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The Manufactured Gas Industry: Volume 1 History

Prof. Russell Thomas

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Front Cover Image: Painting of the Cenotaph Whitehall, lit by gas from Daylight by Night, British Commercial Gas Association, September 1931.

SUMMARY

This set of reports aims to provide a detailed but succinct national overview of the manufactured gas industry to inform Historic England policy and conservation strategies. It provides an illustrated summary of what we know about this once vast industry. It has attempted to draw together the dauntingly voluminous amount of literature on the subject, which is held in a limited number of archives. This report will also be useful to a wide range of interested parties, such as local authority Historic Environment Record officers and others concerned with studying, managing and recording sites related to the manufactured gas industry. The report has been compiled as a desk-top study, although informed by past visits by the author to a number of former gasworks sites and over 22 years of involvement in the subject.

Manufactured gas was one of England's most extensive and important industries for over 150 years. Gas was manufactured on sites referred to as gasworks, which were present in every city, town and many villages across the country. They had a profound impact on both the urban and rural landscape. Not only visually, from the striking features of the gasholders and retort houses, but also culturally, socially and environmentally. The industry started in England but gradually spread across the British Isles, Europe and further abroad. The technology constantly evolved and different processes were developed, which allowed the industry to meet the challenges of increased production and competition from electricity. The manufactured gas era ended in the 1970s, most of the associated structures have been demolished and the last remaining vestiges of this era, the gasholders, are no longer required and undergoing a programme of demolition.

This document provides an overview of our understanding of the development of this industry. It outlines the history of gas manufacture from the first discovery of gas, the distillation of coal and oil, advent of the first factory gasworks, through the growth of the public gas industry (*c*.1800-1850), the introduction of new technologies, rationalisation (*c*.1919-1947), nationalisation (*c*.1949), switch to oil reforming, conversion to natural gas (1966-76) and privatisation (*c*.1986-2000). This is followed by a summary of the development of the processes, buildings, structures and engineering.

CONTRIBUTORS

This Report was written by Russell Thomas and desktop published by Rachel Forbes.

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My tea is nearly ready and the sun has left the sky.
It's time to take the window to see Leerie going by;
For every night at teatime and before you take your seat,
With lantern and with ladder he comes posting up the street.

Now Tom would be a driver and Maria go to sea,
And my papa's a banker and as rich as he can be;
But I, when I am stronger and can choose what I'm to do,
O Leerie, I'll go round at night and light the lamps with you!

For we are very lucky, with a lamp before the door,
And Leerie stops to light it as he lights so many more;
And Oh! before you hurry by with ladder and with light,
Oh Leerie, see a little child and nod to him to-night!
from THE LAMPLIGHTER
Robert Louis Stevenson

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1.INTRODUCTION

1.1 A Brief Description of the Manufactured Gas Industry

The manufacture of gas was one of England's most extensive and important industries for over 150 years. Gas was initially used for lighting, but later in the nineteenth century it started to be used for heating, cooking and a range of industrial uses. Gas was manufactured on sites referred to as gasworks, which were present in every city, town and many villages across the country. They had a profound impact on both the urban and rural landscape. Not only visually, from the striking features of the gasholders and retort houses, but also culturally, socially and environmentally. The industry originated in England, but gradually spread across the British Isles, Europe and all the continents except Antarctica. The technology constantly evolved, becoming ever more efficient and utilising new feedstocks, which allowed the industry to meet the challenges of increased production and competition from electricity. The manufactured gas era ended in the 1970s, most of the structures associated with this industry have been demolished and the last remaining vestiges of this era which survive in any number, the gasholders, are no longer required and where not protected are undergoing a programme of demolition.

This Report describes the historical development of the manufactured gas industry in England, outlining the processes used to manufacture gas from coal and other feedstocks and giving a brief description of other associated processes.

The manufactured gas era effectively began in the 1790s when the Scotsman William Murdoch and the Frenchman Philippe Lebon had started to develop experimental plants to manufacture gas from coal and wood respectively. The industry however, did not start in earnest until 1805 When Murdoch through his employers Boulton and Watt and his former apprentice Samuel Clegg, started to develop and sell commercial gas plants. These gas plants were initially designed for providing gas to factories or mills. Through the efforts of the German impresario Friedrich Winzer, these gas plants became the centre of networks, manufacturing and distributing gas for lighting streets, public buildings and private customers. The gas industry was the first public energy utility industry, with the first gasworks providing a public supply being built in London by 1813. Over the next fifty years the gas industry had expanded across the British Isles and abroad to a majority of the major population centres across the globe, often in part due to British enterprise and engineers.

For the first seventy years the gas industry's primary role had been to provide gas as a source of illumination, although other uses had been promoted with limited success. With advances in utilisation of gas through the development of the Bunsen burner in Germany, it started to find application in cooking and industrial and domestic heating uses, which became its primary markets as lighting gradually lost out to it's new rival electricity.

The gas industry also had significant effects on other industries. Most notably the coal industry, for whom the gas industry was a major customer. The textile industries were one of the earliest beneficiaries, where gas lighting improved the working conditions within the dark and cramped mills. The iron and steel industries were also impacted through demand for gas plant, pipes and appliances.

The gas industry created demand for coal transport from the UK coal fields, via canal barges, sea going colliers and the railways. The gas industry also stimulated industrial expansion through the demand for the by-products it created, namely coke, coal tar, ammonical liquor and spent oxide. The latter three being important feedstocks for the chemical industry. The by-products from gas making became important in their own right, producing fertiliser (ammonium sulphate), wood preservatives (creosote), dyes (azo dyes) and drugs (aspirin and morphine).

In the early 20th Century, British coke manufacturers started to follow their continental counterparts, realising the benefits of recovering the by-products of coal carbonisation. Coke ovens started to produce a surplus coal gas, where available this started to provide a bulk gas supply. Supplies were first provided for local towns, with local gasworks ceasing gas production for all but peak demand, where it could be supplemented with Carburetted Water Gas (GWC). This later evolved into regional high-pressure distribution networks following similar systems developed in continental Europe.

Different ownership models were adopted for gas undertakings, including: private ownership, company ownership and municipal ownership. Most gas undertakings had statutory powers resulting from an Act of Parliament to break open the streets, lay gas pipes and provide gas lighting, though many small undertakings were established without these powers. It became fashionable in the late 19th century for municipal authorities to purchase their gas undertakings.

The city of Birmingham was one such municipality which fought for control of its local gas industry. Birmingham received its first company in 1819, when the Birmingham Gas Light and Coke Company was established, taking over a private gasworks on Gas Street which had opened in 1817. A second gas company, the Birmingham and Staffordshire Gas Light Company was established in 1825, who built a gasworks at Swan Village, West Bromwich. This company in addition to supplying gas to Birmingham also had powers to supply gas to West Bromwich, Tipton, Oldbury, Smethwick Walsall, Bloxwich, Wednesbury and Darlaston. The operation of two rival companies caused significant inconvenience, as both companies were regularly digging up the streets to lay new or replace broken gas mains. In 1874 both companies had bills before parliament to raise more money and expand their operations and both bills were opposed by Birmingham Town Council. The Town Council then decided to promote a bill to parliament for the purchase of the two companies. The Birmingham Corporation purchased the two companies in August 1875. The then mayor and future MP, Joseph Chamberlain (shown in Figure 1.1) was heavily involved in the purchase and development of the Birmingham Corporation Gas Department, which became the largest provincial gas undertaking. The profits of which financed many of the cities improvements (Anon. 1928).

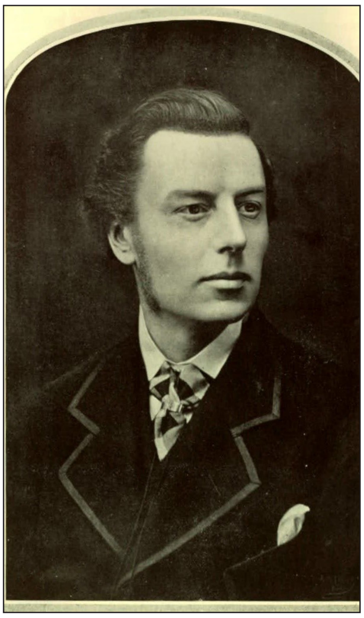


Figure 1.1. Photograph of Mr Joseph Chamberlain, taken during his time as the chair of the Birmingham Corporation Gas Committee. Source National Grid Gas Archive.

Social changes were also reflected through a series of gas workers' strikes in the late 19th Century leading to the unionisation of some of the labour force and the formation of the first union for unskilled workers, the “National Union of Gasworkers & General Labourers”. This was also led to improved working conditions and the 8 hr working day. At the same time George Livesey introduced a profit sharing through co-partnership scheme to stifle the unionisation of the South Metropolitan Gas Company.

The advent of the 20th century brought with it amalgamations, with small gas companies, being purchased by larger local rivals, who then closed the small gasworks and supplied them from their more efficient gasworks at a cheaper price. Some smaller gas companies survived under an ownership model which involved a holding company. Holding companies such as the Devon Gas Association or United Kingdom Gas Corporation provided financial and technical support, improving the efficiency of the small gas companies.

Both the First and Second World Wars had significant impacts on the industry. Many skilled labourers were lost to the war effort, never to return and in the Second World War, the gas infrastructure was heavily impacted by aerial bombardment. As can be seen in Figure 1.2, showing damage to thee Southampton gasworks following an air raid in World War II. Both the First and Second World Wars offered the opportunity for women to play an important role in the operations of the gas industry.

Figure 1.2. War damage inflicted by enemy action during World War II. Source Southampton Gas Light and Coke Company 1848-1948.

Following the end of the Second World War, the Heyworth review of the gas industry, paved the way for its restructuring. Under the labour government of the time this led to nationalisation. The industry in Great Britain was split into 12 area boards on a geographical basis; the gas industry in Northern Ireland was not included. The 1950s started to see a decline in the quality and quantity of gas making coals. The industry needed to adopt new methods of gas making from poor quality coals such as complete gasification. The remaining lower grade coals became more expensive and the industry started to look towards oil and natural gas as a potential replacement. The oil refineries in the UK at this time were producing by-products which could be purchased cheaply and "reformed" into town gas. This provided a stop gap of about 10 years until it was decided to switch to natural gas. Originally the importation of natural gas from the USA was trialled and later imports from Algeria regularly made their way to a terminal at Canvey Island. The discovery of the Slochteren Gas Field in the Netherlands, gave hope for similar gas fields in the UK waters of the North Sea. The subsequent exploration proved successful and in 1967 the first gas was brought ashore at Easington. The discovery of significant gas fields in the UK waters of the North Sea signalled the end of the manufactured gas era and the majority of the gas network converted to natural gas in the 10 year conversion period between 1966 and 1976. The last gasworks on the gas network at - Romford - ceasing production in 1976. and the last gasworks in Great Britain at Millport, on the Isle of Cumbrae (Scotland) closed shortly after in 1981.

1.2 Purpose

This document reviews our current understanding of the development of the Gas Industry in England.

There has been a considerable amount of literature published throughout the long history of the gas industry, from an early account published in the Philosophical Transactions of the Royal Society, to more recent studies of its business history. This has left a detailed history of its technical development, as well as extensive accounts of changes in society and the industry documented in books, industry journals (e.g. Journal of Gas Lighting) and company magazines (e.g. Co-partnership magazines).

Many gasworks and gas companies have been subject to historical accounts whilst operational or more recently in journals or local history publications.

The considerable archive of primary and secondary material is supplemented by the museum preservation of examples of equipment and machinery at the National Gas Museum Leicester and The Fakenham Museum of Gas and Local History. Apart from the former gas managers houses, only a small fraction of structures and other building types survive on former gasworks sites. these include offices, retort houses, purifier houses, stores, and meter houses. Those structures which have survived, have often done so because they had been sold pre-nationalisation and found a new purpose. There are also a few examples of surviving small gasworks buildings, which had been constructed to supply gas to private estates, country houses and hospitals. Surviving *in situ* machinery is very rare and, where it occurs, considerably enhances the value of remains. The most numerous surviving features on former gasworks are the gas manager houses and gas workers cottages. The most significant surviving features on former gasworks are the gasholders, which continued to be used in the natural gas era for gas distribution purposes. No gasholders in England associated with the gas networks are still in operation, they have all been decommissioned. The surviving gasholders and buildings associated with gasworks have a value in explaining the development of the gas industry in England, its regional variation and the way in which gas technology was put into practice and increased in scale and technical complexity.

This framework includes: a technical and historical outline: a breakdown of the archaeological components one would expect to encounter and an attempt to specify sources for identifying sites.

This report deals specifically with the production of gas from coal and other raw materials such as oil. It includes the storage and distribution of gas, covering the period of conversion to natural gas. A description of the gas industry beyond the gas manufacturing era, is provided for context and to assist the understanding of the fate and survival of former gasworks sites. It does not record in any detail the transport of fuel, customer consumption, by-product industries or the manufacture of gas plant or appliances. There are large number of gas lamps still in use in England, primarily in the City of London and Westminster, these are considered outside of the scope of this report and are not included in the gazetteer.

This report is geographically limited to England. It does not attempt to cover the gas industries of Scotland, Wales, Northern Ireland and the Republic of Ireland. It is, however, important to understand that the gas industry developed as a British rather than English industry, with expertise utilised from across the country. Scotland, Wales and Ireland contributed significantly to the development of the industry through their engineers, factories or technological advances. As an industry which developed due to international technology transfer and in order to allow informed judgements to be made, it has been deemed necessary to make reference to the gas industries of these and other countries.

1.3 Common Abbreviations used in the Gas Industry

Gas Plant

CWG – Carburetted Water Gas

VR = Vertical Retort,

CVR – Continuous Vertical Retort

IVR – Intermittent Vertical Retort

HR – Horizontal Retort

HR = Horizontal Retort

IR = Inclined Retort

TG = Tully Gas

PG = Producer Gas

W-D = Woodall Duckham

G-W = Glover West

BTU – British Thermal Unit

Institutions and Gas Companies

IGEM = Institution of Gas Engineers and Managers

IGE = Institutions of Gas Engineers

GLCC = The Gas Light and Coke Company

SMGC = The South Metropolitan Gas Company also known as the South Metropolitan Gas Light and Coke Company

Regional Gas Boards

EGB = Eastern Gas Board,

EMGB = East Midland Gas Board,

NGB = Northern Gas Board

NWGB = North Western Gas Board

NEGB = North Eastern Gas Board

NTGB = North Thames Gas Board

SGB = Scottish Gas Board

SGB = Southern Gas Board

SEGB = South Eastern Gas Board

SWGB = South Western Gas Board

WGB = Wales Gas Board

WMGB = West Midland Gas Board.

Other Terminology

HBR = Historic Building Record.

2. HISTORICAL BACKGROUND

2.1 Origins, Scientific Experimentation and Pneumatic Chemistry to 1800

2.1.1 Ancient Observations of Flammable Gas

There has been an awareness of flammable gases since ancient times, when 'Eternal Flames' formed the centrepiece of religious shrines (Figure 2.1). Some flames such as the fires of Chimera which burn at Yanartaş in Turkey, or the eternal fire of Baku on the Caspian Sea have done so for over two thousand years. These flames are fuelled by seepages of naturally occurring combustible gases from methane reservoirs or coal seams in the ground below (Piccardi & Masse 2007, Hunt 1907).

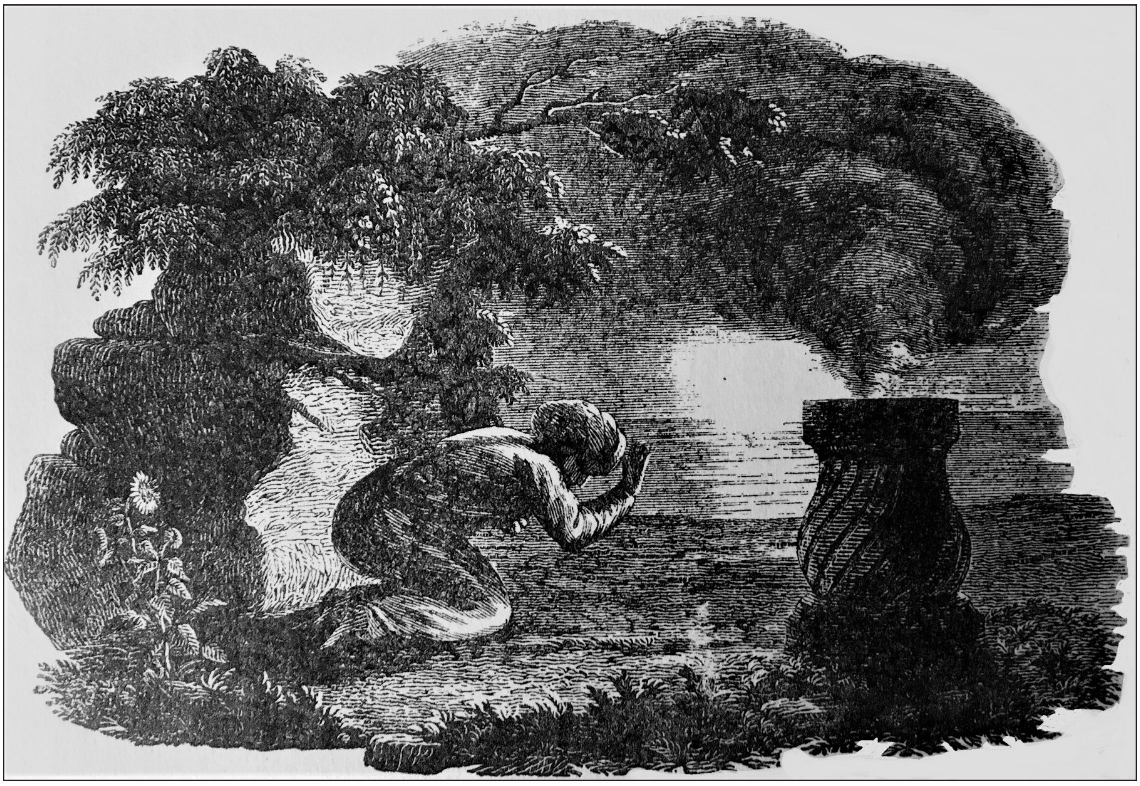


Figure 2.1 The Worship of light - taken from an Old print. Source Layton 1926.

The earliest known use of gas was by the Chinese in the Sichuan Province. A highly advanced system of drilling and extracting brine was developed using tools and pipelines primarily constructed from bamboo. The brine was heated to evaporate the water, leaving behind valuable salt. The brine was originally heated by burning wood, however, the brine extraction, which reached depths of 1500 to 1600 feet, also released natural gas, which was later utilised to heat the salt pans instead (Hunt 1907, Kuhn 2004). The Chinese had also developed a system using animal skins to capture the gas, so it could be stored and transported (Minchin 1966). These developments preceded the general use of gas for lighting in England by about three thousand years (Peebles 1980).

Prior to the advent of effective lighting, people's lives were controlled by the daylight hours, after which people would retreat to the safety of their home for fear, superstition or the imposition of curfews (Ekirch 2005). Organised Street lighting in England dates to the Middle Ages, when street lights, using candles, were introduced reputedly under the patronage of Sir Henry Barton, the Mayor of London in 1417 (Harrison 1930). Similar street lighting was then introduced elsewhere in England.

It was, 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.

The French physician Jean Tardin documented that he had heated crushed coal in a closed vessel producing flammable smoke in his book "l'histoire naturelle de la fontaine qui brûle près de Grenoble, avec la recherche de ses causes et principes et ample traitement des feux souterrains" published in 1618). Tardin had assumed that the source of the "fire well" in Grenoble was smoke escaping from burning coal beds below ground (Tardin 1618).

The Flemish scientist and physician Joan Baptista van Helmont first used the word "gas" in the sentence "I call this Spirit, unknown hitherto, by the new name of Gas, which can neither be constrained by vessels, nor reduced into a visible body, unless the seed being first extinguished." in his Treatise 'De Flatibus' published in 1652 (Partington 1936, Hunt 1907). It is uncertain whether the term gas is derived from the Dutch and German words for spirit which are Ghoast and Geist respectively, alternatively it could originate from the German term of ferment or froth which is Gascht or Gast (Hunt 1907). Van Helmont states in De Flatibus that he was the 'inventor' of gas and had identified that it was different to both air and condensible vapours (Partington 1936).

With the continued expansion of coal and other mineral mining in Britain, shafts had to be sunk ever deeper into the ground to reach new seams. Encountering different types of gases referred to as 'damp' became more frequent. Those commonly encountered were:

- Firedamp - (methane found in mines) known as inflammable air; and
- Chokedamp – (carbon dioxide also found in mines) known as "fixed air".

A similar observation to that recorded by Tardin, was made in 1659 by Thomas Shirley. His was later published in the Philosophical Transactions for 1667 under the title "The Description of a Well and Earth in Lancashire, taking Fire by a Candle approached to it" (Shirley 1667). He identified 'carburetted hydrogen' emanating from a natural spring located near Wigan in Lancashire, which burnt when igniting it with a candle. (Layton 1926).

It had been locally thought that the bubbling within the spring was due to the burning of the water. Shirley proved that the water was neither hot nor required for the flames, by damming the spring and then setting fire to the gas in the absence of water. Shirley believed the source of the gas was coal below the ground, the spring being only 30-40 yards from the mouth of a coal pit (Shirley 1867). The well had gained some local fame before Shirley's interest. The owner of the land on which the burning spring was located, a Mr Molyneux of Hawkley's Ground, had undertaken a demonstration 'to the eating of a Hen and Bacon boiled by that fire', which is documented in a letter to the Royal Society (Matthews 1827, Bradshaig 1663).

2.1.2 Dr Clayton and the Distillation of coal

The first detailed record in England describing that flammable gas could be obtained from coal is attributed to Dr John Clayton, who was at the time the Rector of Crofton near Wakefield. Clayton, continued Shirley's work and, years later in 1684, excavated the base of the spring identified by Shirley, to discover 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, and he announced his discovery of the 'Spirit of Coal' in a letter to Robert Boyle of the Royal Society in 1688. He wrote:

> I… got some coal which I distilled in a retort in an open fire. At first there came over only *Phlegm*, afterwards a black *Oil* and then a *Spirit* arose, which I could no way condense, but it forced my lute or broke my Glasses. Once, when it had forced the Lute… I observed that the *Spirit* which issued out caught fire at the Flame of the Candle, and continued burning with Violence as it issued out, in a Stream, which I blew out and lighted again, alternately, for several times. I then had a Mind to try if I could save any of this Spirit, in order to which I took a turbinated Receiver, and putting a candle to the pipe of the receiver whilst the *Spirit* arose, I observed that it catched Flame, and continued burning at the end of the pipe, though you could not discern what fed the flame: I then blew it out, and lighted it again several times; after which I fixed a Bladder, squeezed and void of Air, to the Pipe of the Receiver. The *Oil* and *Phlegm* descended into the Receiver, but the *Spirit*, still ascending, blew up the Bladder. …And when I had a Mind to divert Strangers or Friends, I have frequently taken one of these Bladders, and pricking a Hole therein with a Pin, and compressing gently the Bladder near the Flame of a Candle it [at] once took Fire, it would then continue flaming till all the Spirit was compressed out of the Bladder… (Clayton 1688, Elton 1958).

Despite his letter to Boyle, much of this work was unknown until Clayton's son, the Bishop Robert Clayton, rediscovered a collection of his father's letters. He submitted some of them to be published by the Royal Society within its 1739 edition of the journal *Philosophical Transactions of the Royal Society of London* (Clayton 1739).

Boyle, had already reported cases of inflammable vapours which had been collected from mines or springs (Boyle 1665). Boyle later reported how he produced inflammable "smoak" or "steam" from iron mixed with "saline spirit", a name used to describe hydrochloric acid (Boyle 1672). The reaction between hydrochloric acid and iron forms ferrous iron chloride and releases hydrogen gas.

At this time chemistry was a science in its infancy, still clouded by its past roots in Alchemy. It was not until 1700 that chemistry rose in its social standing, partly through its inclusion in university medical teaching and becoming the subject of many popular and fashionable lectures (Tomory, 2012). At this time, the nature and concept of gases were not understood, despite the work of Newton, Boyle and their contemporaries on 'Elastic Fluids', a field of science which eventually became known as 'Pneumatic Chemistry'.

In 1681 Johann Joachim Becher and Henry Serle were granted British Patent 214, for making pitch and tar from coal, which they believed was superior to wood tar (Woodcroft 1855). Becher, a German scientist who described coal gas briefly in his book "Närrische Weissheit und weise Narrheit" published in 1682 (Becher 1682, Elton 1958).

In 1709 Abraham Darby, a Quaker metal worker, had used coke to smelt copper in Bristol. In 1708 he founded the Bristol Iron Company and acquired premises at Coalbrookdale, on the River Severn. Coalbrookdale had supplies of low-sulphur coal and he built a blast furnace there in 1709 where he smelted iron ore in a coke-fired furnace. This furnace was larger and much more efficient than smaller furnaces which had previously used charcoal as a fuel, the latter being too weak to support a heavy charge of iron (Hendrickson 2014).

The improvements brought by Darby allowed him to manufacture thinner higher quality castings from iron than had been possible previously, these casting were important in the development of the steam engine and would eventually enable the manufacture of plant for the gas industry (Stewart 1958).

2.1.3 Mines gas

Sir James Lowther a coal mine owner presented a paper to the Royal Society in 1733, which was subsequently published in their Transactions (Lowther 1733). Lowther's workers had encountered a thin broken bed of black rock only 6 inches thick at a depth of 250ft below ground level. Beneath this was found a seam of coal 2ft thick. When the workers broke through the black bed of rock, damp corrupted air was noted to enter the pit, but very little water, as had been expected (Lowther 1733).

This damp air was fire damp, methane draining from the coal which had accumulated in fractured black rock. When the workers put a candle to the damp air, it burned producing a flame about 6ft high and 3ft wide. They managed to extinguish the flame and continued to dig the shaft to a depth of 427ft deep. To deal with the gas, a drain was built within the shaft to collect and carry the gas 13ft above the head of the shaft, where it was burn't. When the paper was written the flame had been burning for two years and nine months. Lowther had experimented with collecting the gas in bladders from which the gas was stored and burnt many days later (Mathews 1827, Lowther 1733).

About 30 years later, Carlisle Spedding, a mining engineer and the manager at Sir James Lowther's, Saltom Pit in Whitehaven (1765) lit his office with 'fire damp' vented from the Saltom mine. He had offered to supply the town of Whitehaven with gas for street lighting, an offer they refused (Stewart 1958).

Carlisle and his son James had been badly affected by underground gas following a rescue attempt at the Corporal Pit, where 23 people were killed. This led him to work with the local Doctor, William Brownrigg, to understand the effects of the gases on workers in the mine. Spedding built a laboratory for Brownrigg where he piped fire damp from one of the mines, which was used to feed a number of furnaces (Dixon, 1801). Spedding was not alone in this concept, Monsieur Jars of the French Academy of Sciences had proposed to utilise the mine gas from the collieries in the Lyonnais, to provide lighting to nearby villages (Jars 1774).

2.1.4 Early Attempts to Analyse the Products of Coal Distillation

At around a similar time to Lowther's observations, Dr Stephen Hales, was undertaking a series of experiments which he published under the title of 'Vegetable Staticks, or An account on the Sap in Vegetables: Being an Essay towards a Natural History of Vegetation'. The book recorded a series of experiments which attempted to record "the quantity of air which arose from anybody by distillation or fusion". A number of different substances were studied, one of which was Newcastle coal.

The apparatus which is shown in Figure 2.2 consisted of a glass retort vessel with a long spout leading down into a water filled bucket over which an inverted water-filled glass receiver was suspended. The neck of the receiver was below the water table, so any gas given off by the retort was passed into the receiver displacing the water inside it (Hales 1727), this device became known as a pneumatic trough, an essential part of the Pneumatic chemists laboratory. The pneumatic trough was important as it can be seen as the earliest form of gasholder. Hales used a different set up for his experiment on minerals and replaced the glass retort with a musket barrel heated in a blacksmith's forge (Hunt 1907). Hales experiment (No. 67) with Newcastle coal showed that 10.2 grams of Newcastle coal produced 2.9 litres of gas, which weighed 3.3 grams, nearly a ^{third} of the weight of the coals (Hales 1727, Matthews 1827).

Caspar Neumann a Professor from Berlin, undertook work on the distillation of coal (from Halle in Germany) to identify the by-products formed. He measured the weight of the by-products formed, this included

- Phlegm (ammonia rich water) - 60cm^3 (2 ounces 1 dram);
- Thin fluid oil – 60cm^3 (1 dram);
- Tar – 28cm^3; (1 ounce); and
- Coke – 1190cm^3 (41 ounces 7 drams) formed.

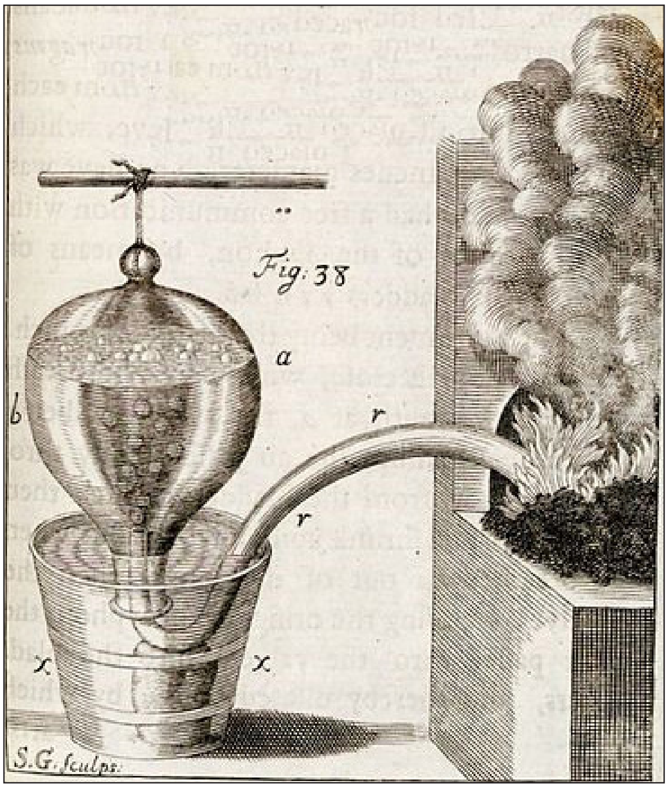


Figure 2.2 Image of the experiment retorting coal, Source Vegetable Staticks, Hales, 1727.

Neumann did not however, investigate the amount of gas evolved from the distillation of the coal (Neumann and Lewis 1759).

Nuemann investigated the effect of pouring dilute sulphuric acid on iron, noting it produced an inflammable vapour which was compressible (elastic), permanent and analogous to the inflammable gas found in mines. The action of pouring sulphuric acid on iron releases hydrogen. Neumann collected the gas in bladders and found it could still be burnt after a few weeks storage (Neumann and Lewis 1759).

A major advance was made by the Scottish Chemist Joseph Black, who isolated carbon dioxide, known at the time as 'Fixed Air' or 'Choke Damp', he proved that it retained its properties, through many stages of combustion (Black 1756).

Black noticed that upon heating or adding acid to magnesium carbonate it produced a gas that was denser than air and would extinguish a burning flame, it was also noted that it was toxic to life. He called this gas 'fixed air', but we now know it as carbon dioxide (Black 1756). Black realised that this gas was the same as "gas sylvestre" which Joan Baptist van Helmont had produced by adding acid to limestone (West 2014).

The British natural philosopher and chemist Henry Cavendish discovered hydrogen, which he referred to as "inflammable air". He published the research as three papers in 1766. He later determined the composition of water, showing that it was a combination of 'dephlogisticated air' (oxygen) and 'inflammable air' (hydrogen) (Cavendish 1884).

The understanding of gases was greatly increased by Joseph Priestley, who discovered 10 new gases, including nitrous oxide, nitric oxide, ammonia, sulphur dioxide and oxygen. Eighteenth-century chemistry was dominated by the phlogiston theory. This theory which had been created by the German Georg Ernst Stahl, was based on the principal that every combustible substance contained a universal component of fire, which he named phlogiston, from the Greek word for inflammable. Priestly like many others supported this theory and therefore referred to oxygen as 'dephlogisticated air' (Priestly 1774.).

This theory was opposed by some, most notably the French chemist Antoine Laurent Lavoisier, ably supported by his wife Marie-Anne. Lavoisier provided a new rational basis for chemistry in terms of the oxygen theory of combustion, being able to explain Cavendish's discovery of the formation of water from 'dephlogisticated air' and 'inflammable air' as the combination of oxygen and hydrogen, the new names he had given to these gases (Lavoisier 1789). Lavoisier was also instrumental in the development of the gasholder mentioned later.

2.1.5. Coal gas from Coke and Coal Tar Manufacture

Antoine de Gensanne, a French naturalist and geologist described the industrial distillation of coal to make coke, which was undertaken at the ironworks belonging to the Prince of Nassau-Saarbrucken at Sultzbach. The ironworks operated several furnaces in groups of three, as a batch process, so that a regular supply of coke was produced on a daily basis (De Gensanne 1770).

The furnaces were constructed from brick and included an inner brick chamber with an arched roof and curved back wall (Figures 2.3 & 2.4). Surrounding this inner chamber was a similar shaped brick structure. Between these two brick walls were placed the fires on metal grates, which would heat the inner furnace. De Gensanne referred to these inner chambers which held the coal to be distilled, as retorts. They were an early forerunner of the by-product coke oven. The retorts would be filled with about 408 kg of coal and the door of the retort, shut and sealed. The vapours and gas escaping from the retort were not collected but observed as a sign as to when the coke was ready, that being when no further smoke was being emitted from the retort vent (Hunt 1907, Lunge 1916). It is believed that this process had be devised by the "Kohlenphilosph" (Coal Philosopher) Stauf (Lunge 1916, p8)

The retort had a gutter built into the sloping base of the furnace to collect any tar produced. The tar was poured into a large tub where it was separated into by-products. One of which was a fatty liquid which could be used as a lubricant and was also used in lamps, where it would burn slower and with a smoky flame. Evidently the value of the gas produced at Sultzbach was never realised, although they were close to those achievements of William Murdoch only 20 years later (Hunt 1907).

George Dixon II was another who could see the potential for extracting tar from coal as they had at the ironworks in Sultzbach. Dixon, an engineer who came from Durham, owned his own mine and had been experimenting with the distillation of coal since 1760, initially undertaking simple experiments heating coal in a kettle and

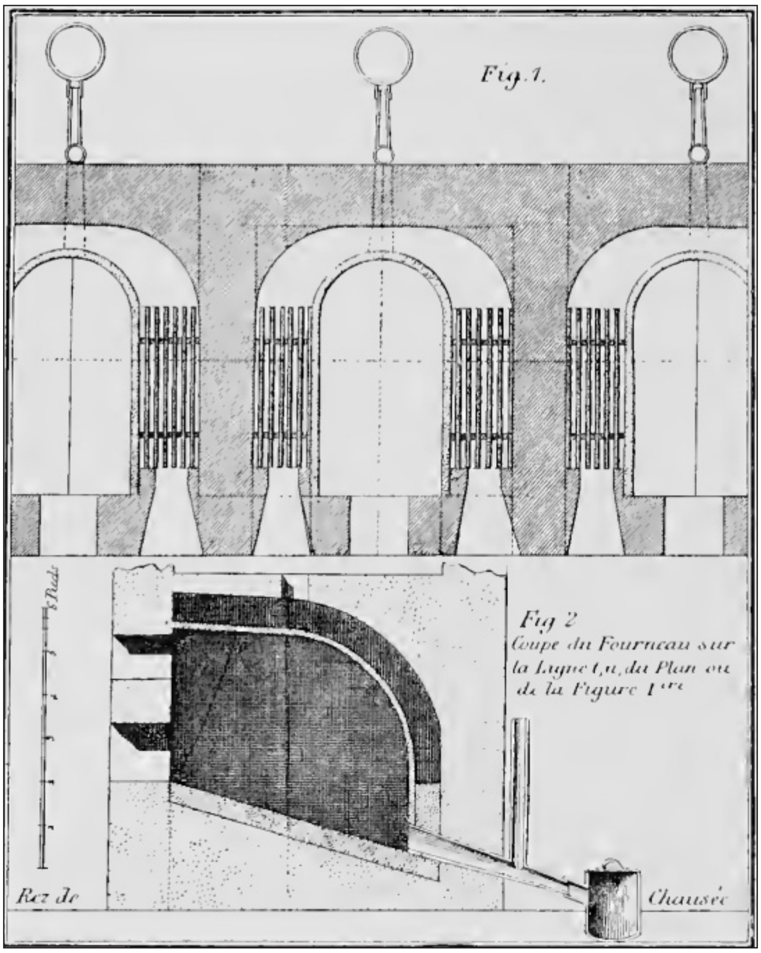


Figure 2.3 Drawings of the furnaces of the Sultzbach ironworks, Germany. Source Hunt, 1907.

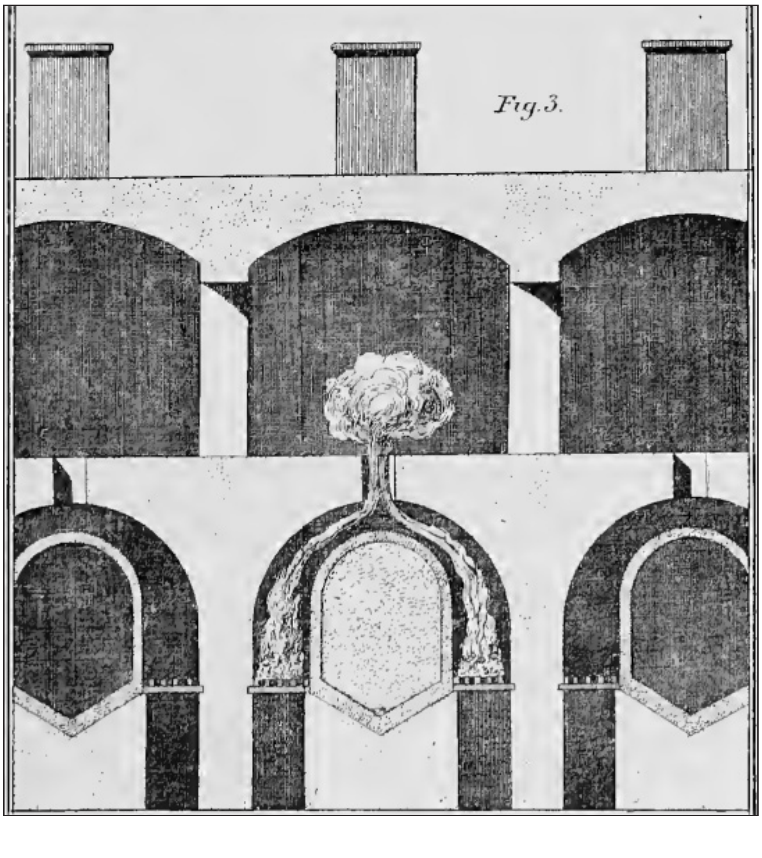


Figure 2.4 Drawings of the furnaces of the Sultzbach ironworks, Germany. Source Hunt, 1907.

igniting the gas which escaped from its spout as can be seen in the diorama shown in Figure 2.5. Dixon developed gas lighting within the rooms of his house and had also considered lighting at his collieries (Bailey 1810).

Tar had for a long time been important to the Royal Navy, for the caulking of ships hulls and protecting them from decay. This had originally been pine tar produced domestically and later imported from Sweden as demand increased. Due to a war between Russia and Sweden, Britain then started to import tar from it's colony in North Carolina, however, unrest there renewed interest in domestic tar production from coal during the 1770s. Coal tar unfortunately was not a direct substitute for pine tar and required more careful preparation (Tomory 2012).

Figure 2.5. A diorama of George Dixon demonstrating burning coal gas. Source Jones and Reeve, 1978.

Dixon constructed a pilot plant in 1779 at his colliery in Cockfield capable of distilling one ton of coal. Dixon operated the plant until 1883. Whilst technically successful, the high cost of transporting the tar to the port at Sunderland made it financially unviable. Dixon was put off the process following an explosion which damaged the plant and meant his plans were abruptly abandoned (Bailey, 1810).
In 1779 John Champion from Bristol was granted British Patent (No. 1224) for extracting tar from coal in the course of making coke for blast furnaces. Champion, however, lacked the financial support, to commercialise his patent (Woodcroft 1854).

Whereas Dixon and Champion lacked commercial success Archibald Cochrane, otherwise known as Earl of Dundonald, had also spotted a market for coal tar as a preservative. He had a particular focus on the Royal Navy, with the aim of providing tar for the wooden hulls of the naval fleet.

In 1781 a British patent (No. 1291) was granted to the Earl of Dundonald for "a method of extracting or making tar, pitch, essential oils, volatile alkali, mineral acids, salts, and cinders from pit coals.", the patent did not cover the gas produced to which he must have seen little value. He undertook tests which proved that after processing, coal tar would prevent them from rotting and fouling (Bailey 1810, Clow and Clow 1942).

He established the "The British Tar Company" in 1780 to produce tar from coal mined on the family estate, at Culross Abbey in Fife. The distillation of the coal produced a gas which if it caught fire was reputed to have produced a bright flame visible from many miles away, he also collected the gas from the kilns in an urn which was brought to the Abbey to amuse the guests, however, like Dixon, the occurrence of a gas explosion, reduced his interest in such events (Hart 1844).

The coal tar did not gain favour with the Royal Navy and by 1793, they were cladding the hulls of all their ships with copper rather than tarring them (Clow and Clow, 1942, Luter, 2006). Despite the lack of any Royal Navy contract, the British Tar Company built additional tar works at Muirkirk, Ayrshire and locations around Coalbrookdale, Shropshire and Staffordshire (Luter 2006).

Dr Richard Watson a Cambridge academic, who later became the Bishop of Llandaff, undertook studies on the composition of coal and wood to ascertain the amount of liquid or tar that they contained. He found similarities between both wood and coal. His work had studied Newcastle coal, as others had previously (Watson 1781).

He "took 96 ounces of Newcastle Coal, and putting them into an earthen retort, distilled them with a fire gradually augmented till nothing more could be obtained from them. During the distillation, there was frequent occasion to give vent to an elastic vapour, which would other wise have burnt the vessels employed in the operation. The weight of the liquid found in the receiver, and of the residuum remaining in the retort, after the distillation was finished, were accurately taken, and was expressed in the following table :

Weight of Newcastle Pit Coal distilled . . . . 96 oz.		
Liquid . 12 oz.		
Weights of the Products	Residuum	56 oz
Loss of Weight	28 oz	
	96 oz	

Watson proved that the gas obtained from coal was still flammable after it had been passed through water, which was later important for the use of water seals in gasworks, such as the hydraulic main (Clegg 1841, Watson 1781).

2.1.6. Gas Production in Continental Europe

Abroad, others were active in experimenting with coal gas, this driver for the interest was not gas lighting but the fashionable new pastime of air ballooning. The Montgolfier brothers' success with their Balloon flights in Paris, had made others want to follow suit and national governments started to support such research, which attracted the attention of scientists such as Lavosier and Berthelot (Tomory, 2012). Whilst the Montgolfier brothers had used hot air from fires, many others had focussed on the production of hydrogen from iron. This was both expensive and difficult to undertake, so the use of coal gas was identified as a cheaper alternative. In Belgium Jan-Pieter Minckelers, was commissioned, along with colleagues at the University of Louvain by the Duc d'Arenberg, to investigate Ballooning with the aim of making large quantities of inflammable air (hydrogen) cheaply. Minckelers eventual method of production was to expose light coals to a high heat, which optimised the production of hydrogen. It was following these investigations that Minckelers lit his lecture theatre at the University of Louvain in 1785, little is known of the apparatus he used, but following unrest in 1790, he returned home to the Netherlands. (Minckelers 1784, Tomory 2012).

Minckelers was not alone in these interests in inflammable gases, in France Louis Bernard Guyton de Morveau and François Chaussier had also been undertaking similar investigations and published an account of different types of gases and how they could be produced (Guyton de Morveau and Chaussier 1784).

Johann Georg Pickel, was both Professor of Medicine and Chemistry at the University of Würzburg in Bavaria. He produced gas from the distillation of animal bones in the pharmacy of the Juliusspital, which he used to light his chemistry laboratory. Pickel had also been involved in the air ballooning fashion, although unsuccessfully (Schuster 1938).

Charles Diller a Dutch chemist and instrument maker had demonstrated his "philosophical fireworks" to the public across Europe and in England in 1788. He unfortunately died in early 1789, but these displays continued to be presented by his pupils. The philosophical fireworks burned with white, blue and green colours, representing well known shapes and animals, some of which even moved (Hunt 1907).

The most influential European who had been investigating the production of gas from distillation was the Frenchman Philippe Lebon (Figure 2.6). Born in Brachay near Joinville in the Haute Marne region of France, Lebon was the son of a retired official of Louis XV. Educated in Paris, he trained afterwards at Chalon-sur-Marne studying mathematics and drawing. Aged 20 he was admitted to the l'Ecole des Ponts et Chaussées, leaving with the highest mark and a considerable reputation. Aged 25, Lebon became an engineer of the Department of Bridges and Roads (Hunt 1907).

Figure 2.6. A drawing of Philippe Lebon. Source Hunt 1907.

Lebon devoted great efforts to gas lighting, which he originally discovered in 1785. Lebon began his studies on the distillation of sawdust in 1796, at a time when deforestation had meant that wood was in short supply and improved efficiency in the use of wood was important. He performed his first public trials in Paris the following year (1797). Lebon was awarded a patent for the distillation of gas from wood in 1799 using the Thermolampe or "Thermal Lamp", which was accompanied by the drawing in Figure 2.7 (Lebon 1799). The patent included the distillation of wood and other substances such as coal. Lebon also suggested that the gas could be used for both heating and lighting. The Drawing in Figure 2.6 shows the retort like chamber marked VVVV with an adjacent central furnace marked FFFF, in which a metal plate (DD) held the fuel, The products of combustion were vented by the flues (CCCCCC) to the chimney (T).

Lebon undertook a public demonstration of his Thermolampe at the I'Hotel Seignelay, on the Rue Saint Dominique, Saint-Germain, Paris in 1801. Two Thermolampes were installed in a workshop, one provided gas to light and heat the various rooms of the house and the other for lighting the garden (Williams 1979). Whilst initially popular with the public, they were put off by the foul smell it produced, which would have been due to the sulphur dioxide produced when the gas was burnt. Whilst an interesting spectacle, Lebon's efforts never led to any commercial application (Hunt 1907).

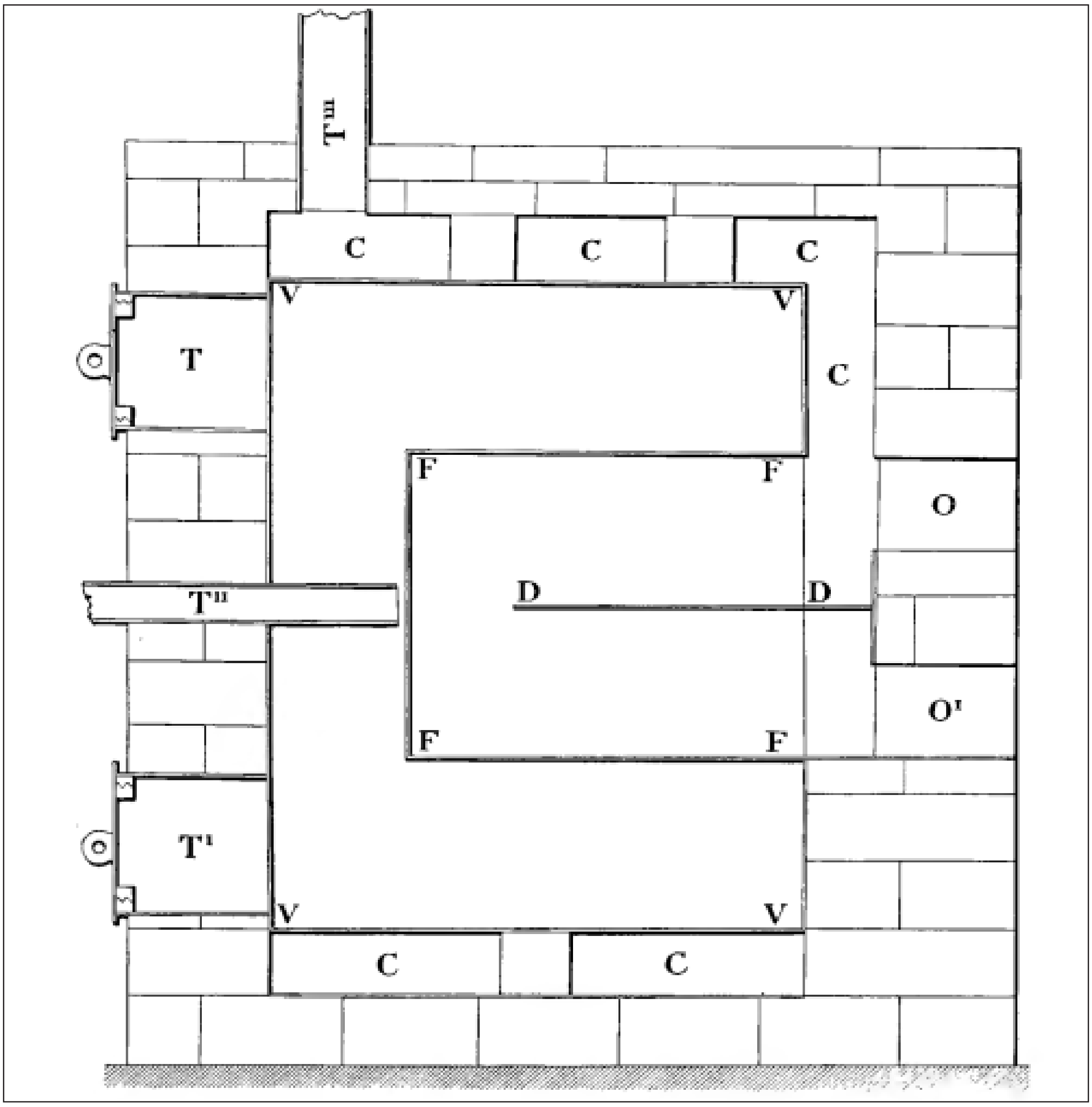


Figure 2.7. Lebon's Thermolampe Source Hunt, 1907.

Lebon received a second patent on the 24th of August 1801, which was largely concerned with using the gas from the thermolampe to power an internal combustion engine, a concept ahead of its time (Lebon 1801). The experiment at I'Hotel Seignelay did raise interest from the French Minister of Marine, who required tar for the French Navy. Lebon was given a concession for a large part of the pine forest of Rouvray near Rouen, where he established a tar works producing tar for the French Navy (Hunt 1907).

Lebon continued to improve the Thermolampe, but unfortunately, he died in 1804. Whilst working at Rouvray, Lebon was still on the roll of the Engineers of the Department of Roads and Bridges. He was summoned back to Paris to assist at the coronation of Napoleon I as Emperor on the 2nd December, 1804. He was believed to have been found dead the following morning under circumstances which are not entirely clear and for which there are numerous contrasting accounts (Hunt 1907, p61).

If Lebon had not died then gas may have been adopted in France much sooner than it eventually was. Lebon was commemorated in the form of a statue erected in 1887, which stands in the town of Chaumont, near to the village in which he was born (Hunt 1907, p61).

He is rightly recognised as the father of the gas industry in France and his work spurred on the development of the thermolampe and with it the early development of gas lighting across mainland Europe (Hunt 1907).

Outside of France, Andreas Zacharias Winzler, a chemist from Unlingen, Germany, was one of the biggest protagonists for the Thermolampe. He undertook most of his work in Austria, building thermolampes in Brno, Znojmo, Vienna and Blansko in the first decade of the 19th century. Gas lighting was not integral to Winzlers work, as he had seen the possibilities for the wider use of by-products and had intended to use the gas for heating.

Winzler wrote the First German treatise on gas manufactures called “Die Thermolampe in Deutschland” and inspired much of the later development of the thermolampe in continental Europe (Winzler 1803). The success achieved by Winzler was limited, but he did inspire many others in the region. Such as Karl Ludwig von Riechenbach, who much improved the airtightness of the thermolampe design (Tomory 2012).

Lebon’s pamphlet on the Thermolampe was translated into German by Johann Michael Daisenberger. Who built two thermolampes, following the design of Johannes Wenzler, the Passau court treasurer (Daisenburger 1802). Other Germans such as Karl Bunger and Johann Wagner also took a similar interest in the use of the thermolampe.

Wilhelm August Lampadius, who is recognised as the being the first true exponent of gas lighting in Germany, took a particular interest in the subject. He was a chemist and metallurgist who had considered the use of inflammable gases in 1796. He studied the distillation of coal and realised the gas could be used within an ironwork. His interests were spurred on by Lebon and he built a thermolampe in 1799. He used the gas to light rooms in the palace of the king of Saxony. Lampadius interest subsided until he got news of Winsor’s attempt to form a gas company in London to provide street lighting. In 1812 he built, in his apartment on Fischergasse in Freiberg, a prototype gasworks which supplied gas light to a lantern outside his house. He later went on to build the first factory gasworks in Germany at the Saxon Amalgamier-Werken at Halsbrucke in Frieberg. Whilst Lampadius was unsuccessful in persuading Frieburg to adopt street lighting, he went on to build small gas plants across Germany and notably at Dresden Castle and the Opera House (Schuster 1938).

Despite the numerous interested scientists across mainland Europe, the Manufactured Gas Industry, developed first in England, widely attributed to William Murdoch, who is described in the next chapter.

2.2 Early Private Gas Works 1800-1812

Despite significant work which had already been undertaken on inflammable gases, most credit for the development of a commercial process for coal gas manufacture goes to William Murdoch.

2.2.1 William Murdoch and the development of commercial gas production

Murdoch, the son of a millwright, was born in 1754 at Bello Mill, near the village of Lugar in Ayrshire, Scotland (Figure 2.8). The Murdoch's tenanted a farm and a watermill on the estate of the Bosworth Family of Auchinleck (Hunt 1907).

Figure 2.8 Bello Mill Cottage – Murdoch's Birthplace. Source Hunt, 1907.

Murdoch is believed to have experimented with producing gas from split coal in a kettle when he was a child (Smiles, 1884). He trained as a Millwright under his father John, a respected engineer. John Murdoch had invented toothed bevelled mill-gearing, an important engineering development in its own right. (Hunt 1907).

William inherited his dad's natural engineering talent and together they built a wooden horse, a forerunner to a bicycle, which William would ride around the district to the wonder of the local people. He is also reputed to have built a stone bridge across the River Nith near Dumfries (Hunt 1907).

In 1777 and aged 23, William Murdoch left home and proceeded to walk to the Soho works at Smethwick, Birmingham. This is where Matthew Boulton had established a number of engineering partnership's, the most notable being that which he had formed shortly before with James Watt to develop Steam Engines, Boulton and Watt (Hunt 1907).

Murdoch was interviewed by Matthew Boulton who was particularly taken aback by an oval-shaped wooden hat that he was wearing. Murdoch explained to Boulton that he had made it himself on a lathe of his own design. Suitably impressed Boulton gave Murdoch a job as a mechanic with Boulton and Watt (Hunt 1907).

Murdoch was probably aware of Watt, a fellow Scot, who had originally erected his improved steam engine at Kenneil, the Home of Dr. Roebuck, who had been a partner in Watt's patent. Dr. Roebuck had established the Carron Ironworks, where the bevelled mill-gearing invented by William Murdoch's father, John, had been manufactured (Hunt 1907). Although promising, the steam engine built at Kinneil was not very successful. Dr. Roebuck, due to financial difficulties, sold his share of the steam engine patent to Boulton. Boulton a skilled negotiator and well connected in society, then managed through an act of parliament to obtain a 25 year extension to the Steam Engine patent. This was obtained in 1775. Watts improved design once perfected, was much more efficient than the old Newcomen engine, reducing fuel costs considerably. The profit Boulton and Watt derived was from a royalty of one-third of the saving over the Newcomen engine which was for a set term of years. Their first steam engine was erected at the Ting-Tang Mine, Gwennap, Cornwall in 1777 (Hunt 1907).

In 1778 Murdoch was given the task of erecting steam engines for the growing number of Cornish mine owners. Watt had previously undertaken this role but struggled both with his health and in this role to deal with the intimidating mine captains. Murdoch, however, was described as herculean in stature and had a strong personality, the mine Captains soon discovered he was not someone who was going to be pushed around (Hunt 1907).

The greater efficiency of Watt's steam engine at extracting water from the mines, was such that they could extend their mines deeper than was previously possible. This was, at the time, Boulton and Watt's most valuable market for the steam engine.

Murdoch was so well liked in Cornwall that in 1785 he married Ann Paynter, the daughter of Captain Paynter of Redruth, a local mine Captain.

Murdoch based himself in Redruth. When he had the time, he experimented with the production of gas from coal. He constructed in his back yard a cylindrical iron pot as a retort, which was set in brickwork (Gas engineers compendium, 1922) to distil the coal and then piped the gas 70 feet into the house through tinned iron and copper tubes (Hughes 1853).

The gas was used to light his house and office in 1792 (Figure 2.9). Murdoch also used bladders constructed from leather or vanished silk and receptacles built from tinned iron fitted with tubes and valves to store the gas and make rudimentary lanterns, which he used whilst travelling between the mines and his home. This novelty, which surprised the locals, is said to have given him the reputation of being a wizard (Hughes 1853).

Figure 2.9. A diorama of William Murdoch demonstrating gas lighting at his home in Redruth, Cornwall. Source Jones and Reeve, 1978.

During this early period of experimentation, Murdoch tried distilling coals from different coal fields in England, Scotland and Wales. He also experimented with different types of burner, however, he generally stuck to the principle of the Argand burner which had been developed by the Swiss scientist Aimé Argand and was later improved for use with gas by Samuel Clegg (Hughes 1853).

Murdoch had realised the need for purifying the gas. The odour left after burning the gas manufactured at Boulton and Watts Soho works had infamously gained the name "Soho stink", which would have been due to the sulphur dioxide produced when the gas was burnt. Murdoch had used water for purifying the gas, but he did not experiment with any other purifying medium (Hughes 1853, Stewart 1958).

Murdoch was an engineering genius, much overlooked when compared to some of his peers. He also built the first working model of a steam carriage in Britain (Figure 2.10) whilst living in Redruth in 1784 (Chandler and Lacey, 1949). Murdoch had intended to patent the steam carriage and was travelling to London when he met Boulton at a carriage stop, Boulton persuaded Murdoch to return to Cornwall and continue his work on the steam engines. He also designed the “Sun and Planet” gears, these converted the reciprocating movement of the steam engine into a rotative movement. This was however, patented by James Watt. Murdoch did patent the D slide valve which was an important improvement in the steam engine, used widely throughout the 19th century (Hunt 1907).

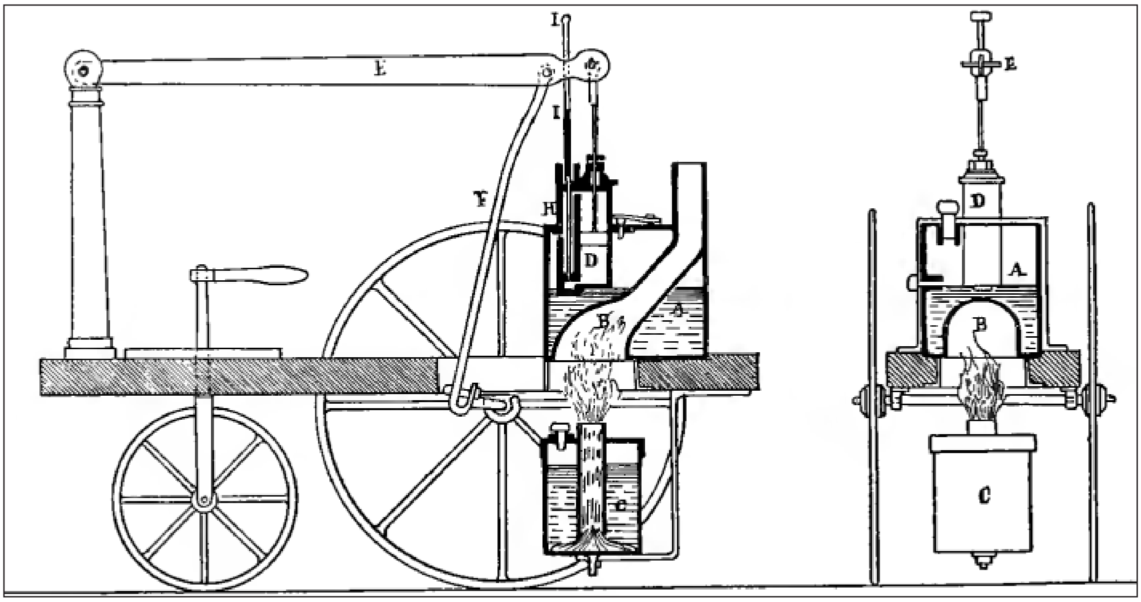


Figure 2.10 A drawing of Murdoch’s working model of a road carriage. Source Hunt, 1907.

In the years 1795 and 1796, Murdoch visited the Neath Abbey Iron Works, near Swansea on two occasions. Here, Murdoch conducted further experiments into the design of retorts, reputedly lighting the counting house of the works. He described the light produced by the gas as ‘Strong and Beautiful’ (Bone 1919). Neath Abbey Ironworks later became a manufacturer of gasworks supplying numerous private and town gasworks for locations Ashburton, Barnstaple and Dover (Stewart 1958).

In 1797 Murdoch is said to have lit a house he was staying at in Old Cumnock, Ayrshire. He did this by filling small bladders with gas from a retort and then attaching the bladders to light fittings to burn the gas (Newbiggin 1904, Bone 1919).

In 1797 Murdoch advised James Watt Jr (James Watt’s son) to apply for a patent for the gas lighting apparatus, he had developed, Watt declined. At this time, Watt had spent 5 years fighting to defend his father’s steam engine patent and he was not certain if gas manufacture was a proper subject for a patent, as others had previously burnt gas to produce light. Watt advised Murdoch to wait until the fate of the steam engine patent had been resolved (Chandler 1936).

Recalled to the Soho Foundry in 1798, Murdoch continued to experiment with gas lighting, he had an iron retort vessel cast, which he used to test different coals and was used to light the foundry at night. Murdoch described his work in his own words as:

> "In the year 1798 I removed from Cornwall to Messrs. Boulton, Watt and Co.'s works for the manufacturing of steam engines at the Soho Foundry, where I constructed an apparatus upon a larger scale, which during many successive nights was applied to the lighting of their principal buildings, and various new methods were practised of washing and purifying the gas. These experiments were continued with some interruption until the peace of 1802, when a public display of this light was made by me in the illumination of Mr. Boulton's manufactory at Soho on this occasion. Since that period I have, under the sanction of Messrs. Boulton, Watt and Co., extended the apparatus at Soho Foundry, so as to give light to all the principal shops, where it is in regular use, to the exclusion of all other artificial light" (Hunt 1907 p80, Gas engineers Compendium 1924).

As mentioned in Murdoch's description, gas lighting was used in the celebrations to make the Peace of Amiens, where extensive lighting was used on the facade of Boulton and Watt's works. There has been a long running discussion over the extent of the gas lighting used. It was reported by Clegg Jr in his treatise, that only two of the lights were supplied by gas, these were referred to as Bengal lights, which were located at each end of the works and were supplied with gas via pipes from retorts mounted within two of the buildings fireplaces (Clegg 1841). The remaining lamps used were coloured oil lamps (Hunt 1907). Such a limited use of gas was probably correct, as Murdoch had only restarted his investigations into gas manufacture in earnest at Soho prior to this event and the gas plant at this point was believed to have not incorporated a gasholder.

Murdoch had continued his interest in gas lighting with little support from his employers – until 1801, when Gregory Watt visited Paris and discovered the rival work being undertaken by Philippe Lebon, James Watts Jr, recalled:

> "At the end of that year my brother (Gregory Watt) went over to Paris; and he wrote me a letter telling me that if we intended to do anything with Mr. Murdock's light, no time should be lost; because he had heard that a Frenchman of the name of Lebon was at the same period endeavouring to apply the gas obtained from the distillation of wood to similar purposes" (Hunt 1907).

With renewed interest, Murdoch was given the financial backing and technical assistance he required to advance the manufacture of gas. This included the assistance of Samuel Clegg, John Southern and the Creighton Brothers (Tomory 2012).

Samuel Clegg was born in Manchester, England, the son of a wealthy businessman, Wheatley Clegg. Samuel Clegg was educated by the eminent scientist and mathematician Dr John Dalton at New College Manchester between 1794 and 1797. Initially Clegg took up a position in the counting house of the company of his uncle (Ashworth Clegg) at Rushworth and Clegg. He did not settle in this position and was reluctantly allowed to follow his interests in mechanical engineering (Bennett 1986, Stewart 1958 p7).

He joined Boulton and Watt in 1798 as an apprentice engineer at the Soho foundry. Completing his apprenticeship, he worked on steam engines. In 1802, Clegg assisted Murdoch on his gas making and lighting experiments including the lighting of the Soho foundry in 1804 (Skempton, 2002, Stewart 1958 p7). 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 (Bennett 1986, Stewart 1958 p7).

2.2.2 Lighting the Salford Twist Mill

Murdoch had experimented with horizontal, inclined and vertical retort designs (Stewart 1958). He decided to use vertical retorts at his first installation at the Mill of Philips and Lee in Salford (Figure 2.11). These vertical retorts were an open pot 3 ft. 6 in. diameter and 5 ft. 6 in. deep, set in an externally heated furnace. Coal (15 cwt) was loaded and unloaded into the retort in baskets lifted using a crane. The poor thermal conductivity of the coked coal prevented the heat penetrating in to the centre of the charge.

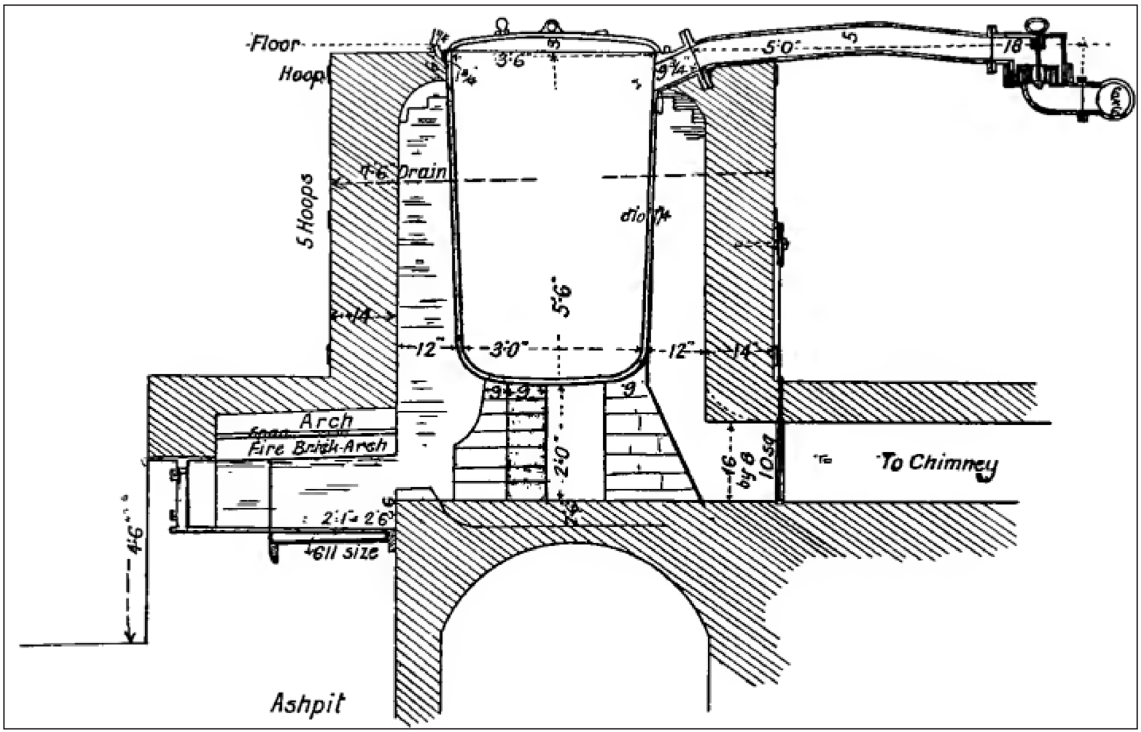


Figure 2.11. The vertical retort designed for the Salford Twist Mill of Messrs Phillips and Lee. Source Hunt, 1907.

Murdoch's vertical retort was ahead of its time and proved impractical with the technology available. In 1808, Murdoch reverted to a horizontal retort of D section, with the flat side at the base. These retorts measured 22 in. x 14 in. and were 3 ft. 9 in. long, which could hold about 1 cwt. of coal (Hunt 1907).

Murdoch initially operated the retorts in a way that required him to light the furnaces twice a day shortly before the gas was required, an inefficient form of operation. Two months after installation, Murdoch's colleague, John Southern, pointed out to James Watt Jnr that if the retorts could be operated continuously, fuel use would be reduced. This would have required greater dependence on the gas storage available within gasholders. These early gasholders were generally square or rectangular and comprised a vat or tank of water in which a vessel, storing the gas would rise or fall. This vessel being constructed of sheet metal attached to a wooden frame (Griffiths 1992 p259, West 2008 p146, Stewart 1958 p32).

Murdoch examined the process of coal gas manufacture and lighting in great detail, experimenting with different apertures for the burners and different methods of washing the gas. His experiments were estimated to have cost Boulton and Watt £5,000 (Hunt 1907, Williams 1981).

Following on from the success at the Soho works, Murdoch looked for opportunities to install gas plants at other sites.

The drive for its commercial up take of gas came from one of Boulton and Watt's existing customers, George Lee, of Philips and Lee, who operated the Salford Twist Mill. Lee was a technophile who constantly looked to improve the mill, adopting steam power and heating. He had been a Boulton and Watt Customer since 1790. Lee's interest in lighting the mill started as early as 1803 and he urged Boulton and Watt to assist, they constructed a small experimental plant initially to light his house in 1804. Once its safety had been proved and convinced by its merits, Lee again wrote to James Watt Jr, encouraging him to develop gas lighting into a commercial proposition (Chandler and Lacey 1949).

George Lee's continued pressure eventually led to Philips and Lee placing the first commercial order for the installation of a gas plant and gas lighting within the Salford Twist Mill. This mill was, at the time, one of the biggest factories in Britain.

A brief description of the Salford Twist Mill installation was provided in Murdoch's paper of 1808 (Murdoch 1808), a précis of this is provided below:

> The retorts installed were large, constructed of iron and were originally vertical in design as shown in Figure 2.11 The coal was held in baskets which had to be loaded by crane. These were later replaced by retorts of a Horizontal design which were then used in future installations. The retorts were constantly worked except for the loading (termed charging) and unloading of coal. The gas produced was conveyed by iron pipes, into gasholders. The water in the gasometer tanks were the only form of washing and purification

applied to the gas. From the gasometers the gas was transported throughout the mill via pipes referred to as mains, of several miles in length and reducing diameter. Each burner was connected to the mains, by a short pipe fitted with an individual stopcock valve, allowing them to be switched off (Murdoch 1808).

Two types of gas light fittings were installed, one in the style of an Argand lamp and the other which consisted of three divergent flames called a Cockspur. There were 271 Argand and 633 Cockspurs light fittings installed. The gaslight produced was equivalent to 2500 candles and required an hourly supply of 1250 cubic feet of gas. Murdoch had envisaged that the gas would be used on average for two hours per day. The gasworks were designed to use the oil rich cannel coal, which produced a superior light and on the consumption listed above he calculated that 110 tons of coal would be used annually in the retorts with another 40 tons required for heating the retorts. The retorts producing 70 tons of coke, which could be sold. Murdoch calculated that about 1250 gallons of tar would be produced and an uncertain amount of ammoniacal liquor, but he did not see a use for these materials at this time (Murdoch 1808).

Table 2.1 Evidence provided by Wm. Murdoch for the cost of lighting the Salford Twist Mill by gas and candles.

Item	Cost
Cost of 110 tons of cannel coal	£125
Cost of 40 tons of common coal	£20
sum	£145
Deduct the value of 70 tons of coke	£93
The annual exp. in coal, after deducting the value of the coke, and without allowing anything for the tar, is therefore	£52
And the interest of capital, and wear and tear of apparatus	£550
Making the annual total expense of the gas apparatus	£602
The price of candles to give the same light, would be about	£2000
Saving	£1398

Table 2.1 Shows the costs calculated and presented by William Murdoch for lighting the Salford Twist Mill. It clearly showed that a significant saving could be made by the mill owners, if they lighted the mill by gas instead of candles.

Mills had up to this point been lit by tallow candles or oil lamps and could use up to 1,500 candles per night in the winter. The cost of traditional illuminants such as whale oil and tallow had increased as a result of the Napoleonic wars with France (Demitri 2001).

In addition to the dim light and smoky flames produced, candles and oil lamps were at a constant risk of being knocked over. They were responsible for large numbers of domestic and industrial fires leading to a considerable loss of life. The number of fires within factories and mills reached an unsustainable level that insurers had started to refuse to insure such sites. The adoption of brick and iron built fireproof buildings fitted with gas lighting instead of oils or candles allowed mill owners such as George Lee to receive insurance coverage and at a reduced premium (West 2014). This proved a great incentive for other owners who rapidly adopted gas lighting.

In 1807 the progressive Mr Lee lit the 300 feet of Chapel Street, a private road, which was located between his house and his mill with gas (Murdoch 1808). To do this Boulton and Watt had installed pipes from the mill gasworks to his house using pipes installed beneath the street. The lighting consisted of two double argand lamps on the street and one double cockspur at his door (Matthews 1827). He followed this two years later, on King George III 50th Jubilee, when he erected a large crown with numerous gas jets on the roof of the mill. It was said to have been "exceedingly beautiful" (Anon. 1937).

Boulton and Watt focussed on the owners of large factories, some of which were existing customers, who would benefit most from their plant. They went on to light some of the largest factories in Britain such as Strutt's calico mill in Derby, Gott's woollen mill in Leeds and the flax mills of Marshall, Hutton & Co and Benyon, Benyon and Bage in Shrewsbury.

Table 2.2 Private Gasworks built by Boulton and Watt (Elton 1958 p268, Falkus 1981 p224, Stewart 1958 p9, Mitchel & Bennett 2006)

Date	Company	Location
1805-6	Phillips & Lee Cotton mill	Salford
1808-9	H. H. Birley & Co. Cotton mill	Manchester
1808-9	James Kennedy Cotton mill	Manchester
1808-9	Wormald Gott & Co. Woollen mill	Burnley Mills Leeds
1808-9	Benjamin Gott Woollen mill	Armley Mills, Leeds
1809-10	McConnel & Kennedy Cotton mill	Manchester
1809-10	Gillespie & Co. Cotton mill	Glasgow
1809-10	Nielsen & Co. Flax mill	Kirkland. Fife
1810	Marshall Hives & Co. Woollen mill	Water lane Mill Leeds
1810	Birley & Hornby Old Cotton Mill	Chorlton, Manchester
1810	Lister, Ellis & Co. Woollen mill	Burley in Wharfdale, Otley
1810	J. T. & E. Lewis Cotton mill	Manchester

1810-11	Thomas Coupland & Sons Cotton mill	Hunslet Leeds
1810-11	Wormald Gott Woollen mill	Park Mills, Leeds
1811	Marshall. Hutton & Co. Flax mill	Shrewsbury
1811-12	Huddart & Co Rope factory	Limehouse, London
1811-12	Benyon, Benyon & Bage Flax mill	Shrewsbury
1814	William Jones Nail factory	Birmingham
1815	John Mabberley Flax mill	Aberdeen, Scotland
1815-16	Birley & Hornby New Cotton Mill	Chorlton, Manchester

Despite this success, the ambitions of Boulton and Watt. Murdoch's employers in the field of gas lighting, were limited. Making gas plant was a small part of a large business empire focussed on manufacturing steam engines. Gas making apparatus was for a short while a useful additional business lighting some of the biggest factories in the country, but it was a side-line and as the competition increased, Boulton and Watt gradually retreated from the sector (Armstrong 1938). Their last gas plant and lighting contract was at Birley & Hornby's new cotton mill, Chorlton, Manchester, which was installed in 1816.

It was Boulton and Watt's lack of focus on the gas plant manufacture which led to the departure of Clegg and others to set up as gas engineering contractors to rival their former employer.

After Boulton and Watt's retreat from the gas lighting market Murdoch devoted his time almost exclusively to mechanical engineering, retiring aged 76 (Armstrong 1938). Murdoch presented a paper to the Royal Society in 1808 entitled 'An account of the application of coal gas to economical purposes'. The paper described the installation of gas lighting at the cotton mill of Phillips and Lee (Murdoch 1808). He received the Count Rumford Gold Medal for this paper, which affirmed his position as the founder of the gas industry (Stewart 1958).

2.2.3. Clegg the Rival Gas Engineer

At the same time as Murdoch was installing gas at the Salford Twist Mill for Phillips and Lee, a former colleague, Samuel Clegg, had set up as a rival gas engineer back in his native Manchester 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, achieving the first commercial installation of a gas plant and gas lighting. He achieved this by working his engineers night and day to complete the installation. Clegg's installation comprised of 40 gas lamps, whereas Murdoch's installation was considerably larger, lighting 271 Argand and 633 cockspur lamps (Bennett 1986, Hunt 1907).

From his small workshop near Deansgate he also installed gas plants at Potter's Cotton Factory in Bury, Barton's Dye House in Manchester, Thornton's Drawing Academy in Manchester and Gallymore's Printing Works in Bury (Skempton 2002).

A great innovator, Clegg experimented with the purification of gas using lime. Clegg invented the gas meter and self-acting governor and adapted the Argand burner for burning gas (Stewart 1958, p8).

In 1809, Clegg moved to larger premises on Major Street, Manchester, which included both a foundry and a gas plant works. He built his next six gas plants in entirety here, including all the castings and fittings (Hunt 1907, Bennett 1986, Skempton 2002).

Clegg's previous gasworks had provided only limited purification and the gas produced had proved to be unsuitable for enclosed rooms. At the gasworks Clegg devised for the Harris Works in Coventry in 1808, Clegg had introduced a separate condenser and made his first attempt at using lime to purify the gas. Clegg had devised a system of placing lime within the gasholder tank which could be kept in suspension by a paddle fitted in the tank base. It did achieve partial purification, but the lime removal was impractical (Hunt 1907, Bennett 1986, Skempton 2002).

In 1810, Clegg commenced two new gas plants, one of which was at Dolphinholme Worsted Mill near Lancaster and the second at Stonyhurst College, an independent Catholic school Nr Preston. Stonyhurst proved a challenge, as Clegg was aware that the gas would need to be purified before being used within the enclosed rooms of the college. Clegg was able to use the science facilities at the college to enable him to experiment on gas purification and, through doing this, he devised a separate lime machine which used lime water. The lime machine allowed for the ready removal of the spent lime and was installed prior to the gas entering the gasholder (Hunt 1907, Bennett 1986, Skempton 2002).

Clegg later claimed that this was the first machine employed for the purification of the gas (Clegg 1820). The lime purifier was universally adopted and created a route for gas to be used in the home. The use of lime as a purifying medium had been discussed by Dr William Henry in his article in Nicholson's journal in 1805 (Henry 1805) and his paper to the Royal Society in 1808, stated "the only effectual method of purifying the coal gas from sulphuretted hydrogen on the large scale of manufacture, will probably be found to consist in agitation with quicklime and water, composing a mixture of the consistence of cream" (Henry, 1808), whist this predates Clegg's work at Stonyhurst, Clegg is believed to have been experimenting with lime purification as early as 1806 (Bennett 1986, Chandler and Lacey, 1949 p47).

At Stonyhurst College, Clegg was able to compress the gas into copper globes allowing him to transport the gas. It is believed that the gas may have been transported to undertake demonstrations at the Preston Literary and Philosophical Society, out of which was later created the Preston Gas Light Company, the first gas company formed outside of London (Bennett 1986).

In the 1810s Clegg devised the standard arrangement for iron retorts (Stewart 1958 p12-15). In 1811, Clegg started to work on the installation of gas lighting at

Greenaway's Cotton Mill in Manchester. The plant he installed had 4 retorts. Whilst previously retorts had been fitted with isolation valves, Clegg decided this approach was both too costly and impractical. This was because the valve needed to be adjusted while the retorts were being charged (filled with coal) which meant they were very hot. To resolve this issue Clegg developed and introduced the hydraulic main into his installation. Each retort was connected to the hydraulic main via an ascension pipe. The gas would flow up the ascension pipe and down through the dip pipe below the level of the water within the hydraulic main. The water formed a seal preventing the flow of gas back into the retort. The hydraulic main became an essential part of the gas plant and was used throughout the coal gas era (Stewart 1958, p9).

In 1812 Clegg undertook the lighting of the Hyde (Manchester) mill of Ashton and Sons. Clegg used the Hydraulic main and the lime purification system, he also introduced improved cylindrical retorts which had finely ground mouthpieces, which obviated the need for clay luting. In the same year Clegg undertook the successful lighting of the house, shops and workrooms of the famous publisher Rudolph Ackerman of London. The wet lime process, which was successful, would in years to come become very problematic, due to the waste it produced known as "Blue Billy". It had a foul stench and its disposal into watercourses or drains caused significant nuisance problems and pollution. Ackermans project proved an excellent advert for Clegg's skills as an engineer (Stewart 1958, p9).

Table 2.3 Private Gasworks built Samuel Clegg

Date	Company	Location
1805-6	Lodges cotton mill	Halifax
1806	Potter's cotton factory	Tottington, Nr Bury
1806	Barton's dye house	Lower Ardwick, Manchester
1806	Thornton's Drawing Academy	Manchester
1806	Gallymore's Print works	Tottington, Nr Bury
1806	Borough Reeve of Manchester (experimental street lighting)	King St. Manchester
1807	Messrs. T and S Knight Mill	Longsight, Manchester
1808-9	Harris Works	Coventry
1811	Dolphinholme Mill	Lancaster
1811	Stonyhurst College	Nr. Preston
1812	Greenaways Cotton Mill	Manchester
1812	Ashton & Sons Mill	Hyde
1812	Ashton & Sons Mill	Stockport
1812	Ackermann lithographers	London
1817	Royal Mint	London

In 1808, Samuel Clegg was awarded the ISIS Silver Medal from the Society of Arts for his works on gas manufacture (a drawing associated with this medal is shown in Figure 2.12). The effort in obtaining the award was due to his uncle Ashworth Clegg, who undertook much of the correspondence. Whereas, Murdoch drifted away from gas, Clegg continued a long association with the gas industry throughout his life and was regarded as the first gas engineer (Bennett 1986).

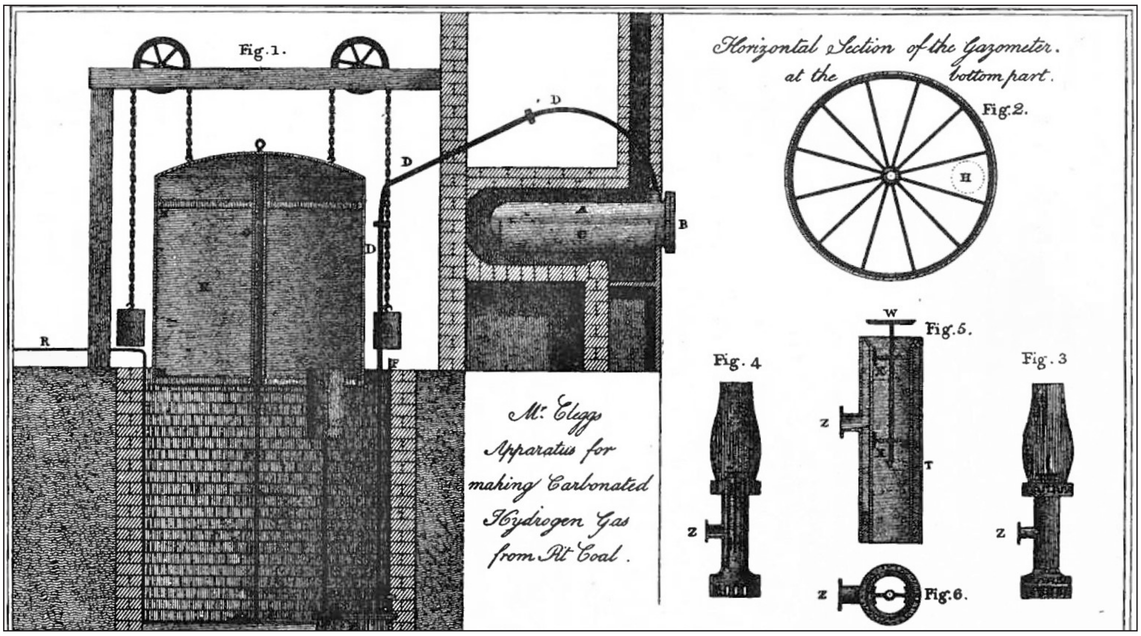


Figure 2.12 Plan of a simple gasworks designed by Samuel Clegg. Source Hunt 1907.

2.2.4 Josiah Pemberton and the Emergence of Competing Gas Engineers

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. Pemberton exhibited gas lights outside his factory in 1806. He went on to build a gas plant for Saunders Button Factory in Birmingham, where the gas was used for both lighting and the soldering of shanks on to buttons (Stewart 1958, p9).

Table 2.4 Private Gasworks Attributed to Josiah Pemberton

Date	Company	Location
1805-6	Saunders Button factory	Birmingham
1806	Spooner Park Slitting Mill	Park Hill, Birmingham
1806	Cook's Brass Works	Birmingham
1807	Golden Lane Brewery	London

One of Pemberton's installations (Figure 2.13), which was constructed at Cook's Brass Works, was reported in a series of papers to Nicholson's Journal written by the owner Benjamin Cook (Cook 1808, Cook 1812), although Cook never mentioned Pemberton's involvement (Hunt 1907). Cook focussed on the application of the technology for lighting small works (of which there were many in Birmingham at this time), rather than the large factories such as the Salford Twist Mill. At the time of his papers, war had increased the cost of oil and candles for lighting significantly. Cook also could see great merit in the use of the by-products, especially the coke and tar. Cook believed coke was more effective than coal and that the tar could be used to derive a tar oil similar to that imported from Russia, for the purposes of varnishing, lacquering and Japanning (Hunt 1907).

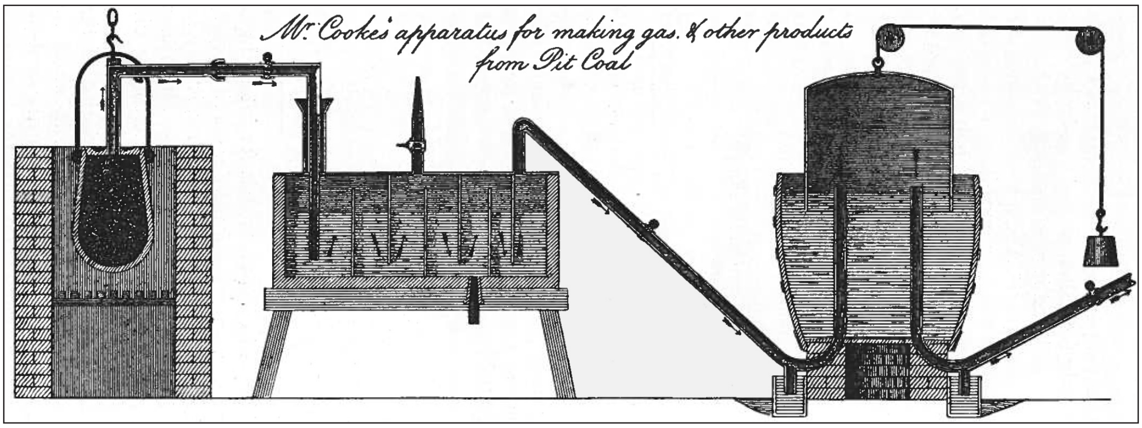


Figure 2.13 Mr Cooks Apparatus from Society of Arts paper. Source Hunt 1907.

He provided evidence for the latter in his 1812 paper. The papers described his small plant which used a small cast iron pot of about 8 gallons and holding 20-25lbs of coal, this would produce about 600 gallons of gas which would be used in the works and to fill a gasholder of about 400 gallons, with any excess burnt as waste. Cook used the gas for soldering purposes, which was both more cost effective and convenient than oil and cotton lamps used previously by his works. Cook demonstrated that gas could be used effectively and economically in small works. He also commented on the use of gun barrels which had become common place for use as gas piping, suggesting they required too many joints and that lead pipes proved more reliable. Gun barrels were used for many years afterwards in the home and for gas main connections. Charles Hunt reported finding such a pipe in the ground as a mains connection in New Street, Birmingham in about 1880 (Hunt 1907).

Pemberton is believed to have installed a gas manufacturing plant into the Golden Lane Brewery in 1807. Gas from this plant was used to light Golden Lane, and part of Beech Street and possibly Whitecross Street. Gas pipes were attached to the wall of the buildings below the windows of the first floor to a distance of about 800ft either direction from the Brewery, placing seven lamps in Golden Lane and four in Beech Street. This is thought to have been the first demonstration of street lighting in London, however, there is not an accurate record of when it occurred. The description of this event was presented in the magazine *Athenaeum* in August 1807 (Anon. 1807).

Between 1805 and 1812, at least 19 operational gas plants were constructed in Britain, primarily lighting factories, but some of them did provide a little local street lighting. No gasworks had however been built for the specific purpose of providing street lighting (Stewart 1958).

2.2.5 The Fate of Private Gasworks

Private gasworks were built for many years at large mills and factories across Britain, most notably the mills of Lancashire and Yorkshire. Whilst many of the factory and mill gasworks appeared small, they often produced more gas than many village and some town gasworks, given the number of lights they needed to supply. An adequately lit mill would 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. In the 19th century gas was also used for some specific industrial purposes. For example, gas torches were used for soldering activities for the production of buttons and other metallic items (Stewart 1958). In mills, gas was also used for 'Gassing' a process of passing newly spun yarn through a flame to remove the loose fibre ends (Redding 1844).

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 lower price than the mill owners could achieve within their own gasworks. The Bobbin Mill belonging to Wilson Brothers at Cornholme near Todmorden had its own gasworks, which provided a public gas supply and street lighting. In 1893, the Todmorden Local Board purchased the mains, meters, service pipes and street lighting apparatus from the mill and then supplied gas from their own works (Golisti 1993). Similar stories occurred for other large mills and factories in England and there are several examples where private gasworks evolved into the public gas company.

Those gasworks which did survive were often built in isolated locations with no alternative but to produce their own gas and survived into the early 20th century.

Private gasworks were not limited to mills and factories, a large number of private gasworks were built to supply country houses and estates, hospitals, asylums, prisons, collieries and schools. These were built from the mid-19th century providing a source of lighting where public gasworks were not available. These gasworks started to be replaced by a public gas supply, alternative forms of gas (e.g. acetylene) or electric lighting by the first decade of the 20th century.

There were numerous examples of private colliery gasworks, listed in the gazetteer, providing a gas supply, selling surplus gas through local gas mains at a profit. Colliery gasworks, such as the Acton Hall and Rotherham Main colliery's in Yorkshire constructed their own gasworks to light the colliery yards and buildings, but also provided a public supply to nearby colliery villages (Golisti 1993).

The gas mains provided by the colliery gasworks often ended up being purchased by the local public gas company. This was the case for the Rotherham Main colliery whose gas mains, meters and service pipes were purchased by the Rotherham Corporation Gas department in 1930, who then provided the gas supply, with the private gasworks closing. A description of the public and private gasworks built in England, is provided in the gazetteer [part 3 of this report]. A substantial number of these were privately owned.

2.3 The First Gas Company 1812-1820

The philosophy of William Murdoch had been to build small gasworks to provide gas to a single establishment, such as a mill or factory. The same approach had been taken by Clegg, Pemberton and their contemporaries (Stewart 1958).

2.3.1 Friedrich Albrect Winzer the Gas Entrepreneur

This philosophy was not shared by another proponent of gas, Friedrich Albrect Winzer (Figure 2.14) who had much wider ranging plans for the future. Winzer was from Braunschweig (Brunswick) in Germany, where he had connections to the royal court (Hunt 1907).

Winzer had been induced to visit Paris after hearing the fame of Lebon's experiments. He attended Lebon's experimental lighting at the l'hôtel Seignelay. He had through M. Charles Pougens, a member of the National Institute of France, tried to persuade Lebon to sell him a Thermolampe. Lebon was not interested, Winzer left Paris empty handed in 1802, but had gained sufficient understanding to undertake building his own Thermolampe (Hunt 1907, Stewart 1858 p8). Winzer recorded that Lebon had received repeated and considerable offers to light theatre's and public gardens, but none were ever taken up.

After Lebon's death in 1804, the development of gas in Paris practically ceased. Lebon's widow Thérèse was unable to continue the operation of the tar factory, due to a decline in its fortunes from a fall in demand from the French navy (its main customer) and dishonesty of one of the workers. She did revive the Thermolampe at a display in 1811 and received a prize of 1200 francs from the Société d'Encouragement pour I'industrie Nationale in 1812 (Hunt 1907).

Lebon's work on the thermolampe cannot be underestimated. It was highly influential in continental Europe and led to significant interest in the process on mainland Europe. Following Lebon's death, Germany became the main centre for interest in the thermolampe, and a number of books and articles were written on the subject between 1802 and 1812 as described in a previous section.

Figure 2.14 Portrait of Frederick Winsor. Source National Gas Museum.

Winzer viewed himself as the 'legitimate and successful imitator and proprietor' of Lebon's ideas. Initially Winzer returned to Braunschweig in 1802 with the aim of securing support of the Duke of Brunswick and his Royal Court to develop the Thermolampe technology. To further these aims he translated Lebon's description of his work into three languages which included a supplement dedicated to the Duke (Hunt 1907). Despite his efforts Winzer was unsuccessful and in 1803 he moved to London where he believed greater success could be achieved. In his own account of 1807 Winzer said “of introducing the discovery for the great advantage of the British realm struck me, five years ago, like an electric spark, which has ever been kept alive in my mind, and added, from day to day, from week to week, fresh fuel to my hope of rendering it generally beneficial.” (Hunt 1907). London may have also been chosen as it would have been one of the few places Winsor could have violated Lebon’s patent with impunity.

Winzer first took premises at 41 Grosvenor Square which had been provided to him by a retired coach builder Mr Kenzie (Hunt 1907). To aid his acceptance in England, Winzer anglicised his name to Fredrick Albert Winsor (Stewart 1958 p9).

In 1803 and 1804, Winsor undertook evening lectures and demonstrations at the Lyceum Theatre in London, these became very popular. His demonstrations included the use of gas pipes conveying gas from his retort to various lamps and burners providing “a light without a wick”. His ingenuous demonstrations showed the public that gas was less smokey than a candle or an oil lamp, did not spark and could not easily be extinguished by wind or rain (Peckston 1819). Unused to public speaking Winsor had used an assistant, Edward Heard, to convey his lectures from a script he had prepared. This was a suitable arrangement until Heard failed to show one evening and Winsor had to eventually cancel the lecture as Heard had the script and Winsor had felt unable to proceed without it (Hunt 1907).

A public meeting was called at a London Tavern in 1804 to raise a subscription for generating a public use from the gas lighting forming a “Society” with £20,000 funds “for a committee for making experiments”, the committee constituted twenty-four Gentlemen, which could be viewed as the earliest foundation of the Gas Light and Coke Company (Chandler and Lacey 1949, Williams 1828).

On the 18th of May, 1804, Winsor took out a patent (No. 2764) for “An improved Oven, Stove, or Apparatus, for the purpose of extracting inflammable Air, Oil, Pitch, Tar, and Acids from, and reducing into Coke and Charcoal, all kinds of Fuel, which is also applicable to various other useful Purposes.” (Anon. 1860). This patent combined the saving and purifying of inflammable gas for producing light and heat and useful by-products with the manufacture of a superior kind of coke (Peckston 1819). It was the first patent to mention the production of gas from fuel (Hunt 1907). The Patent was cancelled in 1808 at Winsor’s request (Anon. 1860).

Winsor’s patent specification went on to describe:

> “a metal, brick, or earthen stove, oven, retort, or vessel so constructed to reduce, by means of fire and heat all raw fuel of any kind into coke and charcoal without any or little consumption of the fuel, by which operation the smoke being extracted from all raw fuel, is then conducted through cold air or water into a condensator, where, after being sufficiently cooled and purified, it undergoes a natural chemical resolution into tar, pitch, oil, acid, ammonia, inflammable gas or air. Thus, by the above means of carbonizing raw fuel with heat instead of burning it, the whole weight is preserved, and resolved into said products. Any metal, brick, or earthen stove, oven, retort, or vessel constructed as above may

> dry, melt, heat, distil, or boil away any copper pan, pot or vessel in refineries, breweries, distilleries, smelteries, forges, steam engine, or any other purpose whatever where much fuel is consumed, which, to save and preserve the above principle of carbonization, can be applied, first to heat any vessel, &c., by the construction of such a carbonizing utensil ; secondly, to heat another vessel, &c., by the hot smoke extracted from raw fuel; thirdly, to heat a third vessel, &c., by the inflammable air or gas made from smoke ; and fourthly, to heat any fourth vessel, &c., with the coke or charcoal saved by this principle of carbonization." After enumerating some of the uses to which the residuals may be applied, it is mentioned that " the inflammable gas or air being purified from that carbon so pernicious to respiration and dwellings, may be led and conducted in a cold state through tubes of silk, paper, earth, wood, or metal, to any distance in houses, rooms, gardens, places, parks, and streets, to produce light and heat." (Anon. 1860).

Winsor regularly advertised in the Times Newspaper and also published two pamphlets in 1804 promoting his patent. The first entitled "The Superiority of the New Patent Coke Over the use of Coals, in all Family Concerns, Displayed Every Evening at the Large Theatre, Lyceum, Strand" The second pamphlet was even more ambitious with the title "Account of the most ingenious and important national discovery for some ages. British Imperial patent light, ovens and stoves". Winsor promoted his Patent Ovens on the basis that they could recover the 80% of the combustible matter that was lost in the smoke. That he could recover valuable products (oil, pitch, acid, coke and gas) from the smoke and this would aid cutting air pollution. He also alluded to the idea that mixing the gas and air could produce a powerful force to supersede the steam engine, which would years later be realised as a gas engine. Winsor also highlighted the dyeing and antiseptic potential of tars and the use of the refined tars for the production of white lead, verdigris, copperas and alum (Winsor 1804b, Chandler and Lacey 1949 p25-46).

Winsor at this point was suggesting the lighting and heating of a house from a Patent Oven located in the kitchen or wash house. He argued that one light (crystal globe) would sufficiently heat and light each room and that a great saving would be achieved by the removal of chimneys, fireplaces and the associated implements. He ventured that it would only cost three quarters of the cost of installing the oven and pipework into the house (Hunt 1907). Winsor also highlighted the use of gas at Lighthouses, a use it eventually found, although oil lamps tended to be the preference.

Despite the vision of Winsor to foresee the future uses for gas, he did little to credit his business acumen when he calculated in the second pamphlet that for each £6 expended on the new patent stove a return of £64 10s would be achieved. Some of his writing also showed a lack of scientific knowledge, in his "Plain Question and Answers" published in 1807, he wrote that a room filled with gas would not catch fire if you entered with a candle, due to the gas being mixed with the air, he also suggested that coal gas was preferable to air and was congenial to the lungs. In both cases Winsor was quite wrong, although Winsor seemed convinced he had cured his asthma through his work on his patent stove (Hunt 1907).

In 1806 Winsor rented No.97 Pall Mall, the former Star and Garter Hotel. In 1807 he also rented two additional adjacent properties on Pall Mall (No. 94 and 95). The Pall Mall properties were chosen because Pall Mall 'being one of the approaches to the King's palace, and the residence of his Royal Highness the Prince of Wales, and, from other circumstances of local convenience, it had advantages for the display of their experiments, far beyond any other situation in the Metropolis'. (Chandler and Lacey 1949, p25-46) Winsor's works was regularly a feature of amusing cartoons in newspaper and Journals (Figure 2.15)

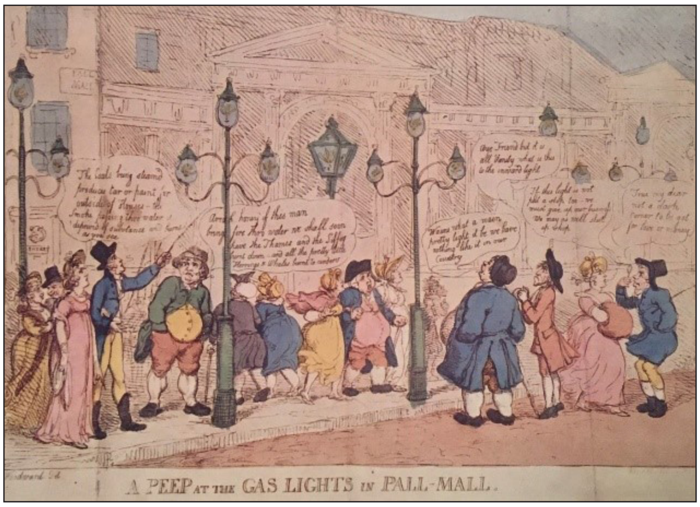


Figure 2.15 A Caricature by G.M. Woodward showing the interest in gas lighting from the lighting of Pall Mall circa 1808. Source Hunt, 1907.

Winsor continued his lectures and experiments at Pall Mall. He installed his patent stoves with money he had obtained from subscribers. Winsor had not used a gasholder in this installation and any excess gas produced was vented to air (Hunt 1907).

The experiments being undertaken with the funds provided by his original "Society" did not fit with Winsor's views and he felt "obliged" to replace this with a larger and better funded "Society" in 1807 (Chandler and Lacey, 1949 p25-46). His lectures continued to create great interest and on the evening of Thursday the 4th of June 1807, to celebrate the Kings Birthday, Winsor used two of his patent stoves to produce gas which was conveyed by tinned iron pipes to gas lights on the garden wall between Carlton House and St. James Park. This lighting received the required permission of the Prince of Wales. The spectacle attracted large crowds which stayed until midnight. There is a Green Plaque on Pall Mall which commemorates the lighting of Pall Mall (Figure 2.16).

Figure 2.16 The Plaque Marking the Lighting of Pall Mall in 1807 by Frederick Winsor. Source R. Thomas 2017.

On the 3rd and 4th of July 1807 a "secret committee" of the "Society" of subscribers attended an experiment conducted by Winsor to test the claims he had made. The tests were reported to be entirely successful and the committee issued a series of resolutions to be inserted in "all the newspapers". They also presented a petition for incorporation to the King. This petition included brief details of Winsor's experiments, and who witnessed them, the by-products produced and potential financial gain estimated at 670%. The petition requested that the King would consider granting a Royal Charter of Incorporation for the exclusive privilege of utilisation of lighting by gas, sale of the by-products and for the apparatus and operations. It was signed by James Ludovic Grant (Grant 1807).

The requirement for a Royal Charter or a Private Act of Parliament was necessary, as companies which lacked these were only regarded as Partnerships. If a partnership became insolvent, all its members were liable to have their private property seized to meet the debts. Given the risky nature of such a new business, a risk of insolvency was very real (Williams 1979).

The Chancellor of the Exchequer who received the petition, deferred the decision to the Privy Council (Williams 1979). The Privy Council decided "that his Majesty could not grant the charter of incorporation until an Act of Parliament had been passed authorising the company". A Bill for an Act of Parliament was prepared but deferred until 1809. During the intervening time Winsor continued to lecture, publish reports and pamphlets and promote his cause. The most important action was his publication calling for a "National Light and Heat Company, for providing our streets and houses with light and heat, on similar principles, as they are now supplied with water". He proposed that this National Light and Heat Company would supply the whole country with gas, requesting what was then the enormous sum of £1,000,000 capital be raised (Hunt 1907, Chandler and Lacey 1949 p25-46).

Winsor had a very entrepreneurial outlook, he recognized that the future of gas was in the production of gas in centralised stations, with distribution to customers at multiple establishments through a network of mains. Such a notion was publicly ridiculed by prominent figures such as the writer Sir Walter Scott who had thought Winsor a madman "Proposing to light London with – What do you think?" Smoke and the scientist Sir Humphrey Davy wondering whether they planned to use the great dome of St. Pauls Cathedral as a gasholder (Norman 1922, Williams 1979). Others argued against it on a patriotic basis, that lighting had at the time depended on oil, and oil was primarily obtained from whales. The whaling fleet had been the training school for the Royal Navy, concluding the switch to gas would ruin the Royal Navy when Britain was deeply involved in the Napoleonic wars (Chandler and Lacey 1949).

Winsor entered into a long running argument over the National Light and Heat Company in Nicholson's Journal of Natural Philosophy in 1807. Winsor was an extravagant publicist who was happy to pen doggerels in his pamphlet, such an example is given below:

Must Britons be condemned for ever to wallow

In filthy soot, noxious smoke, train oil and tallow

And their poisonous fumes ever to swallow

For with sparky soots snuffs and vapours men have constant strife

Those who are not burnt to death are smothered during life.

Winsor's "Society" of subscribers was a body of trustees who elected the aforementioned James Ludovic Grant as its Chairman to assist Winsor. Whilst their ambitions originally stretched to lighting the Houses of Parliament, Pall Mall, Grosvenor Square, Somerset House, Cheapside, the Mansion and India Houses, the Treasury and the Bank of England, they were deemed impractical. The lighting demonstration never extended beyond Pall Mall (Chandler and Lacey, 1949).

In the autumn of 1807, he lit one side of Pall Mall and in January 1808 both sides of Pall Mall were lit with gas and the lighting of Pall Mall continued intermittently until 1810. (Stewart 1958).

Which was the first street to be lit by gas remains uncertain. It is believed that a few weeks prior to the lighting of Pall Mall in 1807, parts of Golden Lane, Beech Street and possibly Whitecross Street, had been lit by gas from gasworks built by a London ironmonger (attributed to Josiah Pemberton) at the Golden Lane Brewery, (Matthews 1827). These are both possibly predated by the lighting of Chapel Street by William Murdoch as part of his installation for the Salford Twist Mill for Phillips and Lee (Matthews 1827).

2.3.2 Establishing the Gas Light and Coke Company

Winsor's breakthrough occurred in 1808 when the trustees for the "fund for Assisting Mr. Winsor in his Experiments" published a report, which they presented to a meeting of their subscribers on the 26th of May (Grant 1808). This resulted in further petition for an Act of Incorporation of a "Heat and Light Company". This resulted in a much-debated Bill which had been put before parliament in 1809. This Bill was vigorously opposed by Murdoch and his supporters, on three key points. Firstly, it did not recognise Murdoch's claim to be the pioneer of gas lighting in Britain, which incited Murdoch to write his "Letter to a Member of Parliament in Vindication of his Character and Claims" (Murdoch 1809). The second objection was that the national reach of the company formed by the Bill would create a monopoly, which would drive other competitors such as Boulton and Watt out of the gas manufacturing business. The third objection raised was the limitation of liability, being a dangerous principal for such a risky venture (Hunt 1907, Williams 1979)

The discussion of the Bill led to a long and detailed investigation by a Committee of the House of Commons. The committee collated extensive evidence from the likes of Humphrey Davy, George Lee, Frederick Accum and James Watt Junior. Watt Jr had argued that the establishment of a public corporation to supply gas would diminish competition and could damage his own company’s trade in manufacturing gas plant, an opinion echoed by George Lee (Hunt 1907).

The Bill was rejected on its third reading, but in 1810, the application for the Bill was renewed and an Act was obtained which gave authority for the granting of a Charter within the following three years of the Act being passed. The original Bill had been significantly curtailed to limit their powers of supply from a national basis to just supplying the City of London, Westminster, Southwark and the adjacent suburbs. The capital which could be raised was also restricted to £200,000 and to shares of a value of £50. To manage the new company a Governor, a Deputy Governor and ten directors were to be appointed (Chandler and Lacey 1949).

It took a further two years to receive the Royal Charter, but on the 30th of April, 1812, Winsor’s vision had become a reality with the formation of the Gas Light and Coke Company (GLCC), (Hunt 1907). The logo of the GLCC can be seen in Figure 2.17. The logo includes the latin motto "*STET CAPITOLIUM FULGENS*" which translates to "Let the Capitol stand gleaming".

Figure 2.17 The Logo of the Gas Light and Coke Company Circa 1922. Source Beckton Gasworks, Gas light and Coke Company, 1922.

To manage the new company James Ludovic Grant was appointed Governor, James Hargreaves appointed Deputy Governor and the German chemist Frederick Christian Accum appointed one of ten directors. Accum was a chemist from Bückeburg, Westphalia, he had worked for the Brande family pharmacy transferring to London in 1793. He worked as a chemical operator at the Royal Institution between 1801 and 1803, after which he had lectured privately and at the Surrey Institute, selling scientific equipment to support his income. Accum had supported Winsor in his scientific experiments from 1805 and had given evidence on Winsor’s behalf in the Parliamentary enquiry (Chandler and Lacey 1949).

By the time the GLCC was formed Winsor had been side-lined and was not given the role of either director or as an officer of the company. Scant reward for his efforts. He remained with the company but his technical abilities and those of Accum were insufficient to produce equipment suitable for a commercial gas company. As well as technical failings, the company lacked any strategy or business acumen. This led to the near insolvency of the company, unhappiness of the shareholders and ejection of the first court of directors. A new court of directors was elected to improve the chaotic situation (Tomory 2012).

The GLCC needed to obtain the authority to break open the streets so it could lay gas pipes and install street lighting before more profitable private customers could be obtained. The Parish of St. Pancras, the City of London, the united parishes of St. Margaret and St. John in the City of Westminster and the Liberty of Norton Folgate all expressed an interest in gas lighting. The novelty of being the first gas company meant that the GLCC had to establish a method charging for street lighting. Previously oil lamps lighting contracts had been let on an operate and maintain basis, however, these did not need to cover the large capital expenditure required for installing gas pipes and lights. Within early contracts such as that for Norton Folgate, the GLCC Co. paid these significant costs but in later contracts these costs were charged to the customer. Although this increased the price, the brilliance of the gas lights meant that contracts were always in demand (Everard 1949, Tomory 2012).

2.3.3 Samuel Clegg and the GLCC

In order to rectify their technical failing, the GLCC approached Samuel Clegg, who joined them on the 25th December 1812. Clegg's exploits in gas engineering had been well known and in 1812 he had been erecting a gas plant for Rudolph Ackermann the famous Lithographer at 101 The Strand. At this time Clegg was one of the few engineers who had experience with gas lighting (Tomory 2012). On gaining his position at the GLCC Clegg closed his business in Manchester and moved to London (Bennett, 1986). Clegg immediately started work on the first gasworks of the GLCC which was located on a wharf at Cannon Row, Westminster. Whilst the wharf was good for importing coal, the site was too small to meet its proposed future needs. The gas plant failed technically and was abandoned, what could be salvaged from Cannon Row was removed to a new and larger site located between Great Peter Street and Horseferry Road, Westminster (Tomory 2012, Everard 1949).

At this time GLCC had Frederick Accum, James Barlow, Samuel Clegg and James Hargreaves who were all working on separate projects to produce gas making plant (Everard 1949, Tomory 2012).

The construction of the Great Peter Street Gasworks, were put under the control of James Hargreaves. With Samuel Clegg working as Hargreaves' assistant on the project. With permission to lay pipes in the streets of the united parish of St. Margaret and St. John obtained in May 1813, the pipes were finally laid in August and a gas supply commenced in September of that year. The first paying customer being St. John's Church (Tomory 2012).

In May 1813 the GLCC entered into an agreement with the Liberty of Norton Folgate to provide street lighting by the 29th September 1813. This small area was in the east of the city and would require its own gas making plant and mains. A site for a gasworks was only purchased in June 1813, leaving the impossible task of building a gasworks and installing mains within three months. An experimental gas plant was built under the supervision of Accum. The construction was rushed and the gasholder tank collapsed, which required Samuel Clegg's skills to repair. It had become apparent during 1813 that, with the exception of Clegg, the management and expertise within the company was lacking sufficient skills and knowledge to run the business and fulfil its contracts. The knowledge which Murdoch and his co-workers had gained about gas making during their years of experimenting at Soho, was lacking from the GLCC. The GLCC management had no understanding of how much gas was needed and no concept of how big the gas plants or mains needed to be to supply future customer demands. Although they tasked Winsor with this job, it was soon apparent that he did not have sufficient understanding to undertake this role (Everard 1949, Chandler and Lacey 1949, Tomory 2012).

The shareholders of the GLCC were soon realising that the court of directors did not have the company in good order, tensions started to grow between the two. This was brought to a head when there was an explosion in October 1813 at the Great Peter Street gasworks due to the leaking of gas from a damaged gasholder and wet lime purifier. Samuel Clegg was badly burned in the explosion, but survived (Everard 1949, Chandler and Lacey 1949).

This explosion led to numerous newspaper reports, with the directors writing letters in response, to try to allay the fears raised. It also led to an investigation by the Royal Society. Clegg recalled the account when he was visited by Sir Joseph Banks and several other members of the Royal Society, who had been asked to report on the Great Peter Street Gasworks and were conversing over the risk of a gas leak at the site. Clegg summoned a worker to bring him a pick axe and candle, after which he used the pick axe to create a hole in the side of a gasholder and then causing great concern to the visitors who quickly retreated, he proceeded to ignite the gas escaping from the hole with the candle. As Clegg had predicted the gas burnt with a strong flame but no explosion occurred (Chandler and Lacey 1949). The Royal Society report was published in 1814.

According to Williams Matthews the Royal Society report provided “Some useful alterations and new modification” in the apparatus and machinery used at gasworks (Matthews 1827). The report was not officially made public until 1823 when Sir William Congreve had been undertaking an enquiry into safety in the gas industry in his role as “inspector of gasworks” (Everard 1949, Congreve 1823).

These fears over gasholder safety required for many early gasholders to be housed within a building. These buildings were later proved unnecessary and also potentially dangerous if they were not properly ventilated. They were soon dispensed with in Britain, with the only remaining examples being the two former gasholder houses built into the frontage of the former Warwick gasworks, similar designs were used at other gasworks including the Northampton Gasworks shown in Figure 2.18.

Gasholders houses were popular in North America, Germany, Russia and Nordic countries, where they were used to deflect heavy winter snows and many examples still exist.

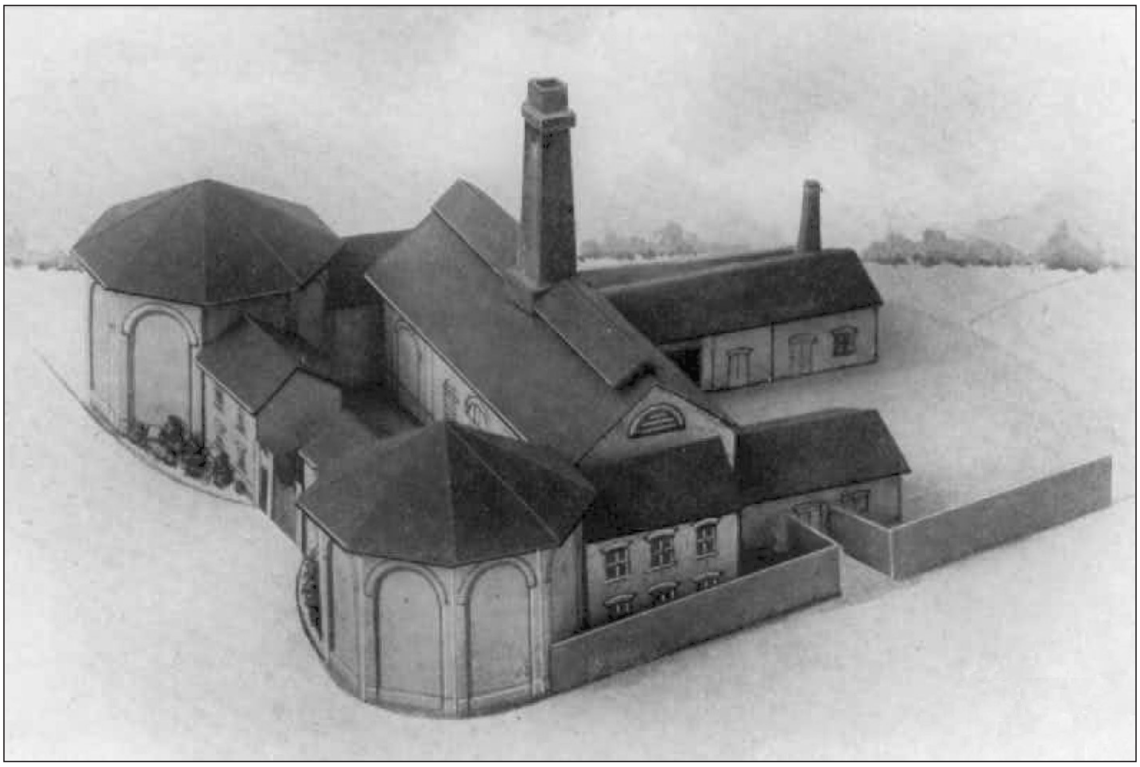


Figure 2.18 The original Gasworks Northampton 1824. These gasworks are very similar to the surviving gasworks frontage in Warwick, with two octagonal gasholder houses. Source National Grid Gas Archive.

Following the explosion at the Great Peter Street gasworks, all 54 shareholders of the GLCC signed a letter demanding that a special committee determine if the directors still held the confidence of the proprietors. This resulted in a general meeting being called on 1st November 1813 and the election of the lawyer David Pollock, one of the shareholders, to the court of directors. In retaliation James Grant offered both his resignation and that of the rest of the directors, which the shareholders accepted and the directors who had not been consulted tried to rescind. At this point Accum worn down by the past year and a half resigned (Tomory 2012). Accum did not leave the industry completely, he later assisted Clegg on the construction of the gasworks at the Royal Mint and was the author of the first treatise on gas manufacture in 1815, followed by a second in 1819. Whilst he was librarian at the Royal Institution, he was reportedly dismissed for embezzlement, a charge against which he was acquitted. He left England for Berlin in 1822 where he took up the role of Professor at the Technical Institute, until his death in 1838 (Chandler and Lacey 1949).

A subsequent meeting was held on the 30th of November in which the special committee delivered a damning report on Grant's reign as Governor. He resigned shortly afterwards and embittered at his treatment after investing 6 years in the project. James Hargreaves who sold his shares in the GLCC, followed him out of the company. The Special Committee then took control of the GLCC with the aim of avoiding its total ruin, with Pollock at the helm. They requested further money from the shareholders to bolster the company's depleted finances, without which the company was likely to fail (Everard 1949).

When Westminster Bridge was lit by gas, amidst great public concern, Samuel Clegg had to light the gas lamps himself for the first few nights because the lamplighters were too scared to do so themselves (Chandler and Lacey 1949).

Despite the many problems the demand for gas continued to grow for the GLCC and under the direction of Pollock and Thomas Livesey who were unofficially running the business on behalf of the shareholders, the business was reorganised. New directors were appointed and a management structure formed. They reviewed the business and looked for savings where possible, ending the free gas lighting to parliament. Both the Great Peter St. and Curtain Road gasworks were in a poor state at this time each with only a single working gasholder. (Tomory 2012).

The running of the business improved in 1814, with better accounting, and the extension of enhanced gas mains and the gas making plant (Everard 1949). By April 1814, the GLCC was able to supply both Norton Folgate and the Parish of St. Margaret's. Clegg worked to improve the efficiency of the retort increasing the ratio of retorts heated by a single furnace from 1 to 4, which significantly reduced the amount of coal used. The company started to attract street lighting contracts in nearby parishes and requests for the lighting of shops, public buildings and private residences (Tomory 2012).

Clegg had believed that six gasworks would be required to supply the city, however, a new site was purchased in 1814 on Brick Lane, for the construction of a new gasworks. Like the two other gasworks it was positioned well to supply gas but not to obtain coal. Experience from the construction of the first two gasworks, Brick Lane was better planned both in the gas making plant and in the distribution system (Everard 1949).

One notable failed contract, was that to mark the meeting of the allied powers who had defeated Napoleon in 1814. A gas lit pagoda was planned and constructed for this celebration, the gas contract had been awarded to the GLCC and Clegg had overseen and successfully tested the pagoda under the watchful eyes of the Royal family. Unfortunately, on the night of the celebration, Sir William Congreve had ordered that fireworks be attached to the pagoda, when lit the fireworks resulted in the pagoda catching fire and burning to the ground before the gas could be lit (Chandler and Lacey 1949).

The GLCC achieved a well-publicised success when they lit the Guildhall on the 9th of November 1815 (Chandler and Lacey 1949, Clegg 1841).

The GLCC started to receive competition from small private gas making concerns, one such private gasworks located on Dorset Street, was offered for sale to the GLCC in 1815. The gasworks were within the GLCC territory, but within an area their gas mains had not yet reached. Clegg advised the GLCC against the purchase. Two years later another offer for the GLCC to purchase the gasworks was made and again they refused. As a result, it's proprietors applied for and obtained statutory powers and formed the City of London Gas Light Company, who became a rival of the GLCC, many more would follow.

By 1815 Winsor's financial situation had become very difficult and he had to flee the country to avoid his creditors. He lost both his annuity and directorship of the GLCC as a result (Tomory 2012).

He departed for Paris, where in 1815 he established the first Gas Company in Paris and France, however like London, this company struggled, he was ejected from the company and it entered liquidation in 1819. A poor man, he wrote to the GLCC who provided a stipend of £200 per year until he died in Paris in 1830, aged 67 a disappointed man, but his influence on the gas industry was significant and long lasting.

To commemorate Winsor, a cenotaph memorial was erected at Kensall Green cemetery, London, which bears the Inscription "At evening time it shall be light" (Zachariah 14:7), This Monument is Grade II listed. There is a similar memorial to Winsor at the Père Lachaise Cemetery in Paris (Figure 2.19) where he was buried, which has an Inscription from David Pollock (Anon. 1900). Winsor's achievements are commemorated by a Green Plaque on Pall Mall and the naming of Winsor Terrace in Beckton, the former approach road to Beckton Gas Works.

The management of the GLCC was resolved in 1815, with David Pollock assuming the role as Governor and Thomas Livesey taking the role as his deputy. They stayed in post until 1846 and 1840 respectively, providing stable leadership during the early years of growth.

It was in 1816 whilst working at the GLCC that Clegg devised the circular design of gasholders that was used from there onwards (Norman 1922).

In addition to the other notable improvements attributed to Clegg, he also developed both the gas meter and gas governor whilst at the GLCC. The first gas meter he developed was a dry gas meter. It was installed at Ackerman's print works on the Strand, it operated for a year

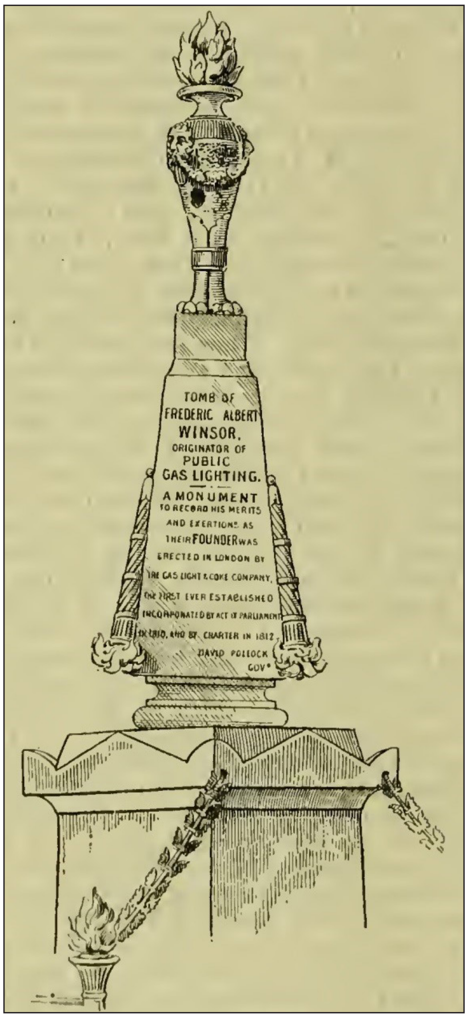


Figure 2.19 The Cenotaph erected for Winsor at the Père Lachaise Cemetery in Paris, where he was buried. Source Gas Journal, Anon, 1900

after which it was found to be defective and therefore had to be removed, and its use discontinued. Clegg had also developed a water filled, wet gas meter which had been used to measure gas production on the gasworks, this proved reliable. This design, used a rotating drum which was partially submerged in water, it was used with some modification by the gas industry for a greater part of its history and became known as a “Station Gas Meter”. This same design was later adapted for domestic gas meter use (Everard 1949).

Clegg’s Governor came about as a need to maintain a constant pressure in consumers’ houses within the ever-expanding GLCC gas distribution network. The gas network had grown to 30 miles by 1815 and the pressure had diminished with distance from the gasworks and also had a tendency to fluctuate. In October 1816 Clegg installed six governors at different locations on their gas network and they became an immediate success maintaining pressure effectively (Everard 1949).

2.3.4 Clegg Departs the GLCC

Clegg’s relationship with the court was never easy and came to a head in 1816, when the court had curtailed his expenditure on experiments and he became aware that they intended to not renew his contract when it expired in December 1816. On hearing these rumours he wrote to the court telling them that he would be glad for anyone to take his place if they could serve the GLCC interests any better than him, and even went as far to offer conditions on which he would consider extending his contract, which included working as an engineer for third parties if they were not competitors (Something he was doing at this point). In return Clegg was asked to provide a cost for his exclusive employment only by the GLCC, but the price he offered was so high, that they offered him a contract on his previous terms as long as they could manufacture his patent gas plant. Clegg agreed, but with it came conditions on the duties which he would do. The relationship had deteriorated so much by early 1817 that Clegg eventually resigned on the 1st of April. At this point the GLCC had sufficient engineers such that his loss was not a crippling blow and the company still managed to thrive (Everard 1949).

Clegg had already lined up consultancy assignments whilst working for the GLCC, for the Royal Mint and in Bristol, roles he continued after he left (Bennett 1986). Clegg was instrumental in the establishment of gasworks at towns and cities across England, these are listed in Table 2.5. Notably some of the original buildings of one of his earliest gasworks, at Gas Street, Birmingham, still stand Figure 2.20. These gasworks were built for a Mr John Gostling in 1817 and later became the first gasworks of the Birmingham, Gas Light and Coke Company, which was incorporated by an act of parliament in 1819.

In 1817 Clegg developed a new innovative gasworks for the Royal Mint which was installed by Accum. It used a new design of retort originally planned for the GLCC, which was circular and rotative, the gasworks also incorporated a collapsible gasholder which had the shape of a triangular prism (Figure 2.21), neither of which were used on future gasworks (Accum 1819). By 1823 Clegg had acted as engineer for the installation of over 30 gas manufacturing plants across Britain, some of which are shown in table 2.5 (Bennett 1986).

Figure 2.20 The recently restored Gas Street gasworks buildings in Birmingham. Source R. Thomas 2017

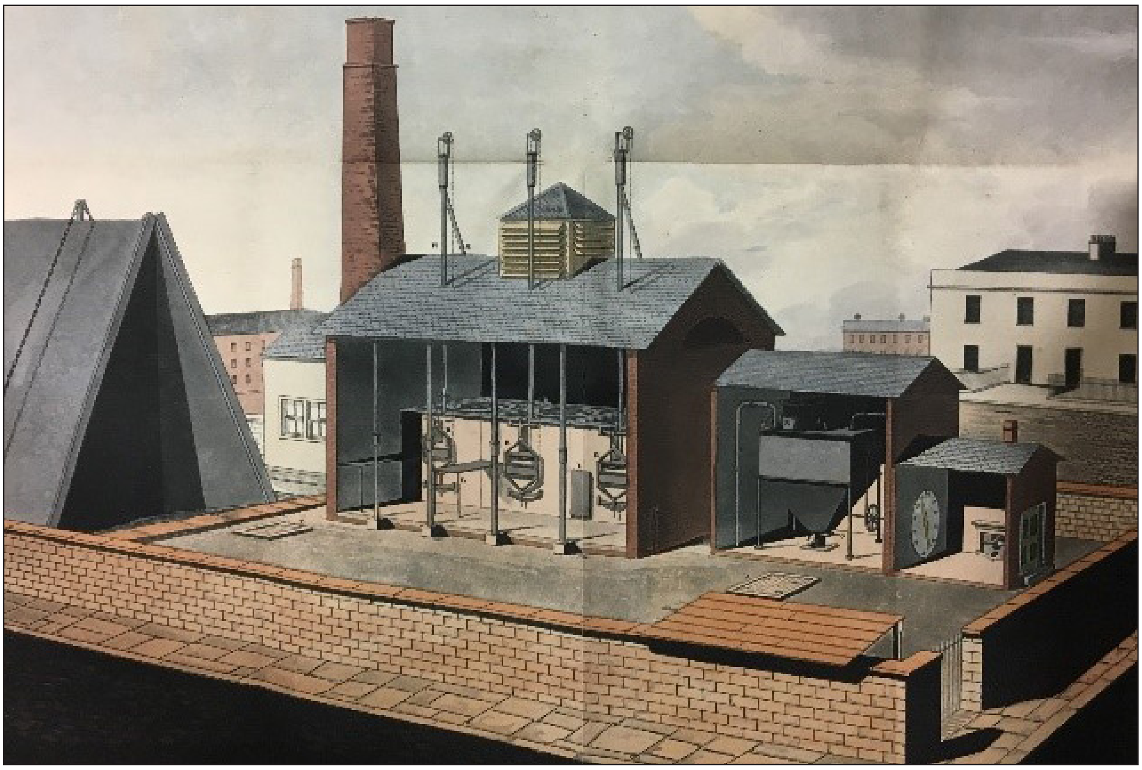


Figure 2.21 A colour depiction of the Gasworks designed by Clegg and built by Accum for the Royal Mint, showing his triangular collapsing gasholder (left of picture), Source Accum 1819.

He left the gas industry in 1824, returning at various times as his fortunes fluctuated. He lost his fortune twice, once in an engineering establishment in Liverpool after leaving the GLCC and later after returning from working as an engineer to the Portuguese government, he became involved in the innovative but ultimately unsuccessful atmospheric railway (Bennett 1986).

Table 2.5 Gas works providing a public supply in which Samuel Clegg acted as consulting engineer.

Town/City	Construction date
Bristol gasworks	1816
Birmingham Gasworks	1817
Dudley Gasworks	1818
Warwick Gasworks	1819
Worcester Gasworks	1820
Kidderminster Gasworks	1821
Shoreditch and St. Pancras Gasworks of Imperial Gas Light and Coke Company	1821-1823
City of London Gas Light and Coke Co.	1823
Fulham gasworks of the Imperial Gas Light and Coke Company	1828-1829

With his son, Samuel Clegg Junior, he produced a key gas engineering text 'A Treatise on Gas Works and the Practice of Manufacturing and Distributing Coal Gas' (Clegg 1841).

By 1817 the GLCC had become well established and both the well informed public and press started to see the advantages of gas. W.T. Brande writing in the journal of Science and the Arts stated that "the best proof of the safety of gas illumination is, that notwithstanding the many thousand lamps nightly burning in London, six accidents only are known to have occurred, and those of a trifling and almost unimportant nature, though the pipes and lamps are generally badly and very carelessly managed. In matters of this kind, fact, and not arguments, must be looked to for evidence" (Brande 1817).

Clegg was replaced as engineer for a short while by John Malam, who had been a draughtsman at the Great Peter Street gasworks. Malam was also a notable inventor, devising a triple lime purifier for use by the GLCC to improve the purification of gas on their gasworks (Peckston 1841, Richards 1877, Newbigging and Fewtrell, 1878). Malam returned to the issue of purification in 1823 when as part of Patent (No.4832) he devised a dry lime purifier based on Reuben Phillips earlier design, which allowed the gas to pass between each purifier sequentially (Anon. 1860, Richards 1877).

Malam left the GLCC later in 1817, in dispute with the Court of Directors, but it appears there were also professional jealousies with Clegg, as Clegg had in 1819 tried to argue against Malam's meter when it was presented to the Society of Arts (Peckston 1841), The Society, dismissed the argument and awarded Malam the same ISIS medal which Clegg had won 11 years earlier. Whereas, Clegg had developed the gas meter, it was Malam who had rendered it a practical instrument. Malam also went on to improve retort settings, using elliptical retorts at Great Peter Street rather than circular retorts (Everard 1949).

The rivalry between Malam and Clegg was highlighted in the Mechanics Magazine in 1842, when they reviewed the books which were available about gas lighting. They had been very critical of the general literature on gas lighting at the time and the first two editions of Thomas Snowdon Peckston's book "A Practical Treatise on Gas Lighting" in particular. The Mechanics Magazine referring to the books as "disgraceful intermixture of quackery and false pretension". Peckston had been overly negative about the importance of Samuel Clegg's involvement in the development of gas lighting and had pushed the claims of Malam, who happened to be Thomas Peckston's Brother in Law (Anon. 1842).

The Third volume of Peckstons Treatise, was published in 1841 and was a much more comprehensive tome than its predecessors, Peckston had also done much to counter his previous unfair claims about Clegg, who was still held in the highest esteem. It is also probably not a coincidence that in the same year Samuel Clegg's Son (Samuel Clegg Junior) published his "A Practical Treatise on the Manufacture and Distribution of Coal Gas, It's introduction and Progressive Improvement" to vindicate his father's fame. Clegg's book was viewed as being a fairer account of the development of gas lighting and less indulgent of the achievement of Clegg senior than Peckston had been of his Brother in Law Malam (Anon. 1842).

2.4 Early Competition from Oil Gas

Whilst coal gas was starting to establish itself as a commercial proposition, it faced early competition from another fledgling method of lighting, oil gas. Oil gas had been developed by John Taylor (Figure 2.22). Taylor was born in Norwich in 1779, where he trained as a surveyor and civil engineer.

Figure 2.22. John Taylor. Source By Mezzotint by Thomas Lawrence after Charles Turner - [1], CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=33008250

2.4.1 Taylor and Martineau

John Tylor showed an interest in mining from a young age, becoming the manager of the Wheal Friendship Mine, near Tavistock in Devon, believed to be the world's largest copper mine at this time. Taylor was also the engineer for two other major projects constructed in the same area, the Tavistock Canal (built 1803-1817) and the Redruth and Chasewater Railway (1824-1826), which served his mining interests. He was well respected and his skills were sought after by the owners of mineral rights in the UK and abroad. He was elected a fellow of the Royal Society in 1825, was a member of the Geological Society and its treasurer from 1816 to 1847 and a founding member of the British Association for the Promotion of Science and its treasurer from 1832-1860 (Taylor 1886).

John's brother Philip was also a well-respected scientist and engineer, who first trained as a surgeon, before becoming a chemist. In 1812 John quit Cornwall to establish a chemical works with his brother in Stratford, East London. John focussed on metallurgical chemistry and Philip focussed on mechanical aspects. Gas manufacture became an interest when John Taylor was experimenting with the heating of various oils to form flammable gases (Taylor 1886).

The two brothers later formed a partnership called Messrs J.P. Taylor and Martineau, with John Martineau, an engineer, wealthy relative and member of the Martineau family that owned businesses in sugar refining, banking and brewing. The business grew to include the manufacture of printing equipment, boilers and steam engines. They developed a number of interesting inventions including patent for the application of high-pressure steam to the purpose of evaporation, which was adopted by brewers and sugar refiners in the UK and abroad.

In 1815 John Taylor submitted a patent (No. 3929) for the manufacture of gas from animal or vegetable oils by introducing the oils into heated retorts (Anon, 1860).

Messrs J.P. Taylor and Martineau, then acquired John Taylor's patent. From 1817 onwards, they manufactured oil gas plants which were installed in notable locations such as the Apothecaries Hall, Covent Garden Theatre and the Post Office on Lombard Street (Richards 1877), orders were obtained from overseas customers such as for the Tsar's Library in St. Petersburg (Taylor 1886).

An account of the oil gas plant devised by Taylor and Martineau is given in Frederick Accum's 1819 treatise work on coal-gas, which read:

> Messrs. J. and P. Taylor are the first persons who have resorted to oil as a substance from which gas for illumination can be easily and cheaply prepared. The apparatus for the purpose is much smaller, much simpler, and yet equally effectual with the best coal-gas apparatus. The retort is a bent cast-iron tube, which is heated red by a small convenient furnace, and into which oil is allowed to drop by a very ingenious apparatus; the oil is immediately volatilised, and the vapour in traversing the tube, becomes perfectly decomposed; a mixture of inflammable gases which contains a great proportion of defiant gas passes off; it is washed by being passed through a vessel of water (which dissolves a little sebacic acid, and which seldom requires changing), and is then conducted into the gasometer.
> The facility and cleanliness with which gas is prepared from oil in the above manner may be conceived from the description of the process. A small furnace is lighted, and a sufficient quantity of the

> commonest oil is put into a small iron vessel; a cock is turned, and the gas, after passing through water in the washing vessel, goes into the gasholder.
>
> The operation may be stopped by shutting off the oil, or to a certain extent hastened by letting it move freely on; the small quantity of charcoal deposited in the retort is drawn out by a small rake, and the water in the washer is very rarely changed.

Oil could produce a brighter flame and as the oil used contained much less sulphur than coal, the gas did not produce the same sulphurous smell when burnt. This was one of the selling points of Taylor and Martineau who marketed their gas making plant as having “great illuminating power”. They supplied the equipment to manufacture gas to many locations in UK and abroad (Matthews 1827, Richards 1877).

2.4.2 Oil gas Companies

Between 1819 and 1830, Oil gas companies were established. The first in Bow, London was established in 1819, its proprietors were members of the Taylor and Martineau Families. Additional oil gas companies were established, often with involvement of Taylor and Martineau, these included Norwich (1820), Liverpool (1823), Bristol (1824), Colchester (1821), Taunton (1823), Hull (1821), Plymouth (1823) and Whitby (1826) as well as at Edinburgh (1824) and Leith (*c* 1824) in Scotland and Dublin (1823) in Ireland. The Edinburgh Oil Gas Company received support from the famous Sir Walter Scott, who had once opposed coal gas but later used oil gas at his home at Abbotsford in the Scottish Borders. The gas produced by these oil gas companies was distributed through the same types of gas pipe networks as employed by coal gas companies. The oil gas plants at Bristol and Norwich using resin dissolved in volatile oil for making oil gas (Stewart 1960, Richards 1877).

John Taylor left the partnership in 1822, returning to his mining interests. His Brother Phillip continued, taking out another patent (No. 4975) for oil gas manufacture from various substances in 1824 (Anon. 1860).

In 1824 a bill for a large oil gas company based in London, the London and Westminster Oil Gas Company, was put before Parliament with the aim of raising £500,000. The existing coal gas companies fought hard and at great expense to oppose its formation. The Inquiry which lasted most of 1824, pitted supporters of oil gas such as Humphrey Davy, Michael Faraday and Sir William Congreve (Government inspector of gasworks) against the lesser known scientist John Dalton of Manchester, Professor Leslie or Edinburgh, Dr Fyffe of Edinburgh, Adam Anderson of Perth and George Lowe of the GLCC. The inquiry is well described elsewhere and eventually led to the defeat of the bill (Chandler and Lacey 1949, Richards 1877, Matthews 1827).

Although oil gas was promoted to be superior to coal gas, obtaining sufficient feedstock oil (e.g. whale/fish oils or vegetable oils) at both a competitive price and on a regular basis was a problem.

This ultimately disadvantaged the industry in Britain and within a few years the oil gas companies had died out or converted to coal gas, though those which had been established in whaling ports surviving longer. Oil gas had greater success abroad where it faced more limited competition from piped coal gas and the cost of importing coal was higher.

2.4.3 The London Portable Gas Company.

In 1819 David Gordon and Edward Heard (Former assistant to Frederick Winsor) patented a method to compress and store gas in cylinders. The cylinders were manufactured from copper and fitted with regulating valves, to allow the gas to come out at a constant rate. The London Portable Gas Company was established in 1819 with the aim of exploiting the Gordon and Heard patent. Gas was supplied from a gasworks at No.30 St. John Street, Clerkenwell in copper vessels which were either spheres or cylinders with hemispherical ends. They had a capacity ranging from 1 cubic foot and 402 cubic inches to 5 cubic feet and 407 cubic inches. The gas was stored at a pressure of 30 atmospheres and was designed to supply a Gordon Patent Lamp, also supplied by the company (Gordon 1823).

The gas vessels were dispatched daily to the customer, so they would never run out of gas and the empty cylinders were returned to be recharged with gas. It provided those wealthy enough to afford gas, but not within reach of a gas main the opportunity to light their house by gas. It found favour with shop keepers to light their premises.

It was sold on the basis that being free of hydrogen sulphide, it created no unpleasant odour and therefore the sulphur dioxide, formed from burning coal gas, could not corrode metallic goods or pictures. It was also sold on the basis of economy, the light could be moved around the house as needed and be used in places it would not normally be practical to install gas (Anon. 1823).

One of the four subscribers to the London Portable Gas Company was John Taylor of Taylor and Martineau, who manufactured the oil gas making plant. Unlike coal gas, the oil gas supplied by the London Portable Gas Company was ‘fixed’ and lost little of its illuminating power on compression. Portable gas companies were also established outside of London, under the auspices of the Provincial Portable Gas Co. – which included the cities of Edinburgh, Bristol and Manchester.

The killer blow to the Portable Gas Company, which happened later (the London company ceased production in 1834) than the other oil gas companies, occurred when the price of coal gas per thousand feet fell from 28 shillings to 21 shillings, a price with which oil gas could not compete (Clarke 1889).

The Royal Institution was first lit by gas provided by the London Portable Gas Company from 1828 to 1834 and for a few years before this experimentally. Whilst the London Portable Gas Company failed in 1834, it did leave the notable legacy of the discovery of benzene in 1825, which was made by Michael Faraday at the Royal Institution, when he investigated the composition of the liquid residue deposited in these cylinders (Stewart 1957).

It was not the end for oil gas. The economics of the process improved many years later, once oil was found in plentiful supply and the price of oil decreased. The compressed gas cylinders found favour again for lighting railway carriages.

2.5 Expansion of the Gas Industry 1820 – 1860

2.5.1 Expansion of the Gas Industry in London

The manufactured gas industry did not provide the considerable returns originally promised by Winsor, but with the establishment of the Gas Light and Coke Company, the spread of gas lighting was swift and extensive. Following on the heels of the Gas Light and Coke Company, many other gas undertakings were established in London (Table 2.6). By 1850 these numbered 13, the most notable rivals being The Imperial Gas Company (formed in 1821) and The South Metropolitan Gas Light and Coke Company (SMGC), (formed in 1829). The SMGC became the big South London rival of the GLCC, but they only operated south of the Thames. The first gasworks in South London had been privately established by Munro in 1814. He later sold the gasworks to a company called the South London Gas Company, but these faced financial difficulties in 1824 and were in turn purchased by the newly created Phoenix Gas Light and Coke Company (PGLC). The PGLC merged with the SMGC in 1880 (Anon. 1924).

Table 2.6 Formation dates of London Gas Companies up till 1850.

Company	Formation date
Chartered Gas Light and Coke Co.	1812
City of London Gas Co.	1816
Imperial Gas Co.	1821
Ratcliff Gas Co.	1823
Phoenix Gas Co.	1824
Independent Gas Co.	1829
South Metropolitan Gas Light and Coke Co.	1829
Equitable Gas Co.	1842
London Gas Co.	1843
Western Gas Co.	1845
Commercial Gas Co.	1847

Despite its growing success, the gas industry continued to face considerable opposition throughout its early years. Even many years after the establishment of the GLCC, Samuel Clegg described that there was a common misconception that gas pipes must carry fire and therefore be hot. The curious would apply their gloved hand to the pipe to ascertain the temperature and when the passages to the House of Commons were lighted by gas, the architect insisted upon the pipes being placed four or five inches from the wall, for fear of fire (Clegg 1841).

Following the Royal Society inspection of gasworks in 1814, the main concern had related to the storage of gas. With recommendations that the gasholders be limited to

6000 cubic feet capacity and that they should be housed. At this time there was one gasholder at the Great Peter Street works of 14,000 cubic feet. The report led to future gasholders being housed, however, the limitations on their size, were overlooked (Chandler and Lacey 1949). Outside of London gasworks built at Birmingham and Chester under the supervision of Samuel Clegg, constructed gasholders without housing and gradually the use of housing gasholders was dispensed with.

2.5.2 Sir William Congreve

Another major explosion occurred at a gasworks in Manchester in 1819 (Richards 1877). Little was done following the Royal Society report until the Home Office appointed the previously mentioned Sir William Congreve (Member of Parliament for Plymouth) in 1822, as the "Inspector of Gasworks", with the role of inspecting the safety and regulation of the gas industry in London. Congreve visited and collated information about the various London gasworks, which was published in the form of a report in 1822 (Richards 1871, Chandler and Lacey 1949).

His Report of 1822 provided the following description of gasworks in London (Richards 1877)

1. The Peter Street works consist of eighteen gasometers; the average contents of each may be stated at 15,000 cubic feet (GLCC).
2. The Dorset Street works contain fewer gasometers; several of them erected in one building, of the enormous size of 40,000 cubic feet each gasometer (City of London Gas Co.).
3. The Brick Lane works are nearly on the same scale as those of Peter Street, consisting of sixteen gasometers, some of them working in coal tar (GLCC).
4. The Whitechapel works contain two gasometers.
5. The Mile End works contain six gasometers.
6. The South London works are in two divisions, one in St. George's Fields, the other near Southwark Bridge; this latter contains two gasometers of about 15,000 cubic feet each, and ten more are to be erected.
7. The Curtain Road works contain six gasometers (GLCC).

Those gasworks, without a name in brackets, were private gasworks, as at this point only the GLCC and City of London Gas Co. had been formed, with the Imperial gas company only being formed in 1821.

Congreve produced a second report in 1823, which was regarded as being much better informed than the first. It recorded the development of the gas industry in London, with him recording that there were four great gas companies (in London – the GLCC, the London, the Imperial and the Ratcliff), having between them 47 gasholders, containing 917,940 cubic feet and supplied by 1315 retorts, supplying 61,203 private customers and 7,268 street lamps (Congreve 1823, Chandler and Lacey 1949).

Congreve was not neutral in his opinions on gas, he had expressed a preference for oil gas believing it to be safer and less explosive (Richards 1877). Congreve was also against unchecked competition which occurred between the GLCC, the Imperial Gas Company and the City of London Gas Company who all vied to supply the same area. Congreve supported the idea of a set district for each gas company, a recommendation which he made as the Inspector of Gasworks in 1821, this resulted in subsequent Gas Acts restricting new companies to specified districts of supply (Richards 1877).

2.5.3 A welcome boost from Royal approval

A boost was given to the industry's respectability when the Prince Regent had gas lighting installed in the Music Room and Banqueting Hall of his Brighton Pavilion in 1821 (Williams 1981). A similar boost was given when the New House of Commons adopted gas lighting in 1852, it continued to use gas until 1900, when it was replaced by electric lighting (Stewart 1958).

Gas spread rapidly throughout the country, often through the passing of 'lighting and watching' Acts of Parliament, which promoted safety and security as a reason to light the streets with gas (Stewart 1958).

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. By 1819 Bristol, Bath, Cheltenham, Birmingham, Leeds, Manchester, Exeter, Chester, Macclesfield and Kidderminster had also been lit by Gas (Stewart 1958, Williams 1981)

Table 2.7 Formation dates of some early English Gas Undertaking formed Companies up till 1818.

Company	Formation date
Preston Gas Light Company	1815
Exeter	1816
Liverpool	1816
Manchester	1817
Bath	1818
Brighton	1818
Leeds	1818
Nottingham	1818
Oxford	1818
Sheffield	1818
Worcester	1818

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 (Chandler and Lacey, 1949).

Lighting was the primary use for gas in the 19th century. The first gas burners were very simple, pinhole burners. Frederick Winsor used Rattail and Cockspur burners in 1807, which had a luminosity of 1.5-2 Candles per cubic foot of gas. The burners 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. Winsor's assistant, Stone, devised the Batswing burner (Figure 2.23), which used a saw cut hole rather than a pinhole, this was further improved as the Union Jet or Fishtail Burner by Milne in 1820 (Stewart 1958).A variety of different burners are shown in Figure 2.24.

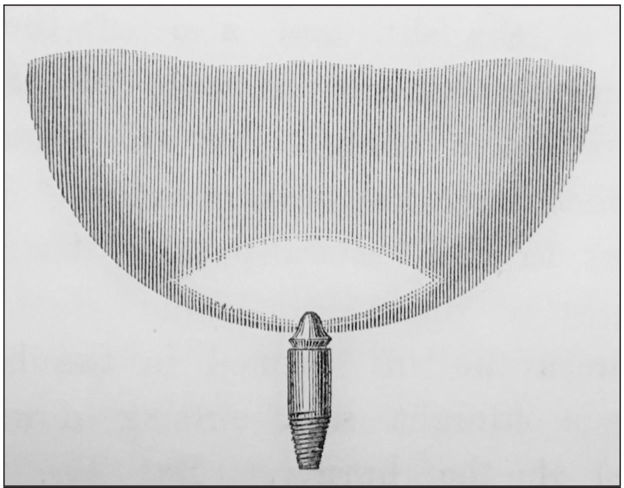


Figure 2.23 A batswing burner. Source Kings Treatise 1878.

Samuel Clegg converted the Argand burner for use with gas in 1809, this improved the luminosity to 3–4 candles per cubic foot of gas. The Argand burner was repeatedly improved by others through the 19th century. Notable developments were made by: Chaussenot (1835), Bowditch (1854), Frankland (1854), Goddard, who invented the duplex Argand Burner (1855), Bengel (1864), Wigham, who developed the Regenerative Argand Burner (1865), Sugg, who developed the 15 Hole Argand (1862) the No.1 London Argand (1869) and arrays of multiple Argand lamps (1870) with a luminosity of between 150-1200 candle power (Stewart 1958).

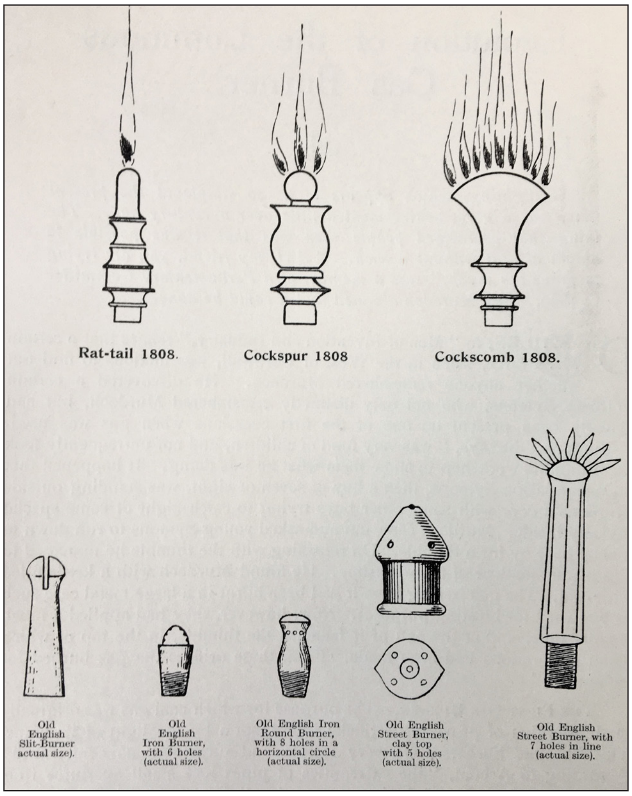


Figure 2.24 Different gas burners Source Chris Sugg. Source Lighting by Gas: An Outline of it's History, Chandler 1936.

These early burners were manufactured from metal and corrosion was a significant problem as the holes would gradually get bigger, which also increased the gas consumption. This was costly for the gas company in the early years as gas was sold based on the number of gas lights a customer would have, not the volume of gas used. This inefficiency became a problem for the customer when charging switched to the amount of gas used after the introduction of the domestic gas meter (Stewart 1958).

Notable displays of gas lighting around 1820 using ornate gas chandeliers, at the Royal Pavilion (Brighton) and Liverpool Town Hall, provided some important press coverage and patronage for the gas industry (Stewart 1958).

Between 1820 and 1830 all the significant theatres in London had installed gas lighting, the brighter light enabled them to use more realistic scenery and costumes (Stewart 1958).

2.5.4 In the Limelight

Another rival to gas light, called “limelight” was developed in the 1820’s by Goldsworthy Gurney, a lecturer at the Surrey Institute, who had been working on the creation of the “oxy-hydrogen blowpipe”. Gurney found that if the blow pipe was used to heat quicklime (calcium oxide), it would incandesce, producing a very bright light. The lime was used in the form of a cylinder which would be consumed quickly, so it had to be manually rotated. Both the intensity of the light and the considerable cost of manufacture prevented its general application (Richards 1877). It found use in theatrical stage lighting in 1837 at Convent Garden, the intense light being particularly suitable for this purpose, and it was in widespread use by 1860. Its theatrical use is where the term “in the limelight” originates from. The light was also known as “Drummond light”, after Thomas Drummond used the light to aid surveying in the mountainous regions of Ireland. The use of gas lighting in theatres was superseded by electric lighting around 1885 (Stewart 1958).

In addition to the local authorities that required street lighting, the early customers were mostly public houses, hotels, theatres, shops and public halls and institutions. It was not until the 1840s that 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 (Chandler and Lacey 1949).

By 1829, there were no less than some two hundred gas companies in Britain, many of which were very small with capital less than £5000 (Armstrong 1938).

2.5.5 Municipal Gas 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 publicly owned gas undertaking (Jessell 1949).

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 (Jessell 1949).

The Manchester Corporation gas department became 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 (Jessell 1949).

In 1823 Charles Macintosh patented a process for the waterproofing of fabric using rubber dissolved in coal tar derived Naphtha. This created one of many industries to be associated with the by-products of gas manufacture. Another notable industry became the treatment of wooden sleepers, telegraph poles and piles which was developed by Franz Moll and John Bethell in the 1830s (Lunge 1916).

2.5.6 Rapid Technological Advances

In 1824 Samuel Crosley patented (No. 5089) an improved gas governor, it was a mechanical system which avoided the use of water (Figure 2.25). When the pressure of the gas increased, the governor would restrict the flow to counteract this to maintain a steady flow of gas. (Richards 1877, Anon 1860).

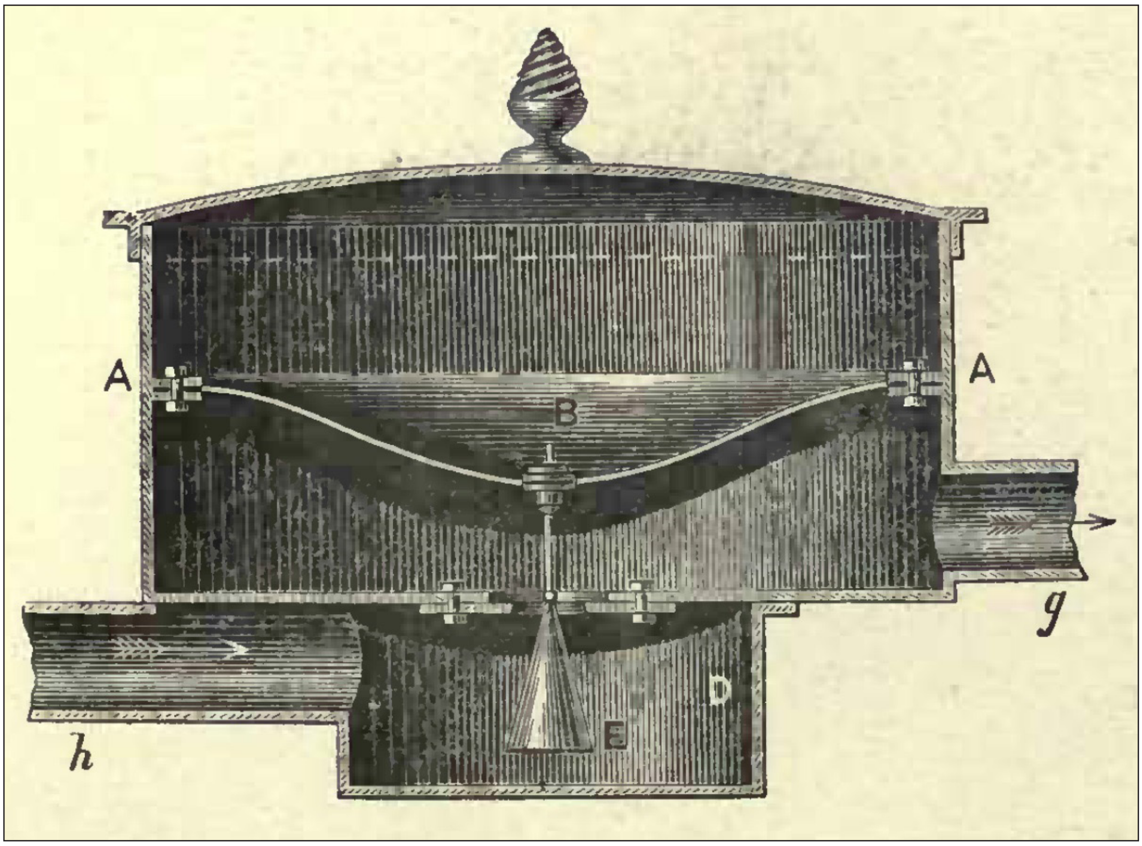


Figure 2.25 Crosley's Dry Governor, Source Richards 1877

Around the same time clay retorts started to be used in Scotland. John Eunson, gas engineer at Wolverhampton Gasworks was making and using clay retorts and separately John Grafton patented a clay retort in 1820 (British patent No.4483). Joseph Cowan was manufacturing clay retorts in 1826 at his Blaydon Burn works in Newcastle (Clegg 1841, Anon 1900b).

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. Initially this was all done by hand which was in hot, dirty and dangerous conditions. A sketch of the conditions within the Brick Lane gasworks retort house of the GLCC can be seen in Figure 2.26.

Figure 2.26. An early painting depicting conditions within Brick Lane gasworks. Source The Monthly Magazine, 1821.

In light of this, in 1824 the GLCC introduced a contributory workers benefits scheme and also appointed a company doctor (British Gas, 1986). The gas industry throughout its history tended to be progressive in the way its staff were treated, especially in the larger companies.

Gradually a fondness for gas street lighting grew and many poems were written on the subject such as the following 'Lamplighters Address' from 1830.

"Grand are the Works which doth Gas produce

But grander far, Sirs is its noble use.

There shines the Gas, a Bright resplendent light

And dissipates the horrors of the night"

Lamplighter Address 1830 (from Stewart 1958)

In 1835 the first attempt at mechanising the horizontal retort was undertaken at the West Bromwich gasworks by its engineer John Brunton. His patented system (No. 6799) incorporated a piston powered screw mechanism so it could be operated continuously (Anon. 1860, Richards 1877).

In 1830 Clegg patented his pulse meter, for measuring gas without the intervention of either water or flexible material (Richards 1877, p276).

The increased demand for gas storage on a gasworks led to a major innovation in gasholders. The telescopic gasholder was developed by Tait in 1824. 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 be engaged by a coupling with the next lift which would then start to rise. Tait's original design shown in Figure 2.27 used a configuration which was the reverse of that was later employed, with the widest diameter lift at the top and the narrowest diameter lift at the bottom. Tait was associated with the Mile End Gasworks, one of the earliest in London, the first examples of a telescopic gasholder were reputed to have been built in Leeds (Stewart 1958) and Mile End London (Nabb 1986).

Another competitor to gas lighting referred to as "Bude light", was patented by Gurney and Rixon, in 1839. As with limelight it received considerable attention, but depended on a supply of pure oxygen to the interior of a flame to produce a bright flame. Again the high cost of oxygen production ruined the cost effectiveness of the process and it never became a commercial reality (Richards 1877).

In 1846 George Lowe patented (No. 11,405) a "revolving perforated pipes for supplying water or purifying liquor to the surface of coke contained in suitable vessels" an invention which became known as the Scrubber, which was used to remove water soluble impurities such as phenol and ammonia from gas (Anon. 1860, British Gas 1986, Meade 1916).

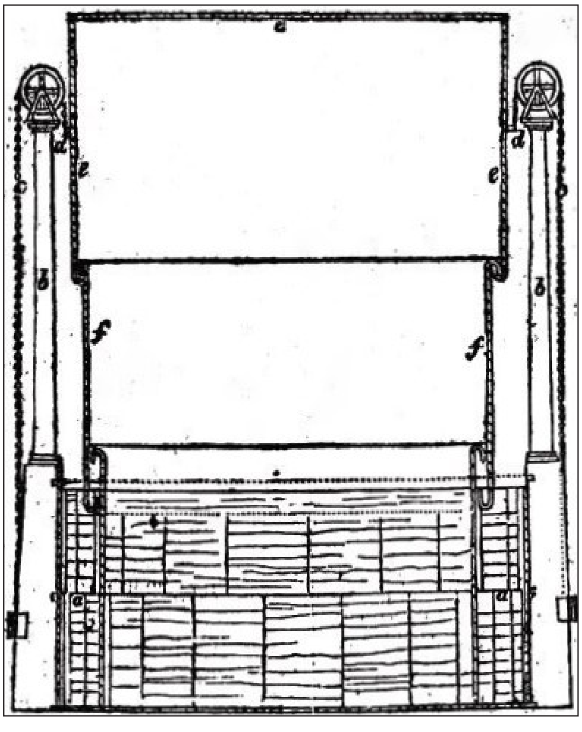


Figure 2.27 Tait's Original design for the telescopic gasholder, Source Mechanics Magazine 1836.

2.5.6 Troublesome Competition and Districting

The approach of restricting companies to a specified area, which had been promoted by Congreve in 1821 and enshrined in subsequent Gas Acts, lasted until 1842, when it was abandoned, and unchecked competition was allowed to keep prices low. In London, almost all areas then had the choice of two potential gas companies to supply them. But the result was a disaster, the competing companies laid their gas mains in all the major thoroughfares in the city, where there was a large consumption of gas. This led to Streets such as Oxford Street, containing the gas mains of six competing gas companies. Such a situation became disorderly, with a constant digging up of the streets and switching of customers. Apart from the inconvenience, the gas companies also struggled to make a profit and pay dividends and all concerned lost out (Richards 1877, Stewart 1958).

In 1853 the four principal Gas companies in London, South of the Thames, came to an agreement on "Districting" to reduce the "wasteful" competition with multiple gas companies supplying the same areas. This gave each company a specified area of supply. As a result the gas prices rose from 4s to 4s 6d and the gas companies entered a period of prosperity and the consumers had a more efficient supply. Seeing the improvements in the operations of the gas companies in South London, 'Districting' was adopted in North London in 1858-59 and became legislation throughout London via the Metropolis Gas Act of 1860 (Chandler and Lacey 1949).

Following the Metropolis Act similar competition gradually ceased across the country. At the same time as the move to districting, there was also a growing 'Consumers Movement', driven by customers who thought that gas could be manufactured and distributed more efficiently(Chandler and Lacey 1949).

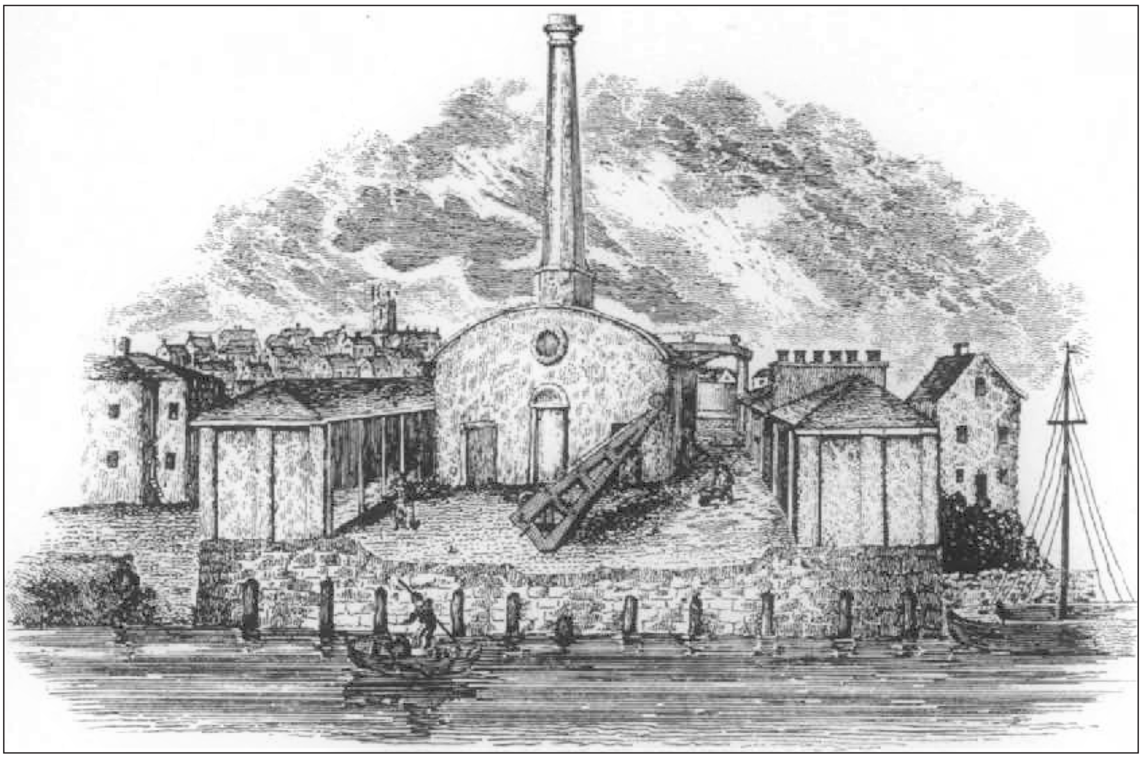


Figure 2.28 A drawing of the York Union Gasworks, Hungate, circa 1840. Source National Grid Gas Archive.

Key amongst those involved in the consumers' movement was the Scottish chemist Alexander Angus Croll. Croll who moved to London in 1836, initially established himself as a chemist at Millwall, London. Inventive, he registered two patents relating to gas manufacture, but ultimately lost all his capital when his business venture failed. Croll joined the GLCC and achieved the position of Superintendent Engineer at the Brick Lane gasworks, by 1841, Croll had made a considerable sum of money from the GLCC with his patent for purifying gas. He left the GLCC in 1844 with his colleague William Richards to start a business to manufacture gas meters. A venture from which Croll gained but Richards lost everything (Moyano Jiménez & Thomas 2016).

Croll later became heavily involved in the formation of the Great Central Gas Company (GCGC). When gas meters were first introduced in London the price of gas was 15s per 1000 feet, this had dropped to 12s in 1832 and by 1849 the price of gas across London was 6s per 1000 Cu ft. Croll believed this could be reduced further to 4s per 1000 Cu ft. In attempts to destroy the fledgling GCGC competition, the established London Gas Companies reduced their prices, firstly to 5s and then to 4s per 1000 Cu ft. By this point the GCGC had created such backing that they were authorised to lay a gas mains from their proposed gasworks at Bow Common to the City of London (Richards, 1877).

Financing the venture himself with his own money, when it was struggling to obtain funds. He made himself personally responsible for the success of the concern when outside influences from the other London gas companies (Figure 2.29), caused the contractors (Peto and Betts) to withdraw from the project (Richards 1877).

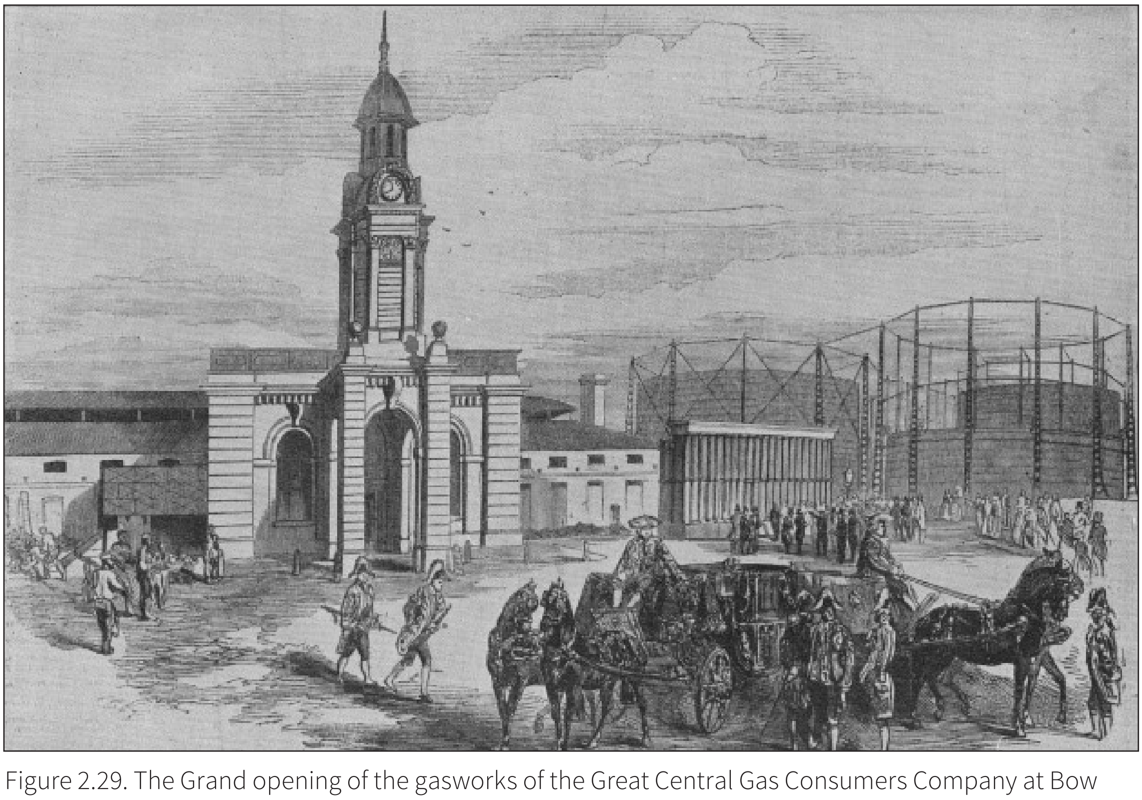


Figure 2.29. The Grand opening of the gasworks of the Great Central Gas Consumers Company at Bow Common in 1853, London, by the Lord Mayor of London. Source National Grid Gas Archive.

Croll personally over saw the laying of 60 miles of mains and 40 miles of services pipe, to ensure he was able to start supplying gas at the promised price of 4s per 1000 Cu ft in 1851 (Richards 1877).

The gas mains laid were so large that a workman was able to pass through the entire line from Bow to the City. The main carried an electric cable, which is believed to have been the first application of telegraphy for private purposes (Anon, 1887). The reduction of the gas price offered by the GCGC led to cheaper gas prices being offered across London (Richards 1877). The GLCC eventually purchased the GCGC in 1869.

Croll's success with the GCGC led to the creation of the Surrey Consumers Gas Association who built a gasworks at Rotherhithe, Croll became involved in the undertaking and was one of those responsible for the 'districting' of the gas companies in the South London area (Anon. 1887).

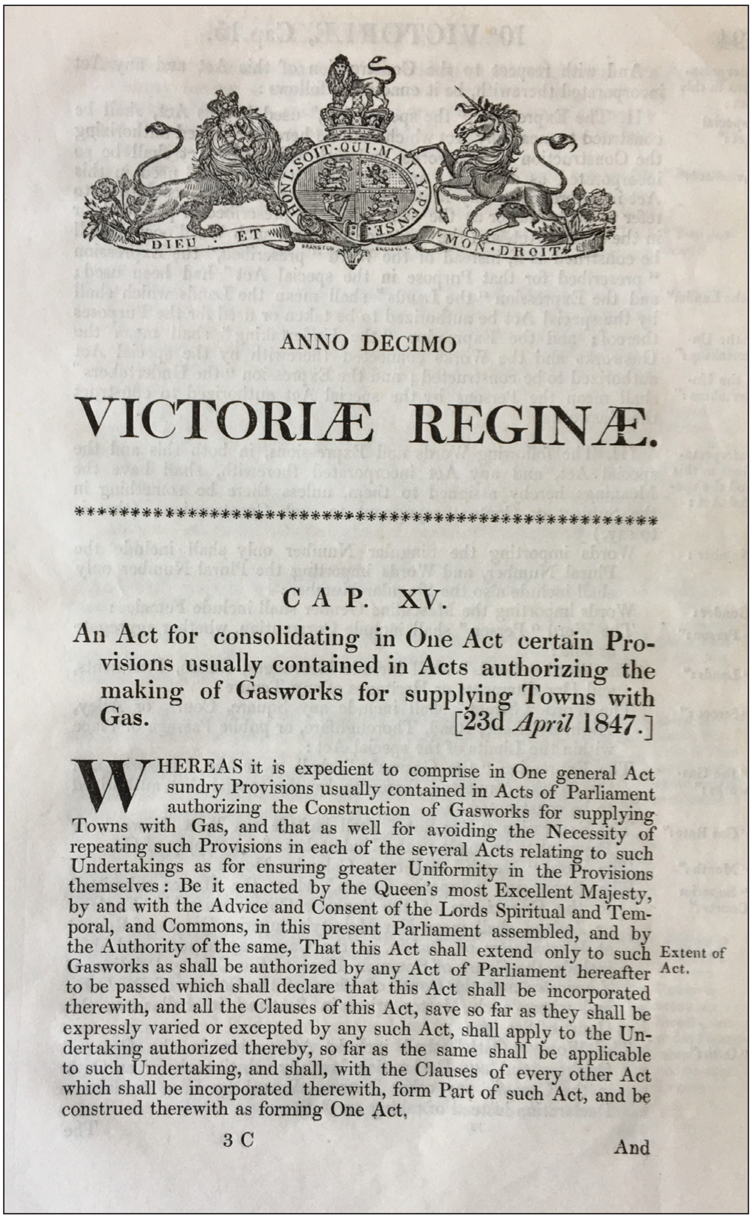
In 1847 Charles Blachford Mansfield obtained a patent (No.11,960) for " an improvement in the manufacture and purification of Spirituous substances and oils" (Figure 2.30). The process simply enriched air by vaporising flammable substances into it, which could then be burnt to produce light (Richards 1877, Anon. 1860).

Figure 2.30 Advert for Mansfields Oil-Gas Apparatus. Source IGEM Archive.

2.5.7 The Rise of Regulation

The gas industry had 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 than other customers. (Stewart 1958).

In 1847, the Gasworks Clauses Act (Figure 2.31) 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, fouling of water, waste produced and by-products. It consolidated previous legislation into a single Act of Parliament with about 40 clauses. It limited profits to 10% and any excess profits to be incorporated into a reserve fund. It became the first of many important pieces of legislation which would regulate the gas industry in the coming century (Stewart 1958, Richards 1877).


HONI · SOIT · QUI · MAL · Y · PENSE

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ANNO DECIMO

VICTORIÆ REGINÆ.

C A P. XV.

An Act for consolidating in One Act certain Provisions usually contained in Acts authorizing the making of Gasworks for supplying Towns with Gas. [23d *April* 1847.]

WHEREAS it is expedient to comprise in One general Act sundry Provisions usually contained in Acts of Parliament authorizing the Construction of Gasworks for supplying Towns with Gas, and that as well for avoiding the Necessity of repeating such Provisions in each of the several Acts relating to such Undertakings as for ensuring greater Uniformity in the Provisions themselves: Be it enacted by the Queen's most Excellent Majesty, by and with the Advice and Consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the Authority of the same, That this Act shall extend only to such Gasworks as shall be authorized by any Act of Parliament hereafter to be passed which shall declare that this Act shall be incorporated therewith, and all the Clauses of this Act, save so far as they shall be expressly varied or excepted by any such Act, shall apply to the Undertaking authorized thereby, so far as the same shall be applicable to such Undertaking, and shall, with the Clauses of every other Act which shall be incorporated therewith, form Part of such Act, and be construed therewith as forming One Act. Extent of Act.

3 C And

Figure 2.31 The front cover of the Gasworks Clauses Act of 1847. Source R.Thomas.

The Great Central Gas Consumers Act of 1851 became the first Act to control standards of illumination quality and provide for a system of testing and inspection. In 1851 Dr. Letheby was appointed by the City of London. His role was to examine the quality of gas supplied by the Great Central Company. His work on gas quality along with that of the chemist, Lewis Thompson, led to the inclusion of conditions in the Metropolis Gas Act of 1860, where gas sold by statutory undertakings in London, had to be independently tested. The failure to meet the standards expected in regard to illuminating power and the removal of impurities such as ammonia and hydrogen sulphide was subject to penalty. The official tests were co-ordinated from 1868 through the introduction of the City of London Gas Act. It introduced Metropolitan Gas Referees appointed by the Board of Trade which prescribed methods and certified testing places provided by each gas undertaking. The Act also regulated illuminating power (16 candle power), gas prices and provided stricter control over sulphur content. Official gas testing was applied across the rest of the country by the Gas Works Clauses Act of 1871. (Stewart 1958 p25, Richards, 1877).

The Sales of Gas Act was introduced in 1859 which regulated the measures used in the sale of gas (Stewart 1958 p25, Richards 1877)

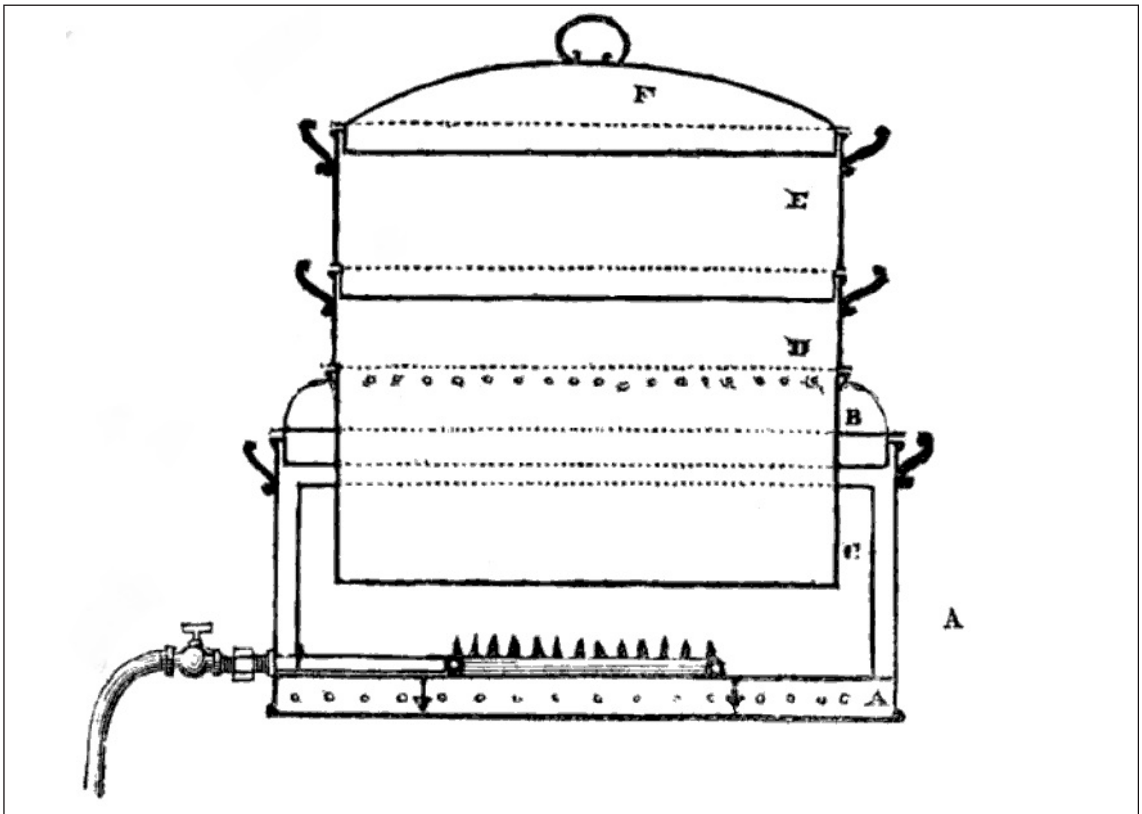

Figure 2.32. Wellers Cooking Apparatus of 1840. Source Mechanics magazine, 1840.

2.5.8 Gas Journalism and the Promotion of Cooking by Gas.

The first journal specifically for the gas industry, *The Journal of Gas Lighting*, was created in 1849 by Thomas Greaves Barlow. This name remained until 1917 (Chandler and Lacey 1949). This publication had been preceded in 1847 by an intermittent publication called the *Gas Gazette* and *Monthly Advertiser*, which had been written by George Barlow. Prior to *The Journal of Gas Lighting*, gas was covered in various publications such as the *Mechanics Magazine* and *The London Journal of Arts and Sciences* (Chandler 1936).

Thomas Greaves Barlow was one of eleven children to John White Barlow, who came to London from Sheffield to establish an Iron Works. John Barlow had taken an early interest in the use of gas in the home and in 1835 was reporting that he only used gas light in his house, and that he used gas to cook and to provide a ready stream of hot water. Barlow's apparatus had been made by James Sharp of Northampton (Barlow 1835).

James Sharp pioneered many early developments in gas cooking. Around 1830, whilst the Assistant Manager of the Northampton Gas Company, he experimented and carried out demonstrations of cooking by gas (Norman 1922). Its relative success won him the patronage of Earl Spencer in 1834, after which he began to produce cookers commercially. In 1847 Sharp became the manager of the Southampton gasworks, where he continued to promote the use of gas cookers until his retirement 20 years later. (Anon 1877)

In 1850 James Sharp delivered a lecture on Gastronomy and cooked a dinner for 120 people on his specialist gas stoves (Norman, 1922). The use of gas in the home to cook was a regular feature in the Mechanics Magazine and other similar press. There were pleasantly worded exchanges between people such as William Weller (whose cooking apparatus is shown in Figure 2.32) and Joshua Beale, who claimed such gas apparatus as their own invention and members of the Barlow family in defence of James Sharp (Barlow 1835, Weller 1840, Occasional Reader 1840).

There was a great surge of interest in the late 1840s, 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. In 1850 Alexis Soyers used a stove consisting of 216 gas jets to roast a joint of meat weighing 535 pounds—he called new dish "Baron & Saddleback of Beef á la Magna Charta." (Norman 1922).

In 1850 Alfred King introduced the Liverpool Gas Cooking Range. A year later an exhibition of gas cookers was held at the Polytechnic Institution, which included a demonstration by Ebenezer Goddard of his "East Anglian Gas Cooking Apparatus", the first cooker to include a form of pilot light (British Gas, 1986). Goddard also manufactured a small portable "Asbestos gas stove" (Anon, 1852).

Alexis Soyer again raised the profile of gas cooking at the City of London Soup Kitchen established in Holborn, which was cooking 1000 gallons of soup per day for the poor (Chandler and Lacey, 1949).

Despite the efforts of the engineers Croll, Ricketts, King, Goddard and Sharp, who all manufactured new cookers, gas cooking did not become popular until the 1870s (Stewart 1958).

An advert for a popular gas cooker of the 1890s a Arden Hill & Co "Titan" is shown in Figure 2.33. David Owen Edwards patented (No. 12,773) the gas space heater based on gas burners of pipe clay, but such devices found little acceptance until the 1880s (British Gas 1986, Anon. 1860, Chandler and Lacey 1949).

The first gas-heated bath was developed in 1850, although such new developments were not without their inherent safety risks. The Bath tub had only been introduced in 1828, by Lord John Russell, and reputed to be the first Englishman to take "a bath a day." (Norman 1922).

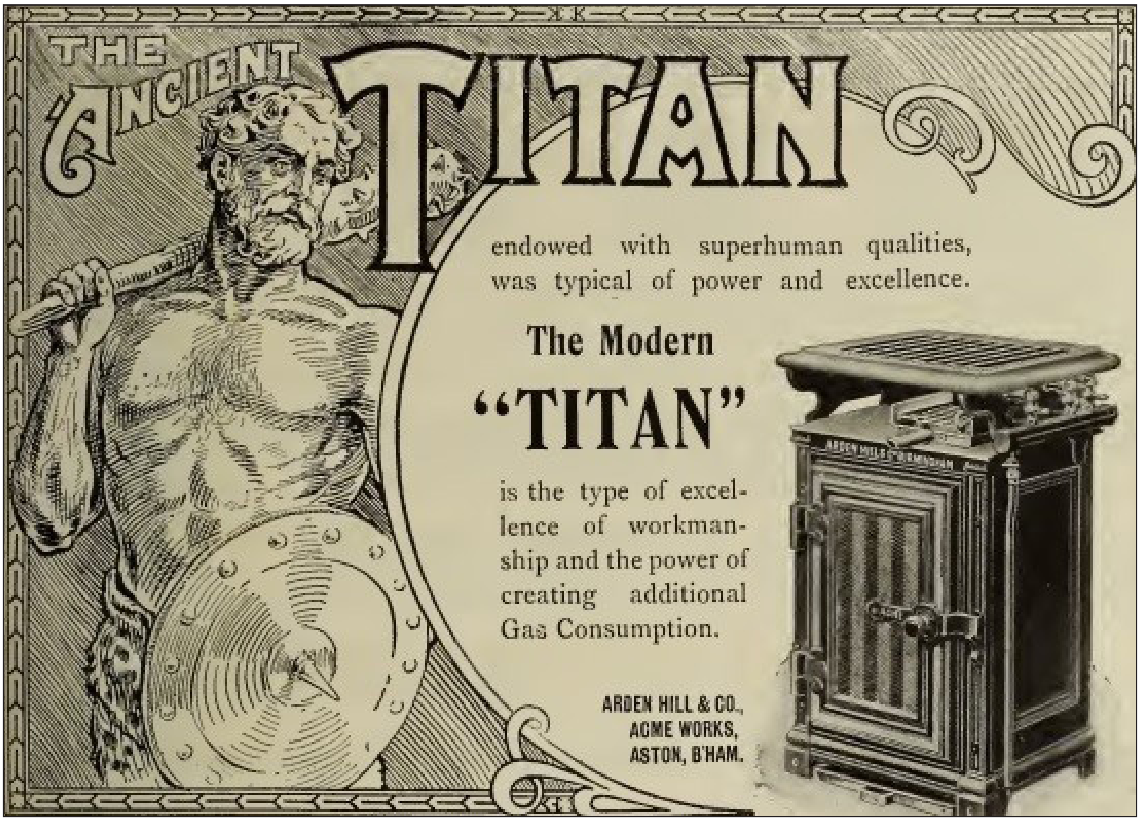

Figure 2.33. Advert circa 1898 for gas fires by John Wright and Co from the Gas Engineer's Textbook and Gas Companies Register 1898.

2.5.9 Perkin and Coal Tar Dyes

A major development which occurred In 1856, was the discovery of the mauvine dye in coal tar. This discovery was made by William Perkin, who was an assistant to the German Chemist Dr August Wilhelm von Hofmann at The Royal College of Chemistry. Dr Hofmann had worked on aniline, which had first been discovered by Unverdorben in 1826, whilst distilling indigo (Gardner 1915).

Aniline was able to form different colours by reacting with other substances and scientist such as Runge, Fritsche and Zinin had discovered it seperately. Dr Hofmann was able to prove all these different substances were aniline. The Mauvine dye had been prepared in small quantities previously, but only for scientific research purposes (Garner 1915). Whilst Von Hofmann was abroad, Perkin constructed a laboratory within his flat with the aim of synthesising the naturally occurring alkaloid quinine, in the hope of impressing Von Hofmann when he returned.

Quinine was important in the fight against malaria, as it could reduce the fever, but was both expensive and in short supply because it could only be extracted from the bark of *Cinchona* family of trees. Perkin had hypothesised that quinine was similar in structure to chemicals which might be found in coal tar (Findlay, 1917). Perkin had reacted aniline with sulphuric acid and potassium dichromate which produced a dark coloured resinous mass, from which he was able to separate out a purple dye (Gardner 1915).

Whilst Perkin failed in extracting quinine he instead discovered the first synthetic dye known as 'Aniline Purple', 'Tyrian Purple' or 'Mauvine', he found that Mauvine was colour fast and remained in the cloth despite washing. As the name suggests Mauvine was a purple dye, which by coincidence was one of the most fashionable colours at the time. Perkin patented the dye and as a result founded the aniline dye industry (Findley 1917, Gardner 1915). A simple early apparatus for manufacturing aniline dyes is shown in Figure 2.34.

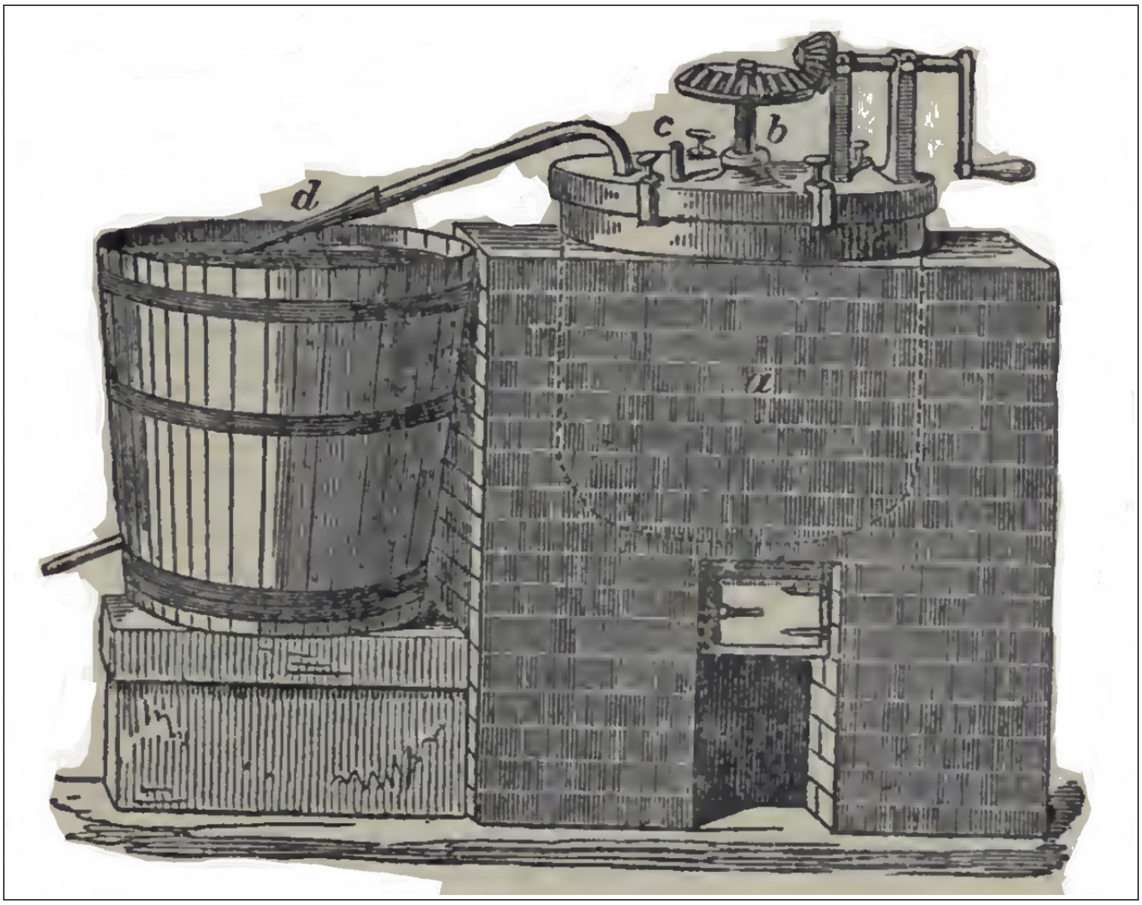

Figure 2.34. An early apparatus for the production of aniline dyes, from the 'British Coal Tar Industry' by William Gardner.

The discovery that Mauvine could be manufactured from coal tar by Perkin demonstrated 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. The industry flourished in Britain between 1856 and 1870, but then started to decline and the coal tar being produced was being exported to Germany. This allowed Germany to build up a highly profitable chemical industry which expanded from dyes to other fine chemicals. By the start of the First World War, it had become apparent that Britain had become entirely dependent on Germany for its supply of dyes and other coal tar fine chemicals. This led to a sudden investment in the sector and the establishment of British Dyes Ltd. (Findley 1917, Gardner 1915).

In 1855, Robert Wilhelm von Bunsen, a famous German chemist working in Heidelberg, invented the atmospheric gas burner known to many as the 'Bunsen burner' (Figure 2.35). This revolutionary design premixed the air and gas prior to entering the burner, this allowed the flame to burn with an intense heat never previously achieved. It made more efficient use of the gas burnt and allowed a greater range of uses, especially in industrial and domestic heating applications (Chantler 1938). This development ultimately saved the gas industry, as heating applications became ever more important as the industry evolved.

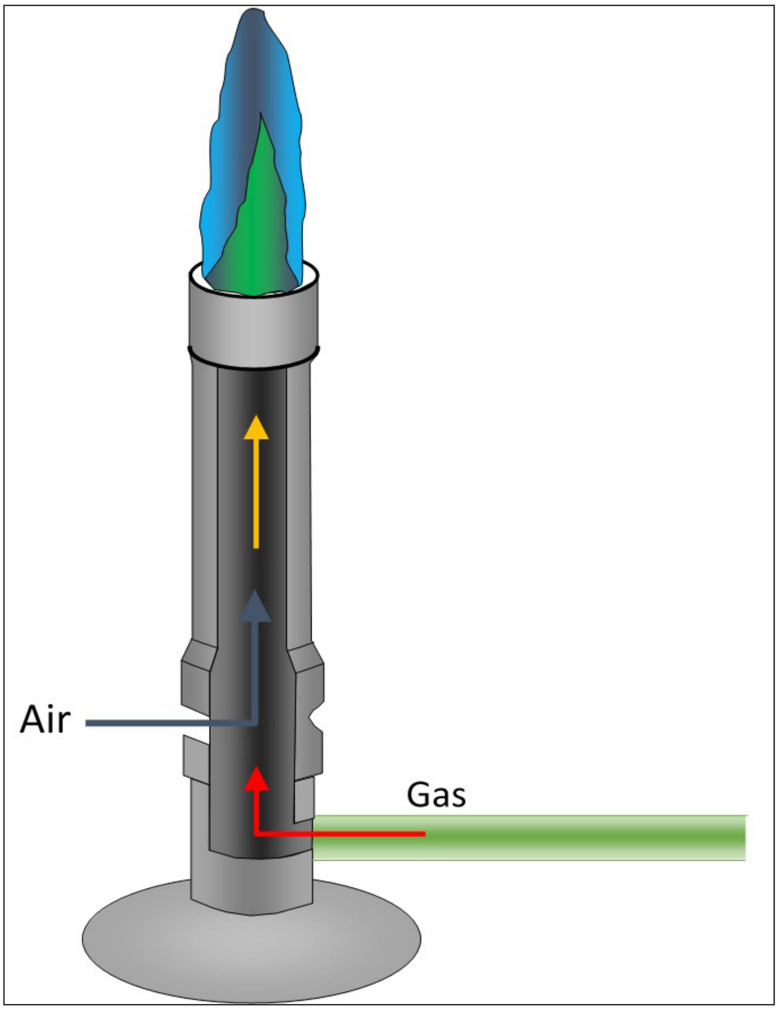

Figure 2.35 A schematic of a Bunsen burner. Source R.Thomas

2.6 Exporting Gas Engineering Technology

Following the development of the gas industry in England, interest grew in gas lighting, firstly in the rest of the United Kingdom (which at this time included the whole of the British Isles), and then across Europe and the rest of the world. This had been driven in part by published accounts of gas lighting and through word of mouth by visitors to London and diplomatic staff. The potential for exporting this industry was soon realised by British industrialists and gas engineers alike.

2.6.1 The Imperial Continental Gas Association

In order to export Britain's new technology and skills in the manufacture of gas, the Imperial Continental Gas Association (ICGA) was established in 1824 (emblem shown in Figure 2.36). The ICGA was chaired initially by Major-General Sir William Congreve.

Figure 2.36. The emblem of the Imperial Continental Gas Company. Source

By 1824 gas was already starting to be manufactured in some European towns. Largely promoted on the back of the success in Britain, the adoption of coal gas manufacture on the continent was both aided, and hindered, by continental engineers who had continued to adopt the Thermolampe. The hindrance was most significant in areas such as Scandinavia, where wood was plentiful.

The first public gasworks in continental Europe was established by an association of people led by Jean Baptiste Meefis who established the "Société de L'éclairage par le Gaz", which was located, in the Saint-Roch district close to the River Senne in Brussels. A commemorative plaque (Figure 2.37) can be found on the St. Rochusstreet in Brussels (Mac Lean 1977).

Figure 2.37 The Plaque in Brussels commemorating the first public gasworks on the continent. Source Pieter De Raedt

In 1825, Congreve toured Europe by stagecoach with the aim of establishing business ventures. The ICGA's first venture was a small oil gasworks in Ghent, purchased from a local company, Roelandt and Co. who were then employed as agents for the ICGA; these gasworks was soon after converted to make coal gas (Anon. 1974).

From this small gasworks in Ghent, a huge business developed, who operated gasworks in the Netherlands, Belgium, Germany, Austro-Hungary and France. The IGCA provided the first public gas lighting in Germany (1825) and Austria (1845) during their history they lit over 16 towns in France and came to control a significant portion of the industry in Belgium. The Forest gasworks in Brussels in 1910 is shown in Figure 2.38 (Anon. 1974).

The contracts to provide gas lighting were generally concessions where the ICGA would build and operate a gasworks for a set period of time, after which the concession would be re-tendered. The nature of these contracts, political changes and war in Europe meant the business model was risky. Their portfolio of contracts could change considerably from decade to decade. Sometimes contracts were cut short and the ICGA had to hope for some form of compensation, but others were extended many times and they often were in a position to turn contracts away (Anon 1974). Despite their challenging business model, the IGCA continued to operate until 1987.

The ICGA was not unique and other British companies were established to target Europe, including the European Gas Company which was established in 1835 and the Danish Gas Company established in 1853.

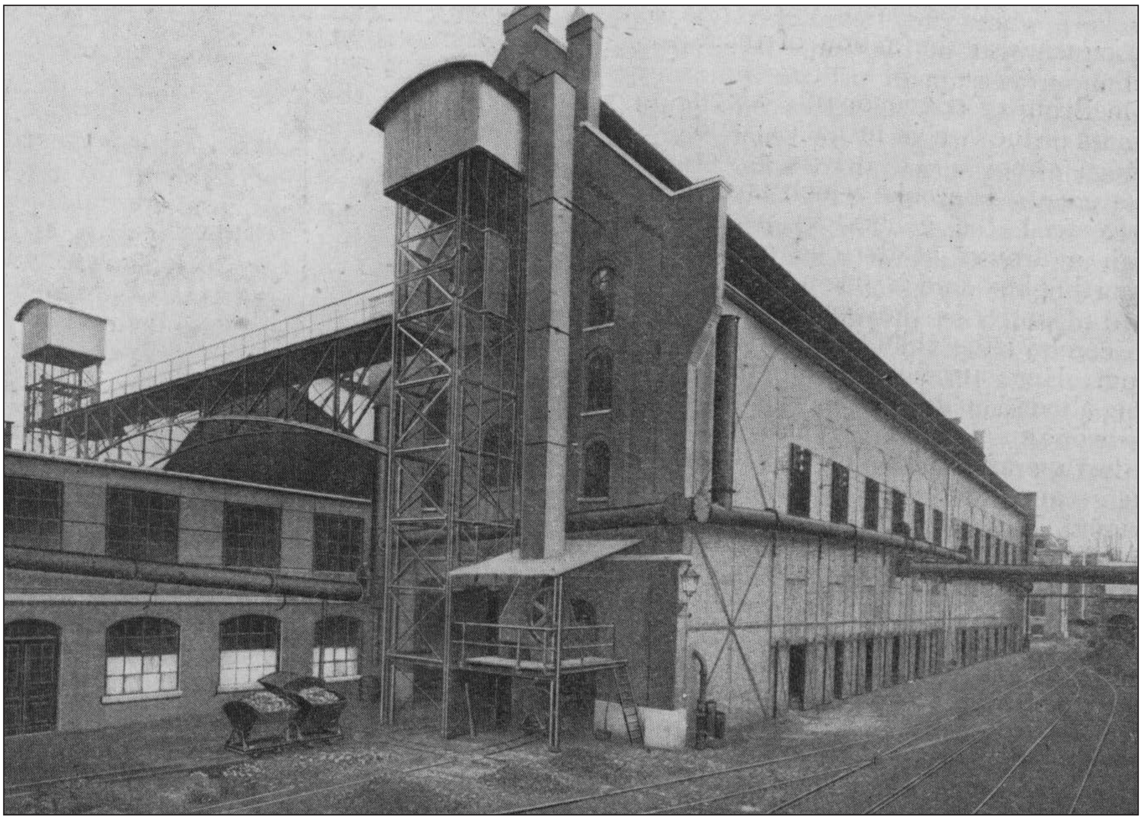

Figure 2.38. A view of the Vertical retort house built at the Forest Gasworks of the ICGA in Brussels, Belgium, 1910. Source IGEM Archive.

2.6.2 Manby and the Emigrant Gas Engineers

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 (Richards 1877). It faced competition from the local French gas undertaking established by Louis Antoine Pauwells, known as the 'Compagnie Francaise' (Richards 1877). These companies operated for many years, with the gradual establishment of other rival companies, until it was decided that the competition between the companies had a negative impact and the companies were then assigned districts of supply, an approach later adopted in London. In 1855, however, it was decided to unite all the gas companies under a large monopoly company called 'Compagnie Parisienne de l'Eclairage par le Gaz' with rights to supply the city for 50 years (Richards 1877).

Manby was also involved in the establishment of the first gas company in Madrid. William Richards, a British gas engineer was responsible for the construction of many of the first gasworks in Catalonia (Moyano and Thomas 2016). The first Gasworks built in Norway were built in Oslo (then known as Christiania) by the British gas engineers James Malam and James Small (Irminger 1949). The gas plant manufacturers W.C.Holmes of Huddersfield and George Bower of St. Neot's, exported entire gasworks in a kit form abroad to erect in countries ranging from Russia to Argentina (Holmes 1950, Bower 1865). French and German gasworks manufacturing companies also entered the market and exported their expertise and technology.

The ICGA and its British rivals soon faced competition from companies from Belgium (e.g. La Compagnie Générale Pour l'éclairage et le Chauffage par le Gaz – Gaz Belge), France (e.g. Compagnie générale du gaz pour la France et l'étranger) and Germany (e.g. Deutsche Continental Gas Gesellschaft) who also bid to provide gas lighting contracts abroad. This subject is described in more detail in Thomas, 2018.

Countries within the British Empire were also targeted with the establishment of British owned overseas gas companies such as the Colonial Gas Company and the Bombay Gas Company (Figure 2.39, Graham 1908). These companies had their headquarters in London, whilst their operations would be across the globe (Thomas 2018).

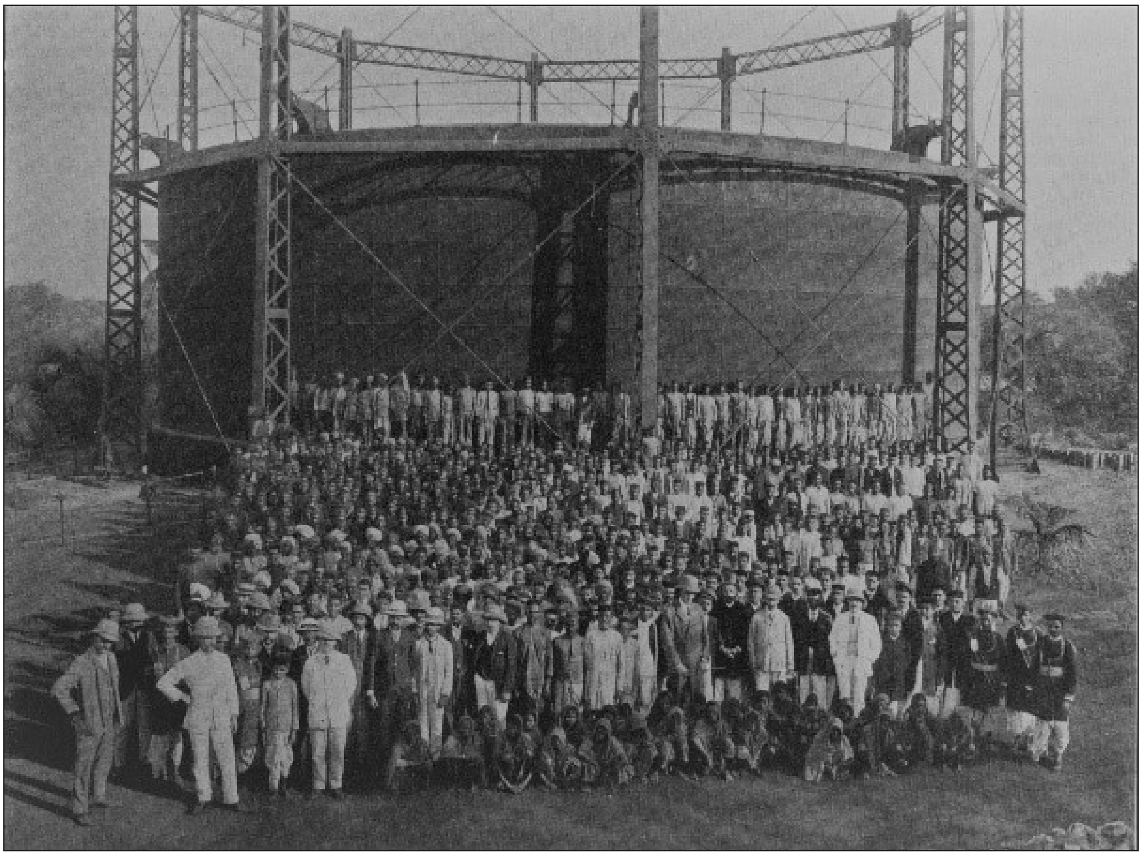

Figure 2.39 A Photograph of the entire staff of the Bombay Gas Company stood in front of one of their Gasholders in 1907. Source Graham 1908

British gas engineers also emigrated across the British Empire to establish new gas ventures or to work for new gas emerging companies. Canada, Australia and New Zealand being popular destinations (Thomas 2018).

2.7 Innovation and Regulation 1860-1890

The districting arrangement which had been legislated through the Metropolis Act of 1860, had tied the gas companies to specified districts. During these negotiations GLCC was short-sighted, taking the central London areas where they had very good existing customers, but where there was limited opportunity for future growth. Many of their rivals had chosen to supply the larger and growing suburban districts, which had much greater future growth prospects.

With districting in place, the civic authorities in London had pressed the gas companies to relocate their gasworks out of the metropolis or risk the creation of new rival companies. This led to the formation of alliances and agreements between gas companies, but no new gasworks. The GLCC decided to go it alone. Fortunately, the GLCC was led by an able team of Simon Adams Beck, who was appointed Governor in 1860, together with the able administrator John Orwell Phillips, and Frederick John Evans as engineer (Sturt 2019).

Beck was a member of the Ironmongers Company, who owned a 150 acres site of the East Ham Levels, which had a 1500ft river frontage. They were willing to sell the site to the GLCC for £50,000. The GLCC then obtained an Act of Parliament to authorise the purchase of the land (Sturt 2019).

2.7.1 Beckton Gasworks

On the 19th of November 1868 the Governor of the GLCC, Simon Beck drove the first pile into the embankment ground at a desolate marsh in North Woolwich. This site was to become Beckton gasworks, named after the Governor. The gasworks were designed by Frederick John Evans and the general contractors were John Aird and Son (Sturt 2019). The gasworks went on to become the largest in the world (Figures 2.40 & 2.41). They were unusual that they were built so far from the area which they supplied, but this allowed the older and less efficient gasworks of the GLCC to cease production and just operate as gasholder stations. The construction of the Beckton gasworks and the financial position of the GLCC, triggered the expansion of the GLCC. Following Acts of Parliament the GLCC purchased the Great Central, Equitable, City of London, Western, Imperial, and Independent gas companies which in 1875 had a united capital of £8,826,500 and a gross revenue of £2,213,331 (Richards 1877, Everard 1949).

Beckton gasworks grew to occupy an area of 350 acres. In 1922 employed 4000 workers producing up to 95 million cubic feet of gas per day. The gasworks which can be seen in Figure 2.40, manufactured gas using horizontal retorts, which were best suited to the seaborne coal it obtained by collier from the mines of Durham and Northumberland (Everard 1949).

There were 14 large horizontal retort houses which were supplied by coal using a high-level railway from two huge piers constructed within the adjacent River Thames where the colliers would dock. In the 1870s 10,000 tons of coal a day was being delivered to the Beckton works. Each retort house contained about 440 retorts which would carbonise 620 tons of coal a day (Everard 1949). Supplying such a large amount of gas from the gasworks outside the city to the customers within the city was a new problem, it required the construction of a huge 48 inch gas main (Everard, 1949). The main was built from 9ft sections of pipe, each weighing between two to three tons and the whole pipeline weighing 15,000 tons (Stuart 2019).

Figure 2.40. Painting of the Beckton gasworks attributed to G. Moira. Source IGEM Archive.

The gas main ran from Beckton to the gas works at Goswell Rd, with a smaller 36 inch diameter main running from Goswell Rd to the former gasworks of the London Gas Company works at Blackfriars. The gas main was first used on the 6th of December 1870, and on that evening the city of London was lit with gas from the Beckton gasworks. Due to increased demand a second 48 inch main was installed the following year (Sturt 2019).

The improved efficiency of Beckton gasworks allowed the GLCC to take over its rivals, through doing this it inherited additional gasworks, some which it closed and some of the larger more efficient ones it continued to operate and expand, integrating them with the Beckton gas mains system to help meet ever increasing demand (Everard 1949, Sturt 2019)

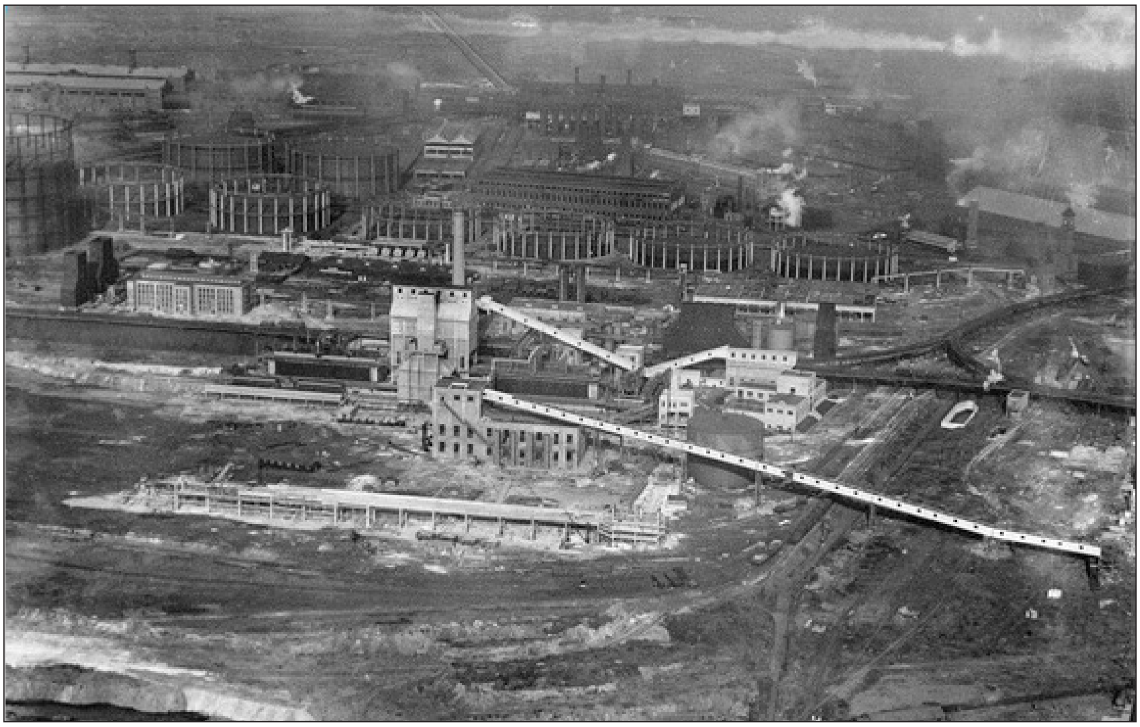

Figure 2.41. Beckton Gasworks during the 1930's. Source Britain from Above – Historic England EPW037098

2.7.2 Improvements in the Heating of Retorts

A significant development occurred in 1856, when Frederick Siemens developed a new type of furnace which he named the 'regenerative furnace'. This furnace was designed for heating puddling furnaces and 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 (Stevenson 1880, Meade 1921).

Other notable regenerators such as that developed by Herr Leigel at Straslund, 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 (Stevenson 1880, Meade 1921).

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 in more detail in Volume 2).

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.

Figure 2.42 A sketch of the Horizontal retort house of the South Metropolitan Gas Company at Old Kent Road. Source National Grid Gas Archive.

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 possible. These improvements along with greater mechanisation, as shown in Figure 2.42 allowed the gas industry to become more efficient.

2.7.3 The Gas Engine

Gas started to be used for providing power. Philippe Lebon had first promoted the use of gas for motive power when he developed his Thermolampe. After Lebon, others tried to develop an effective gas engine, but it was not until another French engineer Étienne Lenoir developed his gas engine in 1860, that it became a commercial reality. Whilst Lenoir's engine gained some users, it was soon replaced by the development of the superior Otto gas engine in 1867. Between 1880 and 1900 gas engines gained popularity, especially in situations where steam power was inconvenient or uneconomical. 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. Towards the end of the 19^{th} Century the gas engine started to lose popularity with the development of Petrol and Diesel internal combustion engines. (Chantler 1938, Robson 1908).

Gas producers remained popular in industry, producing a low-quality gas unsuitable for lighting but able to power gas engines and heating furnaces (Robson 1908).

The only producer-based gas production process to manufacture gas for distribution through mains was the Mond Gas process. This was developed by the Belgian Scientist Ludwig Mond in 1889, its primary role being the production of sulphate of ammonia. It did however, produce a poor-quality gas. Mond gas was rich in hydrogen and carbon dioxide, it was of little use for lighting, although it could be used for industrial purposes such as heating. The South Staffordshire Mond Gas Company was established in 1901, it built a Mond gas plant in Tipton with its own separate gas distribution network. This supplied 160 local industrial companies with gas. (Wood 1903). The Mond gas process is described in more detail in the second volume of this report on Gasworks.

2.7.4 A Professional Body for the Gas Industry

In 1863, Dr Thomas Newbigging founded the British Association of Gas Managers in Manchester. It had been predated by the Waverley Association of Gas Managers, which had formed in Scotland a year earlier (Anon. 1992). The British Association of Gas Managers became the Gas Institute in 1881, which in turn became the Incorporated Institute of Gas Engineers (1902-1928), then Chartered Institute of Gas Engineers (1929-2001) and more recently the Institute of Gas Engineers and Managers (2001-present), which celebrated its 150^{th} Anniversary in 2013. There was a period between 1890 and 1903 when two rival bodies represented the gas profession, these were the old Incorporated Gas Institute and the New Incorporated Institution of Gas Engineers, they amalgamated in 1902 into the Incorporated Institution of Gas Engineers (Braunholtz 1963, Lloyd 2015).

In 1869 Robert Morton introduced Fireclay retort with self-sealing lids. In the same year Magnus Ohren of the Crystal Palace District Gas Company stimulated the use of gas for heating by offering appliances for hire to it's customers (Stewart 1960).

The aerated gas burner was first used in the gas cooker in 1867. B.W.Maughan invented the Geyser for heating water in 1868. (Norman 1922).

In the 1870s there was a trend for the local authorities to purchase their local gas undertaking. Some of these attempts were successful and others were rejected. Municipal ownership became common in particular in the Midlands and North of England. In Birmingham the Town Council promoted a bill at parliament for the purchase of the two private gas companies, which occurred in August 1875. The then mayor and future MP, Joseph Chamberlain, was heavily involved in the purchase and development of the Birmingham Corporation Gas Department, which became the largest provincial gas undertaking. The profits of which financed many of the city's improvements (Anon. 1928).

2.7.5 Improvements in Gas Appliances

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. An example of one of their gas fires is shown in Figure 2.43 (Hasluck 1900 p142-156). Fletcher Developed his improved geyser the instantaneous water heater in 1890 (Stewart 1958 p46).

Appliances were developed by many other gas engineers, including John Wright who started to promote his convector type gas stoves for space heating in 1880. Both Wrights and Fletchers cooker were exported to the USA. In 1890 John Wright introduced Wright's Patent Incandescent Gas Heating Stoves and John Fletcher introduced gas-fired furnaces (Norman 1922, Hasluck 1900 p142-156).

One major issue with making gas from coal was the long time taken to get the gas plant operational and producing gas. This led to a heavy reliance on storage in gas holders. 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.

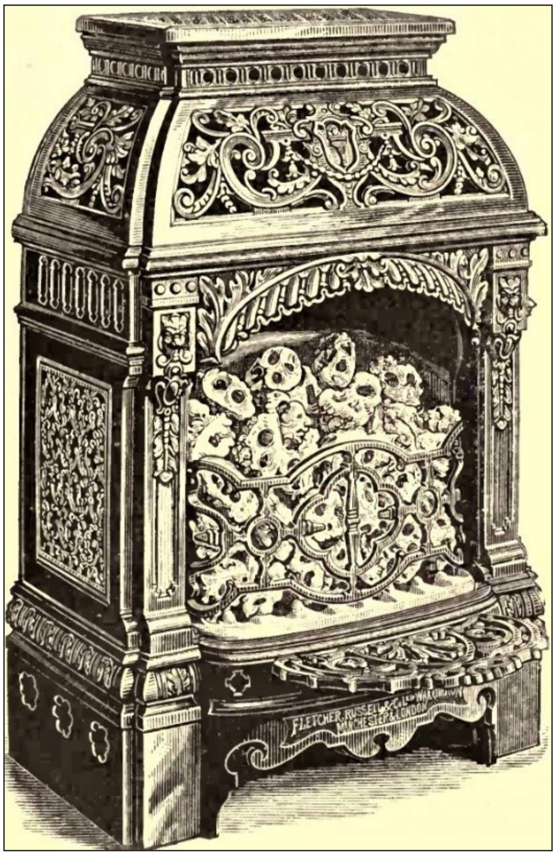

Figure 2.43 Fletcher, Russell & Co.'s Senegal gas fire which produced both radiant and convected heat. Source IGEM Archive.

A solution to rapidly increasing gas production for times of peak demand was found in the form of "Water Gas". Methods to produce water gas had been discovered earlier than coal gas by Felice Fontana. Water Gas was composed primarily of carbon monoxide and hydrogen, but it had limited use for lighting as it burnt with a dim blue flame. Several gas engineers such as Stephen White had devised systems to enrich the gas with vapours of flammable substances such as benzene. It was not until 1873 that the American Scientist and Engineer Thaddeus Lowe devised a commercially viable system for producing enriched water gas, know as "Carburetted Water Gas" (CWG). Lowe devised an intermittent system which produced gas on a cyclical basis, first heating the coke filled generator until it was incandescent and then injecting steam to produce the gas compromised of hydrogen and carbon monoxide and carbon dioxide. This lean gas produced was then enriched by the injection of oil, which was then fixed in the gas in the Carburettor and Superheater, giving rise to the name Carburetted Water Gas (CWG) (Norman 1922, Meade 1916).

The first major installation of a CWG plant in England was in 1890 at the Beckton gasworks (Meade 1916). A slightly later plant is shown in Figure 2.44. This subject of Water Gas and Carburetted Water Gas is covered in more detail in greater detail in Volume 2 "Gasworks".

Sugg's London Argand burner was adopted as the Parliamentary standard for measuring the luminosity of gas through the city of London Gas Act of 1868. It was produced by William Sugg and Company, whose Vincent Works were located in Westminster. The Sugg family has long been associated with the gas industry.

Figure 2.44 The upper floor of the CWG house at East Greenwich c. 1920 Source National Grid Archive

Thomas Sugg made and fitted the original gas pipes for Frederick Winsor in his demonstration of gas lighting on Pall Mall, London, in 1807. Numerous Sugg gas lamps are still operational today and can be found across London and the Sugg brand is still manufacturing gas lighting equipment today (Anon. 1907a p595-597).

Marie Jenny Sugg, the French wife of the gas engineer William Sugg, published 'Art of Cooking by Gas' in 1890 which was the first gas based Cookery book (Sugg 1890).

2.7.6 Prepayment Meters

Prepayment gas meters were invented in 1870 by T. S. Lacey. This was a major development, making gas available to the working classes who previously could not have afforded gas appliances or installation costs. When gas meters started to be widely introduced around the middle of the 19th century, the system adopted was that the customer would pay in arrears, after the meter had been read. This meant that gas undertaking was providing credit. They therefore were careful about credit worthiness of their customers which limited access to the middle classes. The prepayment meter allowed customers to pay in advance for the gas they used making it available to most of society. (Hole 1907, Goodall 1999).

George Livesey referred to the prepayment meter as "This extension of gas supply to weekly tenants is the most extraordinary and remarkable development of the business that has ever been known" (Hole 1907, Goodall 1999).

Gas became 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 (Hole 1907, Goodall 1999).

The Gasworks Clauses Act of 1871, was an amendment to the 1847 Gasworks Clauses Act, and the two acts were expected to be read as one. Whilst the 1847 act could be incorporated into companies through special acts, the 1871, was compulsory for all gas undertakings. It embodied 'obligation to supply' condition to any potential consumer within 25 yards of the gas main and at a suitable gas pressure. Gas undertakings became obliged to undertake formal gas testing by an independent examiner appointed by the local authority and ensure the gas was of sufficient purity. They were also required to publish formal financial accounts. (Anon. 1871, Clifford 1885). By 1885 more than one thousand Gas Bills had been read in the Houses of Parliament (Clifford 1885)

The French engineers Pelouze and Audouin introduced their tar extractor (Figure 2.45) for the removal of tar, in 1873. This device became the most generally used on gasworks. The device consisted of an outer cylindrical casing with the gas inlet entering through the centre of the base. A bell suspended from an overhead pulley or shaft passed over the inlet pipe and had its base sealed in liquor. The weight of the bell was counterbalanced by loading the wheels on the shaft. The floating bell was constructed from cast-iron and was filled with bundles of perforated and slotted plates spaced a short distance from one another. These plates were designed to baffle and break up the gas such that any residual tar after the condensers was removed (Meade 1921).

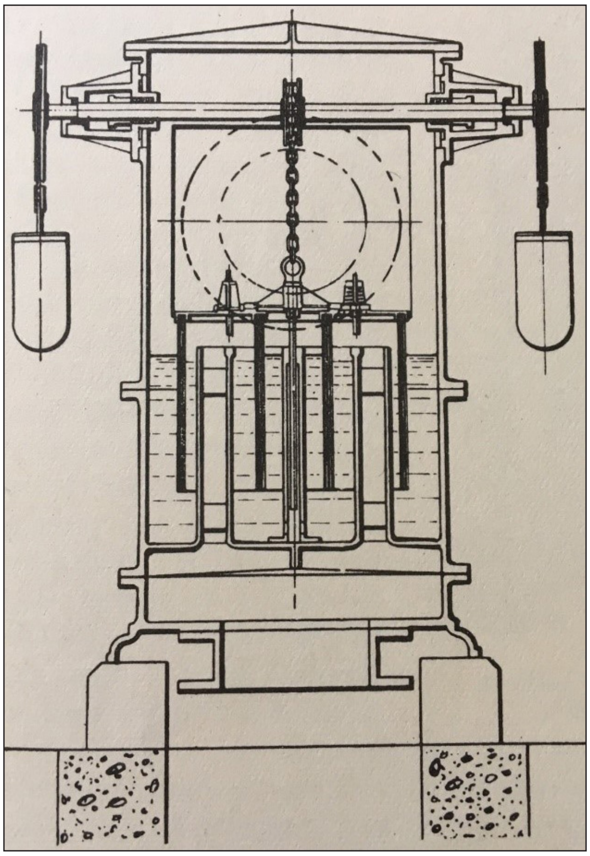

Figure 2.45 The Pelouze and Audain Tar Extractor. Source Meade 1921.

In 1874 the (Royal) Society of Arts introduced examinations in gas manufacture. Four years later the City and Guilds of London Institute for the Advancement of Technical Education was founded. This organisation took over the Society of Arts work on technical subjects. In 1907 separate syllabuses were agreed for gas supply and gas manufacture. In 1923 following a special meeting of the Institution of Gas Engineers, they devised their own scheme of education (Nabb 1986).

2.7.7 Further Developments

In 1875 through the Commercial Gas Act, the Commercial Gas Company adopted a sliding scale charging, which became general practice by the end of the century. This system allowed for a higher dividend to the company if the gas price was reduced (Scholefield 1911, pp7-12).

Gas lighting for railway carriages was first introduced in 1876 by the Metropolitan Railway Company. They used compressed oil gas held in high pressure cylinders to light railway carriages. It had been first been used on the railways in Germany, where Julius Pintsch had modified the oil gas process. The basic process had been adapted from that originally developed for oil gas by Taylor and Martineau. Utilising high pressure gas cylinders in a similar way to that of the London and Provincial Portable Gas companies (Stewart 1958).

Otto and Langen began manufacture of four-stroke gas engines in Germany in 1878. These were later built in Britain under licence by Crossley Brothers of Manchester (Day and McNeil 2002).

In 1882 Board of Trade (BOT) required statutory gas undertakings to make systematic business returns on all key aspects of the business. Private gasworks were not required to make these returns although sometimes they did. These BOT returns are useful for tracking the performance of the different gas undertakings and can be found recorded in the Gas Journal.

The first Electric Lighting Acts were passed in the houses of Parliament in 1882 (Stewart 1958). To combat the growing competition from electricity, the gas industry, through the Gas Institute was persuaded, to provide a display of gas lighting and appliances at the 1882-3 International Electric and Gas Exhibition at Crystal Palace. The exhibition demonstrated a variety of uses for gas in the home to a national audience, it also created a schism in the gas industry. The organising subcommittee of George Livesey, Magnus Ohren and Charles Gandon were accused of showing unfair favouritism to the London based William Sugg (a pre-eminent manufacturer of gas lamps), by George Bray of Leeds (a rival manufacturer of gas lamps). Both manufacturers were successful, with Bray targeting the wholesale market for efficient low-cost gas burners and street lamps for local authorities and Sugg targeting the prestigious London streets and the upper end of the London domestic market. The subcommittee, were all London based and Livesey was a personal friend of Sugg, so given that they decided the location of the exhibition stands and adjudicated the awards, Bray felt hard done by when Sugg received a better stand and fared better in the awards (Hide 2010).

With the growth of the gas industry a rival publication to the *Journal of Gas Lighting* was established, *Gas World* which commenced publication in 1884, was published by Benn Brother.

2.7.8 The Spiral and Rope Guided Gasholders

The spiral guided gasholder was a concept which was developed in Britain, first being proposed by Mr W. Webber. Its successful invention is credited to Mr William Gadd of Manchester, with the first successful prototype introduced into Britain in 1888 (Southwell Cripps 1889, Meade 1921, Stewart 1958). The first spiral-guided gasholder built for a gas company was erected in Northwich, Cheshire in 1890, by Clayton, Son and Co. Ltd. of Leeds. The spiral-guided gasholder dispensed with the requirement for an external frame to support the lifts. The support was instead achieved by increasing the rigidity of the lift with internal bracing called vertical stays and the use of spiral guide rails. Each lift had spiral rails, usually on an angle of 45°, and usually attached to the outside of each lift. As the lifts would rise and fall, they would rotate in a corkscrew like fashion (Southwell Cripps 1889, Hunt 1900, Meade 1921, Stewart 1958).

A rival design to the spiral guided gasholder was developed by Edward Lloyd Pease. This design also removed the requirement for framing using a complex arrangement of ropes. The number and complexity of ropes depended on the size of the gasholder. The wire rope system had been retrofitted to column guided gasholders in areas of ground instability, usually due to mining. These gasholders had failed due to the columns moving and the guide wheels failing to run in the misaligned rails. This design was initially popular but after a number of well publicised failures, the spiral guided system became the preferred design for almost all future gasholders (Hunt 1900, Stevenson 1901, Stewart 1958).

The arrangement of ropes was considerably varied in the patent description. It could consist of upper check-ropes secured at their upper ends to the top curb of the gas-holder and lower check-ropes which were secured to the lower part of the lift or of one of the lifts. The ropes could also be used to support a flying lift on a column or frame guided gasholders (Hunt 1900, Stevenson 1901).

2.7.9 The Incandescent Mantle and Competition from Electricity

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 (Chandler 1949, Stewart 1958).

It should be noted that, in 1826, Drummond had used incandescence in the commercial application of lime-light through the oxy-hydrogen heating of calcium oxide (Norman 1922). Platinum baskets had been tried by George Cruikshank in 1839 (Stewart 1960). Slightly later in 1848/49, platinum mantles had also been used to light the town of Narbonne, France (Norman 1922). Hogg again experimented with platinum mantle burners combined with aerated flame burners in 1864 (Stewart 1960). None of these developments had anything like the impact of Welsbach's gas mantle once it had been perfected (Figure 2.46).

Humphrey Davy demonstrated the first electric arc lamp in 1806, but it was impractical and went no further. Attempts at electric street lighting in London started in the 1870's.

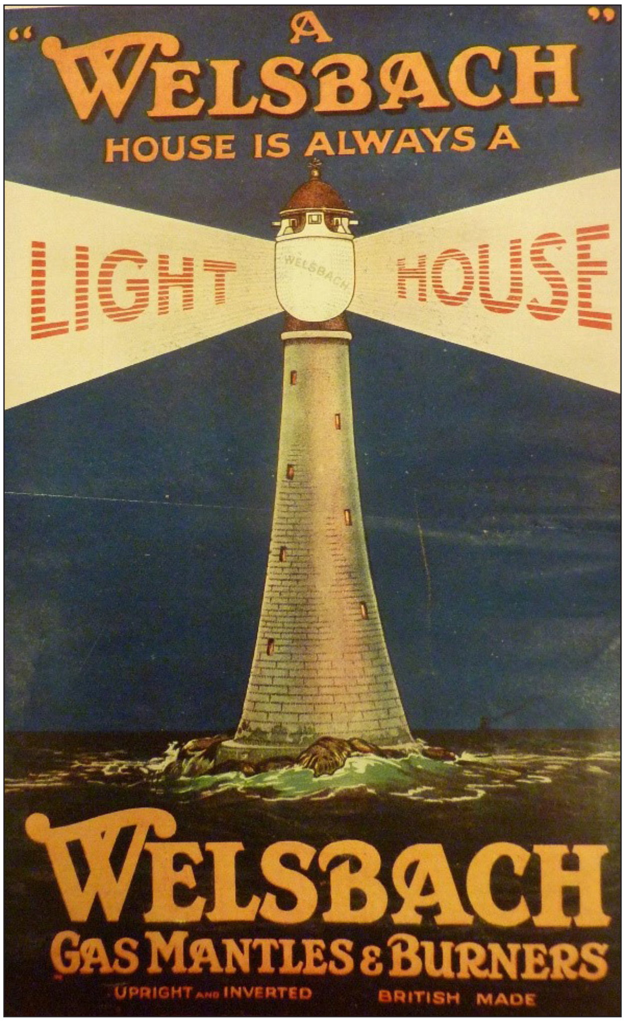

Figure 2.46 An advert for the Welsbach gas mantle 1909. Source National Grid Gas Archive.

The first serious attempts of electric lighting in London, was the lighting of Holborn Viaduct in November 1878 by sixteen Jablochkoff lamps. These 16 lamps displaced eighty-six gas lamps, which demonstrated the brighter light the electric lamps could produce. The demonstration however, was not a financial success and proved this form of electric lighting to not be reliable. A lamplighter had to be retained each night to turn on the gas lamps when the electric lights failed. After the three months trial, it was found that the sixteen lamps cost £10 per night to run compared against £1 7s. I ½ d. for gas. Billingsgate market became one of the first public buildings to be lit by electricity in 1880 (Liberty 1913).

In 1880 the City of London Commissioners again decided to experiment with electric lighting at Ludgate Hill, Cheapside, and King William Street. The companies who provided electric lighting being 'The Brush Company', 'The Electric Light & Power Generator Co." and "Messrs. Siemens", the contracts were to run for one year ending in April 1882. Of the competing companies the lighting provided by the Brush Company proved to be the most commercially successful (Liberty 1913).

The more robust light bulb for everyday use was developed by Joseph Swan (England) in 1878 and Thomas Edison (USA) in 1879. They later collaborated to form the Edison Swan Electric Company Limited otherwise known as Ediswan. Ediswan made a demonstration on Holborn Viaduct with ninety-two glow lamps, which were used instead of 86 batswing burners (Liberty 1913).

In 1892 the first significant installation of 409 open type arc lamps were installed in the City of London's main streets, replacing 1,126 gas lamps (Liberty 1913).

In 1894 the Welsbach gas mantles first started to be used in street lights. Welsbach's invention was timely, enabling the industry to complete with its new rival, the electric light bulb. (Norman 1922).

Electricity did not become a practical reality for the domestic home 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 (Stewart 1958 p44-46). Gas lighting has not completely disappeared in the UK: there are still approximately 2,000 public gas lights in the greater London area.

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 (Stewart 1958).

In 1897 a gas fired water heater using a single copper coil was produced for domestic use (Norman 1922).

2.7.10 Working Condition, Unions and Co-Partnership

The gas industry was a big employer especially in the large towns and cities. It had an important role in the development of the trades union movement in Britain. Various jobs associated with the manufacture of gas, such as stoking, had always been a very arduous and dangerous, although there were many other support roles, for example meter reading, which were much safer. Long and exhausting 12-hour shifts were generally used in gas manufacturing roles during the Victorian era, these could even be as long as 18hrs on the weekend change overs. Some companies such as the Bristol United Gas Company were early adopters of the 8hr shift (Nabb 1986).

The famous author and social commentator Charles Dickens writing in his essay "Genii of the Lamp" described the conditions in the retort houses as:

> The manufacture of gas, although it includes many beautiful scientific processes, is not, on the whole, a sightly operation. What is not seen may be refined and interesting; but what is seen decidedly savours of pandemonium.
>
> There are huge caverns of red hot coke, and a row of fiery ovens, which sooty men are constantly feeding with coal thrust in, out of large iron scoops (Dickens 1862).

Like many other similar forms of employment of the time, there was little job security. Sick pay did not generally exist for those who had become ill or injured, although there were cases such as at Exeter where sick pay was given to Employees as early as 1821. Gasworkers were relatively well paid compared to those who would work in other jobs such as at the docks (Nabb 1986, Chandler 1949).

Employment was however, seasonal, as fewer staff were required to make gas during the lighter and warmer months of the year when gas demand was lower. Such seasonal work and long hours meant that relations with workers were often strained. The relative low cost of labour had stifled technical development in mechanising many of the more arduous tasks in the gasworks (Hobsbawm 1864, Mathews 1987)

To maintain staff loyalties and in part to try to avoid unionisation, the gas industry was forward thinking in the adoption of sports and social clubs and company outings. The most progressive of the gas companies the South Metropolitan Gas Company (SMGC), who provided gas South of the River Thames. It was led by its mercurial Chairman George Livesey, who had introduced paid holidays, sick pay and superannuation schemes in the 1870s. Livesey had also been a strong promoter of the co-partnership movement which allowed employees to benefit in the profits of the company. The board of the SMGC were not supportive of the co-partnership scheme in the 1870's, but as unrest stirred in the workforce and strikes occurred, the co-partnership scheme was adopted by the SMGC in 1889. George Livesey, viewed co-partnership as an alternative to unionisation and was insistent that his work force 'in the interests of the consumers' should not be union members. This stance was not taken by all other gas companies including the SMGC nearby rival the South Suburban Gas Company (Anon. 1907b)

It took its North London rival the GLCC until 1909 to adopt a similar co-partnership scheme, at which point it had 9000 employees enrolled in the scheme. This scheme allowed the companies regular workers to receive a bonus on their salaries as the price of gas fell, the bonus being invested in the company's ordinary shares as soon as sufficient credit was accumulated (Anon. 1912).

The gas industry became one of the largest promoters of co-partnerships schemes, which lasted until nationalisation in 1949.

Despite the efforts of some gas undertakings, the seasonal variations in labour led to flashpoints. In March 1889 many men were laid off from the Beckton gasworks, which led to a protest meeting on the 31st of March attended by gas workers from across the capital. One of the speakers at the meeting was William Turner Thorne (Figure 2.47), who moved to the Beckton area, from Birmingham in 1881 (Thorne 1925).

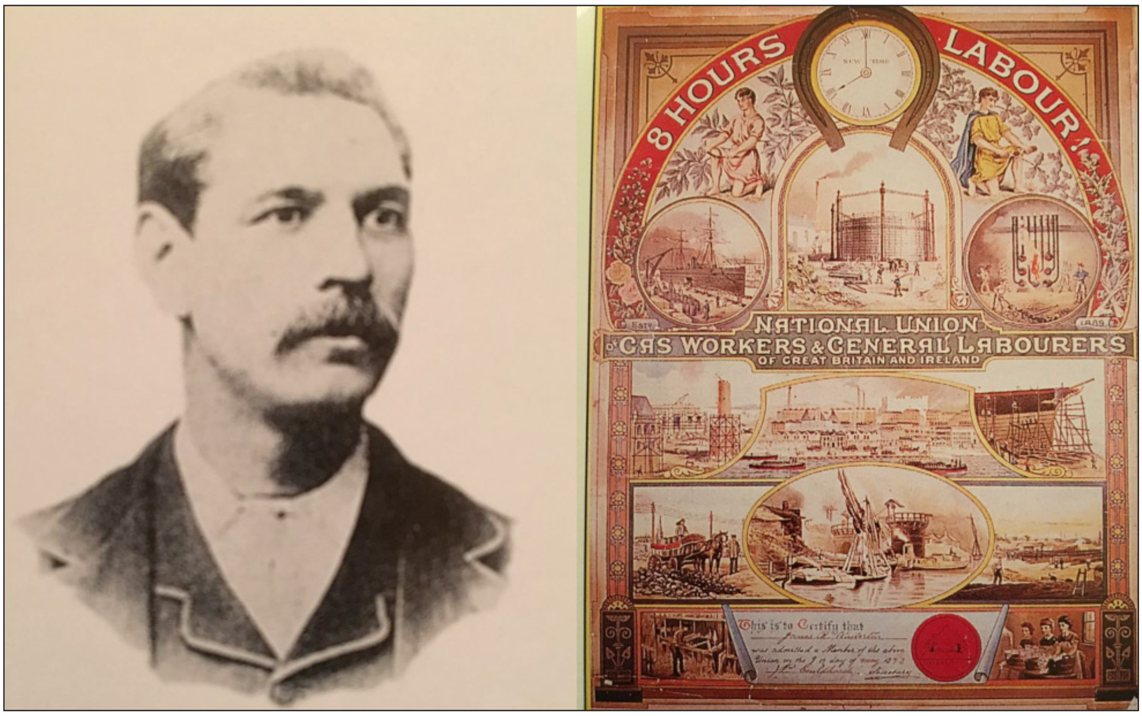

Figure 2.47. A photograph of William Thorne and a Certificate of Membership of the National Union of Gas Worker and General Labourers. Source IGEM Archive.

Thorne had been well versed with the hardship of working in a gasworks. Whilst in Birmingham he had worked winters at Saltley Gasworks of the Birmingham Corporation Gas Department and spent summers working at Brickworks. Whilst at Saltley he negotiated a modification to weekend working hours and tried without success to organise a union. He was sacked from the gasworks in 1881, soon after which he walked to London and found employment at the Old Kent Road Gasworks (Harthill 2003).

Thorne did not settle permanently in London until 1882 and he found employment as a stoker at the Beckton gasworks. He was Interested in politics and joined the

Social Democratic Federation in 1884, the first Socialist party in England (Thorne 1926). He met other leading trades union figures, including Eleanor Marx-Aveling, the daughter of Karl Marx, who taught him to read a write and also played an important role in his future political struggles (Harthill 2003, Thorne 1925).

In 1888, Thorne addressed a group of assembled men at Beckton:

> "I pledge my word that, if you will stand firm and don't waver, within six months we will claim and win the eight-hour day, a six-day week and the abolition of the present slave-driving methods in vogue not only at the Beckton Gas Works, but all over the country."

William Thorne along with Ben Tillett and William Byford formed a three-man committee and soon recruited more than 800 members. The committee established the National Union of Gasworkers & General Labourers, the first Union for non-skilled workers. It was the forerunner of today's GMB union (Thorne 1925).

Thorne defeated Tillet in the elections to become the first General Secretary of the Union. Thorne and the Union were successful with negotiations held with the GLCC and other London gas companies to reduce the length of the shifts of their manual workers to 8 hours, to receive regular breaks and that on Sundays they were entitled to a rest day or paid overtime. The Issue of Sunday working had been considered by the industry as early as 1869, when the British Association of Gas Managers raised the subject in discussions (Chandler 1949).

These conditions became standard for the gas industry and were adopted in other industries and led to strikes elsewhere in the country and violence, most notably during the gas workers strike in Leeds. The gas industry became early adopters of sick pay schemes, pensions and works committees with all ranks of employees represented. It should be noted the ownership of the gas industry was mixed split between listed companies, public gas departments and privately owned with employee ownership only an option in the first business model (Thorne 1925, Harthill 2003).

Thorne became a founding member of the Labour Party, town councillor and mayor of West Ham. He was elected the Member of Parliament for West Ham in 1906 and the Member of Parliament for Plaistow 1918-1945. George Livesey who had opposed the unions and fought a long running battle with them, eventually banned the Unions from the SMGC in 1892 in favour of the staff membership in the co-partnership scheme. Livesey viewed the battle with the unions as a fight for who controlled the gas industry (Anon. 1907b, Harthill 2003). This whole area is more complex than described here, but should allow the reader form a basis for further research.

In 1889 the largest telescopic gasholder ever to be built in Britain, the 'Mammoth' gasholder No.2 (Figure 2.48) with a capacity of 12.5 Million cubic feet was built at the East Greenwich gasworks of the SMGC by Clayton and Sons of Leeds. The gasholder comprised of 6 lifts, the top two being flying lifts which extended beyond the top of the gasholder framing.

Figure 2.48. Gasholders No.1 and No.2 at the former East Greenwich gasworks. Source National Grid Gas Archive.

The SMGC built the East Greenwich gasworks under the direction of its chairman, Sir George Livesey in order to achieve the same efficiencies as the Beckton Gasworks of the GLCC. The No.2 gasholder was built alongside the No.1 gasholder (Figure 2.48), built between 1886-88, which had a capacity of 8.6m cubic feet and was the world's first 'four lift' gasholder (Anon. 1931).

Table 2.8 Statistics of the London gas companies in 1861 (Source Chandler 1949)

Company	Capital employed in £	Coal Carbonised in Tons	Gas made in Cubic Feet
GLCC	719,460	147,700	1,358,840,000
City of London	407,805	57,000	524,400,000
Commercial	330,539	65,000	598,000,000
Equitable	280,400	35,600	327,520,000
Great Central	238,160	38,450	353,740,000
Imperial	1,579,755	243,580	2,240,936,000
Independent	186,782	43,700	402,040,000
London	651,692	75,340	693,128,000
Phoenix	495,000	72,000	662,400,000
Ratcliff	99,097	20,000	184,000,000
South Metropolitan	163,525	30,700	282,440,000
Surrey Consumers	184,894	28,000	257,600,000
Western	26,791	25,700	236,440,000
Total	5,602,900	882,770	8,121,484,000

2.8 Amalgamation, War and Modernisation 1890-1949

Throughout most of the nineteenth century the gas industry had principally been providing gas-lighting. Firstly, by burning the gas in simple batswing and fishtail burners, these evolved into more efficient and brighter burners and then later used the Welsbach incandescent mantle as can be seen in the gas lit snooker hall in figure 2.49. (Chandler 1949).

Its dependence on the lighting market had dictated that gas was regulated on its illuminating quality, which was measured in candle power (Trueman 1997).

2.8.1 Candle Power and Calorific Value

The gas industry in England primarily used coking coals for gas production, sometimes supplemented with about 3% cannel coal. Gas supplied in England typically had an illuminating power of 16 candle power (CP). Candle Power was a measure of the luminosity. In the late nineteenth-century two key factors led to a fundamental switch from the illuminating standard to the thermal standard. The first development was that previously described, the incandescent mantle burner. The second development was the increased use of gas for heating and cooking purposes. The Formal change to the thermal standard was by an Act of Parliament in 1920 (Gas Regulation Act 1920). From this date the calorific value of gas (i.e. the amount of heat released when fully burned) was measured in British Thermal Units per cubic feet of gas (Btu). One Btu is the heat required to raise the temperature of one pound of water by 1 degree Fahrenheit. A 100,000 Btu was equal to 1 Therm, a Therm was equivalent to the amount of heat required to raise 70 gallons of cold water to the boil. Typically, manufactured gas supplied to customers had a calorific value of 500 Btu (Williams 1981, Chandler).

Figure 2.49 A gas lit snooker hall. Source National Gas Museum.

The Gas Regulation Act of 1920 did not specify a fixed calorific value for gas. It required that each gas company had to declare a specific Btu value for their gas, which they were then required to adhere to with little variation (Chandler 1949, Williams 1981).

The calorific value of the gas was just one of the key properties of the gas. In addition to this the specific gravity was also important, specific gravity is the weight per unit volume of the gas in relation to air. Air at standard temperature and pressure has a specific gravity of 1, influenced by its typical molecular composition. Manufactured or 'town' gas as it was often known had a typical specific gravity of 0.40, so it was much lighter than air. The specific gravity of the gas governed at what rate the gas would pass through a burner, the lighter the gas the faster the rate. The heat given by a specified burner, at a given pressure of gas, is directly proportional to the calorific value and inversely proportional to the square root of the specific gravity (Chandler 1949, Williams 1981).

The gas industry had political influence from its earliest days, absorbing a large amount of parliamentary time in the creation of the GLCC and within the many subsequent Acts of Parliament to create other gas undertakings. Those establishing gas companies were often local people of power and civic importance, often businessmen, gentlemen, landed gentry or aristocracy. The Manager and Engineer often holding other civic positions. Throughout the 1870s and 1880s a trend started which led to many gas companies being purchased by their local authority, such as those in Birmingham and Leeds (Anon. 1895a). These municipal gas undertakings then became directly linked to local politicians through the gas committee which was appointed with oversight of the undertaking. By 1910 there were 298 gas plants operated by Municipal gas undertakings (Chantler 1938, Todd 1918 p75)

2.8.2 Vertical Retorts

During the period 1885 to 1905, gas engineers from across Europe undertook a considerable amount of work to improve the gas making process. Firstly producing inclined retort systems, the most noteable sucess being Emile Coze, the gas engineer at Rheims gasworks in France. This design was then adopted and improved upon in Great Britain by Frank Morris at the Brentford Gas Company.

The vertical retort which had first been attempted by William Murdoch, took another century until an effective system was developed. Attempts at a working system had been made by Rowan, Scott, Schilling, Bueb, Settle and Padfield and it had found application in extracting oil from oil shale. It's first effective application for coal gas was not until Dr Julius Bueb of the German Continental Gas Company developed the Dessau intermittent vertical retort at the Dassau gasworks in Germany in 1902. A few examples of this design were installed in England, the first being at Sunderland. But the design was soon superseded by the development of the Continuous Vertical Retort. Two British companies then established themselves as the market leaders in vertical retorts. These companies were Woodall-Duckham and Glover-West (Figure 2.50), they constructed many of the vertical retort plants in the UK (Stewart 1958 pp16-17, Meade 1921, Lewes 1912).

Vertical retort plants operated with the coal being fed by gravity through the vertical retort, with the coke extracted at the base. This replaced the complex charging and discharging equipment required in horizontal retort. It also allowed the process to operate on a continuous basis and the design of the system allowed them to be enclosed such that less atmospheric pollution was emitted. (Stewart 1958 pp16-17, Meade 1921, Lewes 1912). More detailed information and the development of the retort is provided in Volume 2 "Gasworks".

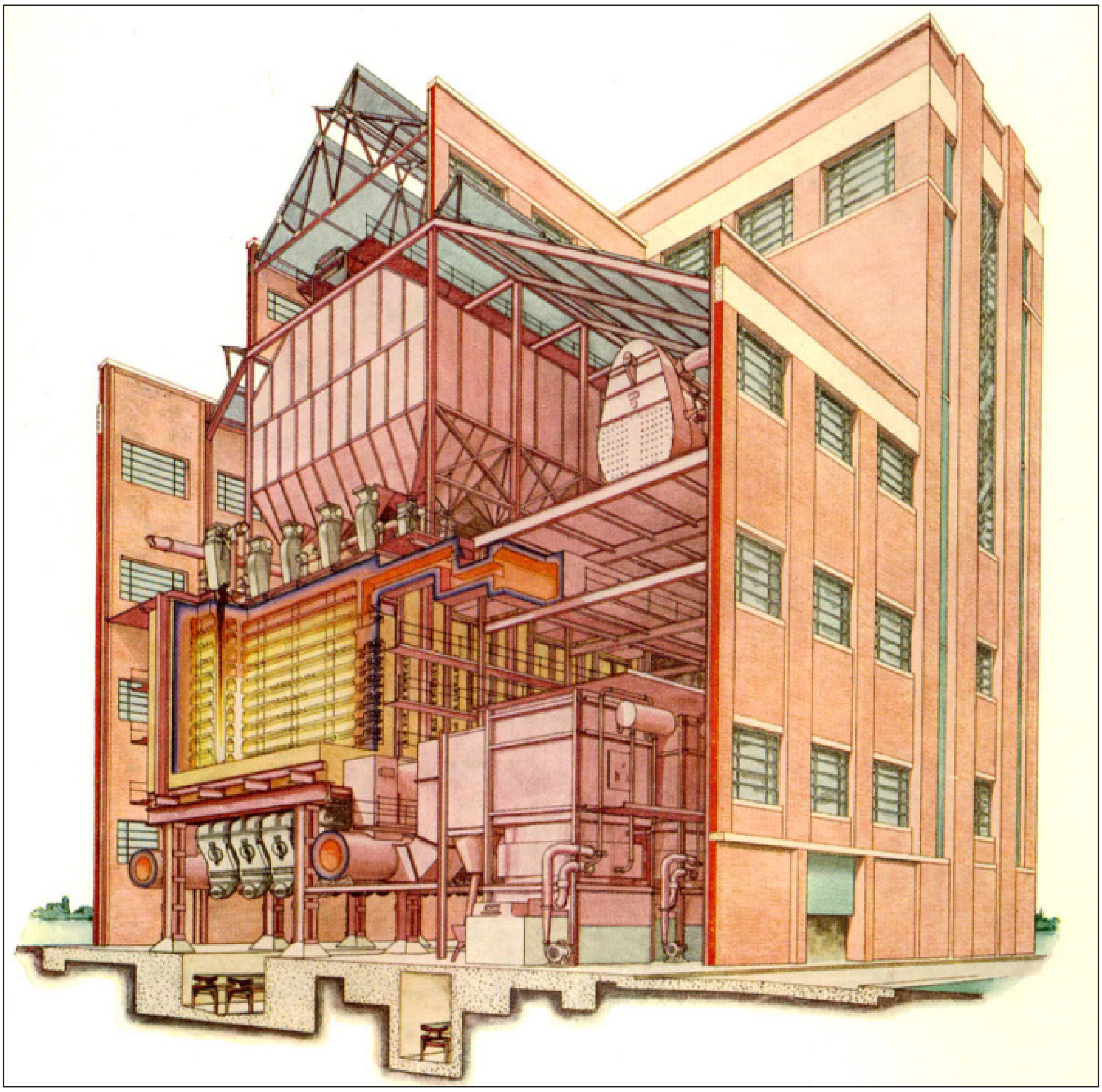

Figure 2.50 An artist's impression of West's vertical retort plant. Source National Grid Gas Archive

2.8.3 Improved Burners and High-Pressure Gas Lighting

The gas fire with columnar radiants was introduced in 1905, this developed into a grid pattern around 1925 (Stewart 1958, p47).

The original gas fired water heater was developed by Maugham in 1868. They constantly evolved and were improved upon by other engineers, including Ewart (1869), Potterton (*c*1904) and Davis (1907). Ascot improved the device in 1932, which became a very popular brand of water heater. Hot water devices were developed for all kinds of domestic tasks from central heating, washing machines and urns for tea making (Stewart 1958, p47). The first gas fired hot water central heating systems were developed by Potterton in 1904, although they did not become popular until much later. Gas fired central heating systems using warm air were developed by Radiation (1953) and Sugg (1956) (Stewart 1960).

The incandescent mantle burner was further improved in 1900 by the introduction of the inverted mantle burner. This burner not only had a higher light efficiency, but a much-improved light distribution. Within a few years the incandescent burner had replaced all forms of direct flame burner (Stewart 1958 p46).

Burners operating on the regenerative principle were used for industrial and street lighting purposes, these had a higher efficiency and were developed by Welsbach and Lucas in 1900 for upright gas mantles. They were later applied to inverted gas mantles in by Selas in 1905 and by Keith and Blackman in 1907. These systems could be used with high pressure gas lighting (Stewart 1958).

In 1901 Blackfriars Bridge was successfully lighted by using high-pressure gas lighting. By 1907 a ring of high pressure gas lighting extended from the Southwark end of Blackfriars Bridge, along Blackfriars Bridge Approach, Queen Victoria Street, Mansion House Street, and Lombard Street, to the Bermondsey end of London Bridge, which led to the removal of some electric lighting. High pressure incandescent burners could eventually produce a light of 3000-4500 candle power, similar to that shown in Figure 2.51, which shows high pressure gas lighting at Birmingham's Victoria Square (Anon. 1907c p419, Norman, 1922, O'Connor 1909, Stewart 1958 p47).

In 1905 the Society of British Gas Industries was founded to represent interests of appliance manufacturers (British Gas, 1986).

The Department of Coal Gas and Fuel Industries was established at the University of Leeds in 1906 to provide degree courses in fuel and metallurgy. The great driving force behind the SMGC, George Livesey died in 1908, to mark his passing The Institution of Gas Engineers invited contributions to a Memorial Fund. In 1910, when a fund of £10,500 was achieved, it was used to endow the Livesey Professorship of Coal Gas and Fuel Industries at the University of Leeds. In recognition of the work already done W. A. Bone, F.R.S. was appointed its first professor (Braunholzt 1963, Hide 2010).

In 1912 the British Commercial Gas Association was founded to serve as publicity agency for the industry (Figure 2.51), it also acted as an advisory and research body representing the gas undertakings of the United Kingdom. It's first Executive Chairman was Sir Francis Goodenough who served from 1912-36 (Norman 1922, Anon. 1915).

The early black cast-iron cookers were gradually replaced by vitreous enamelled cast iron cookers in 1913 and all enamelled version in 1927. Enamelled pressed steel was used from 1935 (Stewart 1958, p47).

Figure 2.51 High pressure gas lighting at Victoria Square in Birmingham. Source British Commercial Gas Association 1931.

2.8.4 The First World War

The country had been involved in many wars since the creation of the gas industry, but it was not until the First World War, that they had a direct impact on the gas industry, as it did on all aspects of British life. The gas industry was damaged by Zeppelin attacks and naval shelling, but it was the constant drain on the labour force which impacted the industry the most (Townsend 1919).

With the call up of men to military service, the industry was impacted directly and through the call up of professions which had supported the gas industry such as coal mining. Many workers were even encouraged by the gas companies through generous allowances to sign up. In London about 3000 workers from the South Metropolitan Gas Company signed up for military service during the war.

The shortage of miners and enemy attacks on coal carrying ships made coal more expensive and harder to obtain. Lucrative continental markets for by-products such as coke and coal tar were lost. It had also become apparent that Britain was dependent on Germany for the chemicals derived from coal tar, that the war effort now required. Equally the Germans chemical industry had become dependent on British coal tar. These by-products were vital for the manufacture of explosives, dyes and fuels and it required a massive investment in the British chemical industry to restore a substantial British chemical industry (Gardner 1915).

The damage on gas infrastructure from enemy Zeppelin attacks (e.g. Southend) and naval shelling (e.g. Scarborough) was limited. There were however some major industrial accidents at munitions works. The two biggest industrial incidents occurred in 1917. The first happened on the 19th of January at the Silvertown Munitions Works in East London, where an explosion caused the collapse of the massive East Greenwich No. 2 gasholder (Figure 2.52), causing the loss of 8 million cubic feet of gas (Townsend, 1919).

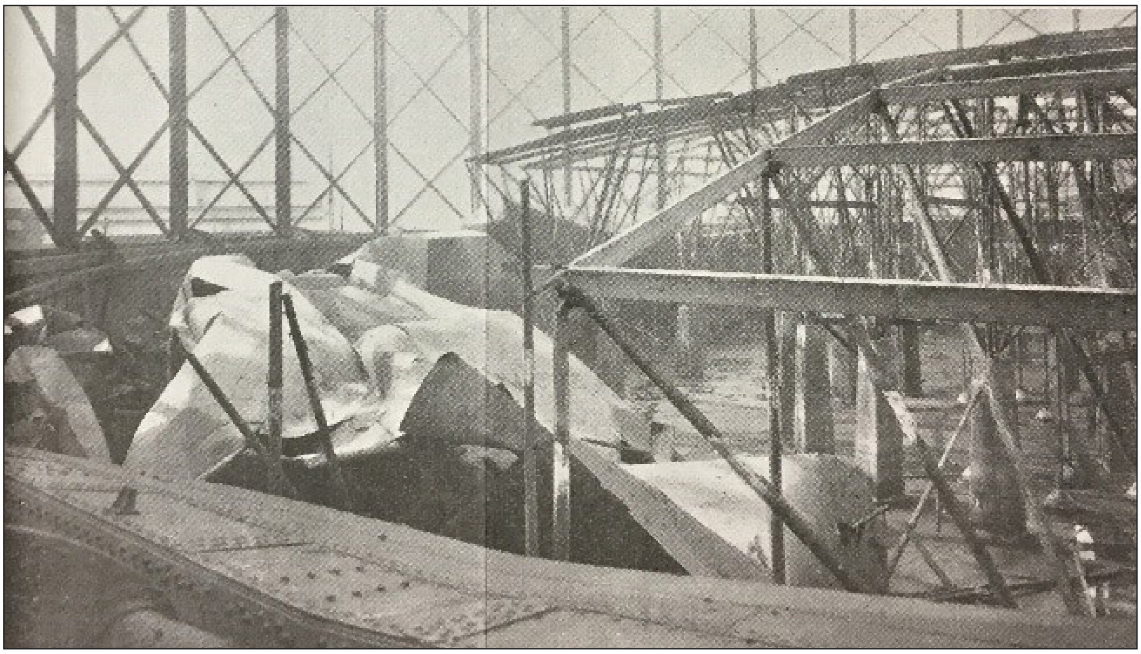

Figure 2.52 The damage inflicted on No.2 Gas Holder at East Greenwich following an explosion at the Silvertown Munitions works. Source IGEM Archive.

The second incident occurred at the 'T.N.T' works in Ashton under Lyme, near Manchester, this explosion within the town of Ashton under Lyme caused a massive loss of life with 49 killed and 700 injured, the blast destroyed two gasholders on the Ashton under Lyme gasworks and both the gasholders and many of the buildings on the nearby Dukinfield gasworks (Townsend 1919).

Gas utilisation by those industries involved in the war effort (e.g. munitions manufacture) increased and the national importance of the industry was recognised and gas workers had become exempted from military service in 1916. But, this alone was insufficient and the gas industry then looked increasingly to female employment. Firstly, female workers were employed in the offices and showrooms, they were later employed as gas meter readers and within the chemical laboratories. As the war progressed female workers had taken some of the most arduous of tasks from loading coal in the retorts houses, shifting sacks of chemicals and repairing the gasholders. Florence Burgess took over the running of the Sidmouth gasworks when her husband was called up. As the men returned from the war, this brief example of workplace equality ended, but not without proving a few points first (Wilkinson 1997).

The Gas industry supplied its own share of decorated heroes to the war effort, most notably three members of the City of Leeds Gas Department, Billy Butler, Wilf Edwards and George Sanders, each of whom won the Victoria Cross for bravery in enemy action (Anon. 1994). Sadly, many never returned, such as second-lieutenant Samuel Glover, an employee of the British Gas Light Company at Norwich and the son of its Gas Manager, Thomas Glover, who is remembered on a company memorial for the British Gas Light Company, now held at the Fakenham Gas Museum in Norfolk (Anon. 1916).

Refrigeration by gas using the ammonia absorption principle was introduced in 1922 by Munters and Allen, who later sold the gas powered fridge under the Electrolux brand. The evaporating liquid (or refrigerant) used in a gas refrigerator was usually ammonia, and this was sealed in the system under pressure. Water and hydrogen were also introduced into certain parts of the cooling system to provide "buffer" and "absorber" circuits respectively. The system worked by the ammonia absorbing heat from the fridge and discharging it into an air-cooled condenser. The gas was utilised by a small gas flame which heated the cooling liquid, driving the ammonia off as a gas. The flame being controlled by a thermostat inside the refrigerator cabinet. (Meade 1921, Gas Council 1956)

The Gas (Standard of Calorific Power) Act of 1916 permitted any gas undertaking to substitute calorific power for illuminating power as measure of quality. This came into effect due to the First World War, where the important chemicals such as benzene and toluene required for the war effort were removed from the gas (British Gas 1986).

The Temporary Increase of Charges Act was introduced in 1918, designed to provide relief from sliding-scale and maximum price provisions imposed by previous Acts. These acts had proved to adversely affect some gas undertaking financially during the First World War. The gas undertakings had to make an application to the Board of Trade for permission to modify their charges (Meade 1921).

The National Gas Council of Great Britain and Ireland was founded in 1918. Provision was made for the National Gas Council to establish a separate Committee of Employers, however, to distinguish more clearly the decisions of the two bodies, the Committee of Employers became the Federation of Gas Employers in 1919. The Federation of Gas Employers was set up as collective bargaining agency. The British Gas Council replaced the National Gas Council in 1946 (Nabb 1986).

The National Benzole Company was established in 1919 to regulate the sale of by-product benzole. A determined effort was made throughout the First World War to extract substantial volumes of Benzol and Toluol from the gas produced at gas works and coke ovens. The National Benzole Company formed a partnership with Agwi Petroleum Company to produce and distribute a motor spirit known as National Benzole mixture. The British Sulphate of Ammonia Federation appeared in 1920 to regulate the sales of ammonium sulphate (Nabb 1986).

2.8.5 The Interwar Years

Between the First and Second World Wars the Gas Industry continued to expand, albeit at a slower rate due to the increasing challenge from electricity (Peebles 1980).

Between 1920 and 1929 gas sales rose from 1177 to 1465 million Therms, but beyond 1929, gas sales started to decline (Peebles 1980).

The automatic control of cooking was improved by the introduction of the Regulo thermostat oven in 1923 (Stewart 1958 p47). By this date gas was serving a wide range of purposes in the home including ironing (Figure 2.53).

Figure 2.53 A Gas-Powered Iron. Source National Gas Museum.

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 19th 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 (Stewart 1958, p16).

Many small gas companies struggled during this time; some went bankrupt and others had to amalgamate to survive. During the first half of the 20th century consolidation between gas undertakings gathered pace. Continued consolidation occurred within the gas industry, as large town or city gas undertaking bought up smaller neighbouring gas undertaking, closing their gasworks after extending their own gas mains to supply gas more cheaply from their more efficient gasworks (Peebles 1980).

A good example of this consolidation was observed with the Swindon United Gas Company. They had started to purchase the surrounding gas undertakings in 1934 with the purchase of the Wootton Bassett Gas, Coal, Coke and Fittings Co. Ltd. A pipeline was built from the Swindon gasworks to the Wotton Bassett Gasworks, gas manufacture ceased there, but the gasholders were retained as a gasholder station. This same approach was applied to the gas undertakings at Highworth, Faringdon, Fairford and Cirencester. A project to link all the gas undertakings under the control of the Swindon United Gas Company was started, with 40 miles of high pressure gas mains laid. Where possible, this included connecting new villages to the gas supply whilst maintaining a reasonably direct pipeline route. The amalgamation strategy followed by the Swindon United Gas Company was depicted in a Wallace Coop cartoon (Figure 2.54). The Marlborough Gas Company was also purchased, but not connected to the Swindon gas network until after World War Two (British Gas South Western 1987).

Figure 2.54 The Big Brollie, a cartoon by Wallace Coop which summed up the amalgamation and integration policy of the Swindon United Gas Company
Source Gas World, 1945.

A similar 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 (Nabb 1986).

Between 1920 and 1938 the number of gas undertakings declined from 793 to 703. During the same time the number of customers expanded from 7.4 m to 11.2 m, but average consumption dropped. This drop was accounted for by increasing competition from electricity, continued loss of gas lighting contracts and the increase in customers who had limited spending power using prepayment meters (Peebles, 1980). The gas undertakings did try to off-set the loss in customers by increasing sales to industrial customers (Peebles 1980).

In 1932, Eric Fraser created 'Mr Therm' (Figure 2.55) as an advertising symbol for the Gas Light & Coke Company. Mr Therm was later adopted by the British Commercial Gas Association as a symbol to promote the use of gas on behalf of the wider British gas industry (Lomas 2001).

Figure 2.55 Mr Therm, the gas industry mascot, promoting cooking by gas. Source National Grid Gas Archive.

The British Gas Federation was established in 1934 to represent the collective interests of the Institution of Gas Engineers, Gas Companies Protection Association, the Society of British Gas Industries, the British Commercial Gas Association and the National Gas Council of Great Britain and Ireland (Nabb 1986).

From the earliest days of William Murdoch and the GLCC, the gas industry's development had been founded on research and innovation with a regular flow of patents throughout the 19th century. The research had been undertaken on an adhoc basis with engineers looking to profit from the implementation of their patented technologies. An interest in formalised research had been voiced by G.W. Stevenson, the then President of the Gas Institute, as far back as 1882, when he stated 'technical research, is undoubtedly one of the chief functions of the Institute', However less than £100 per year was then spent on collaborative research in the industry (Braunholtz 1963).

In 1928 the London Research Centre was opened by the GLCC to study scientific aspects of manufacture, storage, and distribution of gas. This was followed in 1934 by the establishment of the Research Executive Committee by the Institution of Gas Engineers, with the aim to encourage research (Braunholtz 1963, British Gas Technology 1995a).

To encourage greater collaborative research within the gas industry, the Gas Research Board was founded in 1939 under the auspices of the Institution of Gas Engineers and the Society of British Gas Industries to undertake co-operative research. At this time only, the large gas companies such as the GLCC, undertook any significant amount of research. The smaller gas companies neither had the finance nor facilities to undertake research (Nabb 1986, British Gas Technology 1995).

The Gas Act of 1934 opened the way to a more flexible pricing policy: undertakings in England and Wales supplying more than 300 million ft. per year were obliged to obtain statutory status (Stewart 1958, Nabb 1986).

In 1935 the Women's Gas Council (WGC) was formed to provide a network for women working in the gas industry. At the time, most women in the gas industry were employed as demonstrators who promoted the sale and use of domestic gas appliances. They operated through a national network of branches, providing education and training on the usage of gas in the home, with the focus on important social issues of the day, such as child welfare, and hygiene. Such education was offered through classes and demonstrations that mainly took place in the gas showrooms and associated lecture theatres. (British Gas 1986, Doughan and Gordon 2014).

In 1938, the GLCC was instrumental in the construction of the progressive, modernist Kensal House housing scheme in West London, a scheme designed for low income families by British Modernist Maxwell Fry, assisted by the social reformer Elizabeth Denby. The scheme consisted of two curved white blocks of flats and was commissioned and financed by the GLCC whose aim was to show that a modern building, fulfilling the latest safety specifications, could run cheaply and safely on gas power (Jackson and Holland 2016).

2.8.6 The Second World War

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 (chemicals, dyes, explosives and fuel) essential to the war effort (Brown 2000).

The Second World War posed a much bigger burden on the gas industry than the First World War had. Whereas during the First World War there had been a few airborne and seaborne attacks on British gasworks, it was nothing compared to that which was to be encountered in the Second World War. The aerial bombing campaign of the Luftwaffe targeted gasworks (Figure 2.56), but also inflicted major damage to gas mains. The worst bombing was encountered between August 1940 and May 1941 and then again in 1944 with flying bomb attacks in the South East of England (Brown 2000).

The gasworks being quite large and obvious were difficult to defend. Anti-aircraft precautions were taken and black out methods adopted to hide the night time rosy glow of the retort houses. The heavy bombardment of London caused 20,500 gas emergencies, with twenty George Medals awarded to gas company employees (Brown 2000).

The gas industry played a huge role in supplying gas used in the manufacture of munitions and armaments, for example the crankshaft of every single spitfire was made in a single gas fired furnace in Sheffield. And gas plant contractors switched to producing equipment for the war effort, for example West's Gas Improvement Company of Manchester built tanks and W. C. Holmes of Huddersfield manufactured bomb, shell and rocket cases (Brown 2000)

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, As with the First World War women were called into service in a wide variety of roles, from the most arduous task in the gas manufacturing processes (Figure 2.57) to meter reading and back office functions (Wilkinson 1997).

The gas industry was instrumental in producing hydrogen gas for the barrage balloons which formed an important part of the British air defences. Initially Barrage Balloons were flown at a height of around 5000 ft, to obstruct air attacks in defence. They were also later used for attack purposes armed with trailing hooks to damage power lines or timed incendiary devices. Carried on the prevailing wind, both types of balloon caused extensive damage across Europe, which included forest fires and even the destruction of a power station, the random nature of this weapon meant attacks were not always confined to enemy held territory, with damage recorded in Sweden and Switzerland (Davies 2018, Hutchinson 1987).

Skilled staff were lost from the industry to the war effort and funds for new plant were hard to obtain. The gasworkers attempted to repair damage inflicted on gasworks, such as patching up holes in gasholders as seen in figure 2.58. The damage incurred by the gas industry would require major reconstruction investment.

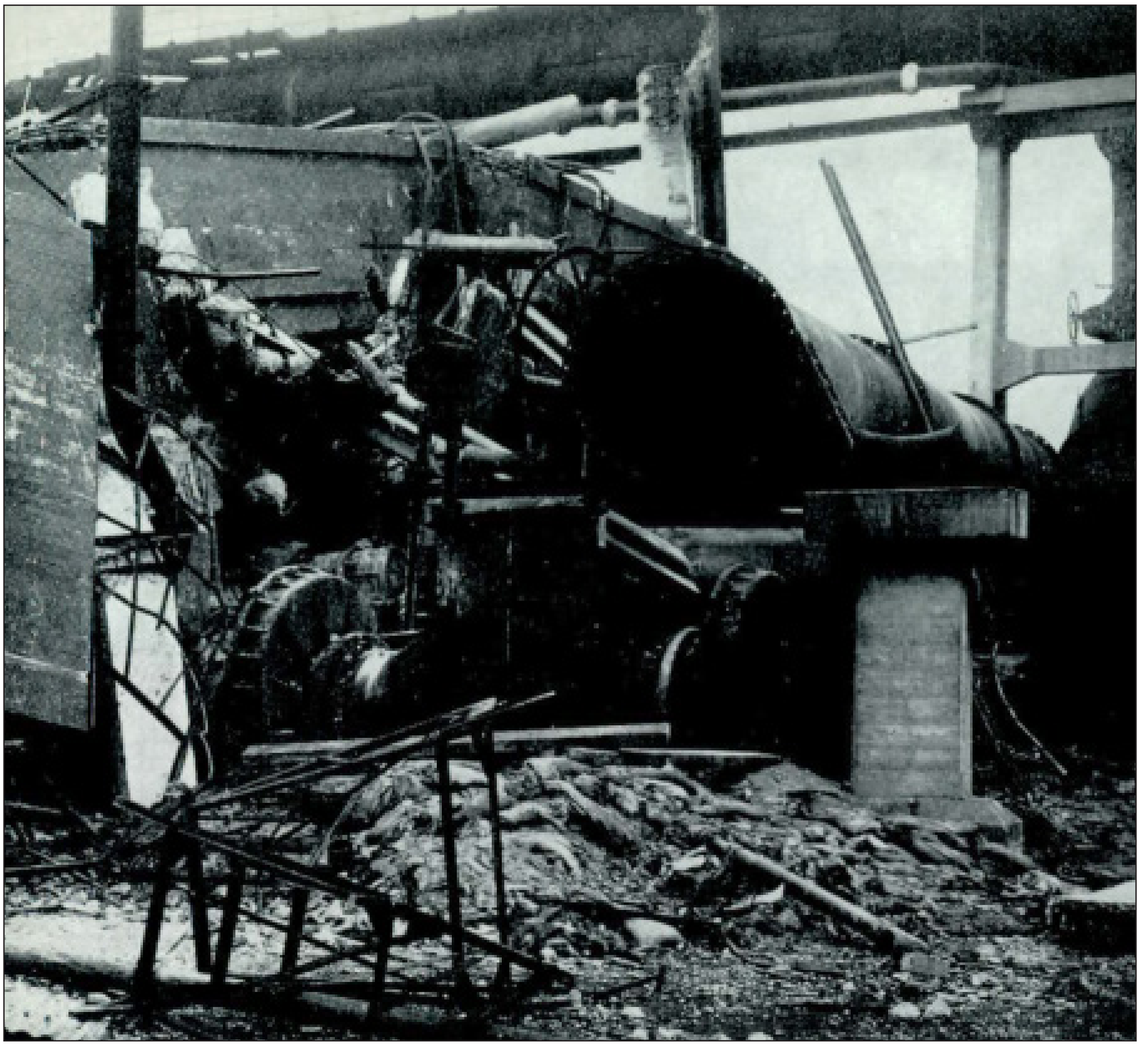

Figure 2.56, Gasworks and gas infrastructure received considerable damage during the Second World War, Beckton gasworks alone sustained over 200 bombs during the war. Source National Grid Gas Archive.

Figure 2.57 (Above) Female stokers open the retort doors ahead of the charging machine, during the Second World War. Source National Grid Gas Archive.

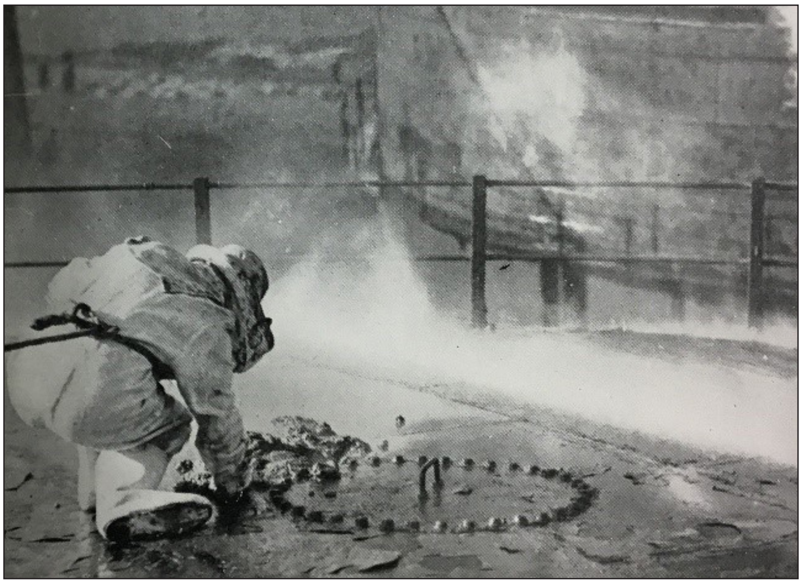

Figure 2.58 (Left) Engineers attempting to repair a burning gasholder, Romford, Essex during the Second World War.Source National Grid Gas Archive.

In 1941 Post-war Planning Committee was set up by the British Gas Federation under the chairmanship of Sir David Milne-Watson of the GLCC. Mr E. V. Evans prepared a report for the British Gas Federation suggesting rationalisation of the gas industry on a basis of centralised authority (Evans 1941), which echoed earlier reports by Chantler (1938) and Political and Economic Planning (1939) (Nabb 1986).

Due to the severe damage inflicted during World War 2, the 1942 Gas Supply (War Damage) Order was introduced which absolved gas undertakings from legal obligation to maintain supply (British Gas, 1986). The importance of the gas industry to the war effort was clearly demonstrated in Figure 2.59.

In 1943 the Post-war Planning Committee led by Edgar Sylvester (who was to become the first Chairman of the Gas Council in 1949) submitted a report on the existing organisation of the gas industry to British Gas Federation. It reported that at the time the industry consisted of 1079 seperate undertakings providing a public supply. The influential report pubished a scheme for concentrating gas production in seven principal areas, suggested the formation of a central council with statutory power to compel integration (Wilson 2002, p155-162).

Shortly after the end of the war in 1946, a Bill was brought before parliament which would nationalise the British coal industry, the act of parliament which followed became effective on the 1st of January 1947 (British Gas, 1986). The Electricity Act was also passed in 1947. This act brought under public ownership the existing electricity undertakings in England, Wales and Southern Scotland, which at this time numbered 560. The Act becoming effective from the 1st of April 1948 (Bending and Eden 1984 p166, Wilson 2002 pp155-162).

The Coal Tar Research Association founded was founded in 1948 by the British Tar Confederation. It established its own laboratories at Gomersall near Leeds and furthered the knowledge of the composition of coal tar and its useful applications (Anon 1950).

Fig. 2.—Diagram Showing the Uses of Gas in Shell-Production.

Figure 2.59 Showing the importance of the gas industry to the manufacture of shells during World War 2. Source National Grid Gas Archive.

2.9 Nationalisation and the Demise of manufactured gas 1949 – 1967

2.9.1 Nationalisation

On the 12th of June 1944, the then Minister of Fuel and Power, Gwilym Lloyd-George appointed the Industrialist and then Chairman of Unilever, Mr Geoffrey Heyworth as chairman of a review into the gas industry. The purpose of the review was to assess the structure and organisation of the Gas Industry, to advise what changes were necessary in order to develop and cheapen the cost of gas for all types of consumers and make recommendations (Peebles 1980, Williams 1981, Nabb 1986, Wilson 2002 pp155-162).

The report was completed in November 1945 and presented to Parliament in December by the then Minister for Fuel and Power, Emmanuel Shinwell. The Heyworth review highlighted many issues, including the need to improve the gas transmission network by amalgamating to form larger companies. The report concluded that the existing structure was restricting further progress and that a fundamental change in the structure of the industry was the only approach that could produce effective results quickly. The approach required was clearly towards grouping gas undertakings into larger units, a view shared by the industry and was consistent with past history, which showed a steady accelerating trend towards integration (Peebles 1980, Wilson 2002 pp155-162).

"The next consideration is how larger units are to be brought into being. No voluntary process is likely to be sufficiently speedy to satisfy present and future requirements. The reason for this is that the difference in structure between the statutory companies and the municipal undertakings is a basic one, and it is unrealistic to expect such a change of climate as will make possible fusion between them in any form which is likely to be effective."

"But, in fact, it is not necessary to decide whether or not the provision of additional machinery would, or would not, bring about acceleration of integration within the different forms of structure. A glance at the map of the structure of the industry as it is today will make it clear that no degree of success along this line of approach could produce a pattern of grouping even approximating to the ideal". The committee suggested that "Pre-determination of boundaries is the only approach that will produce a workable pattern.". The Heyworth Committee were clear that a gasworks needed to be producing at least 1,250,000 therms production per annum in order to secure even the basic efficiency. They estimated that well over 600 undertaking in this country did not meet these criteria (Peebles 1980, Wilson 2002 pp155-162).

At the time of the Enquiry the British Gas Industry (England, Scotland and Wales) comprised of 1047 gas undertakings which ranged in size from the massive Gas Light and Coke Company, which alone accounted for 12% of gas production, to small village gasworks. Many of these undertakings were very small with a capital of less than £20,000. In addition to these there were 19 companies which provided a public gas supply from private gasworks which were operated by railways and collieries.

Total sales at the time were 1.7 billion therms, supplying 10.5 million customers (Peebles 1980).

The enquiry recommended the compulsory purchase by the Government of all existing gas undertaking and organisation of them into nine regional boards in England and Wales and one in Scotland (Figure 2.60) (Peebles 1980, Wilson 2002 pp155-162).

Figure 2.60. A map showing the area boards in England and Wales in 1949; the 12th board covered all of Scotland. Source National Grid Gas Archive.

One benefit of nationalisation was that it would put the gas industry on the same footing as its main supplier, the coal industry, and its main competitor the electricity industry and provide access to cheap government guaranteed capital (Peebles 1980, Williams 1981).

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 (Figure 2.61). Each gas board was an autonomous body with its own chairman and board structure (Peebles 1980, Williams 1981, Wilson 2002 pp155-162).

To ensure communications between the area gas boards and the Ministry of Fuel and Power, the Gas Council was established, its first chairman was Sir Edgar Sylvester. The gas industry was nationalised on 1st May, 1949, being split into 12 area boards, with each area board divided into geographical groups or divisions (Williams, 1981).

Following nationalisation, the gas industry went through a programme of modernisation. It's first objective was to address the lack of investment and damage inflicted on the industry during the Second World War. By acting as a consolidated industry, rather than competing undertakings, it allowed more wide-ranging investment decisions to be undertaken. Between 1949 and 1960, this programme led to the closure of 622 of the small, old and inefficient gasworks. Gas production became centred around fewer, larger and more efficient gasworks. An additional 21,200 miles of gas mains were laid, which in part allowed the closure of the smaller gasworks. This investment did not reverse the fortunes of the gas industry as its domestic sales declined from 1366 million therms in 1953 to 1268 therms in 1960, but industrial sales rose over the same period from 639 therms to 819 therms (Peebles 1980, Williams 1981).

Figure 2.61. The Logo of the West Midlands Gas Board circa 1953. Source National Grid Gas Archive.

2.9.2 Search for new feedstocks

With the ever-increasing cost of coal, the industry began to look for alternative gas feedstocks or gas supplies. One option which was covered by the Ridley Report on national fuel policy (1952) directed particular attention to complete gasification of low-grade coal. This led to the Gas Council joining forces with the German Lurgi company to develop new approaches to gasifying lower grade coal. This is discussed in Volume 2 Gasworks, in the section on Complete Gasification. Construction of Lurgi coal gas making plant at Westfield Fife commenced in 1958 and was operative by 1960 (Scottish Gas Board 1961). A second lurgi plant was built at Coleshill, Warwickshire in 1963.

Another 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 percentage of Britain's requirements (Jones and Reeve 1974).

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 (Dean 2018).

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 (Figure 2.62). 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 (BP 1972, Cassidy 1979 p70-73, Williams 1981 p126-129).

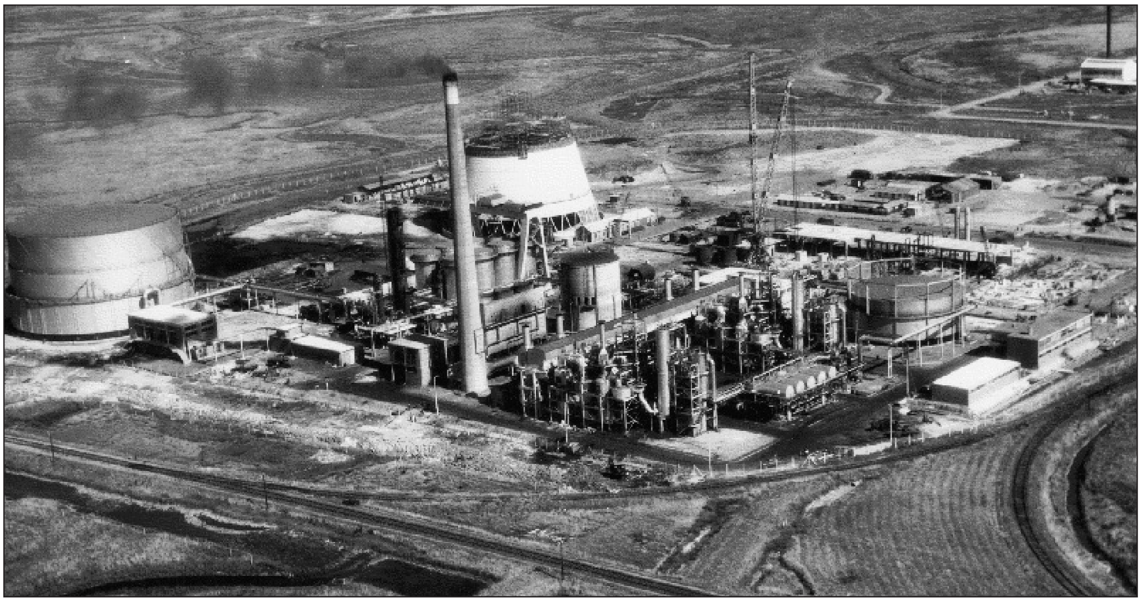

Figure 2.62, The Isle of Grain SEGAS plant. Source National Grid Gas Archive.

The Clean Air Act was introduced in 1957, the relative cleanliness of gas in comparison to other fuels boosted the use of gas fires for heating purposes (British Gas 1986).

In 1960 Sir Henry Jones was appointed the Chairman of Gas Council, this coincided with the Gas Act (1960) which extended the Gas Council's borrowing powers to fund new projects (Williams 1981 p118).

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. This was keenly observed at Coleshill in Warwickshire where both a Lurgi gas plant and an oil reforming plant were constructed. The oil reforming plant proving to be much more cost effective than the Lurgi gas plant which was the only feasible option for future gas making from coal (West Midlands Gas Board 1963, Williams 1981 p125).

In 1961 the Watson House research centre started to move to a new site at Peterborough Road in Fulham. The new site was formally opened by His Royal Highness the Duke of Edinburgh in November 1963 (British Gas Technology 1995b).

In 1961 Lurgi plant at Westfield (Fife, Scotland) was formally opened by Her Majesty The Queen. This plant continued in operation until 1974, when the area it served was converted to natural gas (Scottish Gas Board 1961).

In 1958 a generally acceptable legal definition of the "Continental Shelf" was agreed at the Geneva Convention of the Seas. It was not ratified until 1964, which had required 22 signatures by 22 members of the United Nations. It defined sovereignty over submarine minerals in the North Sea. This was to prove important as much of the future oil and gas reserves in Western Europe were to be found in the North Sea continental shelf. This led to the passing of the 1964 Continental Shelf Act in the same year the first North Sea exploration licences were issued, these covered 42,000 square miles (Williams 1981).

In 1964 the first commercial Catalytic Rich Gas plant was opened by the North Thames Gas Board at the Bromley-by-Bow gasworks. In 1965 the First Gas Recycle Hydrogenator plant was built at Avonmouth, Bristol (shown in Figure 2.63). Both these processes were advancements on the continuous steam reforming process of making gas, and had been developed at the Midland Research Station in Solihull. The Catalytic Rich Gas process produced gas from naphtha under a high pressure at between 500-550°C and in the presence of a catalyst. The gas produced was much richer in methane than that previously produced by steam reforming. The Gas Recycle Hydrogenator process produced gas from reacting hydrogen with heavy oil at high pressure and a temperature of about 750°C. The hydrogen for the process could be obtained from the continuous reforming processes. The resulting gas was about 41% hydrogen and 31% methane (Cassidy 1979 p70-73)

In 1964 the Engineering Research Station (ERS) opened. It was one of five research stations, the others being the London Research Station, the Midlands Research Station, Watson House and the On-Line Inspection Centre. Originally established as a section within the London Research Station, ERS was established at Killingworth, Newcastle and had an emphasis on mechanical engineering, metallurgy and physics. The building became a landmark for its modern architecture (Figure 2.64) and was listed in 2000 and now houses the Planning Department of North Tyneside Council (British Gas Technology 1995c).

Figure 2.63, The Gas Reforming and Gas Recycle Hydrogenator Plants at the Seabank Gasworks, Avonmouth, Bristol. Source National Grid Gas Archive.

Figure 2.64 Exterior view from the north-east of the British Gas Research Station Killingworth, Newcastle taken 2003 © Historic England Archive FF003555

2.10 Conversion to Natural Gas 1967 – 1986

With the diminishing quality and quantity of accessible coal reserves, the British gas industry had started to look to alternative gas supplies. No significant natural gas fields had been found within the UK, despite extensive drilling programmes undertaken during the First and Second World Wars. Small amounts of gas had been detected in wells drilled in locations, such as Heathfield in Sussex(Williams 1981).

2.10.1 Discovery of Natural Gas in the USA

The USA had realised early on the benefits of switching to natural gas, with early discoveries made in Pennsylvania and its neighbouring States at relatively shallow and accessible depths (Williams 1980, Peebles 1980).

Gas was first utilised in the US at the village of Fredonia, 45 miles southwest of Buffalo in New York State. The village was situated above the Upper Devonian Black Shale. The first commercial gas well was drilled along the banks of the Canadaway Creek in 1825, by local gunsmith William Aaron Hart. The well was relatively shallow at a depth of 27 Feet and dug into what was locally described as a "slaty rock" (Lash and Lash 2014).

Hart collected the gas within a crude gasholder which then supplied gas to light several stores and a mill along the creek. Although the productivity of Harts well gradually diminished. In 1857 Preston Barmore, a relation of Hart, persuaded local businessmen to invest in the newly formed 'Fredonia Gas Light and Water Works Company'. In 1857, Barmore drilled two wells along the same Canadaway Creek, less than a mile north of Hart's original well location. (Lash and Lash 2014)

These wells were significantly deeper (approximately 120ft) than Harts original well, but Barmore was not satisfied with the productivity. In an attempt to increase gas flow Barmore attempted to fracture the shale rock by igniting eight pounds of gunpowder at a depth of 122 ft depth. The local Fredonia Censor reported that following fracturing the well-produced "a plentiful supply of gas." This was the first attempt of fracture-stimulation within a shale gas well, a primitive fore-runner of the more recent and controversial hydraulic fracturing of shale. Gas from the well was collected using a lead pipe and pumped to a gasholder housed in an octagonal gasholder house located in the centre of Fredonia. By December 1858, more extensive gas lighting of the village had been undertaken (Lash and Lash, 2014).

Other attempts to utilise natural gas in the US failed generally due to gas leakage from the pipeline which were constructed from wooden pipes, this was until an iron gas main was constructed from Newton to Titusville in Pennsylvania (Williams 1980).

From 1880 natural gas companies were formed throughout North Eastern Pennsylvania, with Pittsburgh being supplied by 6 natural gas companies in in 1887 (Thorpe 1891) By 1935 natural gas had already made up 82% of the gas utilised in in US, this had increased to 91% by 1950, at which time 115,000 miles of high pressure gas transmission mains had been constructed. A key aspect of this infrastructure being the 1840 mile long steel welded Trans-Continental Gas Pipeline completed in 1951. It transported gas from the fields of the Texas-Louisiana Gulf Coast to the heavily urbanised regions of Philadelphia, New Jersey and New York (Anon, 1953). This pipeline was working at a pressure of 800 pounds per square inch, over seven times the maximum pressure of any UK gas pipeline at the time.

Substantial discoveries of gas fields were made across the Soviet Union as well, which established a similar gas transmission system to that developed in the US (Peebles 1980).

2.10.2 Oil and Gas Exploration in the United Kingdom

When the American natural gas industry was visited by British gas productivity specialists in 1952 it was clear to them that natural gas offered some distinct advantages and that any discovery of gas reserves of any magnitude in Britain would be an immense benefit (Anon, 1953). Some minor success had been obtained in 1937 when a trial borehole drilled by D'Arcy (a forerunner to todays BP Exploration) in Eskdale, Yorkshire yielded 2.5m cubic feet of gas daily. Although not utilised further at the time, the site was purchased by the North Eastern Gas Board in 1959 and between 1961 and 1967 natural gas was extracted from three boreholes (Eskdale-2, Eskdale-10 and Eskdale-12). This gas was piped to Whitby where it was reformed into "town gas" at the Whitby gasworks (Williams 1980, Haarhoff ***et al*** 2018).

A small oil field was discovered in Eakring in 1939 by the British Petroleum Company. Critical impact of diminishing oil supplies during the Second World War had led to an upsurge in drilling activity in Britain to obtain local supplies of oil. This led to the drilling of 380 wells of varying depth, 250 of these became production wells and by the end of the war more than 2.25 MMbbl of oil had been obtained (Corfield 2018).

Oil and gas prospecting continued after the Second War World and throughout the 1950s on a modest scale (Williams 1979). The discoveries made were relatively small and had been essential during the war, however, after peace resumed, the annual onshore oil production in Britain in 1954 had only amounted to 0.48 MMbbl (Lees 1954).

In 1953 the Gas Council became involved in onshore gas exploration when following the discussions with the then Anglo-Iranian Oil Company (which later became BP) a sum of £1m was devoted to an extensive search for natural gas. The surveys were undertaken by D'Arcy Exploration (Later BP Exploration), starting with seismic surveys in 1953 and the first drilling of trial boreholes in February 1954 which discovered the small gas field at Cousland near Edinburgh (Williams 1980).

At the same time attempts were made to extract gas from coal mines and the possibility of exploiting underground coal gasification, with a couple of trial projects undertaken in shallow coal seams in Derbyshire (National Coal Board 1964).

Without any significant local supplies of natural gas emerging, the British gas industry had already started investigating the possibility of importing natural gas from abroad. Importing gas by pipeline was at the time unfeasible, as no gas fields were near enough to the UK to be imported via this route.

2.10.3 Liquefied Natural Gas

It was possible to reduce the volume of gas by compressing the gas under pressure, as the volume of gas is inversely proportional to it's pressure. This was only suited to small quantities of gas. An alternative solution to storing and transporting gas had been developed in the USA. This solution involved liquefying methane by cooling, this reduces the volume of methane gas by 600 times, making it much easier to transport. Liquefying the gas can be achieved by cooling the methane to -161°C at atmospheric pressure or cooling to 82.5°C at a pressure of over 4.5 Mega-Pascals (Peebles 1980).

The liquefying of gas dates back over 230 years, with the Dutch scientists van Marum and Troostwijk liquefying air under laboratory conditions (Peebles 1980). Some other notable scientists include:

- The English Chemist and Physicist Michael Faraday, who liquefied, chlorine, carbon dioxide, hydrogen sulphide and sulphur dioxide around 1823.
- The German scientist, Karl von Linde, who devised a method of continuous liquefaction, liquefying, oxygen, nitrogen and air on a commercial scale in 1897.
- The Dutch Physicist Heike Kamerlingh-Onnes, who liquefied Helium, in 1908, the last gas to be liquefied.

The liquefaction of methane is believed to have been first achieved by the French Chemist Louis Paul Cailletet (Cailletet 1877), although the Swiss Chemist Raoul Pierre Pictet was also working on the same research at this time (Peebles 1980).

The US Bureau of Mines first usefully employed liquefaction on natural gas in 1917, when they used it to extract helium from natural gas so it could be used in airships (Peebles 1980). In the same year Godfrey Cabot of Boston, West Virginia obtained a patent for an apparatus to liquefy natural gas using both pressure and cooling. The plant was constructed at Elizabeth, West Virginia where it was successfully used to produce LNG. The proposed use for the LNG was welding, but this proved unsatisfactory and the plant was abandoned in 1921 (Peebles 1980).

Interest in LNG surfaced again in 1930s when H.C. Cooper, President of the Hope Natural Gas Company of West Virginia became interested in the possibilities of LNG. Following a period of research, a pilot plant was built at Cornwall, West Virginia in 1939. The plant was capable of liquefying 400,000 cubic feet per day, but was dismantled in 1940, after 4 months of operation (Peebles 1980).

During the same winter of 1939/40, which was a particularly hard winter, the East Ohio Gas Company became interested in the use of LNG to supplement their peak load demand for gas, a process called peak shaving. The plant which provided liquefaction, storage (in three large spherical tanks) and regasification was constructed by January 1941, operated successfully for 3 ½ years, by which point an additional fourth tank of a different design had been constructed. This forth tank failed on the 20th of October spilling its contents into and over the inadequate bunding. As the LNG warmed it vapourised, this included some LNG which had found its way into the city storm sewers. Coming into contact with ignition sources the LNG caught fire, which caused one of the spherical tanks to collapse as well as spilling its contents and an eruption of fire in the storm sewers. The cause of the disaster was never identified, but the accident set back the use of LNG, whilst improving future design (Peebles 1980).

The next significant development occurred in 1951, when William Wood Price, the President of the Union Stock Yard and Transit Company, proposed to ship LNG from Louisiana gas fields in barges up the Mississipi to its yards in Chicago. The plan had proposed that 8 barges be built, which would be operated as pairs transporting 120m Cubic Feet of gas to Chicago, a journey of two weeks. The plan never came to fruition, but a single innovative new 264-foot-long barge was constructed, which contained 5 tanks, each insulated with balsawood panels. Boil off gas escaping from the tanks was collected and used to fuel the tow boat (Peebles 1980).

In 1954, realising the potential of LNG, the Continental Oil Company joined with Union Stock Yard to form Constock Liquid Methane Corporation, to develop the barge concept for Ocean going LNG transport. Further research and testing was undertaken on a new prototype vessel between 1954 and 1957, which attracted the attention of the Gas Council in Great Britain. The Gas Council announced in late 1957 that a trial importation of LNG from the US would go ahead. Constock constructed a liquefaction and LNG loading facility on the Calcasieu River 8 miles South West of Lake Charles, Louisiana, which was fed by gas from the nearby gas fields belonging to Continental Oil Company. In Britain the Gas Council oversaw the construction of an LNG reception and storage facility at Canvey island, Essex (Williams 1981).

To transport the gas, a liberty freighter, originally called Marline Hitch and built in 1945 for the Second World War effort, was redesigned by the marine architects J. J. Henry Company of New York. It was designed to carry 2200 tons or 5,000 cubic meters of LNG in five prismatic tanks with balsa wood supports and an insulation of plywood and urethane. The ship was renamed Methane Pioneer and it took a total of 7 cargoes of LNG from Lake Charles to Canvey Island, the first departing in January 1959 and the last departing in March 1960.

The Methane Pioneer operated through a whole range of weather conditions, proving that ocean going LNG transportation was both technically and commercially viable (Williams 1981).

In 1960, Shell joined Constock to form Conch International Methane Limited (Shell and Continental Oil each owned 40% and the Union Stock Yard owned 20%) and attention moved to utilising the Hassi R'Mel gas field in Algeria, which had been discovered by the French/Algerian Societe d'Exploitation des Hydrocarbures d'Hassi R'Mel (SEHR).

Conch formed the Companie Algerienne du Methane Liquide (CAMEL) with French Interests, to build a gas liquefaction plant at the small port of Arzew on the Mediterranean coast. To supply the plant a 250-mile gas pipeline had to be constructed from the gas field (Williams 1981).

The success of the original trial led to the Gas Council to embark on a more ambitious project, where it was intended that 10% of the UK's gas requirements could be imported as LNG, a sum which amounted to 300,000 tonnes. On the 3rd of November 1961, the then British Minister for Power, Richard Wood, approved the Gas Council request to Import LNG from Algeria for an initial period of 15 years. The plant was designed to produce 100 million cubic feet of gas per day for the UK (Peebles 1980).

It required that two new much larger LNG tankers be built. These were the Methane Princess (Figure 2.65) built by Vickers at Barrow in Furness and Methane Progress built by Harland and Wolff in Belfast, these ships would continually import gas from Arzew to Canvey Island. They were designed to collect the LNG boil off gas, and used it as a fuel to power the ships (Peebles 1980).

Figure 2.65, The Methane Princess docked at the LNG importation facility at Canvey Island. Source National Grid Gas Archive.

Construction of the 1 million tonne pa (mtpa) plant commenced in 1961 and a Gas Supply Agreement was signed with British Methane Ltd, which was a 50/50 joint venture between British Gas Council & Conch in 1962. At the same time a similar venture was agreed with Gaz de France to import LNG at a special facility built at Le Havre.

The Canvey Island facility also required upgrading to deal with the larger and more regular shipments of LNG. On 26th of September 1964, the Methane Princess loaded at the CAMEL liquefaction plant at Arzew, arriving on the 12th of October 1964 to unload at Canvey Island, signalling the world's first commercial LNG transportation. From 1964, regular trips started between Algeria and Canvey Island, importing up to 700,000 tonnes of LNG per year (Peebles 1980).

The switch to natural gas provided an additional boost to gas distribution. Whereas manufactured gas had been distributed with an energy value of 500 BTU, natural gas was much more energy rich and had a corresponding value of 1000 Btu (Williams 1981).

2.10.4 The development of the National Transmission System

To handle these large imports of natural gas, a cross country gas transmission pipeline was constructed. Known as Feeder One, this pipeline which was constructed in 1966, stretched from Canvey Island in Essex to Leeds in Yorkshire. It had connections to eight of the regional gas boards. The Construction of Feeder One signalled the start of the development of a National Gas Transmission System (NTS, Figure 2.66). The NTS has now expanded considerably across Great Britain, acting as the high-pressure gas network which stores and transports gas from the entry terminals to gas distribution networks, or directly to power stations and other large industrial users.

The Canvey Island LNG project would have developed further if it had not been for the discovery of gas in the North and Irish Seas. The availability of these gas supplies led to the closure of Canvey Island, then the UK's only LNG receiving terminal in 1979 (Helm 2003).

To assist with meeting peak gas demand, LNG was also utilised at a number of peak shaving plants which included those at Ambergate Derbyshire (closed 1985); Dynevor Arms Merthyr Tydfil (closed 2009); Glenmavis Lanarkshire (closed 2012); Partington Greater Manchester (closed 2012); Avonmouth Bristol (closed April 2016); and the Isle of Grain, Kent.

The latter facility was redeveloped in a project which commenced in 2005. This project has gone on to build a large LNG importation facility, which provides gas storage and supplies the National Gas Transmission System. In addition to the Isle of Grain facility, there are two LNG importation facilities at Milford Haven in Wales, the South Hook and Dragon which supply the National Gas Transmission System.

The award of exploration licences under the Continental Shelf Act 1964 resulted in the discovery of substantial reserves of gas in the UK portion of the North Sea.

Figure 2.66. Building the National Gas Transmission System, Laying a transmission pipeline across a River. Source National Grid Gas Archive.

The Sea Gem, operated by BP, first to strike gas off Grimsby on the 17th of September, the first North Sea and offshore gas field was the West Sole. A list of the early gas fields which were discovered in UK Waters are given in Table 2.9. The discovery of substantial gas reserves necessitated the construction of gas terminals on the east coast and a further expansion of the NTS, to enable gas to be transported to the Regional Gas Boards (O'Neil 1996).

By 1967, North Sea gas was being brought ashore at the Easington terminal. The Bacton terminal (Norfolk) became operational in 1968, being officially opened by H.R.H. the Duke of Edinburgh in 1969. The Theddlethorpe terminal (Lincolnshire) became operational in 1972, the St. Fergus terminal (Aberdeenshire) became operational in 1977, being officially opened by Her Majesty the Queen in 1978.

The gas fields of the Morcambe bay were also discovered in the Irish Sea which required the opening of Barrow Terminal in 1985. Gas from Frigg gas field in Norwegian territories were also brought to the UK.

In 1967 the first contract for the purchase of gas was signed was with BP, it lasted for three years in the first instance.

In the 1967 Government published a White Paper on Fuel Policy advocating rapid exploitation of North Sea gas with an emphasis on premium markets.

Table 2.9, Early gas field discovered in UK waters.

Field	Discovered	Operational
West Sole	1965	1967
Leman Bank	1966	1968
Indefatigable	1966	1971
Hewett	1966	1969
Ann	1966	1994
Dotty	1967	1969
Scram (Wissey)	1967	2008
Rough	1968	1975
Viking	1968	1972
Dawn, Deborah, Della and Delilah	1968	1969
Sean	1969	1986
Broken bank	1971	
The Frigg Field (Brit. & Nor. sectors).	1972	1978
Lomond	1972	1993
Amethyst	1972	1991
Alison	1966	1995
Piper (oil field with ass. gas.)	1973	1976
Bruce	1975	1998

The Select Committee on Nationalised Industries published a Report on North Sea oil and gas. The gas reserves discovered in the 1960s were more than sufficient to meet all existing demand at the time. Whilst imported LNG had previously been reformed into "Town Gas", in 1966, the Chairman of the Gas Council, Sir Henry Jones, formally announced that Britain was switching to natural gas and the manufacture of gas would gradually be phased out (Williams 1981).

2.10.5 The Conversion programme: A timeline

To be able to burn natural gas efficiently, all gas appliances operating off mains gas had to be converted throughout Great Britain. 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. The conversion programme required very thorough planning and was undertaken on a regional basis over a period of about 10 years. Preparatory works which included a major expansion of high pressure transmission system had to be undertaken to ensure natural gas could be supplied to each region (British Gas 1986).

Different regions were gradually converted from manufactured gas to natural gas, without loss of supply for any significant period of time. The North West, West Midlands, Eastern, North Thames, and Southern Regions commenced conversion in 1968, Wales and South-Eastern Regions commenced conversion in 1969 and the

Scottish and South West Regions commenced conversion to natural gas in 1970 (British Gas 1986).

The Gas Conversion Association was formed to represent collective interests of main contractors involved in the Conversion Programme.

25-year contracts for purchase of gas signed with Phillips, Shell/Esso, and Gas Council/Amoco Groups for Hewett, Leman, and lndefatigable Fields respectively.

These developments led to amendments to the organisational structure of the gas industry. Halfway through the conversion programme, the Gas Act of 1972 abolished the Gas Council and the British Gas Corporation was formed and assumed control of the 12 Area Boards. This centralised the gas industry into a single business, although the regional structure was retained (Elliot 1980, Williams 1981).

In 1968 a 22-storey apartment block in Canning Town, London called Ronan Point was devastated by a massive gas explosion which led to five deaths. This disaster was attributed to unsafe gas fitting work in one of the apartments. It led to a drive to improve standards and protect the public from any similar future incidents (Griffiths *et al* 1968). This led to the creation of The Confederation for the Registration of Gas Installers (CORGI) in 1970. Its membership was aimed at gas fitters and membership was originally voluntary. In 1991 the Health & Safety Executive (HSE) changed legislation in Great Britain relating to gas work, introducing the requirement that anyone working on gas must be member of a gas safety scheme. The HSE asked CORGI to act as registrar for this safety scheme and it changed its name to the "Council for Registered Gas Installers".

The First major industrial contract for sales of gas were signed in 1968 with ICI for 15 years: followed by 5-year contract with Shell.

In 1969 a proposed bill to reorganise gas industry on more centralised basis was introduced into Parliament, but did not progress as a consequence of the dissolution of parliment in May 1970.

The Morton Report which followed an inquiry into the safety of natural gas as a fuel, was published in 1970. The same year that a national control centre for high-pressure gas distribution was established at Hinckley in Leicestershire (British Gas 1986).

The on-shore gas field at Lockton, Yorkshire, came into production In 1971, however it closed in 1974 (Haarhoff *et al* 2018). Compressor stations for the high-pressure distribution system became operational at Ambergate, King's Lynn, and Peterborough. In 1972 Sir Arthur Hetherington became last Chairman of Gas Council prior to formation of British Gas Corporation. The Gas Safety Regulation Act set new standards for appliances (Williams 1981).

The Gas Act of 1972 prepared the way for greater centralisation. The Gas Council became the British Gas Corporation and the Regional Gas Boards became Regions of the British Gas Corporation (Simmonds 2000, O'Neil 1996).

The British Gas Corporation inherited the monopoly rights over the sale of gas and it also extended the monopsony powers over any gas reserves from the North Sea discovered within the United Kingdom sector. These powers were largely removed in the Oil and Gas Enterprise Act of 1982 (Simmonds 2000, O'Neil 1996).

In 1972 work commenced on a gas liquefaction plant at Glenmavis. Glenmavis supplied LNG by tanker to Scottish independent gas networks at Stornoway, Wick, Thurso, Oban and Campbeltown.

The availability of Natural Gas had the effect of creating a significant increase in the demand for gas, which was further exacerbated by oil price increases in 1973 and later in 1979 (Simmonds 2000, O'Neil 1996).

In 1973 Sir Arthur Hetherington became the first Chairman of British Gas Corporation. In the same year the National Gas Consumers' Council was set up.

A notable change in gas sales occurred in 1974 when sales of gas to industrial customers exceeded sales to domestic customers for the first time.

The Lurgi plant at Westfield closed with availability of natural gas in the area. Work commenced on St. Fergus terminal. First discovery of gas at Morecambe: formally announced as commercial field 1978.

In 1975 the Rough Gas Field became operational with gas brought ashore at the Easington terminal. The British Gas School of Fuel Management was created in 1975 (British Gas 1986).

In 1976 Denis Rooke became Chairman of the British Gas Corporation. The Select Committee on Nationalised Industries published a report on gas and electricity prices.

On completion, the 10-year conversion programme (Figure 2.67 & 2.68) signalled an end to the manufacture of gas in England and Wales. Gas production at Romford Gasworks was switched off on 26 August 1976 (British Gas 1986 & Williams 1981).

Figure 2.67. The Conversion Programme, the burners in gas appliance had to be replaced with those suitable for natural gas.

Figure 2.68, Flaring off town gas from the distribution network outside the Houses of Parliament during the conversion programme. Source National Grid Gas Archive.

As the old gasworks were no longer needed they were gradually demolished and the sites cleared, with only gas storage, transmission and distribution assets retained. With the exception of gasholders, very few gas manufacturing buildings or structures survived this programme of demolition. Whilst a few sites were retained as depots and Operational Control Centres (OCC), such as the OCC built in Swindon, which opened in 1986 (Figure 2.69), surplus land was sold off to third parties where demand existed (Environment Resources Limited 1988).

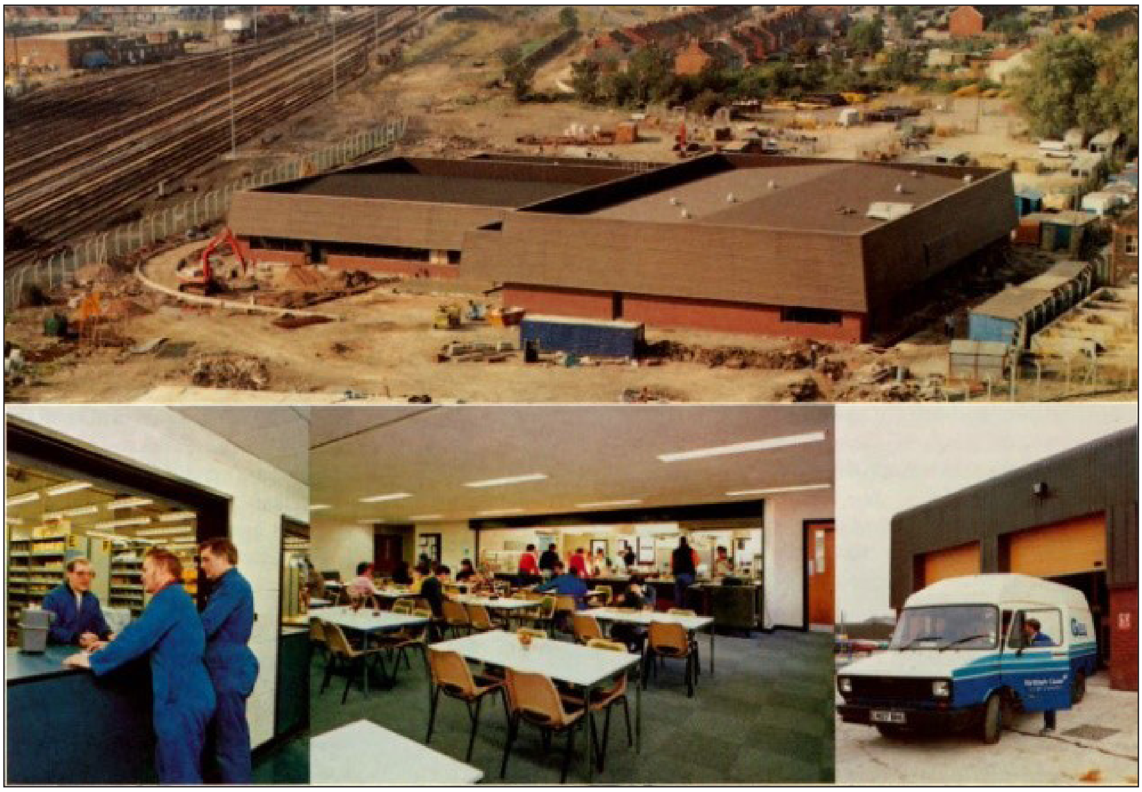

Figure 2.69, The Swindon Operational Control center, built at Gorse Hill, opened in 1986. Source National Grid Gas Archive.

In 1978 the Morecambe Field was formally announced as capable of commercial development (Williams 1981).

In 1979 the first gas treatment plant became operational on the island of Flotta in the Orkney Islands in Scotland to handle associated gas from the Piper oil and gas fields.

In 1980 the British government gave the go ahead for a new gas gathering system to recover gas from the northern basin of the North Sea.

The last gasworks making gas from coal in Great Britain were to be found in the remote areas of Scotland. The last small gasworks was in Millport, on the Isle of Cumbrae, which operated hand-charged horizontal retorts, closed in 1981 (Thomas 2018). Whilst this report has focussed on the manufactured gas industry a brief description is provided of the events which followed conversion to natural gas.

The introduction of natural gas substantially increased the demand for gas in commercial, industrial and domestic markets, which was further exacerbated by the oil price increases in 1973 and 1979. Between The start of the conversion programme in 1967 and 1979, gas use more than doubled.

In the interim, further gas deposits were discovered in the North Sea and the Irish Sea, and input terminals were added to the transmission network at Barrow and St Fergus. (O'Neil 1996).

Figure 2.70 Drilling for gas in the North Sea. Source National Grid Gas Archive.

British Gas also added to a number of upstream investments, which saw its exploration affiliate in the role of a UK Continental Shelf gas producer.

To supplement the limited gas storage available in Britain, the British Gas Corporation purchased the Rough gas field in 1980 with one third of the gas reserves depleted. The intention was to use the gas field as a natural gas storage facility, it became an operational storage facility in 1985. It became the largest gas storage facility built on the UK continental shelf, able to hold 10% of peak UK gas demand. Following subsequent demergers, the ownership of the Rough facility was transferred to 'BG Storage', who in 2001 sold the facility to the American company Dynergy. Centrica purchased the facility in 2001. In June 2017 it was announced that gas injection and storage operations at Rough and the facility would close (Anon 2017). Other depleted gas fields and salt cavity storage facilities such as the Holford facility in Cheshire, still provide gas storage in Great Britain.

2.11 Privatisation and Deregulation

Up until the Oil and Gas Enterprise Act of 1982, the state-owned British Gas Corporation had enjoyed monopoly rights for the sale and distribution of natural gas to end-users, controlling the supply from landfall to the entire industrial and domestic gas markets. This included a requirement that all natural gas discoveries be offered for sale to the British Gas Corporation (Martin and Parker 1997, Simmonds 2000). Although the Oil and Gas Enterprise Act had in theory opened the industry to competition very little changed in the first few years.

2.11.1 Privatisation

In September 1981, Nigel Lawson, a strong advocate of privatisation, became the Energy Minister, he announced the Government's intention for the privatisation of the British Gas Corporation's offshore oil business, the disposal of its showrooms and the abolition of the its Statutory rights over the purchase of gas and its sale to industry. This latter requirement, however, was removed in the Oil and Gas Enterprise Act of 1982 (Martin and Parker 1997, Pearson and Watson 2012).

The privatisation of the gas industry did not occur until 1986, following the passage of the required legislation, primarily the Gas Act of 1986. The form the gas industry would take following privatisation was subject to intense discussion between Nigel Lawson and an alliance between the then Energy Secretary Peter Walker and the formidable British Gas Chairman, Sir Dennis Rooke (Figure 2.70). The latter two wanted to ensure that the privatised business retained the vertically integrated transmission, distribution and retail monopoly operating nationally, whilst Lawson had argued for a competitive regional business model. The approach of Walker and Rooke prevailed, (Martin and Parker 1997).

The Gas Act 1986 made provisions for privatising the British Gas Corporation and established a framework to regulate the newly privatised industry. The businesses of the British Gas Corporation were vested in British Gas plc and offered for public sale in December 1986 (O' Neill 1996).

The Gas Act did not make provisions for the restructuring of the gas industry to facilitate the introduction of competition and British Gas was sold as a vertically integrated industry, split into 12 regional structures (O'Neill 1996, Pearson and Watson, 2012).

The first Director General of Gas Supply (DGGS) was appointed in August 1986 and the Office of Gas Supply (Ofgas) was set up to support the DGGS in his role as industry watchdog. Ofgas later merged with the electricity regulator to become the Office of Gas and Electricity Markets (Ofgem). Gas Act 1986 also provided for the setting up of the Gas Consumers' Council to represent the interests of consumers (O'Neill 1996, Simmonds 2000).

Figure 2.71, Sir Dennis Rooke, he fought hard to ensure that British Gas was privatised as a single entity. Source National Grid Gas Archive.

2.11.2 Deregulation

British Gas plc was a monopoly for most customers, but the Gas Act 1986 did open up the gas market for large industrial consumers, who used more than 25,000 therms per annum. A subsequent Gas Act was enacted in 1995 which amended the Gas Act of 1986. It made a provision for the separate licensing of gas suppliers, gas shippers and public gas transporters, this further opened up the gas industry to competition in Britain (Pearson and Watson, 2012). Despite these measures it was felt that further intervention would be required to achieve full liberalisation of the market (Kopp 2015).

In 1991, a review of the gas market was undertaken by the Office of Fair Trading (OFT), who proposed that British Gas Plc should release some gas it had already contracted to competitors in order to create a third-party supply of gas. Ofgas also supported the findings of the OFT, this resulted in partial adoption by the Government who reduced the volume threshold for competitive supplies from 25,000 therms to 2,500 therms in 1992, increasing the number of available customers to third parties (Kopp 2015).

British Gas Plc provided a counter argument that this action adversely affects its financial strength and also its programme of international expansion. They also put forward the argument that they had been subject to uncoordinated regulation by the Department of Trade and Industry (DTI), the OFT and Ofgas. A series of consultations and discussions were held with Ofgas which led to British Gas Plc referring the whole gas business to the Monopolies, Mergers and Commission (MMC) in July 1992 (Kopp 2015).

The MMC review took a year to complete and concluded that there was a conflict of interest in that British Gas Plc was competing within the gas sale market, whilst simultaneously controlling the gas transportation network. Such a conflict was viewed as making it impossible to provide the necessary conditions for self-sustaining competition. Therefore, the MMC recommended to the government that British Gas plc's trading activities should be placed under separate ownership by 1997 (Kopp 2015).

On the 21st March 1994 British Gas was restructured and the integrated gas business regions were dissolved after 45 years of operation. Transco was created as a business within British gas to transport and store gas.

2.11.3 Fragmentation of the Industry

On the 17th February 1997, British Gas Plc split into two separate companies – Centrica PLC and BG PLC. At the time of the demerger, Centrica PLC was comprised of British Gas Trading, British Gas Services, Energy Centres and the North and South Morecambe gas fields, it retained the right to use the British Gas Brand (Ofgas 1998a). BG PLC contained Transco, which owned and operated the onshore gas transmission, distribution and storage infrastructure, exploration and production, and other operations such as research and technology (Simmonds 2000).

As the monopoly gas transporter in the UK, Transco's network code was the most significant in terms of its impact on the operation of the gas industry. Transco's network code was first introduced in March 1996 and set out the terms of access by shippers, on an open, non-discriminatory basis, to its regulated gas pipeline and storage system (Simmonds 2000, Kopp 2015).

The end of 1998 was introduced as the date by which competition had to be introduced into the domestic gas market. It also opened up the connections and extensions market to competition. The Act provided for the licensing of independent public gas transporters (PGTs) to compete with Transco in extending the gas network, and for the operation of PGTs and unlicensed self-lay installers in the connections market (Ofgas 1999a).

In December 1999 BG PLC undertook corporate restructuring, with BG Plc being renamed BG Group PLC, with two subsidiaries, BG Energy Holdings and BG Transco Holdings. BG Transco Holdings contained BG's UK pipelines business, BG Transco PLC, and other regulated assets in the UK, such as BG's LNG storage facilities. BG Energy Holdings comprised of BG's other major businesses, BG International and BG Storage (Simmonds 2000, Kopp 2015).

A review by the MMC recommended that the gas transportation and storage business of Transco should be regulated through a price control formula with the aim of limiting its overall revenues (Ofgas 1995b, (Martin and Parker, 1997).

Surplus land, primarily from its gas manufacturing operations, was put into a separate business 'British Gas Property', whose role it was to manage, remediate, reuse and sell this land. This operation transferred to BG (BG Property), then to Lattice (Lattice Property) and still exists today as National Grid Property (Walker et al, 1994).

Whilst a small number of gasholders and a few associated gasworks buildings have been listed (see separate section), these represent a small fragment of an industry which in 1958 had employed 142,000 people directly. Of the surviving structures four of the listed gasholders built at the former Imperial Gas Light and Coke Company gasworks at St. Pancras have been dismantled, refurbished and incorporated into a redevelopment at the St. Pancras/Kings Cross site in London. The gasholders have found a new use as a park and a block of three sets of apartments built within the gasholder structures (Figure 2.72). There are plans for some of the other listed gas holders to be incorporated into future developments.

In 1999 Britain became connected to the European Gas Network following the construction of an interconnector linking the gas networks of Belgium (Zeebrugge) and Great Britain (Bacton). This had the effect of linking UK gas prices to those in Europe which were in turn linked to the price of crude oil. Whilst the original intention of the interconnector was to export gas, it also allowed for the importation of gas (Anon. 2007).

Figure 2.72 The Redeveloped Gasholders at the new Kings Cross/St. Pancreas redevelopment. Source R.Thomas.

In October 2000 Lattice Group plc was formed following a demerger from BG Group plc. In October 2002 a 'merger of equals' took place between the Lattice Group and National Grid to form National Grid Transco plc. This was renamed National Grid plc in July 2005 (Kopp 2015).

An additional Interconnector, the Balgzand to Bacton Line (BBL) was constructed to link Great Britain to the Netherlands in 2006.

Interconnectors have been constructed to link Scotland to the Republic of Ireland via the UK-Eire Interconnector and Northern Ireland via the Scotland-Northern Ireland Pipeline (SNIP). The series of Irish and continental interconnectors, LNG Importation facilities and links to the Norwegian gas fields which enter the gas transmission system in Britain, make Britain an important European hub in its gas infrastructure, moving gas to where it is required (Anon. 2007).

2.11.4 Today

Today the Gas industry is split into a high pressure National Gas Transmission System operated by National Grid and four Regional Gas Distribution companies. These four companies own eight distribution networks, four are owned by Cadent, one by Northern Gas Networks, two by SGN and one by Wales & West Utilities. These networks share the boundaries of the twelve regions of the pre-February 1994 integrated gas business. LNG importation facilities exist at the Isle of Grain, Teesport, Grangemouth (Scotland), Millford Haven (Dragon and South Hook, Wales). There are also privately operated below ground gas storage facilities (e.g. Holford), which can store and supply gas as required depending the demand for gas. Gas sales are separate and sold via numerous energy providers. (Anon. 2007).

The last low-pressure gasholders connected to the gas distribution system in England ceased operation in 2015, with diurnal gas storage demands met through line packing in the gas transmission and distribution systems across the country.

Gas lighting still can be found in parts of England with the most numerous examples in the City of London and City of Westminster whose operation and maintenance is overseen by Iain Bell and his team at British Gas. There are also listed and operational gas lamps in the Malverns in Worcestershire and the Park Estate in Nottingham, keeping the tradition of gas lighting going. Examples of gas lights can also be found at the Black Country Living Museum (Figure 2.73), Blists Hill Museum, Beamish Museum, National Gas Museum, Leicester and the Fakenham Museum of gas and local history in Norfolk. A detailed list of surviving features can be found in the Gazetteer (Volume 3).

Figure 2.73 A preserved and operational gas light at the Black Country Museum. Source R.Thomas.

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