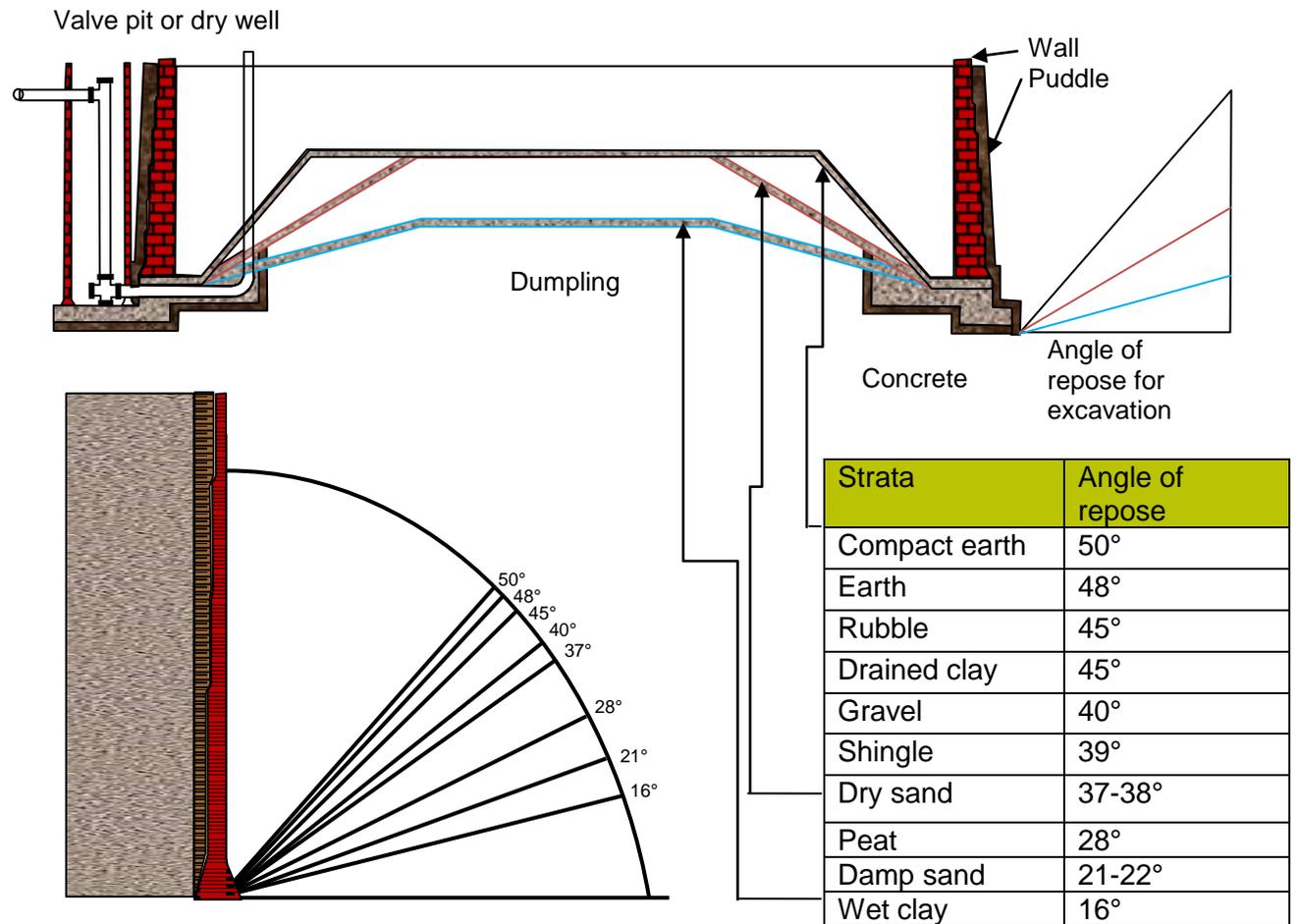
As brick or stone tanks were porous, the outer facing walls and base of the tanks were usually backed with puddle clay. The puddle could be pure clay, but it was thought preferable to mix clay with one-third sand, silt, or soil free from plant matter; this was firmer in texture and less liable to crack when dry. The puddle would be prepared outside of the trench and built up in thin layers as the wall of the tank was built; it was kept moistened, punned well, and backed up with carefully pounded earth.

An alternative method of waterproofing was through the application of 2.5 cm (1 in) render of Portland cement to the internal face of the tank. Applied successfully, this could make the puddle redundant and on such tanks puddle was not always used. The use of 11 cm (4½ in) bricks with a cement lining could also serve this purpose. Tanks built from waterproof concrete did not require rendering or puddle.

The excavations required for the construction of a gasholder tank were dependent on ground conditions. As can be seen in Figure 13, the safe angles of repose varied depending on the strata, with compact earth offering the steepest and wet clay the shallowest.

A few examples existed where gasholder tanks were hewn out of bedrock. Gasholder tanks at the Chester gasworks were constructed this way, and still required waterproofing.

Where ground conditions were favourable, it was more economical to leave a conical mound – known as a cone or dumpling (Photograph 11) – within the centre of the gasholder tank. In tanks whose diameters did not exceed *circa* 18 m (59 ft), it would be more economical to remove all the material if it required waterproofing, leaving a flat base, unless it was constructed in rock, stiff clay or chalk.



**Figure 13. The effect of ground conditions on the angle of repose when constructing an underground gasholder tank, showing angles of repose for different strata. Source: Russell Thomas.**

Occasionally, tanks were built by making a circular cutting in the ground and constructing an iron or brick annular channel to contain the water, with the intervening central space also being covered with a shallow layer of water (Figure 14). These were termed annular tanks. Sandstone versions of these tanks, made watertight with pitch of asphalt, have been found in various locations, including Liverpool and Chester which had suitably shallow and solid bedrock.



**Figure 14.** A schematic representation of an annular gasholder tank. Source: Russell Thomas.

The weakest point on a circular masonry tank was always the point at which the gas pipes entered and exited the gasholder. These pipes were used to transfer the gas to and from the gas mains to the gasholder, through the water seal. The gas pipes were generally situated within a recess in the tank walls; however, by passing through the wall, the wall circle was broken and the tank was weakened, making it more likely to fail. A recess was only used on small gasholder tanks in modern times, a dry well being preferred (as shown in Figures 3, 5 and 9). Methods used to minimise stress on the circular tank wall included the installation of iron struts or the use of square pipes built into the wall.

Large gasholder tanks required wall-strengthening methods which included layers of thick Portland cement, at 60-90 cm (2-3 ft) intervals, into which the brick or stone was



**Photograph 12.** Concrete foundation slab of an above-ground gasholder.

placed. As an alternative, hooped-iron or flat-iron rings were built at intervals into the wall.

If ground conditions made it very expensive to construct good foundations to build a tank, or there was a high water table in a porous strata (e.g., sand), then an above-ground tank would be used. Above-ground tanks were generally constructed of flanged cast iron (later, wrought iron or steel plates), bolted or riveted together and built on a reinforced concrete slab (Photograph 12). These tanks could be easily dismantled and reused elsewhere. Buried remains of these tanks are uncommon, except for tank bottoms and the first row of plates. If ground conditions were too unstable even for an above-

ground tank, then the concrete slab would require piled foundations. These above-ground tanks placed the gasholder in a more elevated position than an underground tank, putting it at greater risk from wind damage. They were therefore sometimes seen as an option of last resort. After *circa* 1920 it was unusual for below-ground tanks to be chosen; however, all gasholders were built on the most suitable design for the conditions encountered on that specific site.

## 12. Gasholder Site or Gasworks?

Not all sites containing gasholders were active gasworks. During the expansion and development of the gas industry and its



**Photograph 13. The famous Kennington Gasholder, backdrop to the Oval Cricket Ground.**

distribution network, some new sites were developed purely for the storage of gas; these were referred to as gasholder stations. These gasholder stations were developed either because there was insufficient room for the construction of new gasholders on the gasworks site, or new areas of supply had been developed and a new remote gasholder was required to store and distribute (via pressure of the gasholder) to this area. In larger cities, the

gasworks sometimes expanded to fill the entire footprint of the site, making it necessary for some or all of the associated gasholders to be placed elsewhere. Thus the Nine Elms gasworks had gasholders at Battersea, while Vauxhall gasworks had gasholders at the Kennington Oval (Photograph 13).

These gasholders would have been supplied with gas under a greater pressure (medium or

intermediate pressure) than used for local distribution (low pressure) from large centralised gasworks on the distribution network. From the early origins of the gas industry until about 1920, gas would have only existed in the mains at a low pressure of up to 40 mbar. Prior to the introduction of booster pumps, the only pressure to the gas mains was provided by the weight of the gasholder. Descriptions of gas pressure in the gas distribution networks have gradually changed over time as gas networks became more integrated at a local, regional and finally national level (Table 1).

The gasholders were connected to the low-pressure gas mains, which are used for local distribution to domestic properties and businesses. The intermediate-pressure and medium-pressure gas distribution systems are supplied from the high-pressure gas transmission system through Pressure Reduction Stations (PRS). PRSs also reduce the gas pressure from the intermediate- and medium-pressure mains into the low-pressure distribution system. The PRS is designed to ensure that the pressure in a gas main or gas service pipe does not exceed its maximum design pressure.

**Table 1: Different types of gas mains and their pressures.**

Type of Mains	Pressure
Low	0-75 mbar
Medium	75 mbar - 2 bar
Intermediate	2-7 bar
High	Above 7 bar
National Transmission System	85 bar

In addition to the gas distribution networks, there is a national transmission system (NTS) which operates at 85 bar. This transports gas around

Britain at a speed of approximately 25 miles per hour from North Sea gas fields, continental gas interconnectors, gas storage facilities and Liquefied Natural Gas (LNG) importation sites. The NTS supplies major industrial customers as well as the gas distribution networks.

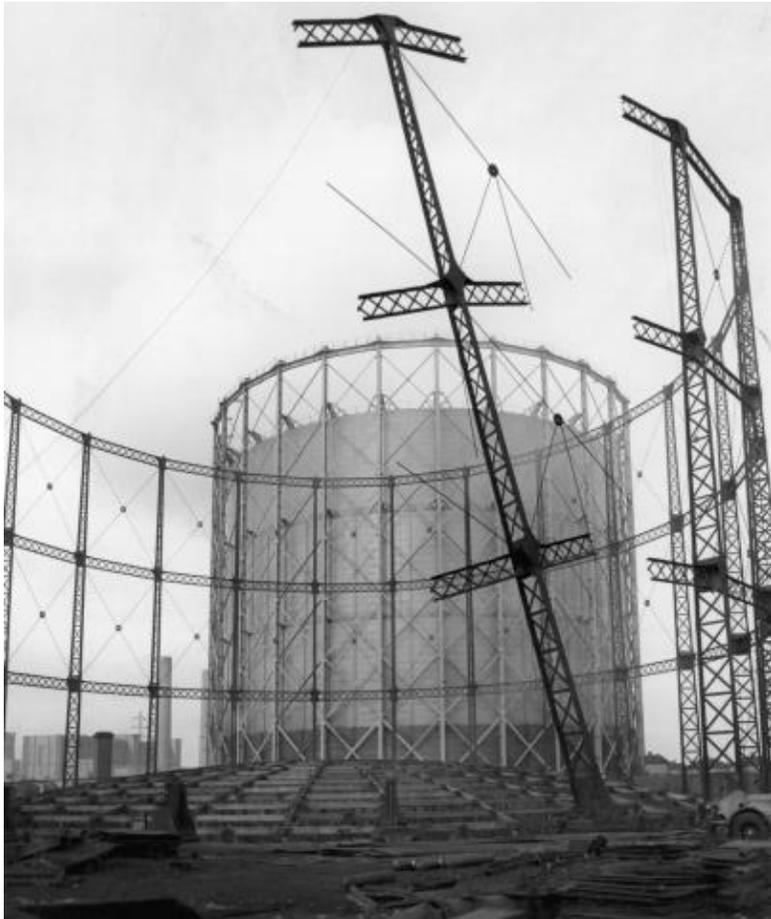
### 13. Demolition of Gasholders

As the demand for gas increased, so did the requirements placed on gasholders, whose size and capacity increased over time. Many early gasholders were replaced by larger models.

These redundant gasholders would have been decommissioned and filled in, decommissioned, removed and replaced by a larger gasholder, or the gasholder removed and the tank retained and modified for use as a tar tank.

Gas infrastructure developments in Britain meant the gradual disappearance of the requirement for low-pressure gasholders. From the 1950s onwards, many small gasholders (retained on small former gasworks sites to maintain local distribution) became redundant and were decommissioned. The local gas network was

instead supplied from a larger centralised gasholder station elsewhere. More recent developments in improving the gas networks across Britain have led to alternative storage capacity being developed in the gas mains, at storage sites such as depleted gas fields, salt caverns and LNG storage facilities. Coupled with the faster transmission of gas across the country, this has made low-pressure gas storage in gasholders redundant, leading to the decommissioning of gasholders across Britain.



Photograph 14. The decommissioning of a gasholder at Croydon in the 1970s. Removal of the guide-frame standards (left) and the partially infilled gasholder tank (right).

In simple terms, decommissioning would include the gas connections to the gasholder being disconnected and blanked off, and the gasholder purged of explosive gases. The outer horizontal trellises and each standard or column would be cut, then demolished individually as shown in Photograph 14.

The lifts would then be removed, with the crown being removed before the columns or standards. The iron or steel work would be taken as scrap for recycling and the money obtained used to offset the cost of the project. If below-ground tanks were present, these were often infilled with demolition rubble and any residual site wastes such as ash or spent oxide, a waste material from the purification of town gas. Gasholder tanks were ready-made landfills given their often watertight bases and side walls and were capable of being capped.

Tanks which contained a dumpling also contained an annular trench or annulus; this was located just inside the tank wall. The annulus would provide a flattened circular trench for the lifts to rest when the gasholder was empty of gas. It varied in size, but reviewing numerous records it appears that it was generally between 0.91 m (3 ft) and 1.82 m (6 ft) wide. Where encountered in infilled gasholders, they are generally found to contain a depth of 200-300 mm (8-12 in) of gasholder sludge as well as the rest blocks.

Recent gasholder demolitions have been undertaken to much higher environmental standards, with the gasholder tanks backfilled with a suitably clean aggregate or site-won materials with the appropriate geotechnical properties.

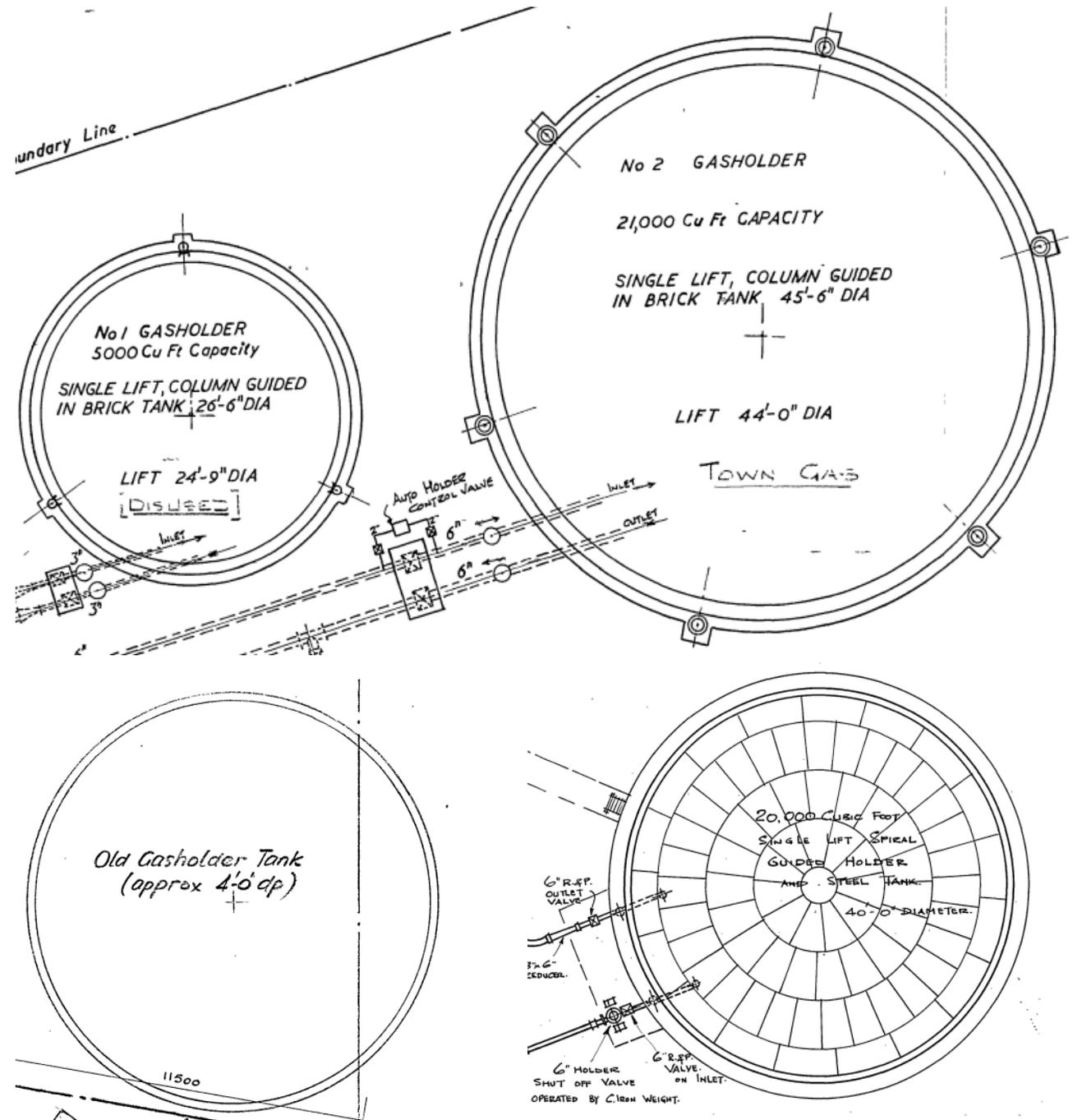


Figure 15. Examples of details of gasholders tanks found on gasholder plans.

## 14. Calculating the Size of Gasholder Tanks

The first task is to establish whether the gasholder tank was above ground (Photograph 15), partially below ground, or below ground.

This can be worked out from the information available for the gasholder, including plans, photographs and records. Records may show whether the tank was above or below ground and give the depth of the tank, its capacity and the number of lifts. If this information is not available, then the construction material provides an indication. Brick, stone and concrete tanks were normally used to construct tanks which were totally or predominantly below ground. Iron and steel were generally used for tanks which were above or predominantly above ground; however, they were, on occasion, also used for below-ground tanks.

Photographs provide a vital source of information, revealing the type of gasholder and the position of the tank. All types of gasholder (with the exception of waterless types) could have an above-ground (Figures 2, 8, 9, 10 and Photographs 2, 6, 7, 9, 12, 15, 16) or below-ground gasholder tank (Figures 3, 4, 6, 7, 12, 13, 14 and Photographs 1, 2, 3, 5, 11, 14). If a tank is not visible on the photograph, it can be assumed the gasholder had a below-ground tank.

An important point to remember is that even above-ground tanks had concrete slabs which could be buried significantly below ground level (approximately 1-1.5 mbgl) due to ground-raising activities on redeveloped sites. Waterless-type gasholders only had above-ground tanks (Figure 10 and Photograph 9).



Photograph 15. Construction of an above-ground steel tank.

### 14.1 Methods for Estimating the Depth of the Gasholder Tank with Limited Information

#### Single-Lift Gasholders

##### *Simple Ratio for Single-Lift Gasholders*

For single-lift holders the height of the vessel varied from 0.3 to 0.4 of the diameter of the tank. The height of the vessel was usually about 0.30 m (1 ft) shorter than the depth of the tank.

For example, a 20 m diameter gasholder would have a tank depth of between 6 m and 8 m.

##### *Calculation for Single-Lift Gasholders Based on Diameter and Capacity*

If the capacity of the gasholder and the diameter of the tank are known then the approximate depth of the tank can be calculated using the following equation (valid for metric or imperial units).

$(\text{Capacity} / (\pi \times (\text{radius})^2)) = \text{depth of tank (approximately)}$

This rough estimation for tank depth works better with single-lift tanks, but it can also be applied to multiple-lift tanks. It should be used along with other measures to calculate the potential tank depth. An assumption can also be made based on the graph in Figure 16.

### Multiple-Lift Gasholders

Each lift would have been of a similar depth; i.e., the depth of each lift is approximately equal to the total height of the inflated gasholder divided by the proposed number of lifts, due allowance being made for the depth of cups and grips. The depth of the tank would have been roughly equal to the depth of the average lift height.

### Simple Ratio for Multiple-Lift Gasholders

For telescopic gasholders, the normal proportion for the depth of the tank varied between 0.5 and 1.0 of the mean diameter. Modern Gasworks Practice suggested that 0.64 could be used as a ratio between total height and diameter of a four-lift gasholder. It also suggested that 0.5 could be used as a ratio between total height and diameter of a three-lift gasholder. On this basis it could be assumed that for a two-lift gasholder the ratio would have been about 0.4. The depth of the tank was usually slightly longer than each of the individual lifts of the gasholder (they were roughly the same length, inner vessels being slightly taller than the outer vessel).

### Calculation for Multiple-Lift Gasholders Based on Diameter and Capacity

The same equation could be used as highlighted above, but the number of lifts must be factored in. An assumption could also be made based on the data in the graph in Figure 16.

### 14.2 Methods for Estimating the Volume of the Gasholder Tank with a Dumping Present

It should be remembered that while only below-ground tanks had a dumping, many underground tanks did not have them. Tanks less than 16-18 m in diameter and requiring waterproofing did not generally have dumpings unless built in rock, stiff clay or chalk. Some smaller tanks of brick or stone had floors paved with flagstones.

The dumping was a mound of earth left within the gasholder tanks for economical reasons (i.e., it was cheaper to leave the material *in situ* than excavate it. It was often covered in a layer of cement, or consisted of puddle covered with stone or brick.

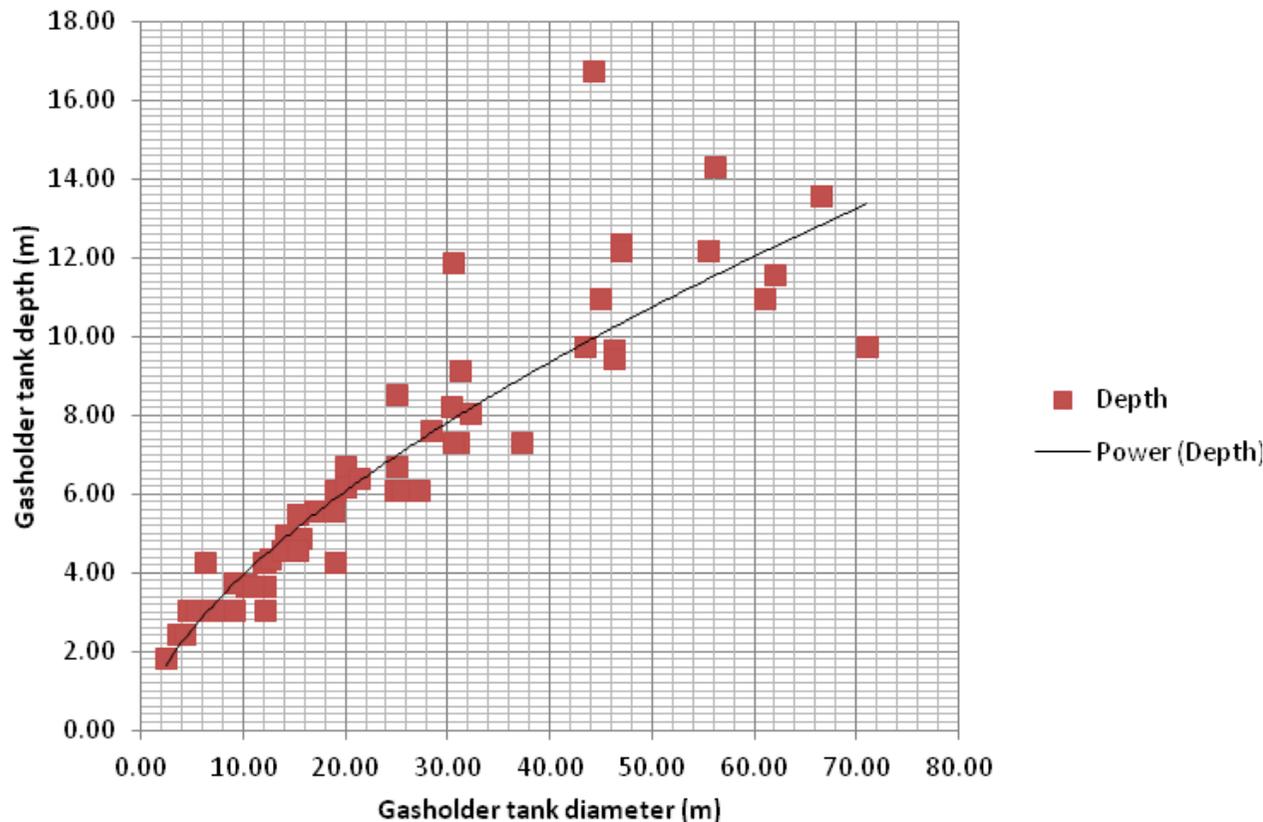


Figure 16. A plot of the gasholder tank diameter against depth for brick, stone, concrete and composite tanks. Source: Russell Thomas.

The dumpling was not a uniform structure and its shape as highlighted in Figure 13 would be highly dependent on the strata in which the tank was constructed. An annular channel was built between the edge of the tank wall and the start of the dumpling, measuring roughly 0.91 m (3 ft) and 1.82 m (6 ft) wide.

The dumpling was generally cone shaped with a flat top (e.g., Figure 13) although dumplings which were more dome shaped were also constructed. On this basis, calculating the volume of a dumpling cannot be easily presented here, and it must be made on a case-by-case basis.

The simple calculation for working out the volume of a cone can be used to roughly estimate its size. This calculation is the volume of a cone =  $(\frac{1}{3}) \times \pi \times \text{Radius}^2 \times \text{height}$ . This calculation does not take into account that the dumpling was often a wide short cone with a flat top (a frustum of a cone), with the angles dependent on the strata. A more accurate approach would therefore be to work out the volume of a frustum of a cone as below.

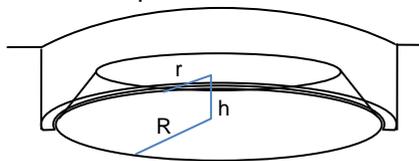
$$V = \frac{(\pi \times h)}{3} (R^2 + r^2 + Rr)$$

v= volume

h = height

R = radius of the base of cone,

r = radius of the top of the cone



Ideally, the height of the dumpling needs to be known. This can be worked out from previous investigations, if boreholes were correctly placed.

This information is generally not available from site plans or gasholder records for infilled tanks.

Old gasholder records did provide a lot of detail relating to the gasholders tanks, but these records are rare, as they were generally disposed of when the gasholder was decommissioned. Where this information is not available from records or site investigation details, previous experience of investigating gasholder tanks or reference texts must be brought to bear.

Alternatively, assumptions can be made based on a standard rule of thumb, which is the volume of the dumpling is 30% of the tank. However, this does not take into account the significant variation encountered based on ground conditions. It would be more accurate to calculate the size of the dumpling based on the angle of repose used in the strata in which the tank was built, and use this to guide the size of the upper flat surface of the cone.

Despite these problems, the presence of a dumpling is very important and it should be taken into account when investigating former gasholder tanks. The volume of the dumpling is very important when working out the volume of infilled material present within the tank and remediation volumes. Subtracting the volume of the dumpling from the cylindrical volume of the tank will provide the volume of potentially infilled material within the tank.

## 15. Selected Bibliography

Below is a selected bibliography of books which may be of interest to the reader:

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Photograph 16. Construction of two above-ground spiral-guided gasholders at a former gasworks in South-West England. Source: IGEM PHI.

## Gasworks Profile C: Water Gas Plants

A profile of water gas plants, their history, design, development, application and the type of contaminants which may be associated with them.

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## Gasworks Profile C: Water Gas Plants

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### Units

All units used in this profile have been converted to SI Units. Some are also shown as their former imperial units, as the data was taken from documents using this format. One unit commonly used in the gas industry and still in partial use is the British Thermal Unit (Btu), a common unit for the measurement of energy in the gas industry. 1 Btu is equivalent to 1.055 Kilojoules (0.001 MJ). The Btu was often expressed as Btu/ft<sup>3</sup>; this has now been replaced by the Megajoule per cubic metre, expressed as MJ/m<sup>3</sup>.

### Gasworks Profiles

Gasworks Profile A: The History and Operation of Gasworks (Manufactured Gas Plants) in Britain

Gasworks Profile B: Gasholders and their Tanks

Gasworks Profile C: Water Gas Plants

Gasworks Profile D: Producer Gas Plants

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## 1. Introduction

This profile describes the manufacture of gas using the water gas process. Early water gas plants were based on retorts used for coal carbonisation; however, later water gas plants (Photograph 1) more closely resembled producer gas plants in the design of the generator and in their mode of operation. Water gas plants were popular in the UK and worldwide, particularly in the USA where they were first successfully commercialised.

One of the major issues with producing gas by carbonising coal was the length of time taken to get the gas plant operational and producing gas. This led to a heavy reliance on storage in gasholders. Without sufficient gas storage, the retorts would have to be kept heated on standby to accommodate rapid increases in gas production. This was both inefficient and uneconomic for the gas manufacturer. An alternative method to meet peak demand for gas was required, leading to the development of water gas plants.

Water gas plant could produce gas much more rapidly (within 1-3 hours) than traditional coal carbonisation plant, allowing gas companies to satisfy peak demand more effectively. Whilst this process was commonly employed on many larger town and city gasworks to supplement coal gas supplies, plant was also developed for smaller gasworks. In Britain, water gas was mixed with coal gas (30% water gas to 70% coal gas) prior to distribution.

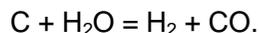
## 2. The Early Development of Water Gas

The discovery of water gas was attributed to the Italian physicist Felice Fontana in 1780. He



Photograph 1. The inside of the water gas plant building at the former East Greenwich Gasworks. Source: National Grid Gas Archive.

discovered that when steam was passed through incandescent carbon, the oxygen of the water molecules in the steam had a greater affinity for the carbon than the hydrogen to which it was bonded. This led to the formation of carbon monoxide and hydrogen from the water and carbon in the reaction:



This finding predated William Murdoch's discovery of a commercial process to produce coal gas. Given its composition, water gas had little or no illuminating power when burnt, so little use was made of the discovery. Henry Cavendish, Antoine Lavoisier, Charles Meusnier and others also later made the same discovery as Fontana.

The first patent taken out for water gas production was believed to have been by W. Vere and H.S. Crane in 1823. The patent described the use of admitting water or steam into a retort containing coal, oil or other suitable material undergoing decomposition, but was not developed further.

In 1824, John Holt Ibbetson made the first attempt to utilise water gas on a commercial scale. He experimented by steaming the coke which remained in the horizontal retorts at the end of the period of carbonisation. Ibbetson published a patent in 1826 but did not develop the technology further. On 6 October 1830, Michael Donovan received a patent for lighting by water gas. To improve the illuminating ability he mixed the gas with vapours of turpentine, tar, naphthalene and other illuminants. This was tested on the street lights of Dublin. The scale of this demonstration is uncertain; however, it did not meet with much success and soon failed.

Despite earlier work by others, George Lowe is often quoted as the first exponent of a carburetted

(oil enriched) water gas process when he discharged hot coke into a water gas generator and intermittently injected steam and air. His patent described that the gas produced should be enriched with essential oil. The process did not achieve commercial success.

A Belgian scientist (M. Jobard) successfully experimented with water gas production *circa* 1833. It is reported that he sold his invention to Alexander Selligie of Paris and Florimont Tripier of Lille. Selligie was then recognised as the inventor. Under Selligie's name, the water gas process was introduced to Dijon, Strasbourg and Antwerp, as well as parts of Paris and Lyon. The Jobard/Selligie process started by decomposing the water; the resulting hydrogen was then mixed with hydrocarbon (either oil vapour or heated resin) which then passed into a retort containing hot coke. The process lost popularity when Selligie was unmasked as a fraud.

The next major interest in water gas occurred in 1847 when Stephen White of Manchester took out a patented 'hydrocarbon process' which had similarities to that of Jobard. White's idea was to produce a very rich gas, from fat, oil or tar, and dilute it to a reasonable candle power using a cheap, low-grade carrier gas. White's success was boosted by favourable reports from Samuel Clegg and Dr E. Frankland. White's method was tested on a large scale at a mill gasworks in Manchester and at the gasworks of the South Metropolitan Gas Company in London. Whilst these trials did not lead to permanent installations, White's method was adopted as the original form of gas lighting in the town of Stockport in Lancashire until 1853. White claimed that 60% more gas could be produced from his method than from conventional coal carbonisation.

White's usual method was to set the stop-ended retorts in a single setting (above one furnace).

The central (water gas) retort contained hot iron scrap (or coke) onto which a trickle of water would fall, producing water gas. The other two 'coal' retorts made rich coal gas, being operated in the conventional way and receiving a supply of water gas by a connecting pipe from the mouthpiece of the central retort.

Ruthin in Wales, and Comrie and Dunkeld in Scotland, also adopted White's process for gas manufacture. The town of Petersfield, Hampshire adopted White's method but using coke instead of scrap iron in the central retort. The main failure of White's process was the greater complexity of controlling this water gas process compared with coal gas. The relative amounts of rich gas and water gas produced had to be carefully controlled to ensure correct gas quality.

The process was exported, and in 1850 it was trialled over several months at the Philadelphia Gasworks (USA), but the results did not support full-scale adoption.

Joseph Gillard made major advances in his works at Narbonne, France in 1856. Gillard managed to light the town by burning blue-water gas with argand burners over which platinum wire cage mantles were placed. Argand burners were the first scientifically designed burners, originally designed for oil lamps but later adapted for use in the gas industry. They consisted of a cylindrical wick housed between two concentric tubes. Air rose in the internal tube through supporting combustion on the inner surface of the flame as well as the outer surface. A glass chimney increased the draft. The blue-water gas flame heated a platinum mantle, which would emit a bright light. The high price of platinum made the cost effectiveness of this process very poor, and it failed.

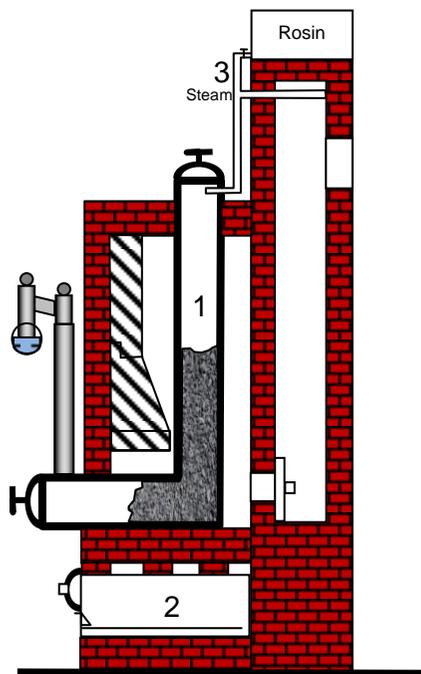
The term 'blue-water gas' came from the fact that the water gas burnt with a blue flame which produced little light, so was no use for lighting purposes. The blue colour was due to the complete combustion of hydrogen and carbon monoxide in the water gas, the latter burning a pale blue colour. When coal gas was used for lighting, soot formed from the incomplete combustion of the organic compounds in the gas. When soot particles entered the flame front of the gas burner they glowed, emitting bright white light.

Further developments in America were undertaken by Dr J. M. Sanders. In 1858, he erected a plant in Philadelphia consisting of an L-shaped cast-iron retort (Figure 1, No.1) which was externally heated by a furnace underneath (Figure 1, No.2). The retorts were filled with charcoal and superheated steam together with melted rosin (a form of resin obtained from pine and some other plants) which was injected into the top of the retorts via a pipe (Figure 1, No.3). The gas produced from the process was 10% more expensive than coal gas, it was not stable and the retorts deteriorated rapidly, these factors prevented the adoption of this process commercially. Similar work had also been undertaken by Mr Brown of Baltimore and Mr Aubin of Albany in the 1850s.

In the 1870s, Mr R.P. Spice made water gas in horizontal retorts at a gasworks he leased in Chichester (England) for experimental purposes. He went on to build a fairly large water gas plant at Wormwood Scrubs, London. This used vertical retorts developed for Scottish shale-oil practice and was successful, but the gasworks' lease reverted to the Great Western Railway in 1880 and the water gas plant was no longer used.

A historical review led by John Cresson for the Philadelphia Gasworks and reported in Scientific

American in 1861 concluded that water gas failed mainly because of economics, it being more expensive than coal gas. Deterioration of the plant and difficulties in controlling the process also contributed to its lack of success. At the time of the review, water gas was being produced at the Northern Liberties Gasworks in Philadelphia.



**Figure 1. The design of the Sanders water gas apparatus. Source: Russell Thomas.**

### 3. Different Systems Used for the Manufacture of Water Gas

A wide range of different systems were developed to manufacture water gas, many unsuccessful or impractical. Systems for making water gas could be classified under three headings: (1) The Intermittent System; (2) The Continuous System; (3) The Neat-Oxygen Method. In reality, only the intermittent system was a commercial success,

however, short descriptions of the others are provided for historical reference.

The intermittent system with 'run' and 'blow' phases succeeding each other at regular intervals was the most widely used and thought to be the only practicable method. This is described in detail in section 5 of this document.

The continuous system was heavily investigated in the early development of water gas as it sought to make the process more efficient (by independent external heating of the vessels) and enable the continuous production of gas. It suffered from practical difficulties due to problems with heat transfer and general process inefficiency.

The third system was the neat oxygen method which produced a gas practically free from nitrogen, but containing 65-70% carbon monoxide. Steam entered the base of the generator along with a stream of pure oxygen. Whilst steam combined with a portion of the carbon to form water gas, the heat lost by the endothermic reaction was replaced by the exothermic combination of the oxygen with the carbon. If steam and oxygen were regulated correctly, the process would work effectively; its drawback was the difficulty obtaining pure oxygen economically.

All water gas processes were gasification processes where the fuel (coke/oil) was converted to gas.

### 4. The Development of Intermittent Water Gas Plants

Intermittent water gas systems were introduced *circa* 1873 when two similar methods were developed in the USA: the 'Strong process' and

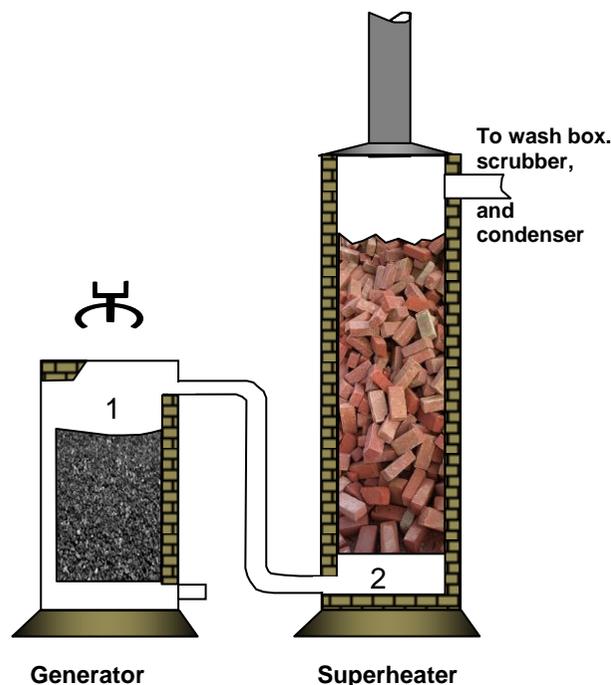
the 'Lowe process'. These systems were both based on alternate periods of 'run' and 'blow', described in more detail on page 5.

The Strong process (not shown) employed a high generator made from firebricks and two secondary chambers also packed with firebrick. These latter chambers, heated up during the blow, were employed as superheaters for the steam. Strong aimed purely at making a gas suitable for the purpose of heating.

Thaddeus Sobieski Coulincourt Lowe set out to make a gas for illumination purposes. The original Lowe plant design was very similar to that employed in later water gas plants. The Lowe system consisted of a generator, a brick-lined cylindrical vessel (labelled 1 on Fig. 2), the outer shell of which was made from wrought iron. The fuel was placed in the generator on grate bars above a closed ash-pit. Air and steam were introduced alternately into the generator. Air was used to heat the chamber by combustion of the coal, with the steam injected to generate the water gas which was passed on to a large superheater (labelled 2 on Fig. 2). The superheater was packed with firebricks. Lowe's original idea of 1874 was to spray oil on to the coke in the generator to enrich the gas. Lowe's later design of 1884 incorporated an additional chamber called the carburettor, between the generator and superheater. This was a similar brick-lined vessel into which the oil was sprayed and gasified.

Lowe's development coincided with the availability of cheap naphtha and oils in the USA which could be used to enrich the gas. These had come from the production of lamp oils and lubricating oils from petroleum in the USA. This gave the development of Carburetted Water Gas (CWG) a massive boost and by 1882 a considerable portion of gas production in the USA

was made using this process. Possibly, Lowe's main contribution was constructing the plant from refractory material in a steel shell; this gave the plant both rigidity and flexibility to cope with the temperature changes caused by the cyclical nature of the intermittent process.



**Figure 2. The Lowe water gas system. Source: Russell Thomas.**

The first water gas plant built in Britain was a small plant erected by the British Water-Gas Syndicate in 1888. This company was wound up in 1893 by its Chairman, Samson Fox, a proponent of water gas.

Two of the biggest companies involved in the manufacture of water gas plant were the United Gas Improvement Co. and Humphreys and Glasgow Ltd, two closely related companies.

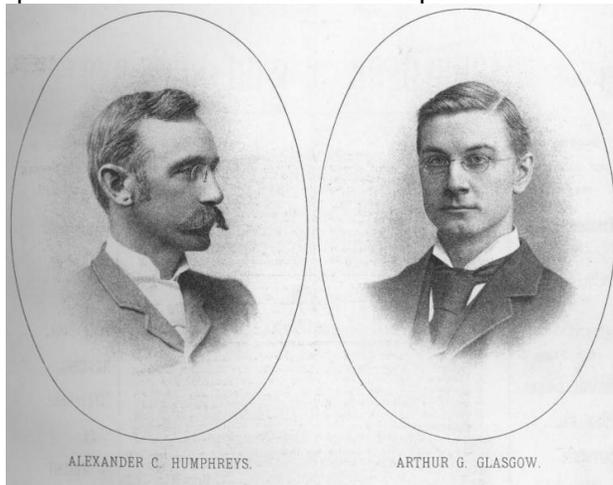
United Gas Improvement Co (UGI) was incorporated in 1882 in Pennsylvania to exploit the new process of water gas manufacture developed by Lowe.

UGI manufactured, sold and installed equipment needed for the Lowe process. The company also leased the production and distribution facilities of existing gasworks, operated the plants and sold the gas. UGI moved into the supply of gas and electricity, eventually moving away from the manufacture of gas, and into natural gas. The company still exists in the form of the UGI Corporation. Whilst UGI was very big in the American market, it had limited interest in the European market. The Gas Light and Coke Company (GL&C Co) of London took an interest in the development of water gas and sent its chief engineer to visit UGI. As a result, two 14,000 m<sup>3</sup> (500,000 ft<sup>3</sup>) per day plants were ordered by the GL&C Co. Arthur Glasgow (Photograph 2) was dispatched by UGI to assist the GL&C Co to commission the water gas plants which were to be built at Beckton, near London. On Glasgow's return to the USA, he tried to persuade UGI to expand into Europe, without success.

Glasgow then persuaded Dr Alexander Humphreys (Photograph 2), then a senior UGI executive, to set up Humphreys and Glasgow in London in 1892. Both were American and experienced gas engineers, Dr Humphreys having undertaken much of the pioneering work on water gas at UGI. Humphreys and Glasgow (H&G) had an agreement with UGI to use its patents and any improvements developed.

H&G became the major player in the British and European market. H&G's first contract was to build two water gas plants in Copenhagen. Its first contract in the UK was at the Belfast Corporation Gasworks in Northern Ireland. H&G established operations in London, Brussels and

New York. It was very successful and its gas plants were to be installed all over the world. By 1898, it had undertaken 91 water gas plant installation projects and by 1914 had installed 1,303 water gas plants across the world. H&G prospered until the 1960s, with many contracts from the Area Gas Boards in post-war Britain. The company diversified into petrochemicals but its fortunes declined as Britain switched to natural gas. What remains of its on-shore operations is now owned by Jacobs Engineering Group. H&G was later bought by an American company and split into on-shore and off-shore operations.



**Photograph 2. Dr Alexander Humphreys and Arthur Glasgow, founders of Humphreys and Glasgow.**

The Power Gas Corporation Ltd (PGC) was a very keen competitor of H&G and produced many British water gas plants. The PGC was formed by Dr Ludwig Mond to exploit his Mond Gas process patents. PGC became a major supplier of both producer gas and water gas plant (Figure 12), and later expanded into petrochemical technologies. The remains of the PGC business exist within Davy Process Technology, part of Johnson Matthey.

Many other companies produced water gas plants (e.g. R & J Dempster built Dellwik plants in the UK) and some of these are also featured in this document.

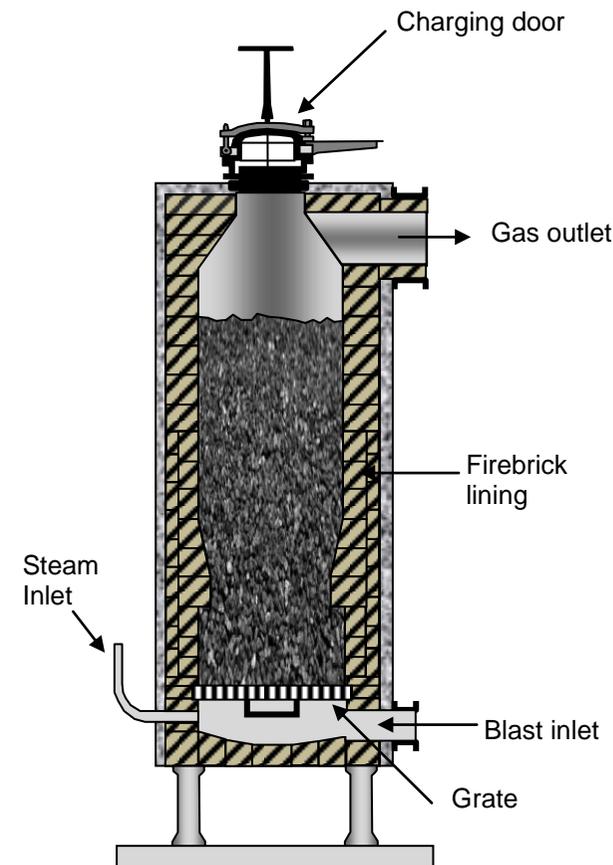
In Britain, water gas allowed the gas undertakings to meet peak gas demand whilst utilising by-product coke and enabling some control over the price of coke by reducing its supply. Most medium and large town gasworks in Britain operated water gas plant at some point during their operational history. In the north-eastern states of the USA, CWG became the pre-eminent method of gas production, being cheaper to produce than coal gas. It was often supplemented by coke oven gas, where available. Another regional variation in the USA occurred on the western Pacific coast, where coal and coke were dispensed with completely and gas was made directly from oil (oil gasification).

The water gas process generated gas through the action of steam upon red-hot carbon (generally in the form of coke). The generator (Figure 3) would be filled with fuel, ignited and brought to temperature through the 'blow' phase. Once brought to temperature, the system would enter the 'run' phase and steam would be admitted.

The gas was produced on the principle that heated carbon acted as a reducing agent for the steam as it passed through, the oxygen in the water combining with the carbon and giving off hydrogen gas (the oxygen having a greater affinity for the heated carbon than for the hydrogen).

## 5. The 'Run' and 'Blow'

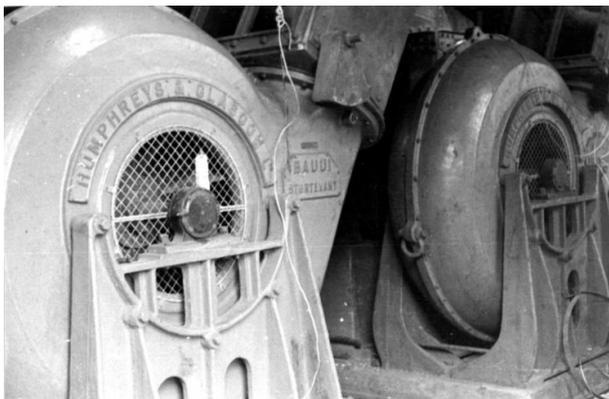
The 'run' and 'blow' were the principal components of the manufacture of water gas, each working in sequence to produce the water gas in a cyclical fashion.



**Figure 3. A hand-clinkered water gas generator, typical of those used on smaller gasworks. Source: Russell Thomas.**

The objective of the blow period was to store the maximum quantity of heat in the generator fuel bed (usually coke) which could then be used in the endothermic steam:carbon reaction during the run stage.

During the blow, air was blown by fans (Photograph 3) into the base of the fuel bed, providing oxygen to allow the fuel to burn and heat the generator.



**Photograph 3. Blowers (fans) used to provide the blast air on an H&G Water Gas Plant. Source: National Grid Gas Archive.**

The following reactions occurred within the fuel bed, which overall were highly exothermic.

- (i)  $C + O_2 \rightarrow CO_2$  - exothermic
- (ii)  $C + CO_2 \rightleftharpoons 2CO$  - endothermic
- (iii)  $2C + O_2 \rightarrow 2CO$  - exothermic
- (iv)  $2CO + O_2 \rightarrow 2CO_2$  - exothermic

These would form carbon dioxide in much larger proportions to carbon monoxide. As the carbon dioxide rich gas passed through the remainder of the hot fuel bed, some of it was partially reduced to carbon monoxide. This was formed by a secondary reaction between the carbon dioxide and hot carbon which was endothermic, in effect cooling the generator. For this reason the presence of large amounts of carbon monoxide at this stage was not desirable.

The gas exiting the generator was similar to a poor-quality producer gas which would be burnt in the subsequent carburettor and superheater, heating them. Burning carbon to carbon dioxide released about three times as much heat as when it was burnt to carbon monoxide only.



**Photograph 4. The upper floor of a water gas plant. Source: National Grid Gas Archive.**

As the blow proceeded, the temperature of the fuel bed rose, increasing the amount of carbon monoxide in the gas leaving the generator. The blow had to avoid excessive combustion of the carbon (coke), so the air supplied was carefully controlled.

By the end of the blow, the generator, carburettor and superheater would all be sufficiently hot for the run to take place.

During the run, steam was injected into the generator and reacted with the carbon. As the run

proceeded, the fuel bed started to cool, and gradually the proportion of carbon dioxide in the gas produced increased. This had the effect of increasing the amount of inert substances in the gas, reducing its heating qualities.

During the run, within the lower part of the fuel bed, the water (steam) reacted with the heated carbon forming carbon dioxide, and some carbon monoxide as shown below.

- (i)  $C + 2H_2O \rightarrow CO_2 + 2H_2$  - endothermic
- (ii)  $C + H_2O \rightarrow CO + H_2$  - endothermic

The carbon monoxide generated could also react with the steam, forming carbon dioxide and hydrogen, which was an exothermic reaction

- (iii)  $CO + H_2O \rightarrow CO_2 + H_2$  - exothermic

As the carbon dioxide formed passed up through the bed of coke, it was reduced by further hot carbon higher up the fuel bed forming carbon monoxide through an endothermic reaction:

- (iv)  $C + CO_2 \rightleftharpoons 2CO$  - endothermic

This reaction was reversible and the amount of carbon dioxide converted to carbon monoxide was highly dependent on changes in pressure and temperature. A decrease in pressure and increase in temperature made the formation of carbon monoxide preferential; whereas if this was reversed, the formation of carbon dioxide was preferential. At 850°C, the reaction forming carbon dioxide was found to proceed 166 times more rapidly than the reverse reaction.

A schematic of the H&G water gas plant is shown in Figure 4.

### Down Run

Experience showed that if steam was continually admitted to the base of the generator, the lower portion of the fuel-bed (which had continually to perform the heaviest duty of decomposing the steam) became cool and inactive over time, and the steam condensed instead of being converted into gas. The succeeding blow, therefore, further chilled the lower layers of the fuel bed instead of rekindling the fire.

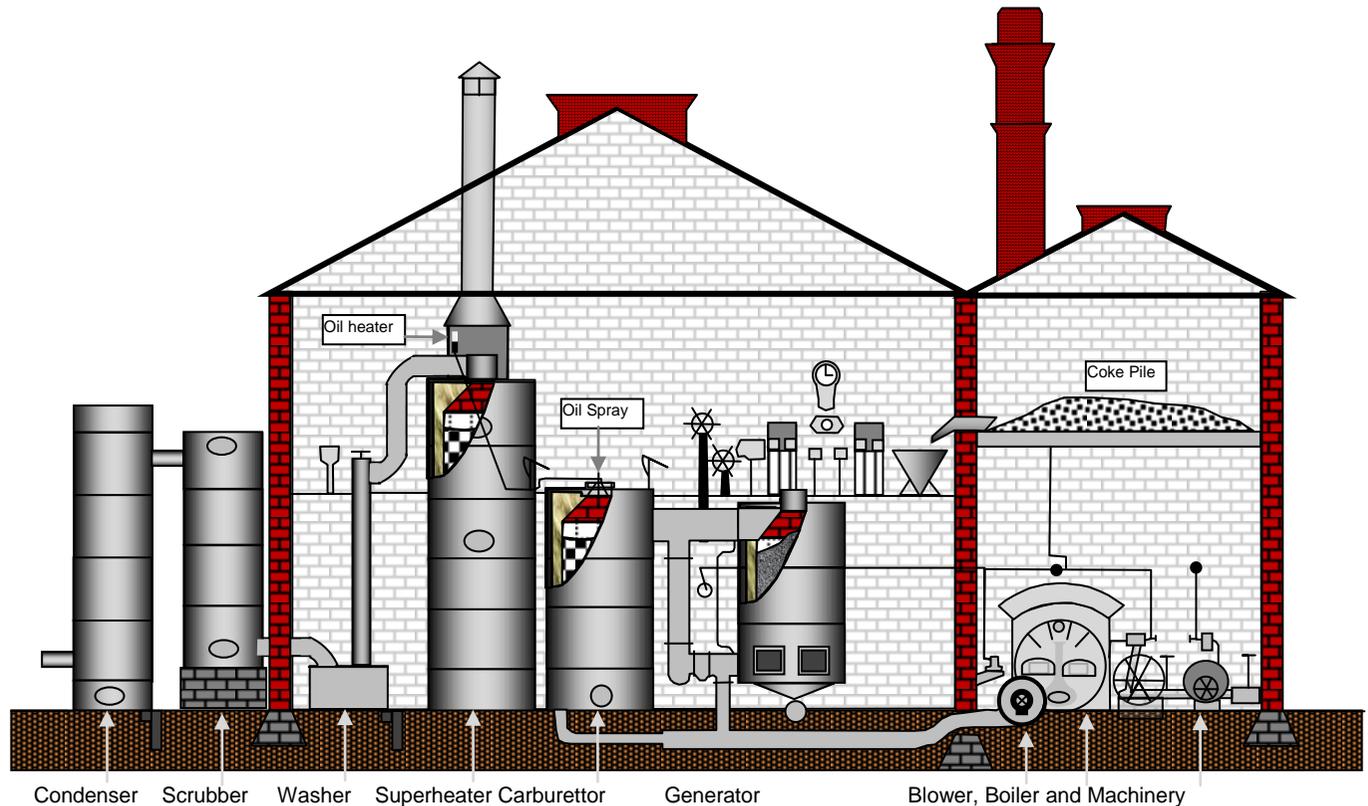
To rectify this, one of the developments introduced by Dr Humphreys was the 'down run' (Figures 11 and 12). He discovered that the control of the water gas generator and also the management of the clinker could be greatly improved if the operation of the generator was periodically reversed. After every few runs, the steam was admitted to the top of the generator above the fuel and it descended through the fuel bed and was withdrawn at the bottom.

Following this, the gas flowed to the carburettor as usual.

## 6. Types of Intermittent Water Gas Plant

Although a wide variety of water gas plants were developed, the main difference between the plants was whether they produced raw 'blue' water gas or enriched 'carburetted' water gas (CWG). As mentioned earlier, the blue gas was purely an unenriched gas comprising primarily carbon dioxide, carbon monoxide, hydrogen and nitrogen. It derived its name from the blue colour of the flame, which gave little light.

Many plants originally built as blue-water gas plants were later retrofitted with a small carburettor, enabling them to yield enriched gas.



**Figure 4. A schematic of a carburetted water gas system based on the Humphreys and Glasgow design. Source: Russell Thomas.**

CWG was the same as raw blue-water gas which was then enriched by oil (and in some cases resin or tar) to improve its calorific value and illuminating power. This enriching process is described in more detail in sections 10 and 11.

Blue-water gas had a calorific value of 10.8-11.1 MJ/m<sup>3</sup> or 290-300 Btu/ft<sup>3</sup> (British Thermal Units per cubic feet were the standard units of measurement at the time). The enriched CWG had a calorific value of approximately 14.1-18.6 MJ/m<sup>3</sup> (380-500 BTU/ft<sup>3</sup>); by comparison, natural gas which is currently used in Britain has a calorific value of between 37.5-43.0 MJ/m<sup>3</sup> (1009-1154 BTU/ft<sup>3</sup>).

Water gas was originally seen as a cheap method of producing gas, but if CWG was to be produced, its economics became heavily reliant on the cost of oil. Whilst in the early years of its development a plentiful supply of gas oil was available, this later diminished when motor vehicles used this fuel. The oil-enriched CWG was more important when gas was predominantly used for illumination.

Later, when illumination was not so important, unenriched blue gas became more popular, especially at times when oil costs were high.

## 7. Blue-Water Gas Plants

Two popular blue-water gas plants were those built by Kramers and Aarts (K and A, Figure 5), and the Dellwik plant (Figure 6).

The K and A Plant (Figure 5) had two generator vessels as opposed to the single generator vessel used on the Lowe-type system. During the run, the generators were used in series, while during the blow they were used in parallel; this reduced the duration of the blow to a quarter of that used on a Lowe-type plant, allowing more gas to be produced.

In addition to the two generators, the K and A plant also had a regenerator. During the blow phase, the regenerator was heated through the passage of hot gases from the generator. During the run phase, steam was introduced into one of the generators where it would undergo the water gas reaction, forming hydrogen, carbon dioxide

and carbon monoxide and then enter the regenerator.

Within the regenerator, the surplus steam was also split into hydrogen and the gas superheated; from here, the gas passed through to the second generator where the carbon dioxide was reduced to carbon monoxide.

When the plant was run again, the direction of flow through the system was reversed, making the final generator the first generator and *vice versa*. K & A plants were supplied in Britain by the K & A Water-Gas Co. Ltd. of London. The Dellwik blue-gas plant developed by Karl Dellwik produced a gas which was very similar in composition to the K and A plant, but the plant was structurally very different, using a single generator preceded by a superheater. The latter heated the steam before it passed into the generator. The gas then passed directly from the generator to the superheater, and then through a coke scrubber. Karl Dellwik was

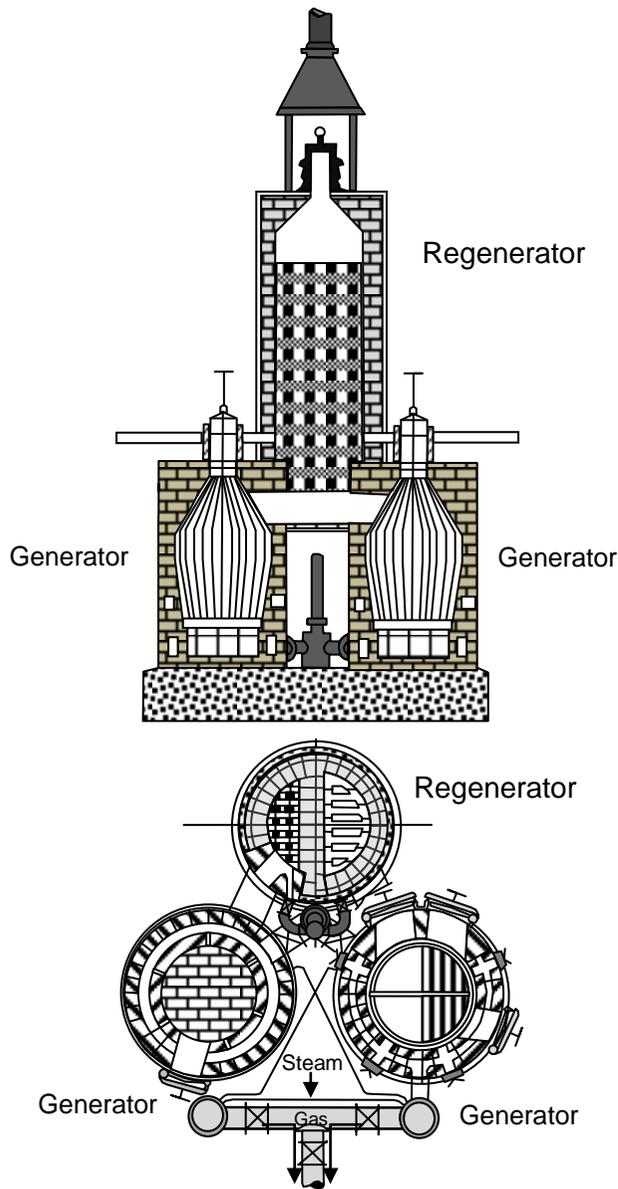


Figure 5. A schematic of Kramers and Aarts blue-gas plant. Source: Russell Thomas.

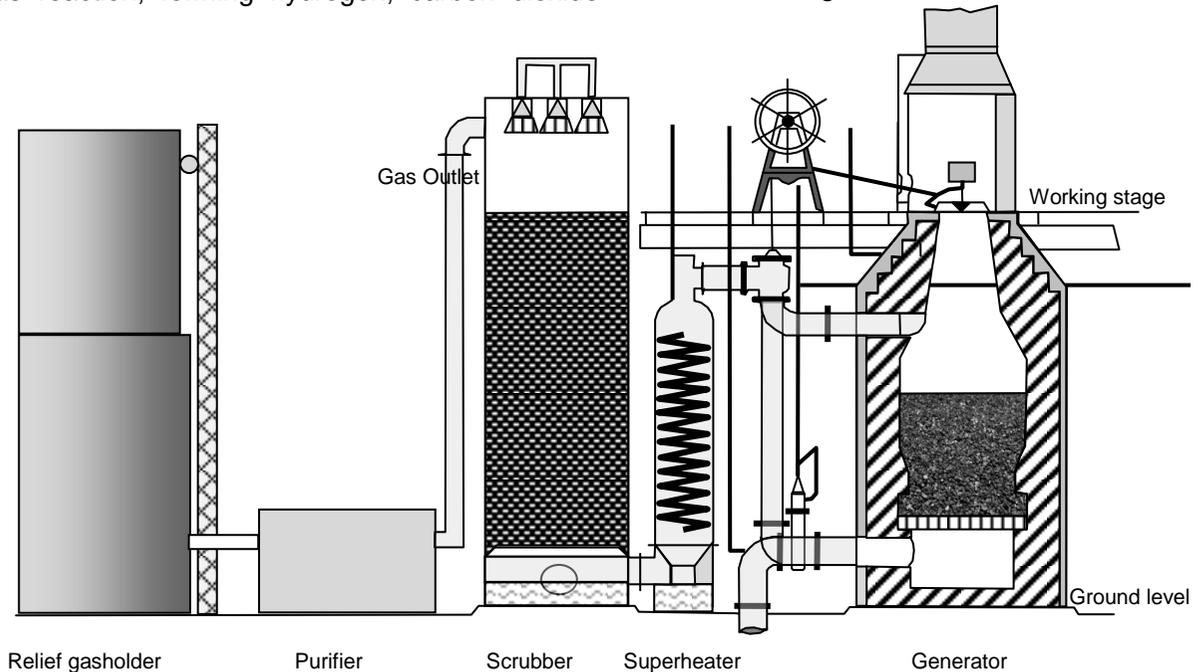


Figure 6. The Dellwik blue-gas plant. Source: Russell Thomas.

known for his work in restructuring the air supply to the water gas plant. This minimised carbon monoxide production during the blow, increasing the heat generated in the water gas plant during the blow and maximising the amount of water gas production during the run. Dellwik plants were built by R & J Dempster of Manchester in Britain.

Another type of water gas plant was the Simplex plant. Designed as a low-cost method of producing gas quickly, it was primarily suitable for smaller gasworks.

Unlike other water gas plants which used oil in the carburettor, the Simplex plant used tar. The Simplex plant was also built without an outer steel shell, just brickwork. These plants were produced in Britain by the Vertical Gas Retort Syndicate Ltd of London.

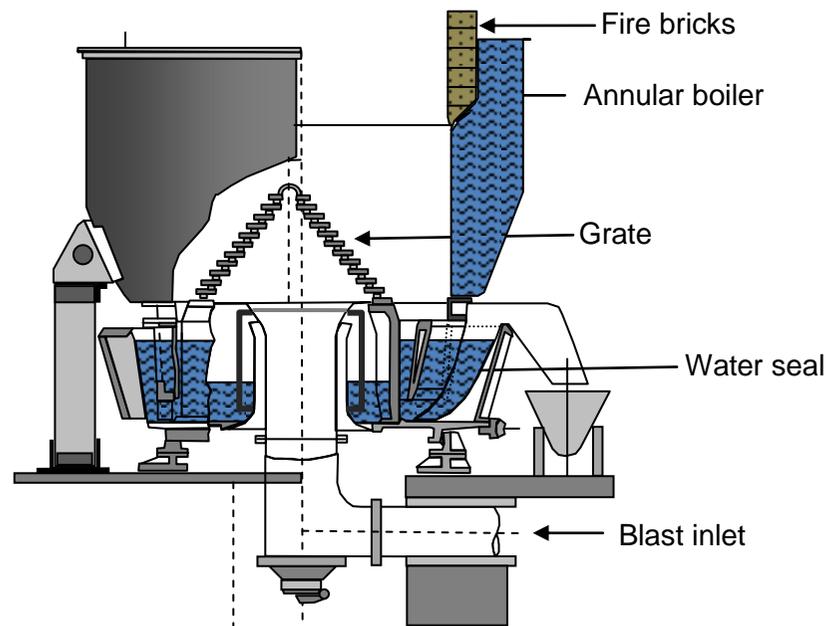
A variation of the water gas plant was the single superheater plant (SSP) which varied significantly from the traditional layout shown in Figure 4 for the Humphreys and Glasgow plant. In the SSP, the carburettor and superheater were merged into a single large vessel, similar to the original plant developed by Lowe and shown in Figure 2. One of the benefits of this plant over the Lowe-type water gas system was the reduced capital expenditure.

## 8. The Operation of an Intermittent Carburetted Water Gas Plant

From looking at the figures in this document, it can be seen that there were many different configurations of a carburettor water gas plant.

There follows a description of the key plant involved in the process.

A typical CWG apparatus is shown in Figure 4, consisting of a generator, carburettor,



**Figure 7. A water-sealed self-clinking grate.**  
Source: Russell Thomas.

superheater, oil heater, washer and condenser. The cylindrical generator, carburettor and superheater all looked similar, the outer shell of the units constructed from steel plates and lined with firebricks. More modern CWG plants can be seen in diagrammatic form in Figures 11 and 12. A flow diagram of the CWG process can be seen in Figure 8.

### Generator

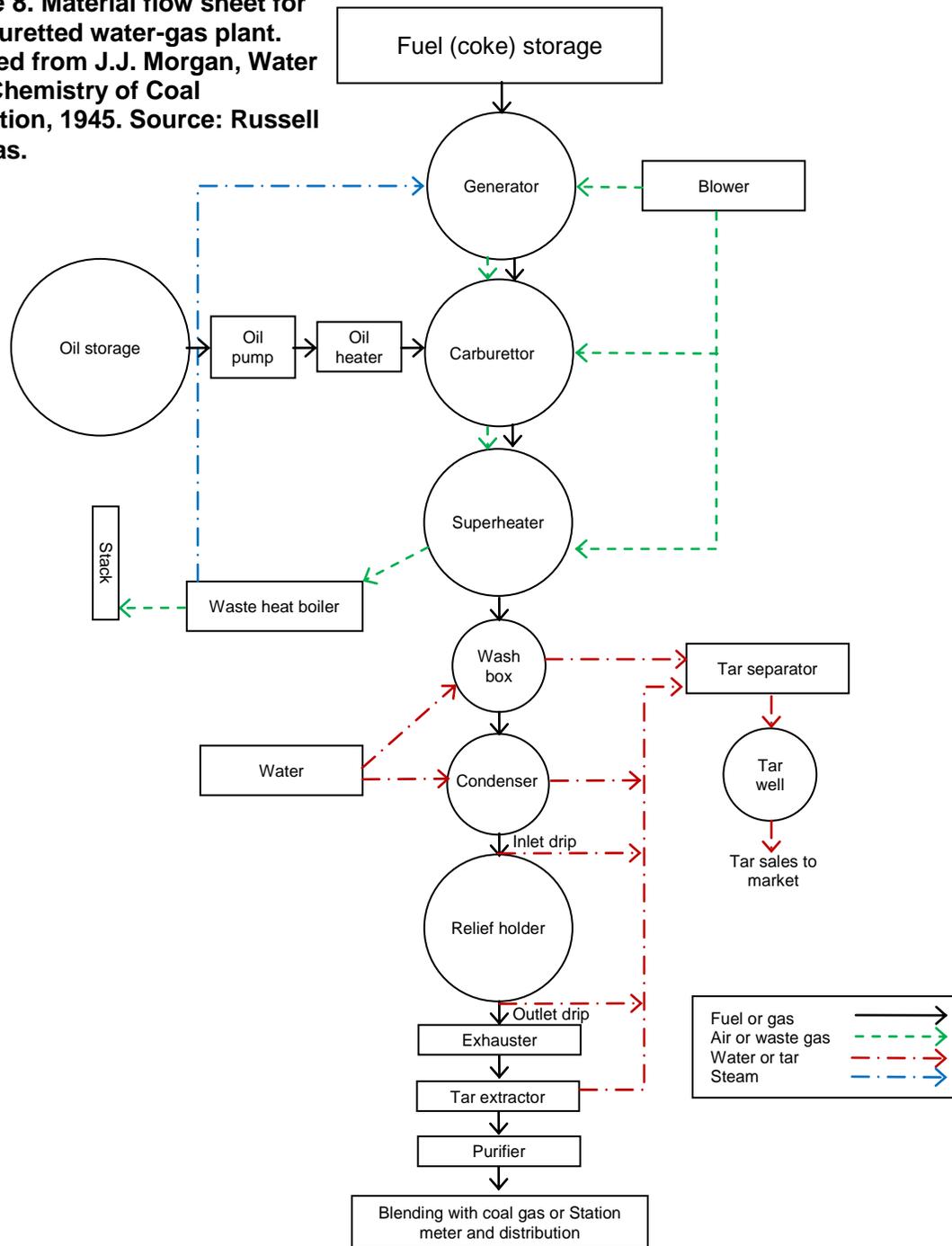
The function of the generator was to contain the fuel bed which, as described earlier, was used for heating the system and generating incandescent carbon to decompose the steam during the run. These processes and reactions have been described already so will not be described further here.

The generator was quite simple in design, being a circular vessel lined with firebricks. It contained a grate at its base supporting the fuel bed,

underneath which were two pipes, one which supplied steam and one which supplied blast air. At the top of the generator was a charging door through which fuel could be added. Below this was the outlet through which the gas was removed. The grate was a very important feature of the generator, as removing the ash could be problematic, especially if clinker formed instead of ash, as it often did. The clinker would affect the reactions in the fuel bed and reduce the amount of control which could be exerted on the system.

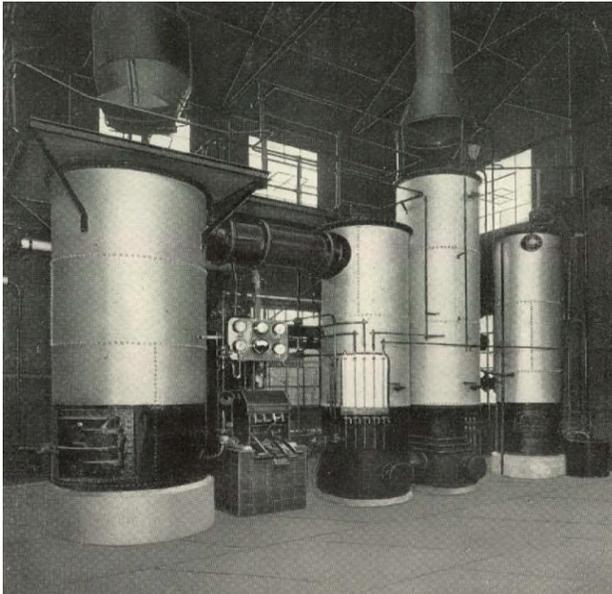
Removal of clinker by hand was very arduous and could reduce the amount of time the generator was making gas by 10%, as well as giving rise to additional unwanted heat loss. A diagram of a simple hand-clinkered water gas unit is shown in Figure 3. Most CWG plants producing over 28,000 m<sup>3</sup> (1,000,000 ft<sup>3</sup>) of gas per day were mechanically operated with a self-clinking grate. Circa 1948, mechanically operated plant with a capacity of 280,000 m<sup>3</sup> (10,000,000 ft<sup>3</sup>) of gas per day were routinely being used at large gasworks.

**Figure 8. Material flow sheet for a carburetted water-gas plant.**  
 Adapted from J.J. Morgan, *Water Gas, Chemistry of Coal Utilisation, 1945*. Source: Russell Thomas.



Whilst the grate in a hand-clinkered unit was little more than a set of iron bars, a Kerperley-type grate was used in a self-clinkering unit. These had a pyramidal or cone shape appearance (Figure 7). The grate was mounted eccentrically on the generator base. The base plate and the grate rotated slowly and, as this happened, the clinker and ashes were crushed in the annulus between the grate and generator wall. The crushed ash was removed by a stationary plough dipping into the outer water seal. The base of the generator had water lutes internally and externally, providing a water seal (Figure 7). The depth of the water seal was dependent on water pressure. Where high blast pressures were used, a dry seal (Figure 9) was preferable as deep water seals could surge under high pressure.

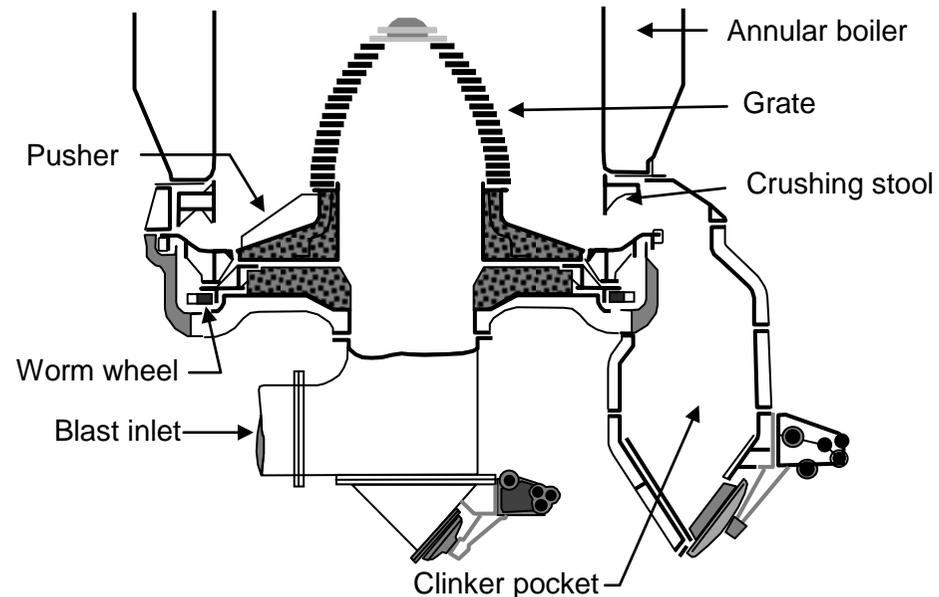
The dry grate used a revolving motion of a different design to sweep ash into compartments for its collection (clinker pocket). On dry grates, the base of the generator was surrounded by a water jacket which prevented clinker sticking to the lower part of the generator and blocking the fuel bed, whilst serving as a boiler for steam production. Given the available fuels for gasmaking, the wet seal was preferred for use in British water gas plants.



**Photograph 5. A small CWG plant. Source: National Grid Gas Archive.**

The firebricks within the generator were prone to wear and tear, and so generators would have an inner lining (to take the wear and tear) and an outer lining (to act as an insulator) of fire bricks (Figure 3). This double layer often only extended two thirds of the way up the fuel bed, to avoid disturbing the latter.

There was a gap of between 2-5 cm (0.8-2 in) between the outer firebricks and the steel outer shell. This was filled with asbestos, slag wool, silocel or celite and it allowed the lining to expand on heating. If possible, large bricks were used to reduce the number of joints required. Joints were areas where clinker would more readily adhere to the walls of the generator. There was, however, a limitation to the size of the brick, as above a size of approximately 22 cm (9 in) they had a tendency to crack and spall.



**Figure 9. A Humphreys and Glasgow dry-sealed grate. Source: Russell Thomas.**

#### Carburettor

Both the carburettor and superheater were filled with firebricks arranged in a chequerboard pattern. During the blow, the firebricks in both were heated by the hot gases carried over from the generator and from the combustion of any gases which were not burnt in the generator. A centrifugal oil spray was fitted in the top of the carburettor. Oil was supplied from a tank using a steam pump and passed through an oil heater located in the outlet pipe from the superheater. The carburettor was responsible for heating and vapourising this oil and the extensive brick surface aided the cracking of the oil into smaller gas phase molecules which would remain in a permanent gaseous state.

It was important that both the generator and subsequent superheater were operated at the correct temperatures, the chequerboard firebrick

was maintained in good condition, and the rate of oil spray and its distribution in the generator was such that the gasification of the oil was maximised.

#### Superheater

The superheater fulfilled a similar function to the carburettor, thermally cracking as much as possible of the remaining oil into a gas. Although the carburettor was designed to maximise the amount of oil gasified, some oil would still pass through the superheater as oil, especially if heavy oil was used.

At the top of the superheater was a stack valve which was opened during the blow. The gas escaping the valve would be between 600-750°C and could contain unburnt carbon monoxide gas. In 1916, waste heat boilers were introduced in Britain; these could recover this escaping energy by using it to heat water and raise steam.

The stack valve was closed during the gasmaking run phase, and the gas made its way through the remainder of the purification plant. Benefits could be gained by injecting the oil at multiple points in the carburettor and superheater and against the flow of gas. This caused the most volatile components of the oil to vaporise immediately into the gas. The higher molecular weight oils, which would be thermally cracked, descended to the base of the vessel before being carried on the flow of gas from the base to the top of the superheater.

### Purification Plant

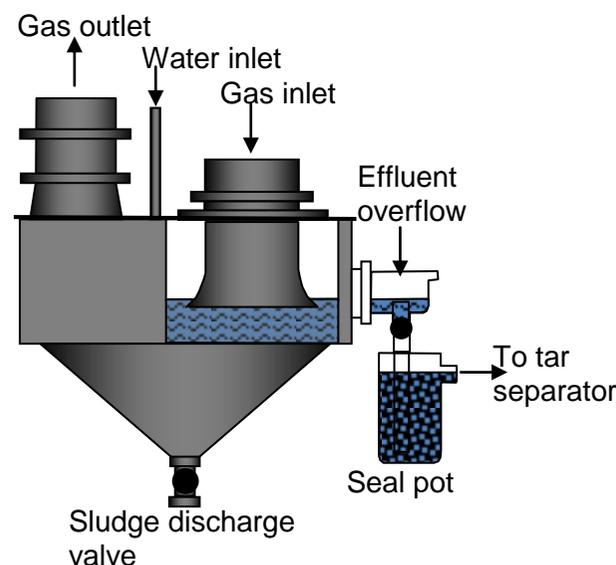
Like coal gas, water gas required purification after production. The non-carbureting water gas plant was relatively 'clean' when using coke, producing little or no tar and placing a limited burden on the purification plant. However, the CWG purification process was very demanding, given the burden of tar and oil which had to be removed from the gas. The difficulties and amount of tar produced were dependent primarily on the type of oil used and whether coke or coal was used as the fuel.

The plant used to purify water gas was similar to coal gas, but additional plant was used to attempt to separate the CWG tar from water, e.g. tar separators and settling tanks. Containing up to 85% water, CWG tar could have a similar density to water and could readily emulsify, making its removal very difficult.

### The Washer/Seal/Wash Box

The first part of the purification process was the washer (also known as the seal or wash box). The role of the washer was to provide a safety seal which prevented the gas from being pushed back into the superheater (by the pressure exerted by the relief holder) during the periods of the blow. Another role for the washer was to remove

considerable amounts of tar formed from CWG plant (tar formed from blue-water gas plants using coke would be negligible). As the gas bubbled through the washer, some of the residues from the gas were removed. Certain washers (e.g. Western seal tar batter) were designed with baffles and water sprays to aid tar removal.



**Figure 10. A cut-through diagram showing a conical-bottomed washer. Source: Russell Thomas.**

Whilst operational, the water within the washer was kept hot by a continuous flow of water from the boiler. Tar condensing out would leave the washer by the effluent overflow and via the seal pot to the tar separator (Figure 10). During the run (up-run and back-run), gas would exit through the washer.

### The Scrubber and/or Condenser

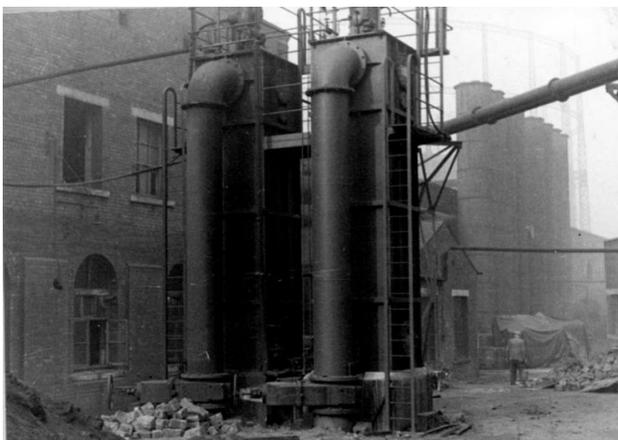
The purpose of both the scrubber and condenser was to cool the gas and remove tar, oil and any dust/free carbon which remained suspended in

the gas. A scrubber tended to be used on plants which produced below 28,300 m<sup>3</sup> (1,000,000 ft<sup>3</sup>) of gas per day; above this volume a condenser was used.

From the washer, the gas passed into the scrubber, a cylindrical tank fitted with trays made from wood, containing coke or other inert material; this provided a large surface area, kept moist by a spray of water.

Most of the tar residues were removed here and drained to the base of the scrubber. The scrubber also cooled down the gas to a normal temperature prior to condensation. The gas was generally free from ammonia (when coke was used), but occasional traces existed and would be removed by the scrubber. Within the scrubber, the water directly cooled the gas, creating problems for the disposal of the large amounts of potentially polluted water generated.

Condensers were used with large water gas plants. The condensers could be atmospheric air cooled or water cooled (the two condensers in Photograph 6 were the latter). To cool the gas, the air-cooled condenser relied on the differential between the ambient air temperature and that of the hot gas. This process was more successful in the winter, when the outside air temperature was cold.



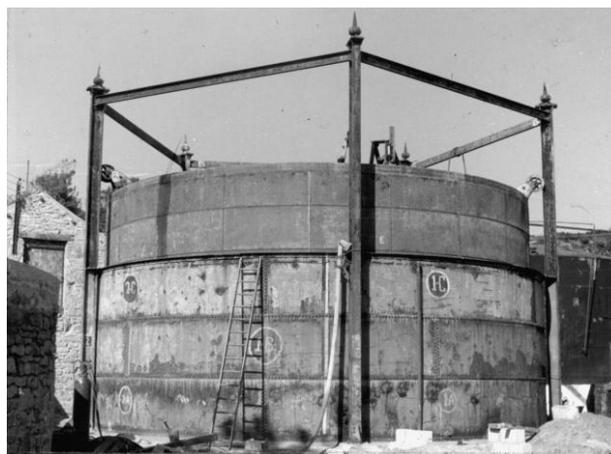
**Photograph 6. Condensers used on an H&G carburetted water gas plant. Source: National Grid Gas Archive.**

Within a water-cooled condenser, the gas was passed through rows of pipes cooled by water flowing in a countercurrent direction. There was no direct contact between the cooling water and the gas, so the water did not need to be treated and instead could be recycled. Later plant used more efficient and complex spiral-tube condensers. The cooled gas was temporarily stored in a relief gasholder

#### Relief Holder

Although constructed in the same way as a normal gasholder, a relief gasholder had a different function: to buffer the cyclical run and blow phases of gas production (Photograph 7).

The relief holder was often (but not always) an old gasholder which had become too small for general gas storage requirements. Alternatively, new gasholders were purpose built. It was possible to replace a relief holder with a much smaller compensation holder, if there was insufficient space.



**Photograph 7. A gasholder typical of the type employed as a water gas relief holder. Source: National Grid Gas Archive.**

#### Exhauster

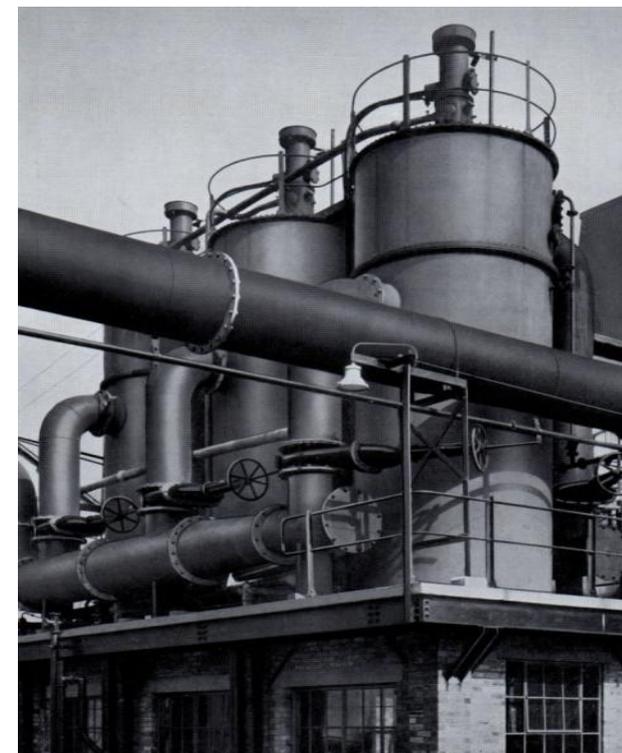
The exhauster was a gas- or steam-driven pump which would draw the gas from the relief holder and push it through the tar extractor and purifiers until finally being mixed with coal gas in the gasholders. Water gas was mixed with coal gas at a proportion of approximately 30% water gas to 70% coal gas.

#### Tar Extractor

Prior to tar extraction, the gas was sometimes passed through filter boxes filled with layers of coke (as they did at the Garston Gasworks in Liverpool). The coke would remove any heavy tar which remained trapped within the gas.

A range of tar extraction systems were developed, but the most popular (prior to the development of electrostatic detarrers) was a Pelouze and Audain tar extractor. This consisted of an outer cylindrical casing with the gas inlet entering through the centre of the base. A bell similar to a small gasholder was suspended over the inlet pipe and had its base sealed in liquor. This created various

perforated walls through which the gas would have to travel, providing the greatest possible disturbance to the gas and maximising the possibility for removing tar. This machine was automatic and could increase its surface area if gas flows increased.



**Photograph 8. Electrostatic detarrer. Source: National Grid Gas Archive.**

The electrostatic detarrer was introduced into Britain on some larger gasworks post-1930. It removed tar using an electrostatic attraction. As the gas passed through the electrostatic detarrer (Photograph 8), it was exposed to a very high negative voltage, giving the tar particles a negative electrical charge. As the gas continued through the detarrer, it was exposed to a high positive voltage. The negative charge obtained by

the tar particles would then attract them to the positive electrode, where the tar would be removed.

Further processing was not normally required for tars produced from coal carbonisation; it was, however, required for CWG tars, as their neutral density (similar to water), made them very hard to separate from water and they could emulsify. The following two sections describe plant used specifically for the treatment of water gas tars.

### Tar Separator

Tars from the processing plant described above would be passed to the tar separator. The latter was a relatively simple device operating on the principle of gravity separation. Tar separators used on gasworks would typically be installed at least 1.8m (6ft) below ground, so the top of the separator was at ground level.

The separator was built from concrete and the top was covered by planks. If not built robustly, tar and liquor could escape from cracks in the separator wall. If volumes of tar were too great, it could escape over the top of the separator. Separation was achieved by gravity across a drop of about 0.3 m (1 ft), with wooden planks inserted to increase the flow path across weirs to encourage separation. The separator was usually adjacent to the point of discharge for the gas-liquor waste water. Tar separators were not effective for all tars and some required further treatment.

### Tar Settling Tanks and Lagoons

The tarry emulsions which could form under certain conditions required a large storage capacity to allow the emulsions to settle. The tank of the relief holder often provided part of this storage capacity, but specific tanks were also constructed. These tanks allowed the tarry

emulsions to very gradually settle into the constituent tar and water, so the tar could be decanted off.

Difficult tar emulsions could be treated by heating, reducing the viscosity of the tar, and making it easier for the water droplets to coalesce. High temperatures were required to produce very fine particles of water. These tanks were heated indirectly by steam, and the tar and water decanted off. Heating could also be undertaken at high pressures to aid separation.

Some CWG plants used lagoons for tar settlement; including unlined lagoons constructed as a temporary measure to deal with large volumes of tarry emulsions. Being unlined, they also operated as soakaways and could be a major source of pollution. Such lagoons have been well documented in the USA, however their use in other countries is less well understood.

On larger gasworks' centrifuges, distillation units or spray baths would have been used. The former Tottenham Gasworks (UK) used both centrifuges and cyclones to separate waste-gas tars. Post-1945, chemical treatment (e.g. surfactants) to separate the tar and water phases became a regular practice.

### Purifiers

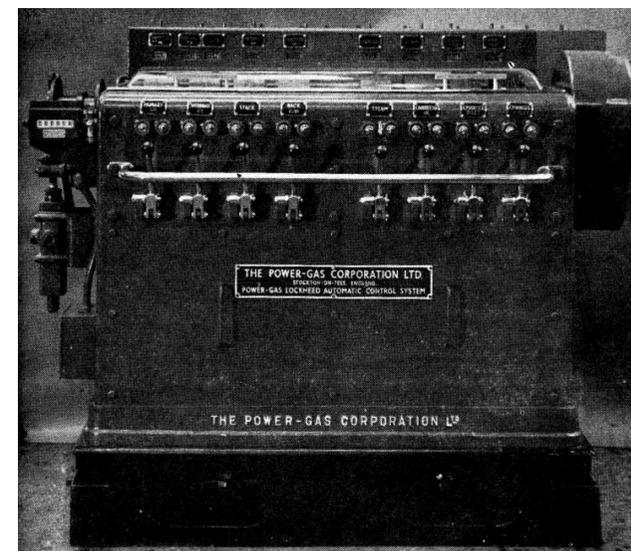
Water gas contained hydrogen sulphide and organic sulphur compounds (e.g. carbon disulphide), which required removal. This was achieved by using a purifier, a square cast-iron box supported on wooden grids and containing layers of iron oxide mixed with wood shavings. If tar reached the purifiers it was filtered out of the gas by the wood shavings.

### Waste-Heat Boiler

The blast gases from the blow phase exited the plant via a waste-heat boiler (Figures 11 and 12). This recovered some of the heat and energy from the exiting blow gases, which would otherwise be lost. This was a common feature of plant in excess of 28,000 m<sup>3</sup> (1,000,000 ft<sup>3</sup>) per day.

### Operation

Early water gas plants were manually operated. Given the cyclical nature of the process, this was time consuming and could be prone to error. To minimise the risk of mistakes, interlocking gears were developed to prevent operation at the wrong time or out of sequence. This allowed all operations (except removal of clinker) to be controlled mechanically from the raised floor at the top of the generator (Photographs 4 and 5). Later, the removal of clinker also became mechanically automated.



**Photograph 9. A Power Gas carburetted water gas plant hydraulic operator. Source: National Grid Gas Archive.**

As water gas plants increased in capacity, the manual effort required to operate them became so great that, in 1915, hydraulic operating systems (Photograph 9) were introduced. These systems had progressed so much by 1921 that a single centralised operating unit was introduced, automating the whole process. In the early 1920s, automatic coke-charging units were introduced, allowing continuous operation of the plant.

### Up-run and Back-run

As the water gas process became more advanced and sophisticated, the run became split into two separate phases: the up-run and the back-run (Figures 11 and 12).

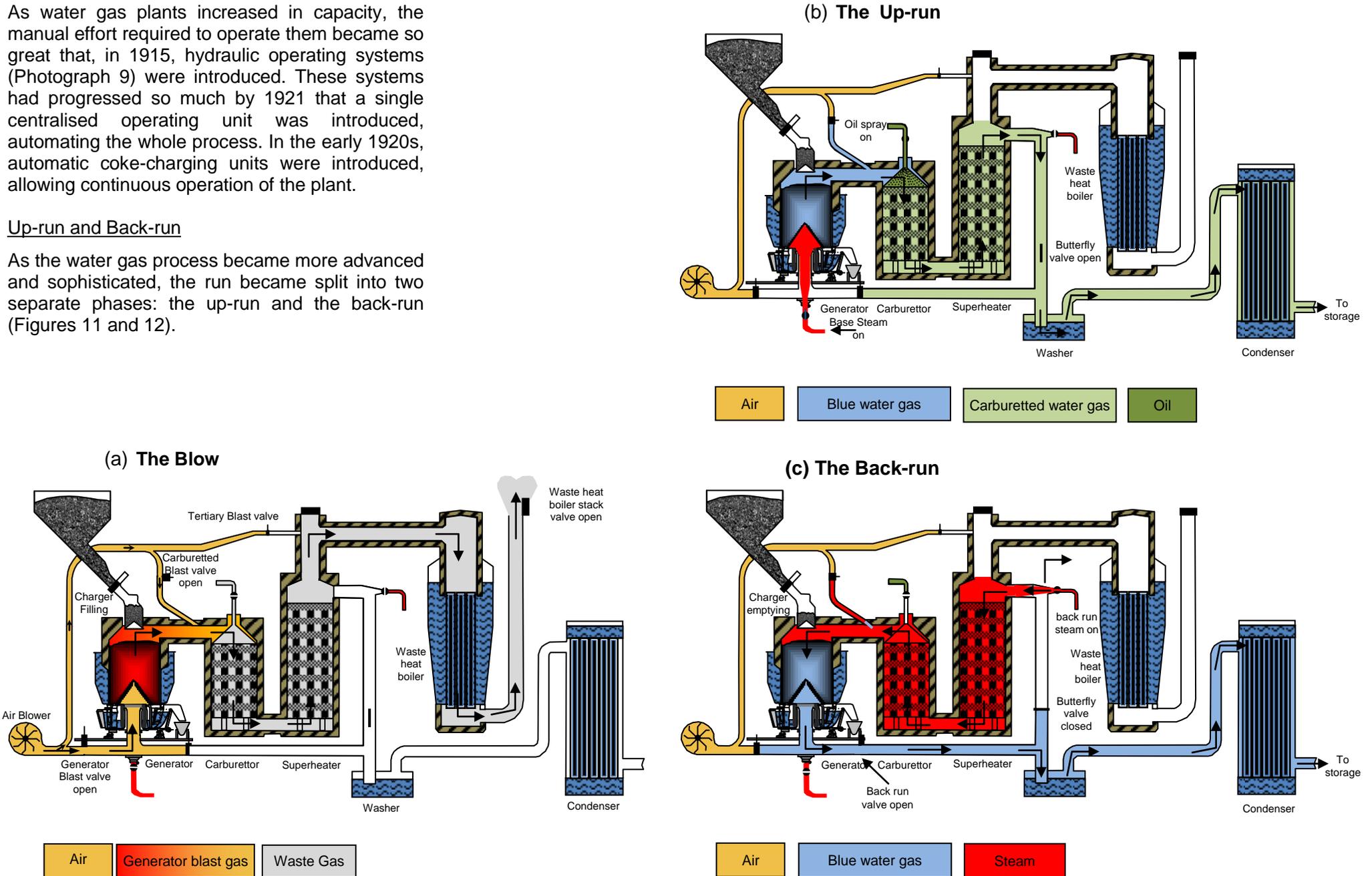


Figure 11. Operation of a water-sealed Humphreys and Glasgow type water gas plant, showing the Blow (a), Up-run (b) and Back-run (c). Source: Russell Thomas.

The up-run (Figure 12) was the phase during which all the enriching oil was added to the gas. It was the main gasmaking phase, analogous to the 'run' described earlier.

After reaching a temperature of approximately 1200°C during the blow phase, steam was admitted to the base of the generator forming blue-water gas as it passed upwards through the fuel bed (by the processes described earlier). As gas passed through the carburettor, oil was sprayed; this vaporised in the chamber and on the chequer brick, becoming fixed in a gaseous state in this chamber and the superheater. The gas then passed through the washer and other auxiliary processing plant."

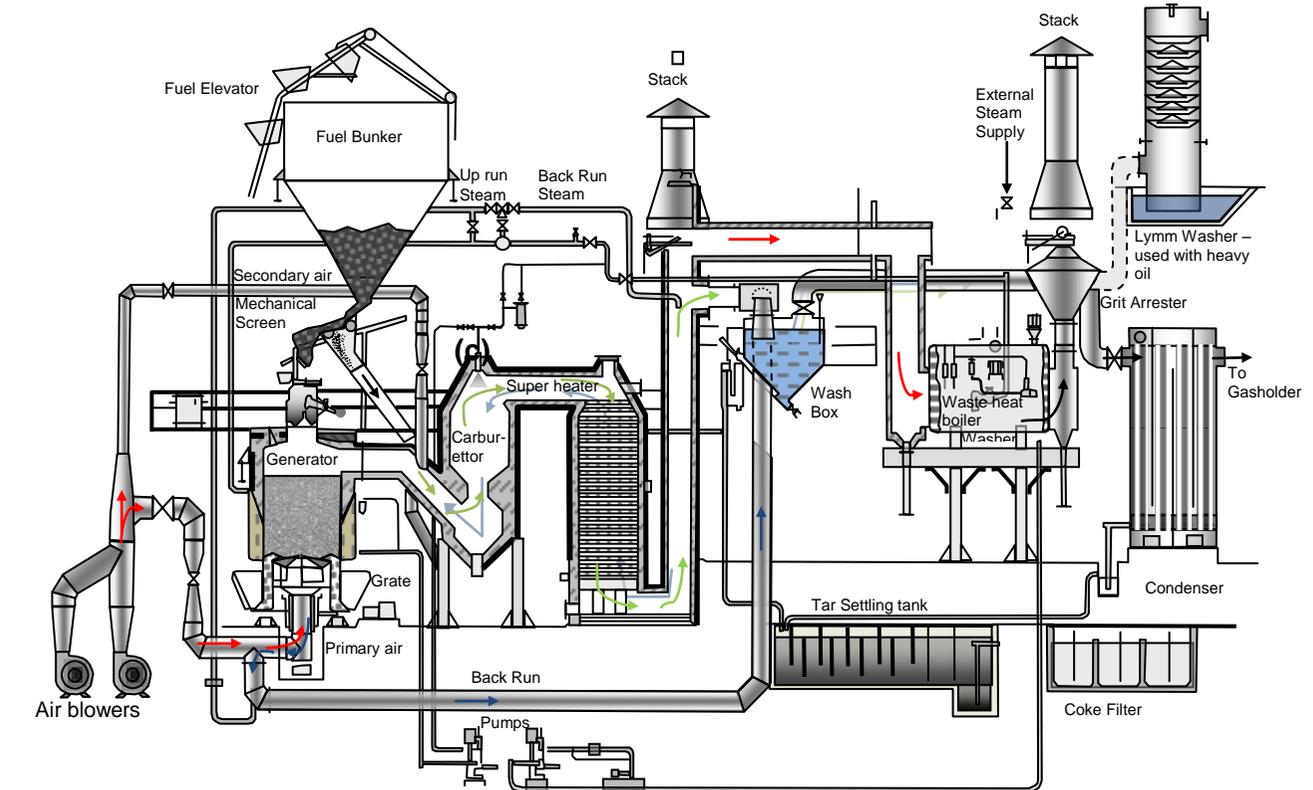
During the back-run, the plant was run in reverse. Steam was admitted to the top of the superheater, travelling down and up through the carburettor, and absorbing heat in the process. It then entered the fuel bed (generator), returning the heat and also producing blue-water gas.

## 9. Types of Fuel used

Coke and anthracite (a high rank coal) were the fuels most commonly used in Britain for the water gas process. When these fuels were in short supply, unavailable or very expensive, other forms of coal were used. The fuel type affected the design of the water gas plant, so adaptations needed to be made. Fuel use varied from region to region, depending on availability.

### Coke

Coke was the preferred fuel source for water gas plant in Britain. Coke used for gasmaking would be egg-sized lumps of uniform coke and free from fines. If the coke was produced on a gasworks to make water gas, it would be screened to remove breeze below 2 cm (0.8 in) diameter size.



**Blow** → **Up Run** → **Back Run** →

**Figure 12. A section through a CWG plant manufactured by the Power Gas Corporation, using reverse-flow carburettor and superheater. Source: Russell Thomas.**

Denser coke would allow more fuel to be stored in the generator, but less-dense coke was thought to be more reactive. The important factors were a low sulphur content and low ash content.

### Anthracite

Anthracite was the most dense form of carbon that could be used in water gas plant. It was also used at an egg size, with minimal fines, and contained approximately 10% ash, although the lowest possible ash content was preferred.

### Bituminous Coal

Bituminous coal could be used in water gas production, but was avoided where possible given the complications it would cause within the generator and in the gas purification. It was not until 1917-18 that war restrictions on coke supplies in the USA led to alternative fuels being tested. In states such as Illinois, where the availability of coke or anthracite was limited, cheaper sources of bituminous coal were available and could be sourced locally. The USA

continued to use this coal after 1918. It presented three main problems:

- i) Reduced plant capacity due to problems associated with maintaining the burning fuel bed.
- ii) The chequer brick in the carburettor and superheater became covered in fine fuel from the generator.
- iii) Smoke generation from the incomplete combustion of the tarry matter from the coal when freshly charged.

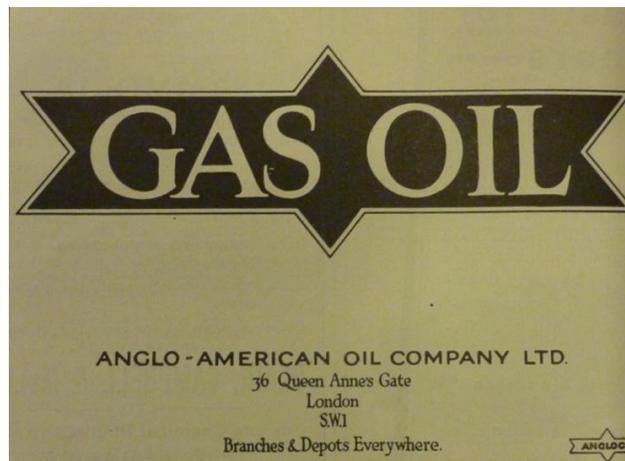
When used in the water gas plant, bituminous coal would act in a similar way to coking coals in a coke oven. Most of the activity would be confined to the peripheral edges of the fuel bed; the latter would then shrink away from the wall, forming a plastic mass in the centre of the fuel bed. This was more resistant to both the blast air and the steam, and minimised the areas of activity in the generator. This could be overcome by a modified design called the pier design, in which the generator would contain one or two central piers. Further reference to this method can be found in Lowry (1945), listed in the Bibliography.

Coal was rarely used in British gasworks to fuel water gas plants, as coke was generally available. When used in CWG production, bituminous coal was found to increase the formation of emulsions within the tar produced, although this was more dependent on the type of oil used.

## 10. Oil Feedstocks used to enrich Water Gas

The choice of oils used in CWG production was originally limited to gas oil as prescribed by Lowe. Given the fluctuations in the availability and cost

of oil feedstocks, a variety of oils were eventually used, ranging from light fractions such as naphtha to heavy fuel oils such as Bunker C or #6 fuel oil.



**Photograph 10. An advert for gas oil by the Anglo-American Oil Company (circa 1920), a company set up by Standard Oil of New Jersey.**

In the early development of CWG technology, the preferred oils for use in the carburettor were in the range between naphtha and gas oils. Their specific gravity was between 0.845 and 0.865, their colour varied from yellow to green, and they were viscous in appearance. These light distillates produced little or no tar when used with coke or anthracite.

Across the world and in the USA in particular, different practices developed in operating water gas plants largely as a result of the availability and cost of generator fuels and oils. Gas oils became more expensive as they became in greater demand for motor vehicles. At the same time, demand for oil opened up new fields in the US Mid-Continent and Gulf Coast. These new fields contained oils with much greater asphaltic content

than the previously used paraffinic oils from Pennsylvania.

In Britain, early supplies of oil came from Russian/Azerbaijani oil fields, Romania or Scottish oil shales. Oils from the USA and Middle East became available later. As oils with a greater asphaltene content and a higher carbon-to-hydrogen ratio were used, more tar was formed. For heavy oils, as much as 30% of the volume of the oil could be converted into tar. Some plants became specifically designed for use with heavy oils, such as the UGI heavy-oil process.

There was therefore a great deal of variation in oil feedstocks used in CWG plants, regionally and internationally, based on the availability of supply and economics.

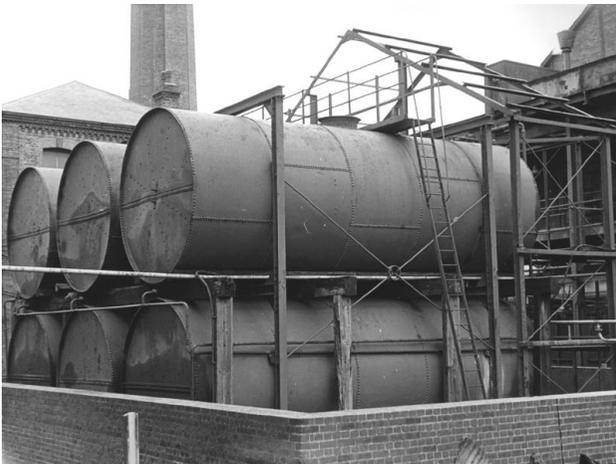
### Storage of Gas Oil

Gas oil was almost always stored in above-ground cylindrical tanks constructed from steel. These tanks were generally placed vertically (Photograph 11) but could also be horizontal (Photograph 12). Some later tanks were built from reinforced concrete, and special paints were developed to make the tanks impervious to oil.

These tanks often had minimal or no bunding. Logically, the oil tank would have been located near the CWG plant, but often this was not the case. This was due to site space constraints, the practicality of importing oil to the site from roads or rail sidings, or the historical development of the site using oil tanks from previous builds of CWG plant.



**Photograph 11. Construction of a traditional above-ground oil storage tank at Brentford Gasworks in 1929, showing the perimeter wall protecting the tank and the construction of the tank roof and walls. Source: National Grid Gas Archive.**



**Photograph 12. Horizontal cylindrical gas oil tanks at the Glynne Gap Gasworks in 1962. Source: National Grid Gas Archive.**

## 11. Oil Gas

'Oil gas' was sometimes incorrectly used as a name for water gas, in particular CWG. This is a slightly contentious point as CWG is a combination of blue-water gas and oil gasification.

Oil gasification was first practiced in the early 19<sup>th</sup> century where gas was made from fish and vegetable oils. It was manufactured by heating the oil in an iron retort, producing a gaseous mixture of hydrocarbon vapours resulting from the direct conversion of oil into gas by thermal cracking. The oil gas would have an illuminating power of 60 to 70 candles. As with the CWG process, the cracking of the oil produced a tarry residue consisting of free carbon, light oils and high molecular weight hydrocarbons which had not been converted to gas. The gas was washed with oil to remove any hydrocarbons in a non-gaseous phase, the residue remaining as a coke. This early type of oil gas led to a number of oil gas companies being established in Bristol, Plymouth, Edinburgh and Dublin. Many soon failed and those that survived switched to coal gas production. Many of these companies were established in the European continent and were longer lived in areas where coal was not easily available.

Conventional oil gasification, as practiced in the USA, was never a popular process in the UK, as a ready local supply of oil was not available. Exceptions to this were found in areas of Scotland such as Broxburn, where the Broxburn Gas Company was established to make gas from the local oil shales.

Oil gas manufacturing processes which were popular in the USA, such as the Jones process and Hall process, used carburettors for a similar function to the CWG process: to crack the oil into

gas-phase hydrocarbons. These plants were not particularly popular in Britain, the most notable installation being at the Gloucester Gasworks. Later, catalytic oil gas plant such as the SEGAS and ONIA-GEGI did become popular at gasworks across Britain. These plants sprayed oil onto a hot catalyst to crack it into gas-phase hydrocarbons. One industry which did use oil gas in Britain was the railway industry, which produced oil gas using the Pintsch oil gas process. This was used for lighting railway carriages and stations.

Gasmaking from oil and refinery by-products became more popular with the introduction of cyclic and continuous catalytic reforming processes (Photograph 13). This complex technology is discussed in more detail in *Gasworks Profile A - The History and Operation of Gasworks (Manufactured Gas Plants) in Britain*. Reforming was a more intensive process than the typical cracking process, and would require higher temperatures and the use of catalysts. Reforming processes were generally 'clean', and did not produce significant quantities of tar.



**Photograph 13. Oil reforming plant at the former Tipton Gasworks. Source: National Grid Gas Archive.**

It should be highlighted that, as an added point of complexity, some water gas plants were adapted to undertake fuel bed reforming, a common practice in some parts of Britain, such as South Wales. These processes would have also produced tars where heavy oils were used and could add yet another level of complexity to understanding the implications of the types of tars produced by CWG plants.

## 12. Water Gas Composition

Tables 1 and 2 provide a comparison of the various types of water gas and coal gas.

**Table 1. Composition of manufactured gases.**

	% composition			
	Coal Gas	Carburetted Water Gas	Blue-Water Gas	Dellwik Fleisher gas
H <sub>2</sub>	47.0	30.3-35.0	52.0	50.8
CO	7.75	29.1-32.0	38.0	39.65
CO <sub>2</sub>	3.5	3.4-4.5	4.5	4.65
CH <sub>4</sub>	27.5	21.3-13.0	1.0	0.82
Hydrocarbons	3.5	10.0-12.3	0	0.95
N	10.5	3.1-5.3	4.3	3.83
O	0.25	0.2-0.5	0.2	0.2
Candle Power	13.5	18.0	0	N/A
MJ/m <sup>3</sup>	19.3	21.6	11.1	N/A
BTU/ft <sup>3</sup>	520	580	300	N/A

Water gas was seldom used as a sole source of gas in the UK, but instead was mixed and blended with coal gas at a rate of approximately 30% water gas to 70% coal gas prior to distribution. In some areas of Britain (e.g. Newport, South Wales and parts of West and South Yorkshire) where coke oven gas was available, the local gasworks stopped coal-gas production, but maintained the ability to produce CWG gas for periods of high demand.

**Table 2. Composition of water gas, based on data compiled in Chemistry of Coal Utilisation (1945) and Gasmaking (1965). BWG = blue water gas and CWG = carburetted water gas.**

	US 1 BWG	US 2 BWG	UK 1 BWG	UK 2 CWG with gas oil	UK 2 CWG with light distillate
CO <sub>2</sub>	5.4	4.5	5.3	0.7	4.3
O	0.7	0.1	0.2	0.3	0.2
CO	37.0	40.7	39.2	32.7	27.0
H <sub>2</sub>	47.3	49.2	48.6	42.7	52.6
N	8.3	4.9	5.8	6.7	5.3
CH <sub>4</sub>	1.3	0.6	0.8	4.9	7.7
C <sub>2</sub> H <sub>6</sub>	-	-	-	1.1	0.1
Hydrocarbons	-	-	-	4.9	2.6
Total heating value in MJ/m <sup>3</sup>	10.6	11.0	10.6	14.4	14.4
BTU/ft <sup>3</sup>	287	296	285	389	389

## 13. The Advantages and Disadvantages of Water Gas Systems in Gas Manufacture

The advantages of using water gas were:

1. Water gas plants required a relatively low capital outlay, estimated by the gas engineer Alwyn Meade to be about one-third of the cost of a coal gas plant.
2. The footprint of a water gas plant was considerably smaller than that of a coal gas plant, requiring only a ninth of the space, approximately. Water gas plants were effective in reacting to sudden increases in demand and could produce gas within 1-3 hours of starting operations, compared to much longer timescales for a retort bench.

3. The calorific value of the gas could be easily adjusted by regulating the amount of oil added for gas enrichment.
4. Coke use could be reduced by not having to have retort furnaces operating on a slow burn.
5. Coke could be used for water gas production; as coke was a by-product of coal-gas manufacture, it gave greater flexibility and independence with regard to coal supplies.
6. As water gas could be made from coke, the water gas plant exerted influence over the coke market, avoiding the build-up of large stocks of coke.
7. The sulphur impurities in water gas were much lower than in coal gas, between 76% and 85% less hydrogen sulphide and between 80% and 58% less carbon disulphide and other sulphur compounds.
8. Operating a water gas plant required less manual labour than a coal-gas plant.
9. The wear and tear involved in a water gas plant was less than for a horizontal-charged coal-gas plant.
10. The system was relatively flexible; it could be used with a range of petroleum-derived oils and a variety of fuels from coke to bituminous coals.

The disadvantages of using water gas were:

1. Water gas contained a very high percentage of carbon monoxide, three or four times the amount found in coal gas. Carbon monoxide is highly toxic and therefore water gas posed a greater risk of poisoning.
2. At times of high oil costs, the manufacturing costs of carburetted water

gas were higher than for coal gas. The relative costs of oil and coal varied throughout the history of the gas industry, with coal eventually losing out when the price of oil fell.

3. The process required good quality coke or it was liable to fail.
4. As the CWG process used oils, it made the water gas process much more potentially polluting, especially if using heavy oils and/or bituminous coals; these made the tar much more difficult to separate and dispose of.
5. CWG was dependent on the availability of reasonably priced oil or oil by-products.

#### 14. Contaminants Associated with Water Gas Plants

Water gas plants posed slightly different environmental risks to traditional coal carbonisation plants. Whilst the blue-water gas process was relatively 'clean', producing little or no tar, the CWG process produced more contaminating by-products, especially water gas tars. The properties of these tars were highly dependent on the oil feedstocks used to enrich the gas.

##### Ash

Ash was the waste material remaining after the burning of the coke in the generator, and it was removed from the base of the same (Photograph 14). It contained heavy metals (e.g. arsenic and lead), though generally only at low concentrations, and some polycyclic aromatic hydrocarbons (PAH) such as benzo(a)pyrene. Ashes were often used for raising ground levels or on cinder paths.



**Photograph 14. The base of the H&G water gas plant installed at the former Southall Gasworks. Source: National Grid Gas Archive.**

##### Ammonia/Ammonium

Ammonia was not a problem generally associated with water gas production, as most nitrogenous components of coal which would form ammonia were removed from coke during the prior carbonisation process. Any residual ammonia forming in the gas would have been removed in the washer/seal or scrubber. Ammonia would become a more serious issue if bituminous coals were used in the generator. This situation would then be analogous to gas produced from coal carbonisation, and larger washers and scrubbers would be required to remove ammonia.

##### Tars

Blue-water gas plants would not generate significant amounts of tar. By comparison, CWG plants could generate significant concentrations of tars, especially if they used heavy oil to enrich the gas. The exact composition of the tar produced was dependent on many factors, the most important being the type of oil used for carburetting the gas.

In Britain, CWG plants were operated primarily with coke or anthracite (a high rank coal described earlier), but bituminous coals may have also been used. In the USA, the country where the CWG process developed into a commercial reality, coke and anthracite were used; however, there was also a tendency to use bituminous coals as generator feedstock, especially in the Midwest.

*Circa* 1903 there was a shift from eastern (Pennsylvanian) paraffinic oils to Texan and Californian asphaltic oils, which produced more tar. These problems were exacerbated when direct contact cooling became prevalent around 1907.

In the 1920s, there was competition from motor vehicles for gas oil, increasing its cost. For this reason there was also a tendency to use crude or other heavy oils such as Bunker C or #6 fuel oil within the carburettor. This change to heavier oils was also observed in Britain, although to a lesser degree.

Tars produced in the CWG process from coke and gas oil were not particularly voluminous or difficult to treat. Switching to heavier oil increased the amount of tar produced by up to 30% of the volume of the oil gasified. It also increased the moisture (water) content of the CWG tars, creating what came to be known as 'tar-water

emulsions'. These had greater than the 4-5% water content limit which was generally imposed by purchasers of gasworks tar (the tar distilling industry). Tar emulsions could contain up to 85% water content. To combat this issue, 'tar separators' were developed to separate the CWG tars and gas liquors, as described earlier.

Emulsions became an issue with the switch to heavier oils. Emulsions are a mixture of two or more liquids that are normally immiscible (unblendable), such as egg yolks and oil or milk.

The mixing of such fluids incorporates small particles of one into the other. In the case of CWG tar, fine droplets of water would become incorporated in the tar (the reverse could also occur). The characteristics of these tar and water emulsions could be quite different to the characteristics of the water and tar separately. As water content increased, the tars became more viscous.

It was shown in research undertaken in the 1920s and 1930s that the emulsified water droplets were surrounded by an outer layer of carbon-based particles (composed of particles of elemental carbon and pitch) and a membrane of asphaltene. These prevented the water droplets from coagulating and kept them stable within the emulsion.

These carbon particles acted as nucleation points, enabling the emulsions to form. The free carbon may have originated from fine particles of carbon exiting the generator or from smoke/soot produced when bituminous coal was used but insufficient air supplied. Alternatively, it could have been caused by using too high a temperature in the carburettor, forming carbon black from cracking heavy oils.

CWG tars are problematic in that they were often neutral Non-Aqueous Phase Liquids (NAPL), which makes them much more difficult to recover from the ground than dense or light NAPLs, as they formed the emulsions described above when agitated.

The composition of one particular CWG tar is given in Table 3. This CWG tar was produced using Russian 'Solar' type oil, probably sourced from the oilfields near Baku in the country now known as Azerbaijan.

**Table 3. Composition of water gas tar manufactured using Russian oil (Royle, 1907).**

Component of water gas tar	% composition by weight
Benzene	1.19
Toluene	3.83
Light paraffin	8.51
Solvent naphtha	17.96
Phenols	Trace
Middle oils	29.14
Creosote oils	24.26
Naphthalene	1.28
Anthracene	0.93
Coke	9.80
Other unidentified compounds	3.10

Sludges would form in the base of the washer as shown in Figure 10, and contained dust and grit carried over, as well as tars; these would have drained to a sludge tank prior to disposal. The main contaminants of water gas tars and sludges were:

- Aromatic and aliphatic petroleum hydrocarbons (including paraffins & naphtha).
- PAH.
- Phenolic compounds (e.g. phenol & cresol).
- Benzene, toluene, ethyl benzene and xylene (BTEX) compounds.
- Ammonia, organic and inorganic forms of sulphur, styrene, carbazole and dibenzofuran.

#### Spent Oxide

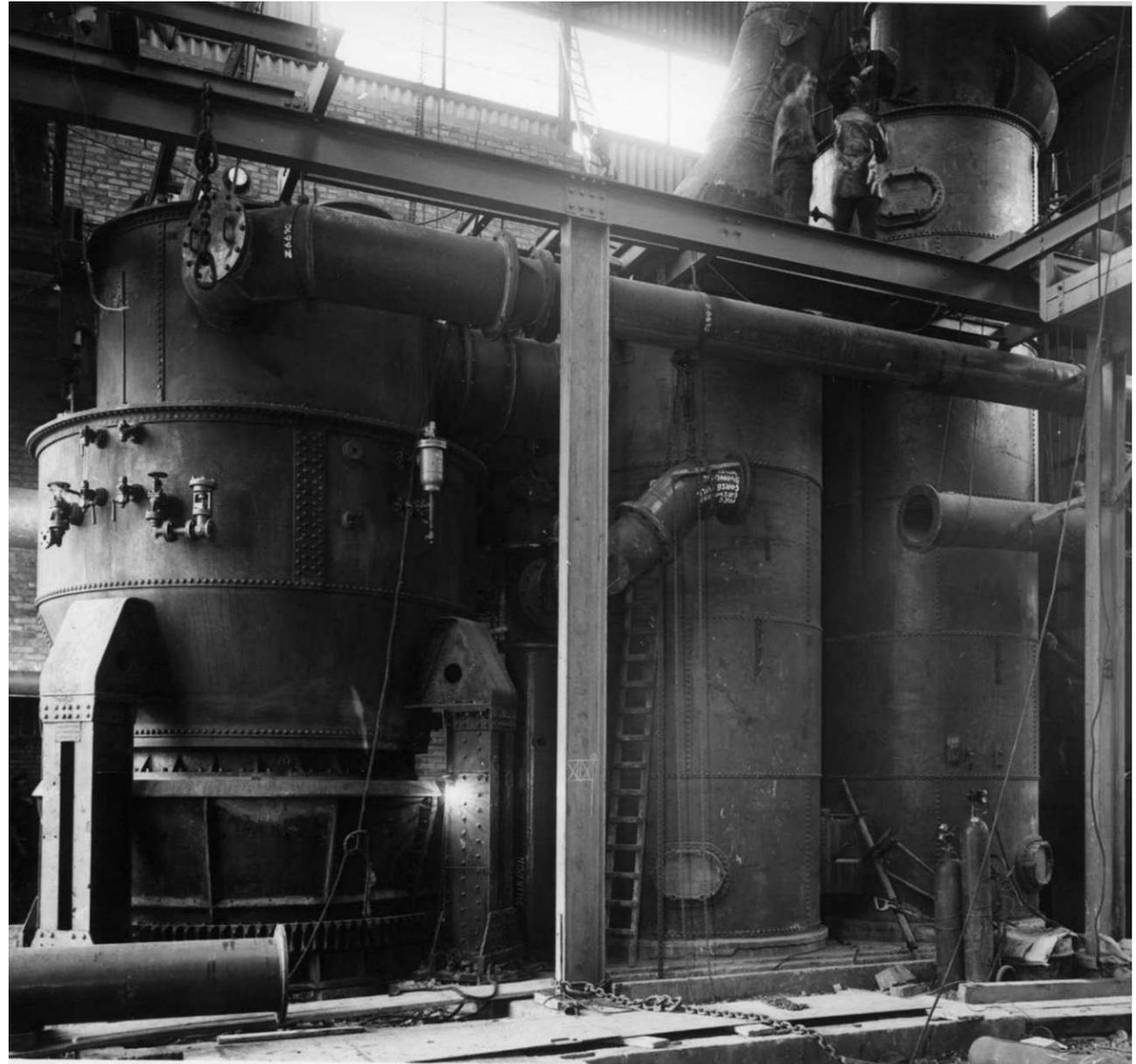
Bog iron ore, a fine granulated form of iron, was used to purify gas from water gas plants. Like coal gas, water gas would also contain hydrogen sulphide and organic sulphur compounds such as carbon disulphide, which would require purification prior to distribution. Like ammonium, the nitrogenous compounds which would form cyanide would have been removed from the coke during carbonisation, so little cyanide would be expected in the resulting spent oxide. Additionally, hydrated lime may have also been used in combination with the the iron ore in the purification of the gas.

The sulphur-saturated bog iron ore could be regenerated up to three times by exposure to the atmosphere, after which it became spent oxide, which contained about 50% sulphur. Any cyanide contained in the spent oxide would be much less than the approximate 8% cyanide found in spent oxide from coal carbonisation.

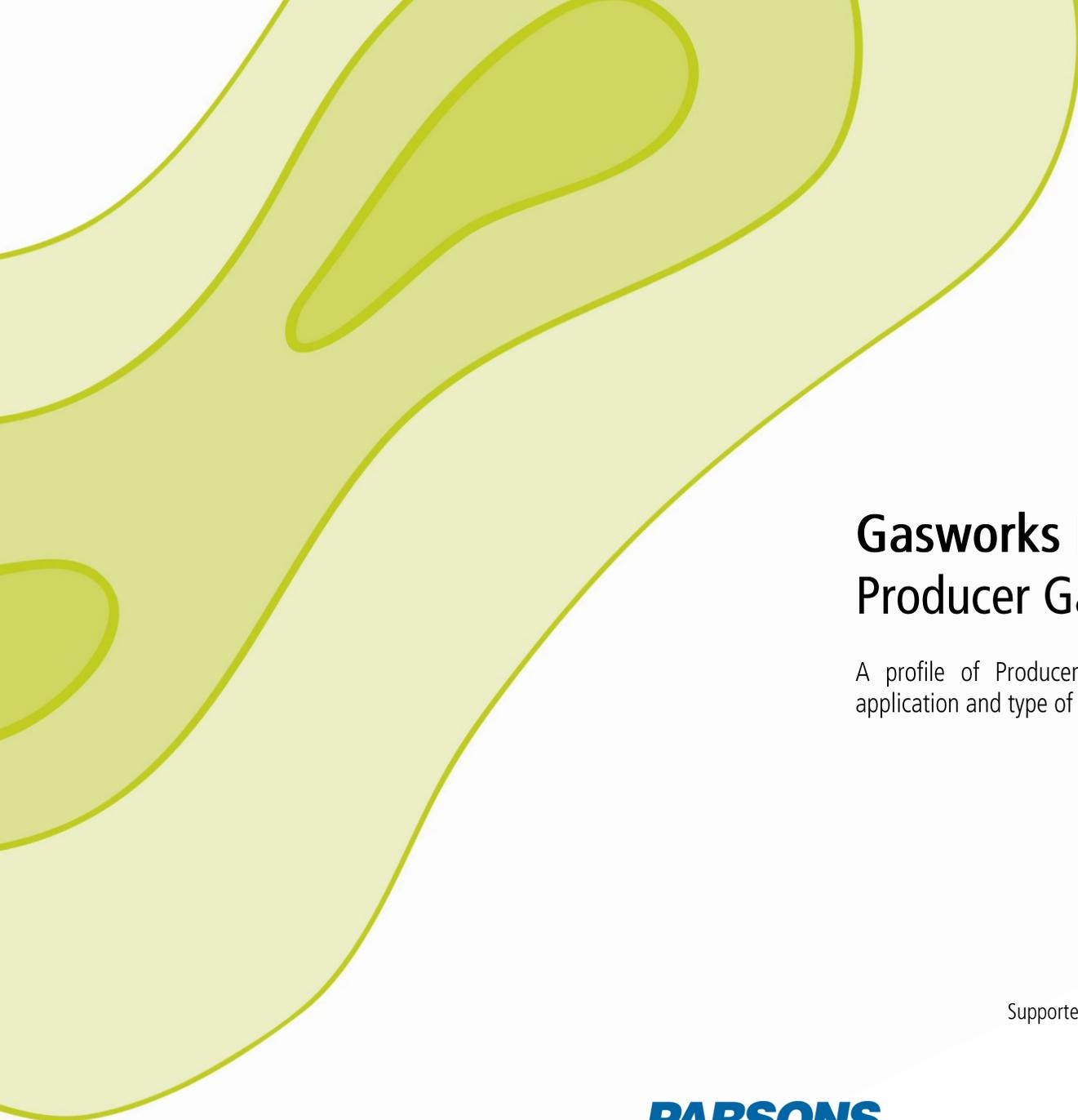
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**Photograph 15. Installation of a CWG plant at the Swindon Gasworks, showing from left to right the generator, carburetter and superheater. Source: National Grid Gas Archive.**



## Gasworks Profile D: Producer Gas Plants

A profile of Producer Gas Plants, their design, development, application and type of contaminants present.

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## Gasworks Profile D: Producer Gas Plants

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## Gasworks Profiles

Gasworks Profile A: The History and Operation of Gasworks (Manufactured Gas Plants) in Britain

Gasworks Profile B: Gasholders and their Tanks

Gasworks Profile C: Water Gas Plants

Gasworks Profile D: Producer Gas Plants

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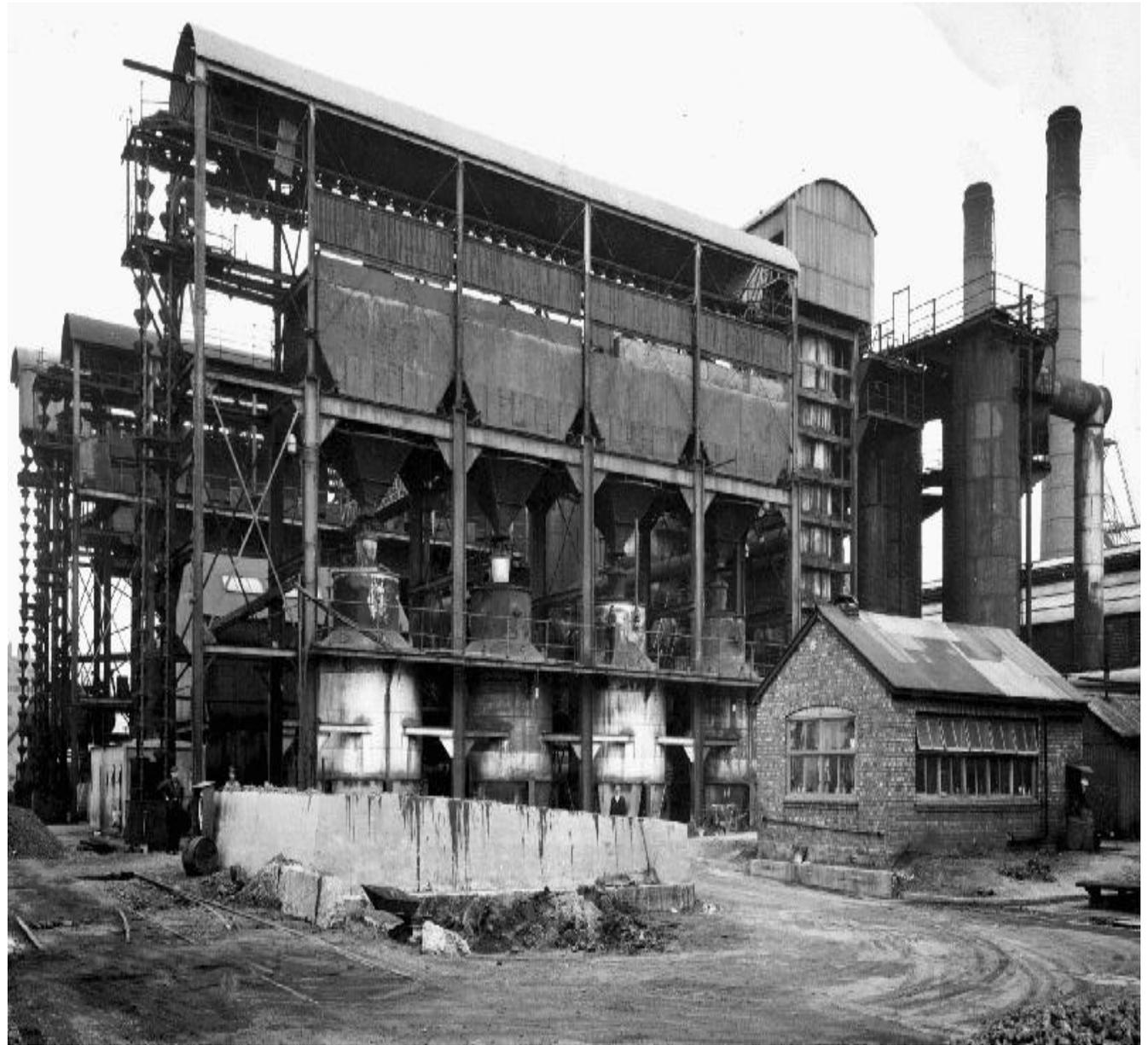
Disclaimer: The purpose of this document is to act as a pointer to the activities carried out on former producer gas plants. The Author and Publisher will not be responsible for any loss, however arising, from the use of, or reliance on, this information. This document ('this publication') is provided 'as is', without warranty of any kind, either expressed or implied. You should not assume that this publication is error-free or that it will be suitable for the particular purpose which you have in mind. The Author and Publisher assume no responsibility or liability for errors or omissions in this publication. Readers are advised to use the information contained herein purely as a guide and to take appropriate professional advice where necessary.

## 1. Introduction

When William Murdock used coal gas to light his house and office in Redruth in 1792, it was the first practical demonstration of how coal gas could be used commercially. Different combustible gases have been used ever since for commercial, industrial and domestic applications. Gas was first manufactured from coal and later from oil until its replacement in Britain by natural gas in the mid 1970s. The conventional production of gas from coal is well documented; however, there was also another simpler method of gas production which is less well known, called “producer gas”. Although producer gas was manufactured at gasworks, it was not generally used to provide a public supply. Its main application was supplying a cheap low calorific value gas for industrial heating purposes.

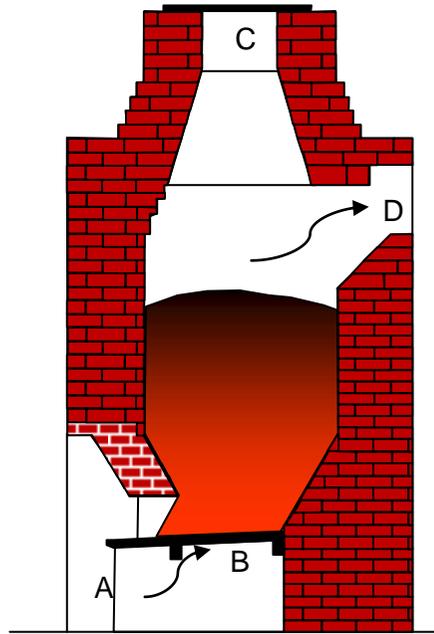
Producer gas plants started to become popular in the early 1880s and were in extensive use by 1910. As producer gas plants developed from the first plant built by Bischof (Figure 1) until their demise in Britain from competing technologies in the mid-20<sup>th</sup> century, many varied types evolved.

The German Bischof undertook the early pioneering work on the development of the gas producer. Bischof, from Magdeburg in the Saxony-Anhalt region of Eastern Germany, constructed the first gas producer in 1839. This was built simply from bricks as shown in Figure 1. It worked under suction conditions with air drawn through the producer from the top of the fuel bed. Bischof was closely followed by Ebelman in France in 1840. Ebelman’s design was based on a blast furnace and operated quite differently to Bischof’s. Ebelman’s producer was of a slagging type, using a mixture of coke and charcoal as fuel which was admixed with lime or furnace slag to produce a fusible ash. The producer was



**Photograph 1. The Mond gas plant at the former South Staffordshire Mond Gas Company plant, Tipton. Source: National Grid Gas Archive.**

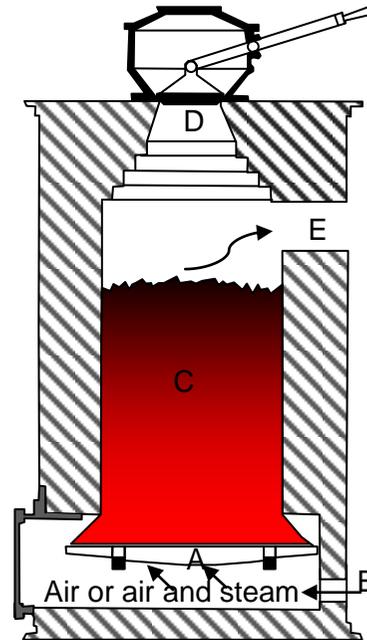
operated at a high temperature to ensure the slag was removed in a molten form.



**Figure 1. Bischof Gas Producer.** Air was drawn into the producer (A) through the fire bars (B) and fuel, exiting via the vent (D). Fuel was loaded via door C. Source: Russell Thomas.

The next major development was that of Fredrick Siemens who developed a combined gas producer and regenerative furnace in 1857. This system was gradually improved and introduced to the UK through William Siemens. Producer gas plants provided a considerable benefit to those industries requiring high and uniform temperatures. This greatly aided those industrial processes which were unable or found it very difficult to use directly fired solid fuel furnaces. It also saved fuel as the gas could be burnt at the exact point required.

A simple drawing of a gas producer using just air or air and steam is shown in Figure 2. A represents the fire bars or grate, B is the air inlet, C is the column of fuel, D is a hopper with a close-fitting valve through which the fuel is introduced, and E is the gas outlet.



**Figure 2. Gas producer working with air or air and steam.** Source: Russell Thomas.

The next major advance in the application of gas producers came in 1878, when Dowson developed the Dowson complete gas plant. This plant could be used both industrially and domestically. Dowson went on to demonstrate the effectiveness of gas engines (developed by Otto *circa* 1876) when in 1881 he combined one of his producer gas plants with a 3 horsepower (HP) Otto gas engine. These early gas engines had a maximum of 20 HP, equivalent to 14.9 kilowatts. But by 1910, gas engines had reached 2,000 HP, equivalent to 1,491 kilowatts.

*Circa* 1900, suction gas plants and engines were introduced; these plants were able to make more effective use of the lower quality producer gas and became a popular system in their own right.

## 2. Principles of Producer Gas

Producer gas manufacture differed from traditional gas production in the way and conditions in which the gas was made. A traditional gasworks would manufacture gas by indirectly heating coal contained within a retort through a separate furnace located beneath the retort. The retort was an oxygen-free environment, meaning that as the coal was heated, it would not combust but instead would thermally decompose, releasing gas and other by-products such as tar. This gas has a complex composition.

By comparison, and in simplistic terms, a producer gas plant would manufacture gas by partially combusting coke in an oxygen-limited atmosphere. The gas produced primarily consisted of carbon monoxide, carbon dioxide and nitrogen.

In slightly more detail, the producer gas plant made gas by forcing or drawing air, with or without the addition of steam, through an incandescent deep bed of fuel in a closed producer vessel. The fuel was gradually consumed during the process and the gas was simply piped to where it was required.

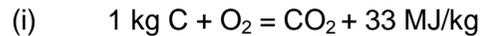
An important characteristic of the producer gas process was that no external heat was applied to the producer: it was heated by the combustion of the fuel within the producer itself. The skill in effectively operating a gas producer was to ensure that the fuel bed was of sufficient depth

and the air supply was not too great, limiting the amount of combustion.

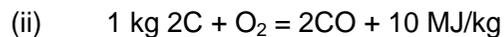
Once the fuel inside the producer had started to burn, the air supply was carefully controlled to allow continuous combustion in the lower regions of the fuel bed. This provided the high temperature required to produce the necessary reactions higher up the fuel bed and, if steam was added, to decompose the steam.

The producer gas process focussed on the incomplete combustion of carbon to maximise the carbon monoxide produced and minimise the amount of carbon dioxide (which has no calorific value). This was achieved through the reactions shown below.

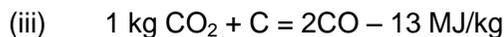
Within a conventional fire, the carbon in coal would react with oxygen forming carbon dioxide, an exothermic reaction where each kilogram (kg) of carbon would produce 33 megajoules (MJ) of energy.



This reaction also occurred within the fuel pile at the base of the producer. Due to the limited oxygen supply, carbon monoxide was also formed in the fuel bed according to the reaction below. This was also exothermic, producing 10 MJ for each kg of carbon.



As the carbon dioxide formed passed up through the bed of coke, it was reduced by further hot carbon higher up the fuel bed. This formed carbon monoxide through an endothermic reaction where 13 MJ of energy would be consumed for each kg of carbon:



This reaction was reversible and the amount of carbon dioxide converted to carbon monoxide was highly dependent on temperature. At 850°C, the reaction forming carbon dioxide was found to proceed 166 times more rapidly than the reverse reaction.

Where moisture was present in the fuel, or where steam was injected into the producer, additional reactions between the carbon and carbon compounds and water would occur. When steam interacts with carbon at a high temperature, it decomposes and the oxygen is transferred to the carbon, producing hydrogen. The oxygen released from the reaction of the steam could, depending on the conditions, combine with carbon to form carbon monoxide or carbon dioxide. These reactions are the basis of water gas production, which is the subject of *Gasworks Profile C - Water Gas Plants*. It is also discussed later in the section on Mond gas.

When coal gas was produced in a retort, complex organic compounds within coal would thermally decompose, forming gaseous and vapour phase organic compounds within the gas. If soft or bituminous coal was used in the producer, similar by-products would form in the gas (Table 1). In Great Britain, coke and anthracite were primarily used as the fuel in a gas producer. These fuels were primarily composed of carbon and produced few organic by-products within the gas (Table 1).

Theoretically, producer gas would consist of 34.2% carbon monoxide and 65.2% nitrogen, but these conditions would never actually occur. A composition of 25% carbon monoxide would have been the target.

Considering the composition in more detail, producer gas was a mixture of carbon monoxide, hydrogen, carbon dioxide and nitrogen, in varying

proportions, and a very small quantity of gaseous hydrocarbons (predominantly methane).

**Table 1. Composition of producer gas from coke and American soft coal.**

Component of the gas	% composition	
	Coke	Soft coal
Carbon monoxide	25	27
Carbon dioxide	5	4
Hydrogen	6	10
Methane	1	3
Nitrogen	63	55
Oxygen	-	0.5

The carbon monoxide, hydrogen, gaseous hydrocarbons were combustible (30-45% of the gas composition), and the calorific value of the gas was dependent on the relative proportions in which they were present. The carbon dioxide and nitrogen were diluents which lowered the calorific value and subsequent flame temperature of the combustible gases when burnt.

The nitrogen concentration in producer gas was much higher than in coal gas. This was because the producer was aerated by a restricted supply of air (nitrogen forms 78% of air) and coal gas was an enclosed process and not aerated.

Gas from producers can be split into two different types: "hot unpurified gas" and "cooled and purified gas". For most industrial heating purposes, the gas was used in a hot and unpurified state, allowing the entrained heat in the gas to be used in addition to the heat generated from burning the gas and any tar which may be present in the gas.

This avoided the cost of cooling the gas and minimised the use of regenerators to heat incoming air. There were problems using producer gas in this way; in particular, any precipitated tar

and dust could block pipes, allowing only short pipe runs to be used. Using coke would minimise tar deposition and bituminous coal would greatly exacerbate the problem.

If the item being heated was sensitive, such as kilns fired for glass or ceramic ware, then the dust and tar could damage the finished product. In these situations, and when used for heating retort/coke ovens or powering gas engines, the gas would be purified, removing any dust, ammonia and tarry residues. The gas was cleaned with a scrubber, which is described further below.

Producer gas could be obtained from almost any carbonaceous fuel. The type of fuel used depended not only on the purpose for which the gas was to be used, but on its cost and the ease with which each fuel could be purchased locally.

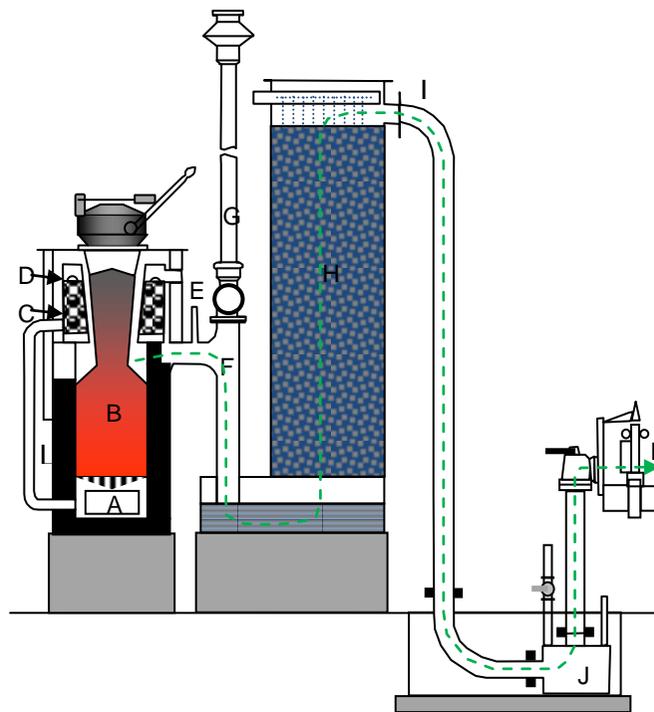
Producer gas was predominantly made from anthracite or coke, especially where the gas use was sensitive. Where the end use of the gas was not sensitive, bituminous or semi-bituminous coal could be used, and in some circumstances it was also possible to use brown coal, lignite, peat or charcoal. The composition of the gas and by-product was largely influenced by the nature of the fuel used as a feedstock.

### 3. Suction Gas

Early gas producers operated using the suction of gas through the fuel; this was later disregarded in preference to pressurised gas injection. Developments in the 1860s gradually led to the construction of efficient suction gas plants based on Dowson's design (Figure 3).

Suction gas plants were very effectively employed in combination with gas engines optimised for

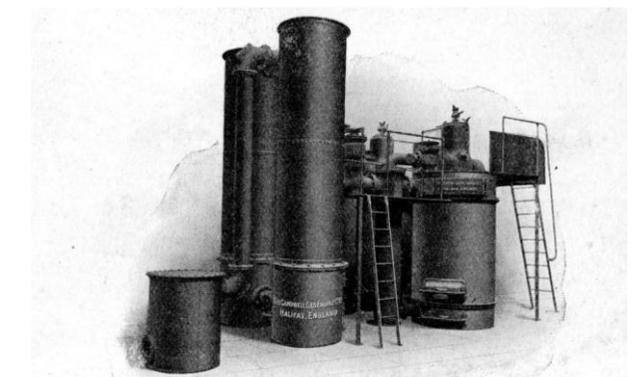
suction gas producers. The operation of the system can be explained by referring to Figure 3, where A was the grate on which the fuel was placed; B was the container holding the store of fuel, which entered through the hopper and valve at the top; C was a circular chamber filled with broken firebrick; D was a circular pipe which sprayed water into the system; E was the air inlet and F the gas outlet; G was the chimney; H was the scrubber with a water seal at the bottom; and I was the gas outlet leading to the expansion box (J) and gas engine (K).



**Figure 3. A suction gas plant of the Dowson design. Source: Russell Thomas.**

To ignite the fuel in the producer some oily waste and wood were placed on the grate and the producer was filled with small pieces of anthracite or coke. The feeding hopper was closed and the fire then lit. The fan (not shown in Fig. 3) was set

in motion, and the exiting gases from the producer were initially allowed to escape through the chimney. Once combustion was effective, the water supply would be turned on; as soon as the gas produced was burning effectively it was connected to the gas engine. The engine would be started and the fan stopped. From this time, the engine itself would suck the air required into the producer. Before entering the engine, the gases passed upwards through the coke-filled scrubber, ascending through a column of coke continually sprayed by water. The role of the scrubber was to purify the gas, removing fine dust, ammonia and tarry residues in particular. The gases then passed along the pipe main and into an expansion box, which was in direct communication with the engine cylinder.



150 B.H.-P. SUCTION GAS PLANT FOR ANTHRACITE. Provided with Duplicate Producer.

**"CAMPBELL"**  
**Suction Gas Plants**  
 FOR ANTHRACITE, COKE, CHARCOAL, Etc.

**THE CAMPBELL GAS ENGINE CO., Ltd.,**  
 HALIFAX, ENGLAND.

LONDON: 114, Tooley Street, S.E. GLASGOW: 104, Bath Street.

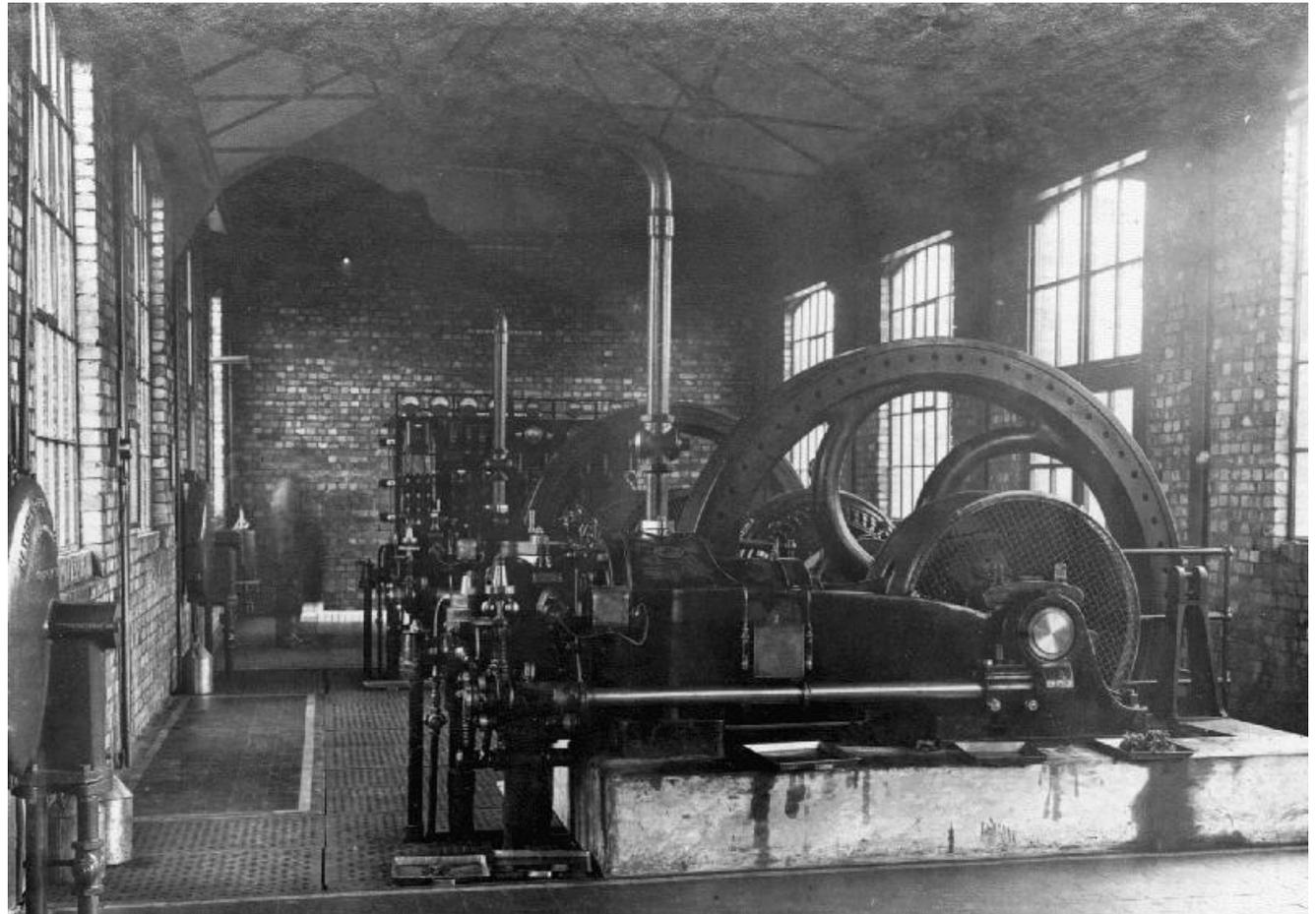
**Figure 4. An advert for a suction gas producer plant. Source: Russell Thomas.**

#### 4. Mond Gas

Mond gas was a variant of producer gas and was in essence a form of complete gasification whereby coal would be fully converted to ash, rather than to coke as would happen in a retort. The Mond gas process was designed to enable the simultaneous conversion of bituminous small coal (slack) into flammable gas, largely composed of hydrogen, and at the same time recover ammonium sulphate.

Sir George Bielby and William Young (of oil shale fame) did much of the early work on both the complete gasification process and the steaming of the char subsequently produced. Despite this, recognition for the Mond gas process goes to its namesake, Dr Ludwig Mond, who commercially developed the process. Mond realised that by greatly restricting the air supply and saturating that air with steam, the fuel bed could be kept dark red in colour, providing a low working temperature. There were two key reasons for the low temperature. Firstly, it was below the temperature of dissociation for ammonia, which prevented its destruction and maximised the amount of ammonia which could be obtained from the nitrogen entrained in the bituminous coal. Secondly, the low temperature prevented the formation of clinker which would hamper the operation of the process, the ash being easily removed from the water seal around the base of the cone of the producer.

The first Mond gas plant was put into operation at the Brunner, Mond & Co's Works at Northwich, Cheshire. These plants required a massive capital outlay in order for them to be profitable, as only very large plants were economically viable. They had to use over 182 tonnes of coal per week for the ammonia recovery to be profitable. The efficiency of the Mond plant was as high as 80%.



**Photograph 2. Two gas engines installed at the former Wandsworth power house. Source: National Grid Gas Archive.**

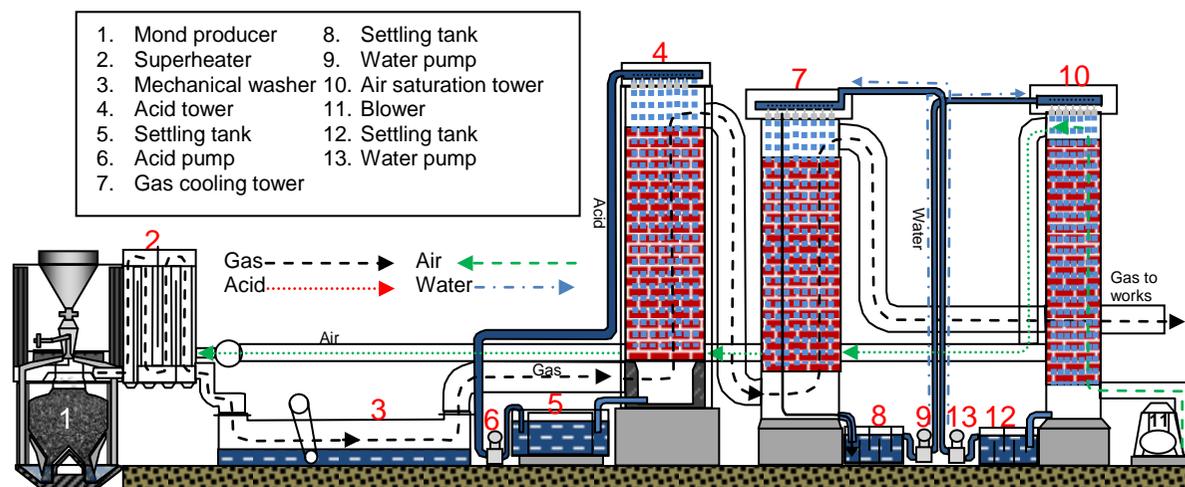
In order to achieve this, however, a large excess of steam was required so that the small proportion of steam which was decomposed (about one third) was sufficient to absorb the heat evolved in the formation of carbon dioxide and carbon monoxide from air and carbon. For each tonne of coal, two tonnes of steam would be required for the process. This amount was reduced to one tonne of steam if ammonia was not being recovered by the plant.

Coal would be fed by coal elevators, as can be seen on the left side of the building in Photograph 1, up to hoppers which would feed the small pieces of bituminous coal down into the Mond producers. The Mond producer operated at about 600°C and was fed with hot moist air (250°C) from the superheater.

Following the mechanical washer, the gas was subjected to treatment in the acid tower (labelled as 4 on Figure 5), which was designed to remove ammonia. The gas passed upwards through the tower against a counter-current flow of weak sulphuric acid sprayed down the brick- and tile-filled tower, forming ammonium sulphate. The weak sulphuric acid solution would be recirculated until a concentration of between 36 and 38% ammonium sulphate was reached. At this point, the solution would be removed and replaced by fresh weak sulphuric acid. The ammonium sulphate solution would be removed and evaporated, yielding the solid ammonium sulphate. The acid tower was lead lined (steel would have been corroded by the acid), as lead was resistant to corrosion and had been commonly used in processes involving acids (e.g. lead chamber process). The acid tower was therefore a source of potential lead contamination on these former Mond gas plants.

With the ammonia removed, the gas was then passed through the gas cooling tower (labelled as 7 on Figure 5), where the upflow of gas was met with a downward spray of cold water, cooling the gas. Following this treatment, the gas could be used for its intended purpose. The water from the gas cooling tower emerged hot, and any suspended tar within the water was removed in the settling tank (labelled as 8 on Figure 5). This hot water was then pumped up to the top of the air saturation tower where it was used to heat (to 85°C) the hot moist incoming blast air being blown into the Mond producer.

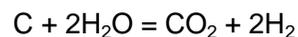
The Mond gas process would produce between 19 kg and 40 kg of ammonium sulphate and between 3,960 m<sup>3</sup> (140,000 ft<sup>3</sup>) and 4,530 m<sup>3</sup> (160,000 ft<sup>3</sup>) of gas per tonne of coal. The amount of ammonia produced was dependent on the nitrogen content of the coal, the latter having a preferred nitrogen content higher than 1.5%. The



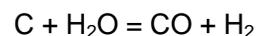
**Figure 5. The Mond system of gas production and ammonia recovery. Based on historical process drawings. Source: Russell Thomas.**

predominant reaction in the Mond gas process is between carbon and water forming carbon dioxide and hydrogen. The water gas process which predominates at higher temperatures forms carbon monoxide and hydrogen. Both reactions are shown below.

Predominant reaction in Mond gas process:



Predominant reaction in water gas process:



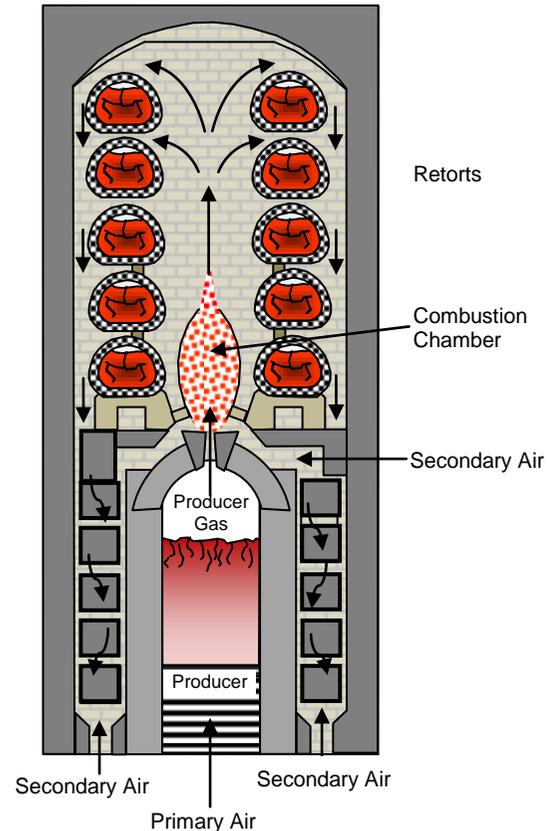
The gas manufactured was hydrogen rich and carbon monoxide poor (water gas has a much higher carbon monoxide content). It was of limited use for heating or lighting, but it could be used for some industrial purposes and power generation. The tar produced would have been brown in colour and typical of a low temperature coal tar, being high in paraffinoid components and tar

acids. It would have been removed and processed elsewhere.

The Mond gas process was further developed by the Power Gas Corporation as the Lymn system. This process was found on some larger gasworks and was more popular than the earlier Mond gas system. It was similar to the Mond gas system but used much weaker sulphuric acid and a different configuration of washers. Lymn washers can often be found recorded on plans of large former gasworks. The gas leaves the Mond producer via a piece of plant referred to as either a superheater or a regenerator (labelled as 2 on Figure 5). The purpose of this plant was twofold.

The heat of the gas and steam leaving the producer is transferred to the incoming blast of air and steam from the air saturation tower (heated to 250°C). The reverse of this is that the gas and steam leaving the producer is cooled by this process equally. From the superheater, the gas enters a mechanical washer (labelled as 3 on

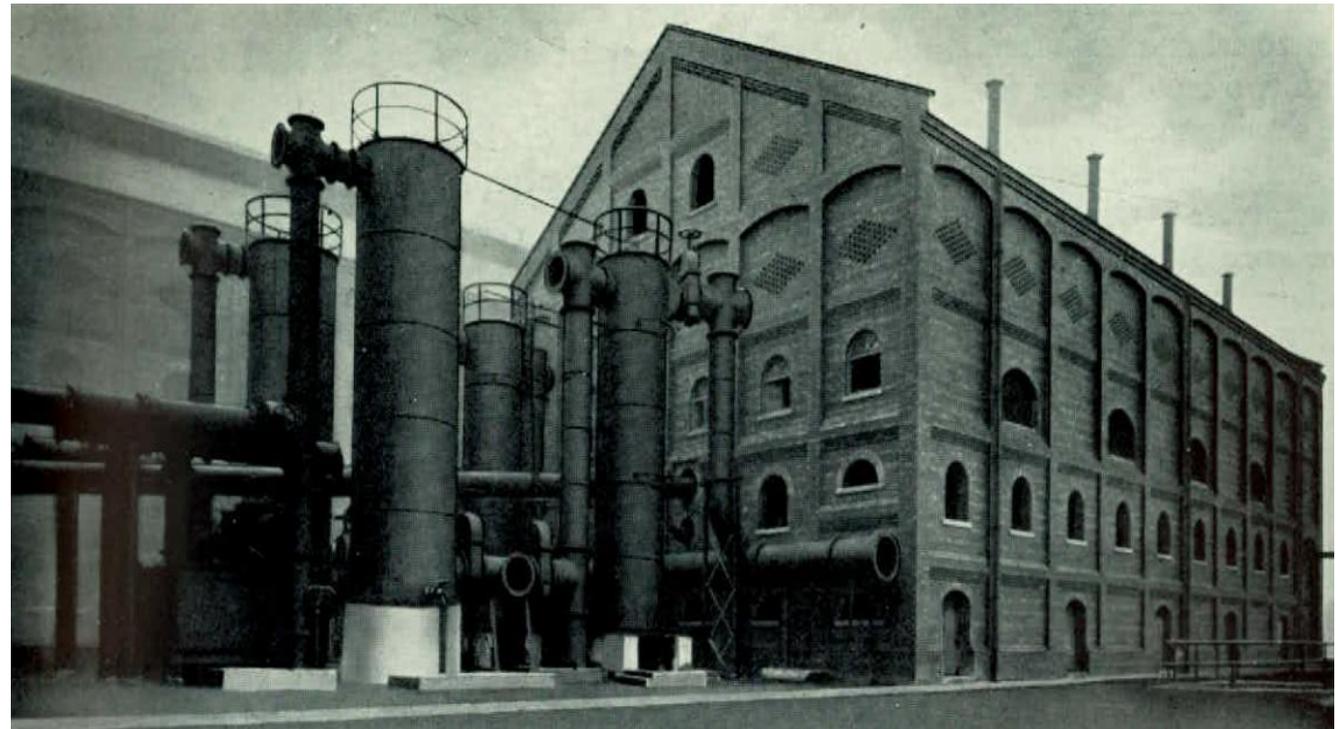
Figure 5), a rectangular iron chamber where the gas was thoroughly washed with a fine spray of water generated by rotating dashers. This further cooled the gas (to 100°C), whilst removing dust or heavy tarry residues.



**Figure 6. Cross section of a horizontal retort, showing the gas producer. Based on historical drawings, Source: Russell Thomas.**

## 5. Gas Producers, Gasworks and Coking Works

Gas and coking works were major users of gas producers, not for producing gas to distribute



**Photograph 3. The Trefois producer house, built by Drakes at the Partington Gasworks, Manchester, which supplied producer gas to the retorts. The ancillary washers and scrubbers can be seen outside the building. Source: National Grid Gas Archive.**

(although it was sometimes used to dilute town gas) but to produce a cheap low-grade carbon monoxide gas for the heating of the retorts.

Early gasworks used horizontal retorts which were heated directly by a shallow fuel bed of coke lit beneath the bench of retorts. The direct radiant heat from the fuel bed in the furnace and the hot waste gases heated the retort. This approach was not very efficient and was only able to heat the retort to temperatures of approximately 600°C. As a result, the amount of gas produced was relatively low in comparison with later methods and the decomposition of the organic compounds in the gas and resulting tar was limited.

The heating of the retorts developed from these early directly fired settings, through semi-gaseous fired settings (allowing some secondary combustion of gases), to gaseous producer fired settings, as shown in Figure 6.

The gaseous-fired setting used a gas producer to provide gas to heat the retorts. This system was used on all the different retort designs from horizontal to vertical. The gas producer did not need to be adjacent to the retorts (as shown in Figure 6), although if it was the heat loss was minimised. The producer could be located remotely on the gasworks supplying multiple benches of retorts. The fuel bed in a producer would be approximately 1.5 m to 1.8 m (5-6 ft)

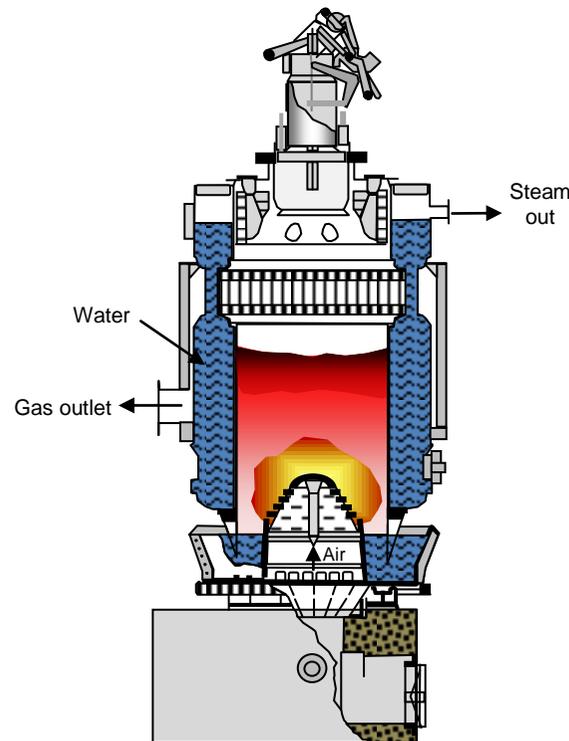
deep and the primary air supply was very carefully controlled to enable the correct composition of the producer gas. The producer gas was channelled to a combustion chamber directly adjacent to the retorts, where it was mixed with a secondary supply of air and burned. The subsequent hot exhaust gas was routed through flues around the retort, heating the coal in the retort.

The gas producer was the most efficient method of heating retorts. Fuel consumption was improved further in gaseous-fired settings if advantage was taken of the waste heat in the gas after heating the retorts. If the hot waste gas was used to heat incoming air via a heat exchanger then this was called a recuperative or regenerative gaseous-fired setting. If the hot waste gas just passed out of the chimney directly or via a waste heat boiler then it was termed a non-recuperative gaseous-fired setting. These developments helped make the gasmaking process more cost effective and much more efficient.

For large gasworks such as those at Partington and Garston, the producers were housed in external buildings (Photograph 3) and the gas was purified through washers and scrubbers before being piped to the retorts. Like most other producers, this plant was generally located above ground; therefore little evidence is found on former gasworks sites where the plant had previously existed.

Later gasworks, for example the one at East Greenwich in South London, used larger more advanced gas producers such as the Marishka type gas producer shown in Figure 7. This type of gas producer was separate from the gasmaking plant which, at the East Greenwich works, included both retorts and coking works. The producer gas was used for heating coke

ovens as well as retorts. It was common practice at coke works to use producer gas to heat the ovens. As the value of coke oven gas dropped (it could not easily be sold for domestic or industrial use) and the value of the coke increased, most coking works used coke oven gas to heat the coke ovens, rather than producer gas.



**Figure 7. Cross section of a Marishka type gas producer. Based on a historical drawing, Source: Russell Thomas.**

The more advanced gas producers, such as the Marishka producer, used steam injection into the air blast. The purpose of the steam was to control the endothermic water gas reaction, the temperature of the zone of combustion, the degree of fusion of the ash, and the temperature of both the grate and exiting producer gas. The

formation of water gas raised the calorific value of the gas above that of producer gas.

Producer gas production was a highly efficient process. It had low capital costs and became one of the most widely used industrial gas production methods in Britain, as it did not require cooling or gas treatment. As natural gas, liquid petroleum gas and oil-based town gases became available and coke became costly and scarce, the popularity of gas producers diminished; they are now largely obsolete.

## **6. Contaminants Associated with Producer Gas Plants**

In general terms, producer gas plants were not as contaminating as traditional coal gas production methods which used retorts to produce gas. This was primarily because the feedstock fuel used within a producer was predominantly either coke or anthracite (a high-rank coal with a low concentration of volatile hydrocarbons). In some circumstances, however, other feedstocks such as coal were used; these would produce much greater concentrations of oily and tarry components when heated. The Mond gas producer and other later developments, such as the Power Gas Corporation's Lymn System, did produce tar, typically of a low temperature. The Mond gas process used an acid-washing process to produce ammonium sulphate which required a lead-lined acid tower.

### **6.1 Ash/Coal Dust**

Ash was the waste material remaining after the burning of the coal or coke in the producer; it contained heavy metals (e.g. As, Pb, Cu, Cd, Ni, Zn) though generally only at low concentrations. Ashes were often used for raising ground levels or for use on cinder paths.

## 6.2 Ammoniacal Liquor and Ammonium Sulphate

Ammonia-rich liquors were formed in the scrubber of a conventional producer by spraying the gas with water. In the Mond gas process, ammonia-rich liquors were formed by spraying the gas with a weak sulphuric acid solution within the acid tower. The action of the water or weak acid dissolved the soluble ammonia and if phenolic compounds were present they would also be dissolved. In conventional producer gas plants, the ammoniacal liquor would consist of up to 1% ammonium and a much lower concentration of phenol. Ferrocyanide and thiocyanate may also be present. Within the Mond gas process (and similar subsequent processes) the concentration of ammonium could reach 38% and then solid ammonium sulphate would be produced from the concentrated liquor by evaporation.

High concentrations of ammonium may be found in the ground around scrubbers, washers and settling tanks and the connecting pipes.

## 6.3 Coal Tars

Significant concentrations of coal tars were generally not produced by producer gas plants, however those plants designed to be operated using bituminous coal (e.g. Mond gas) did produce coal tars. The exact composition of the coal tar produced depended on many factors, the most important being the type of gas producer operated (e.g. conventional or Mond type) and the type of coal or other fuel used.

In terms of elemental composition, coal tar is approximately 86% carbon, 6.2% hydrogen, 1.8% nitrogen and 1% sulphur, with the remaining 5% composed of oxygen and ash. In terms of the types of organic compounds present, a

composition of a typical crude coal tar carbonised in retort is given below.

- Saturates 15%
- Aromatics 37%
- Resins 42%
- Asphaltenes 6%

The exact proportions are likely to be different in producer gas tars. Producer gas tar was recorded by Young in 1922 as being very viscous and containing large amounts of water which would prove difficult to separate. If distilled, producer gas tar would contain no light oils, paraffins or high boiling tar acids, but would contain a large percentage of pitch. This suggests it was a highly degraded tar, similar to coke oven tar.

Mond gas tar, which was produced by a relatively low temperature process, would produce a low-temperature tar which would be brown, oily and contain unsaturated hydrocarbons (olefins), naphthenes, paraffins, phenols and pyridines; benzene and its homologues and aromatic compounds naphthalene and anthracene would be absent.

The main contaminants of concern within coal tar would be:

- Polycyclic aromatic hydrocarbons (PAH), in particular carcinogenic PAH such as benzo(a)pyrene.
- Phenolic compounds (e.g. phenol, cresols, xylenols).
- Benzene, toluene, ethylbenzene and xylenes (BTEX).
- Aromatic and aliphatic petroleum hydrocarbons.

- Ammonia, styrene, carbazole and dibenzofuran.

## 6.4 Lead

Lead was used to line the acid towers of the Mond gas plant. Lead may therefore be found associated with the site of the former acid towers on Mond gas plants.

## 6.5 Sulphuric Acid

Weak sulphuric acid was used within the acid towers in the Mond gas process to remove ammonia from the gas as ammonium sulphate.

## 7. Scenarios Where Producer Gas Plants Were Used

Gas producers were employed in Britain in many and varied industrial, commercial and domestic settings from 1880s to the mid-20<sup>th</sup> century. They are still used in some other countries.

Gas producers were used in the following settings:

- Gasworks, to heat the retorts and occasionally to produce gas at times of high demand.
- Coking works, to heat the coke ovens.
- Steel works.
- Ore roasting plants.
- Power stations.
- Factories and mills.
- Railway works.
- Glass works.
- Potteries and kilns.

- Muffle furnaces.
- Chemical works (e.g. those using the Mond process).
- Country estates to power gas engines for electricity generation and to directly drive plant such as saw mills.
- Large schools, hospitals or other public institutions to power gas engines for electricity generation and to directly drive plant.

Unlike conventional coal gasworks which are often visible on Ordnance Survey maps, producer gas plants are not always clearly marked. They did not always use large gasholders which would be marked on maps (labelled gasometer). Often, if the plant was small, it would be housed within a building and therefore not visible to the map surveyors. They may, however, be marked on site plans.

## 8. Case Studies

### 8.1 Small-Scale Gas Producer Plants - Canwell Estate

Canwell was typical of many country estates; it consisted of a substantial house, containing 43 rooms. The estate also included stables, garages and farms with associated tenanted cottages. As with many such estates, lighting would be very desirable, as would a readily available source of power.

The estate was powered by a conventional coal gasworks until 1905, providing light and power to the whole estate. Power came from two gas engines powered by the gasworks and was used for both pumping and powering the farm machinery. Where the tenants used gas, they were charged at the cost of production.

In 1905, an electric plant was installed to replace the gasworks. The plant consisted of two 30 HP gas engines (equivalent to 22.3 kW), each with suction-gas producers and two generators. The generators powered an accumulator (battery) capable of maintaining all the lights that were required for nine hours (overnight). The plant powered a maximum of 720 lights plus two additional 15 HP motors (equivalent to 11.1 kW) running various pieces of plant such as a saw mill and laundry. The conversion to the producer gas system was approximately 10-15% cheaper than the previous energy provided by the gasworks. This conversion to gas producers and electric power generation was common place *circa* 1900, when many country estates ceased coal gas production.

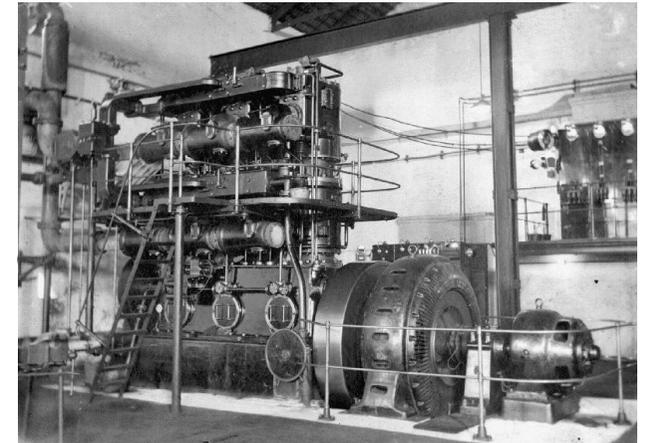


**Photograph 4. Suction Gas Producers at Canwell. From Country House and Its Equipment, L. Weaver, Country Life 1912.**

### 8.2 Medium-Scale Gas Producer Plants - Electrical Generating Stations and Gasworks

During the gradual switch to electrical power generation, some power plant used gas producers to power gas engines which in turn powered generators producing electricity.

Towns such as Chelmsford and Walthamstow switched to producer gas powered electricity generation. The electricity generating station of the Urban District Council of Walthamstow provided electric power for the electric lighting of the town and also for powering the electric tramway service. In this particular plant, the gas engines were built by Westinghouse and the producer gas plant used was a Dowson steam-jet type.

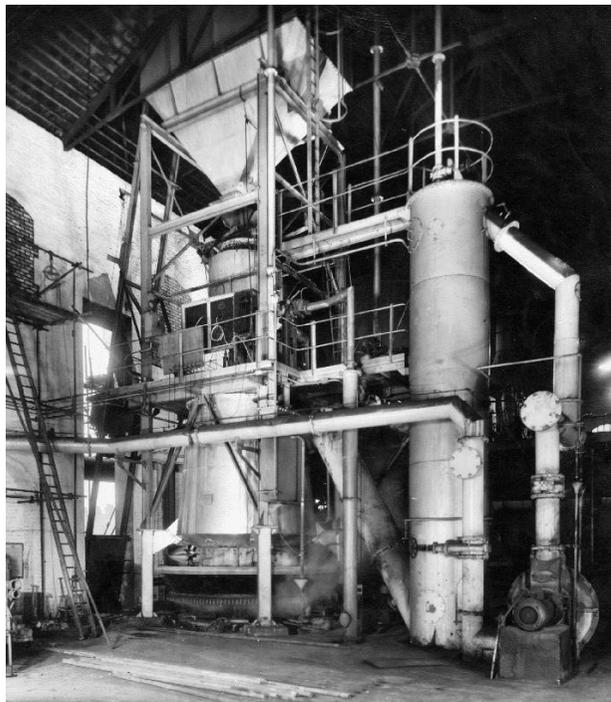


**Photograph 5. Gas engine powering an electrical generator at a colliery powerhouse, 1914. Source: National Grid Gas Archive.**

These works had an aggregate power of 3,000 HP (equivalent to 2.2 MW) in 1905.

As mentioned previously, gasworks were major uses of producer gas plants. They provided a cheap source of low calorific value gas which could be used to heat retorts and utilise the ready supply of surplus coke generated by the coal gasification process. Photograph 6 shows a gas producer at the the Garston gasworks located near Liverpool.

This plant operated producers for heating retorts, however it is also known that the producers were used to dilute the town gas supply at times of peak demand. Given that producer gas contained high quantities of nitrogen and carbon monoxide, then care would have had to be used not to dilute the gas too significantly.



**Photograph 6. Gas producer (left) and Scrubber (right) at the former Garston gasworks, 1947. Source: National Grid Gas Archive.**

The gas from the producers was cleaned using gas scrubbers, shown on the right of Photograph 6. These towers would be filled with material with a high surface area such as coke, ceramic or wood and would be continually sprayed with water to remove dust, any residual tar and ammonium.

### 8.3 Large-Scale Gas Producer Plants – South Staffordshire Mond Gas Company

The largest example of a producer gas plant in the UK was that built at Dudley Port, Tipton. This Mond gas plant was built by South Staffordshire Mond Gas Company *circa* 1902 after it had obtained the parliamentary powers to distribute producer gas in South Staffordshire via a gas distribution network. The plant was designed to house 32 producers, capable of gasifying over 600 tonnes of coal per day. To ensure a supply of gas could be maintained, the plant was designed in duplicate, including the producers, ammonia recovery, gas washing and cooling apparatus.



**Photograph 7. The former South Staffordshire Mond Gas Company works. Source: National Grid Gas Archive.**

The gas was distributed from the plant through the use of compressors at a pressure of 68.9 kilopascals (10 psi). The mains were manufactured as specialised asphalt-covered steel mains. The works provided gas to industrial customers via a specialised high-pressure gas network which covered a large area of South Staffordshire, competing against other gas companies. This was the first example of such as high-pressure gas network in the UK.

When the Mond gas plant switched to coke as a feedstock, the resulting gas was of a lower calorific value, as volatile and semi-volatile hydrocarbon and organic compounds were not present in coke. Gas from the plant therefore had to be mixed with conventional coal gas from a nearby gasworks to enrich its calorific value to make it suitable for use.

## 9. Known Producer Gas Plants

The sites listed below are examples of known sites or companies in the UK where producer gas plants were previously installed. This is not an exhaustive list and many other sites were also known to have existed, especially small producer gas plants such as that described at Canwell. It should also be noted that most medium- and large-scale gas manufacturing plants and many coke ovens also used gas producers to heat the retorts and coke ovens. These gas producers could be integrated or separate from the retort house or coke ovens.

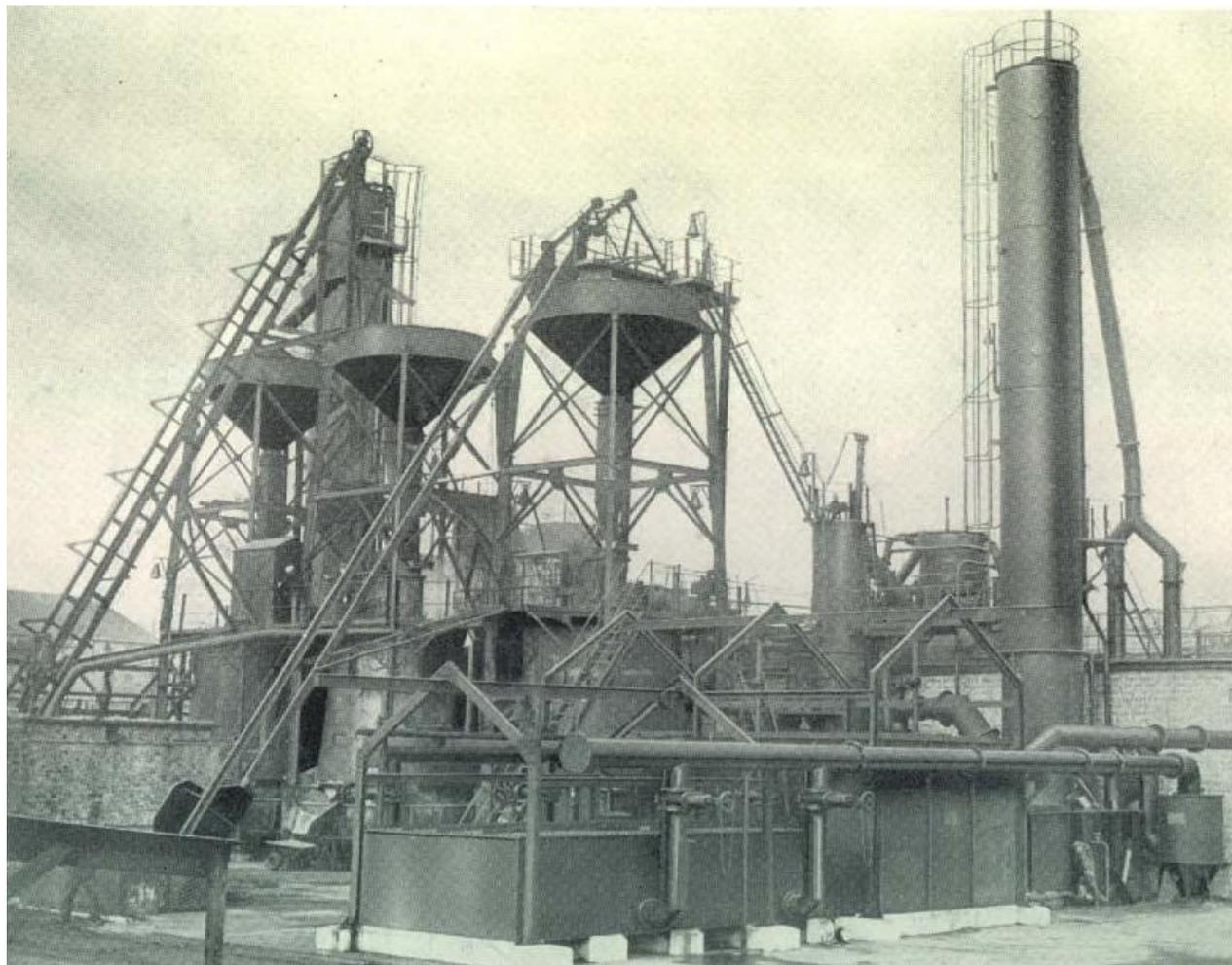
- The Castner-Kellner Alkali Co Ltd, Runcorn
- Albright & Wilson Ltd, Oldbury
- Ashmore, Benson, Pease & Co Ltd, Stockton-on-Tees
- Gloucester Asylum, Coney Hill
- The Railway and General Engineering Co Ltd, Nottingham
- Birmingham Small Arms Factory, Smallheath
- The Salt Union Ltd, Liverpool
- The South Staffordshire Mond Gas Co
- Brunner, Mond & Co Ltd, Northwich

- Cadbury Bros Ltd, Birmingham
- D&W Henderson & Co Ltd, Glasgow
- The Premier Gas Engine Co Ltd, Nottingham
- J&E Wright of Millwall
- The Trafford Power and Light Co Ltd, Manchester
- Walthamstow District Isolation Hospital
- The Farnley Iron Co.Ltd, Leeds

## 10. Selected Bibliography

Below is a selected bibliography of books which may be of interest to the reader:

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**Photograph 8. A producer gas plant with cooling and purifying plant for gasification of bituminous coal. Source: National Grid Gas Archive.**

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| <ol style="list-style-type: none"> <li>9. Meade, A., Modern Gas Works Practice, 1916, 1921, 1934, Benn Brothers, London.</li> <li>10. Newbigging, T., and Fewtrell, Wm., three volumes published between 1878-1913 King's Treatise on the Science &amp; Practice of the Manufacture &amp; Distribution of Gas, Walter King, London.</li> </ol> | <ol style="list-style-type: none"> <li>11. Smith, C.A.M, Suction gas plants, 1909, London, C. Griffin.</li> <li>12. Terrace, J., Terrace's Notebook for Gas Engineers &amp; Students, 1948, Ernest Benn, Ltd., London.</li> <li>13. Wyer, S.S. A treatise on producer-gas and gas-producers, 1906, New York, McGraw-Hill.</li> </ol> |
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