Country House Gasworks.

A profile of the sites, the processes undertaken and type of contaminants present.

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Introduction

Gas was manufactured continuously in the UK between 1792, when William Murdock first used coal gas to light his house and office in Redruth and the mid 1970s, when it was replaced by natural gas from the North Sea. One particular aspect of gas manufacture which has often been overlooked was the use of gas in remote country houses. These large properties were often expensive to light using oil lamps and candles, with their owners often keen to have the most up to date technologies used where possible to show their wealth. Coal gas lighting was much cheaper to use than candles or oil lamps and being fixed were relatively safe and actually resulted in lower fire insurance premiums when fitted.

As these sites were remote they were not able to connect to local gas mains and their only option was to build a small gasworks of their own. These small gasworks were very much in line with the philosophy of William Murdoch who proposed the use of small gas plants at individual establishments rather than that of Fredrich Winsor, who proposed the concept of large gasworks with gas distribution mains supplying towns and cities.

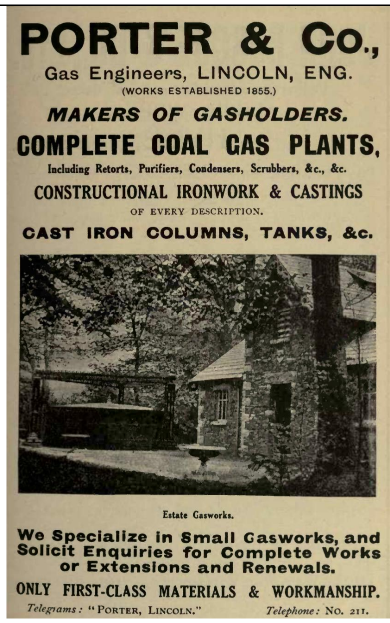
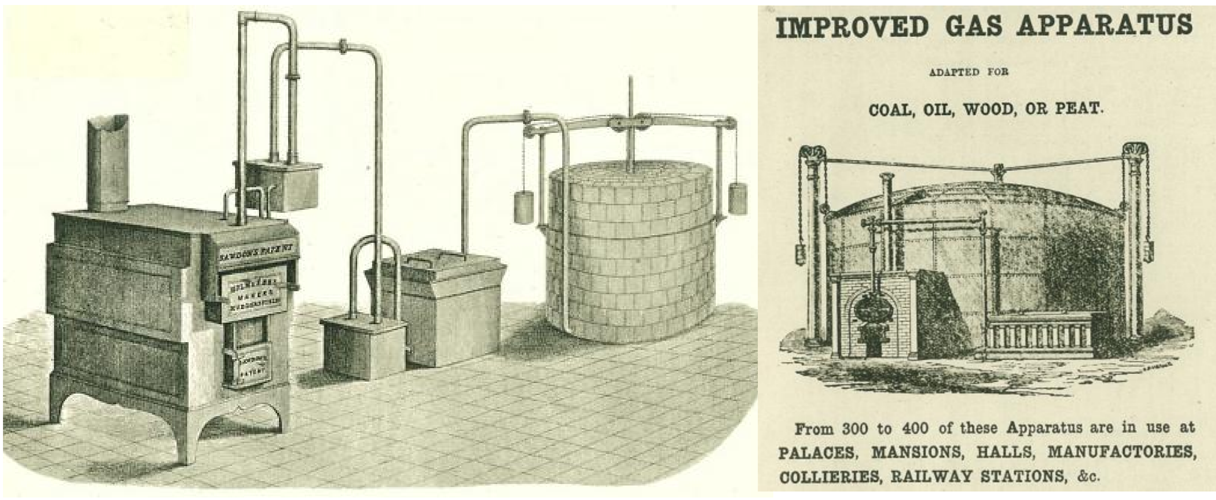


Fig. 1 Porter and Co. Advert from c 1880

The first small gasworks was built by Murdoch at the Soho Factory of messrs Boulton and Watt in Smethwick in 1798 and later works were built at the cotton mills of Henry Lodge in Sowerby Bridge (by Samuel Clegg) and Philips and Lee in Salford (by Murdoch). Many small gasworks were built at mills providing a cheaper, more effective and safer source of lighting, improving working conditions, safety and productivity. Although city and town based gas companies throughout Britain grew rapidly (>50 in 1823, >1000 in 1859), many country estates and houses, were too remote to receive such a supply. For large country houses, asylums or estate villages, the only option was to build a gasworks near the house (e.g. Blenheim Palace, Oxon, Cliveden House, Bucks and Holkham Hall, Norfolk) or within the local village (e.g. Harewood, Yorks., Cragside, Northumberland and Petworth, Sussex). Many isolated asylums had their own private gasworks to ensure sufficient light for safe living and working conditions.

Figure 2.(left) The early Sawdon's Patent Gas Plant and a later gasworks both built by W.C. Holmes.



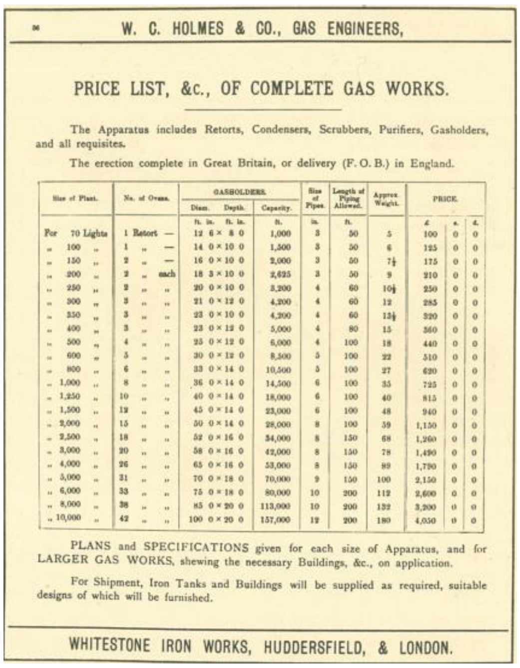
Some early gasworks designed for lighting small country houses such as the "Brook's Water Bottom Gas Producer" and "Sawdon's Patent Gas Plant" (see Figure 2) as built by W.C. Holmes were small units which could be fitted within a building. Later gasworks were larger and generally housed in a "gas house" with the purification plant and gasholder outside. These gasworks were located a reasonable distance from the house as the gas making process produced steam, smoke and unpleasant odours and generally at a point lower than the house, as the gas was lighter than air it would flow up towards the house and gain slight pressure. These small gasworks were manufactured by a wide number of companies, such as W.C. Holmes of Huddersfield, George Bower of St Neots, Edmundson of Dublin and J.T.B. Porter & Co. of Lincoln. The gasworks were sold as complete units by the companies named above and the size of the works were dependent on the number of lights required. Often only the downstairs of the country houses were lit with coal gas, but this regularly included the stable block. The option of lighting the bedrooms or gardens and courtyards was dependent on the owner. Sometimes the owner of a country estate also chose to light the streets or houses of the nearby village, especially if it was part of an estate (usually at a costs to the occupants), which in turn required a larger gasworks. The specification for a range of gasworks supplied by W.C. Holmes can be seen in Figure 3.

The gasworks generally consisted of the following items:

- Retort Bench, (the furnace) generally housing a minimum of three retorts.
- a chimney stack
- Condensers
- Scrubber (sometimes a washer on large plant)
- Purifier
- Tar well
- Gasholder

The retort bench was housed along with the purifiers within the retort house, also known as the gas house. These buildings varied in design depending on the size and manufacturer of the gasworks. The gas works built by J.T.B. Porter & Co at Holkham Hall had a 40 ft. x 20 ft single story building which consisted of three-rooms and a chimney. A coal store was located in the eastern room, the retorts were located next to the chimney in the central room, and lime purifiers and lime store in the western room of the building.

Figure 3. Price list for WC Holmes Gasworks



W. C. HOLMES & CO., GAS ENGINEERS,

PRICE LIST, &c., OF COMPLETE GAS WORKS.

The Apparatus includes Retorts, Condensers, Scrubbers, Purifiers, Gasholders, and all requisites.

The erection complete in Great Britain, or delivery (F. O. B.) in England.

Size of Plant.	No. of Ovens.	Gasholders. Diam.	Gasholders. Depth.	Gasholders. Capacity.	Size of Pipes.	Length of Piping Allowed.	Approx. Weight.	Price. £	s.	d.
		ft. in.	ft. in.	ft.	in.	ft.		£	s.	d.
For 70 Lights	1 Retort —	12 6	× 8 0	1,000	3	50	5	100	0	0
" 100 "	1 " —	14 0	× 10 0	1,500	3	50	6	125	0	0
" 150 "	2 " —	16 0	× 10 0	2,000	3	50	7½	175	0	0
" 200 "	2 " each	18 3	× 10 0	2,625	3	50	9	210	0	0
" 250 "	2 " "	20 0	× 10 0	3,200	4	60	10½	250	0	0
" 300 "	3 " "	21 0	× 12 0	4,200	4	60	12	285	0	0
" 350 "	3 " "	23 0	× 10 0	4,200	4	60	13½	320	0	0
" 400 "	3 " "	23 0	× 12 0	5,000	4	80	15	360	0	0
" 500 "	4 " "	25 0	× 12 0	6,000	4	100	18	440	0	0
" 600 "	5 " "	30 0	× 12 0	8,500	5	100	22	510	0	0
" 800 "	6 " "	33 0	× 14 0	10,500	5	100	27	620	0	0
" 1,000 "	8 " "	36 0	× 14 0	14,500	6	100	35	725	0	0
" 1,250 "	10 " "	40 0	× 14 0	18,000	6	100	40	815	0	0
" 1,500 "	12 " "	45 0	× 14 0	23,000	6	100	48	940	0	0
" 2,000 "	15 " "	50 0	× 14 0	28,000	8	100	59	1,150	0	0
" 2,500 "	18 " "	52 0	× 16 0	34,000	8	150	68	1,260	0	0
" 3,000 "	20 " "	58 0	× 16 0	42,000	8	150	78	1,490	0	0
" 4,000 "	26 " "	65 0	× 16 0	53,000	8	150	89	1,790	0	0
" 5,000 "	31 " "	70 0	× 18 0	70,000	9	150	100	2,150	0	0
" 6,000 "	33 " "	75 0	× 18 0	80,000	10	200	112	2,600	0	0
" 8,000 "	38 " "	85 0	× 20 0	113,000	10	200	132	3,200	0	0
" 10,000 "	42 " "	100 0	× 20 0	157,000	12	200	180	4,050	0	0

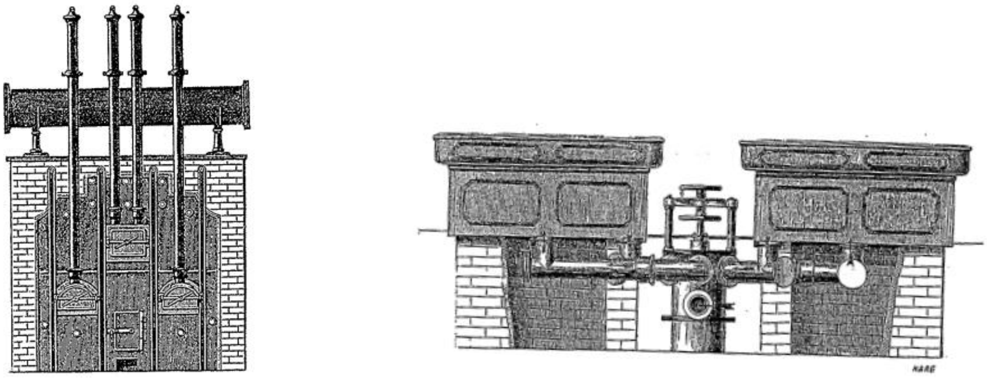
PLANS and SPECIFICATIONS given for each size of Apparatus, and for LARGER GAS WORKS, shewing the necessary Buildings, &c., on application.

For Shipment, Iron Tanks and Buildings will be supplied as required, suitable designs of which will be furnished.

WHITESTONE IRON WORKS, HUDDERSFIELD, & LONDON.

The gasholder was located in the yard outside the gashouse, it was 23 ft in diameter and had a 10 ft lift, giving a capacity of approximately 30,000 cubic feet of gas. One hundred and sixty seven gas lights were lit by the Holkham hall gasworks, but it was able to be extended to 300 lights. An estate gasworks built by George Bower in the Midlands was 60ft x 26.8 ft with a central main building housing the retort and two wings containing the coal store and lime purifier.

Figure 4. Examples of gas plant built by George Bower of St. Neots, including: a retort bench with three retorts and one furnace bench (left) and a Lime Purifier (right).



Examples of gas plant built by George Bower of St. Neots can be seen in Figure 4 and the general layout of a small country house gasworks by W.C. Holmes can be seen in Figure 5. The coal tar and ammoniacal liquor recovered from the hydraulic main (above the retorts), condensers and scrubbers would be stored in a tar well located outside the retort house but close to the condenser and retort setting (see Figure 5). Gas was generally made during the day and the gasholder filled with sufficient capacity to maintain the lighting for two to three days, before gas was required to be made again. The labour requirements for a small country house gasworks were not great, one man could look after a small installation, often this task would be included with others roles. The development of gas mantles by Carl Auer, Baron von Welsbach, became available in the 1890s and considerably improved illumination by gas lighting as much as ten times for the same volume of gas used by an open flame.
Although most buildings associated with these small former gasworks have since been demolished, a few still remain adapted for modern use, such as the retort house at Holkham Hall (Now a Garden shed) and Culzean Castle retort house (Now a Museum Exhibit) there are also a few now known to be occupied as residential properties, but for obvious reasons these will not be named here.

The Operation of a Country House Gasworks

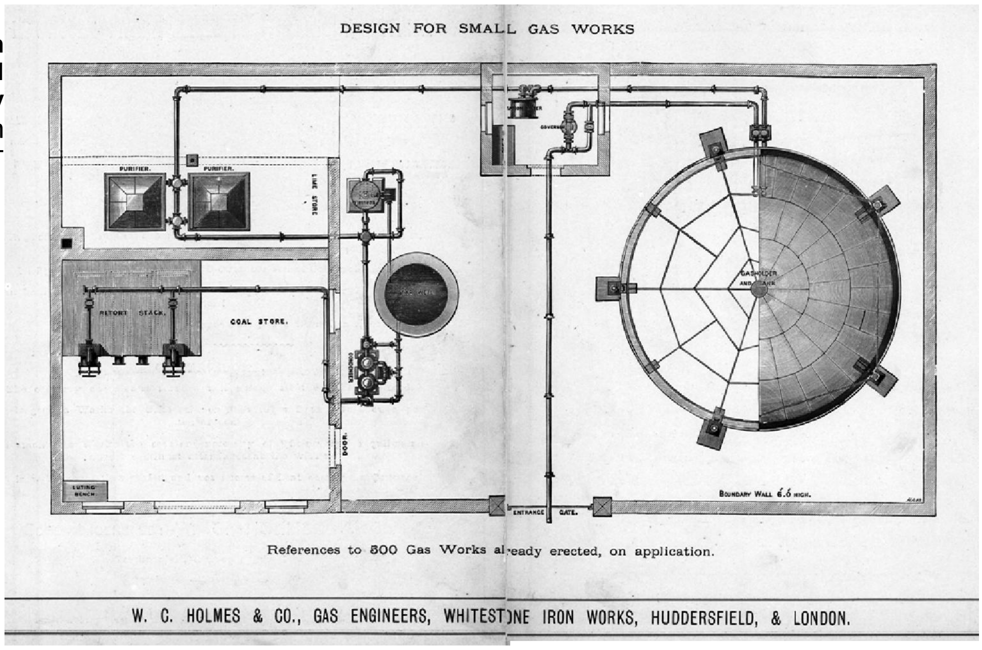


Figure 5. A design for a small gasworks built by W.C Holmes. Plan courtesy HGT archive'

The Retort House

The gasification of coal was a relatively simple process; it was carried out by heating coal in an oxygen-free environment to a temperature of about 1100ºC. This was carried out in a vessel called a ‘Retort’, which was heated by burning coke beneath the base of the retort in a furnace. Instead of combusting as coal would in an oxygen-rich environment, the volatile components were driven off, leaving coke as residue which was then used as fuel for the furnace. Waste ash and clinker was left in the furnace, this had to be removed and disposed of. Horizontal retorts were only ever found on these small gasworks, but there were many different types of retort systems developed for large town gasworks such as inclined or vertical retorts, which enabled continuous operation.

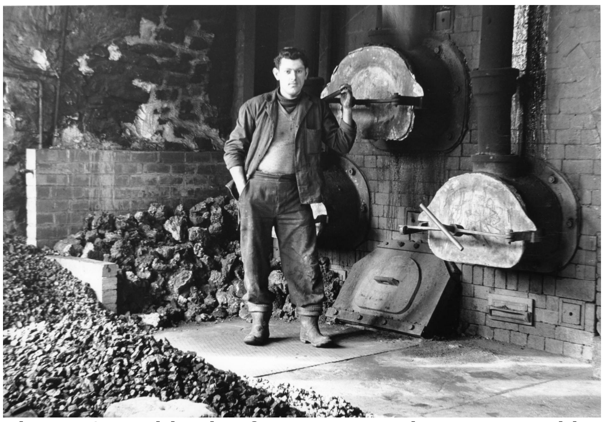


Figure 6. Inside the former retort house at Robin Hoods Bay gasworks, Yorkshire. The stoker is stood in front of the retort bench, showing the entrance to the retorts and furnace (ground level) and piles of coal and coke. Photograph courtesy HGT archive'

In a country house gasworks one person would be responsible for the operation of the gasworks, where as in larger gasworks the retort house was controlled by the team of stokers under the guidance of the engineer. The coal was heated until all the volatile components were driven off, leaving the coke as residue. (about 8 hours). The retorts were horizontal D-shaped (See figure 7, approx 10ft long) closed at one end with an iron door and ascension pipe at the other. Originally retorts were made of cast iron but evolved through fireclay to be made of Silica.

The gas containing the volatile components passed vertically out of the retort through the ascension pipe into the hydraulic main, a tank half filled with tar and water, which acted as a trap or seal and a primary condenser. A secondary condenser was located outside. Water vapour/ammonia and tars were removed in both these vessels. The gas was then processed through a variety of pieces of plant described in the following sections, leading to the separation of different components of the gas. After 8 hours the remaining hot coke was removed from the retorts and quenched with water and deposited in the yard to cool or directly into the furnace, before being added to the coke pile. Over a period of weeks, a residue of pure carbon was also deposited on the inside surface of the fireclay retorts- called scurf. This was burnt off by leaving the discharge door open over a day or so. 'Scurf' Was a form of almost pure carbon and lumps were sometimes removed from the retort and sold off.

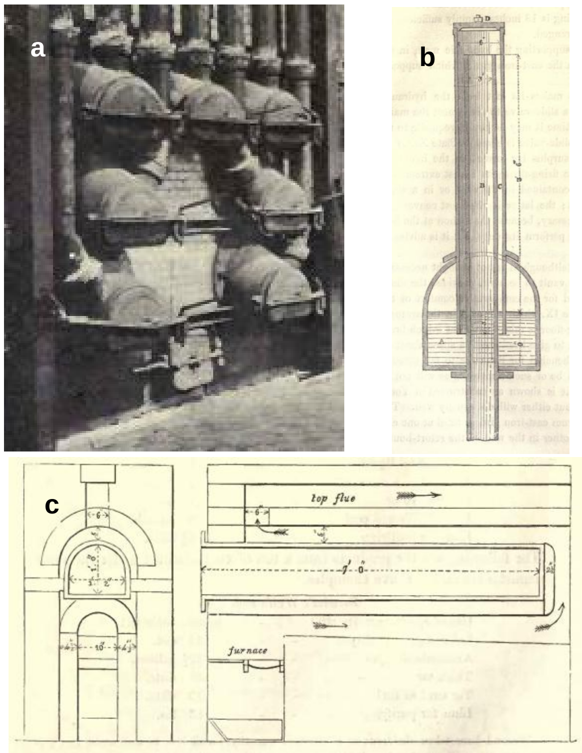


Figure 7a) a set of horizontal retorts, and b) design of a hydraulic main and c) early retort (b & c after Clegg 1841).

Potential Waste/By-products associated with the process.

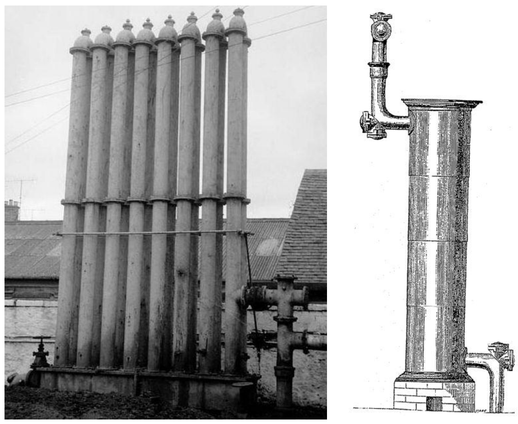
- Coal Tar
- Ash
- Coal Dust

The Condensers

The role of the condenser was to cool the gas and remove a majority of the tar not removed by the hydraulic main. Condensers came in a range of designs (Figures 5 and 8), the more typical design used a series of connected iron tubes (of approximately 6 inch diameter) in the open air, through which the gas passed. As the gas cooled the coal tar and ammoniacal liquor condensed out and drained into an underground tank (tar tank, See Figure 5).

Other methods also existed. These included the annular condenser (right b)), which were supplied as either one or a set of connected cylindrical towers, being formed, as its name implies, from two concentric cylinders. The inner one being open to the atmosphere, the gas passes between the annular space between the two cylinders and is spread over the surface of the condenser in a thin layer. Another method used long iron pipes set in a shallow water filled brick trench, these were used as early as the 1830's by the Neath Abbey Iron Works and even were used much later on the large South Metropolitan Gas Company works at Old Kent Road.

Figure 8. Examples of: a) condensers, atmospheric (left) and an b) annular condenser as designed by George Bower (right).



Potential Waste/By-products associated with the process.

- Coal Tar
- Ammoniacal liquor.

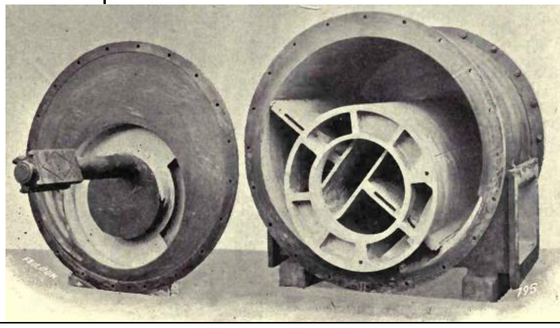
The Exhausters

Small country houses generally did not have exhausters, larger estate gasworks may have had them. The exhausters (a form of gas or steam driven pump) kept the gas moving from the retorts to the gasholders and were lubricated by the creosote in the gas. Due to the variation in the quality of the gas during the gasification of the coal (highest at the start and lowest at the end) then the exhauster was required to draw the gas at different rates to ensure the gas remained at the accepted standard.

Figure 9. Exhauster with end plate removed and placed alongside to show internal arrangement.

Potential Waste/By-products associated with the process.

- No specific waste associated with process.



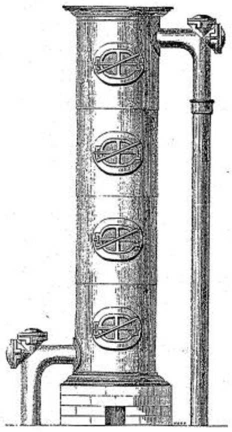
The Scrubbers

Ammonia and phenol were removed from the gas by scrubbers, these came in many designs but the most popular were tall cast iron towers filled with coke (Fig. 10), bricks, wooden boards or ceramic rings. As the gas flowed slowly up the scrubber it met a spray of cooled water passing down the scrubber, which absorbed the ammonia and then drained into the tar well, where it would float on top of the tar. Larger estate gasworks may have also included a washer, which had a similar function.

Potential Waste/By-products associated with the process.

- Coal Tar
- Ammoniacal Liquor

Figure 10. A Coke Scrubber as built by George Bower of St. Neots.



Tar Tanks/wells

Tar and liquor were stored together in underground tanks or wells as shown in figures 5 and 11. These tanks which were either made from cast iron plates bolted together or brick built circular or square tanks, lined with puddle clay, and were gravity fed by tar and liquor from the hydraulic main, condensers, and scrubbers. They had a wooden cover to prevent debris (or the occasional animal or person) falling into them. The tar was invaluable as a preservative and used to protect things such as wooden fences, the ammoniacal liquor was promoted as a very effective fertiliser especially when diluted. Occasionally when the tank was too full of solid tar residues and pitch they would have to be dug out by hand. Tar wells on larger gasworks were generally more complex and tar was also stored in above ground tanks where it could be transferred to tankers for refining elsewhere, this was unlikely to have been economical on these small gasworks. However, it was a valuable by-product.

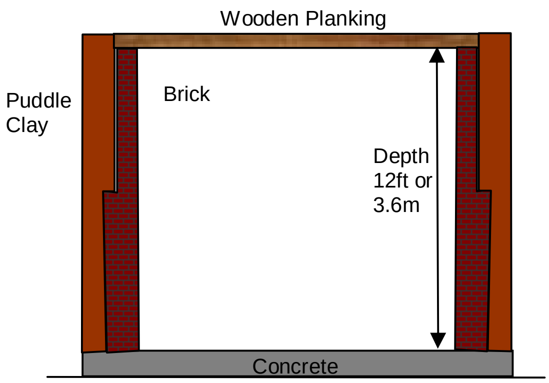


Figure 11. A cross section of a circular tar well which may be found on a small gasworks

Potential Waste/By-products associated with the process.

- Coal Tar/ Pitch residues
- Ammoniacal Liquor
- Coal Dust

The Purifiers

After the removal of the coal tar and ammonia, hydrogen sulphide and hydrogen cyanide had to be removed. The gas was generally purified in iron boxes containing slaked lime (Figures 4, 5 and 12). This produced a waste called foul lime, a rock solid waste of greenish white and high pH. This would be the predominant method used on these country house gasworks. The foul lime process was superseded on some sites by the use of bog iron ore. This precipitated the hydrogen sulphide and hydrogen cyanide on the iron ore as iron ferricyanide and iron sulphide. The bog ore was in layers, placed on wooden grids in iron boxes (purifiers) and the gas passed through in series. When the boxes became saturated they were removed from the circuit, opened and the layers of material dug out. The used material was dug out of the boxes and layed out in the yards and the action of the air, revivified it allowing it to be used again. After multiple uses the bog ore became saturated and was known as "spent oxide" and where practicable was sold off to make sulphuric acid.

Potential Waste/By-products associated with the process.

- Foul Lime
- Spent Oxide

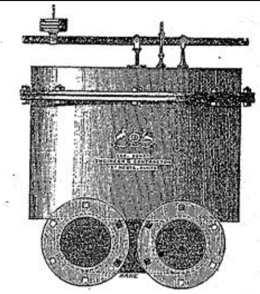
Figure 12. Spent oxide (right) and purifiers at Fakenham Gas Museum (below).

The Station Meter and Governor

The Station Meter was generally housed within its own building or along with the Station Governor. The meter was a cast iron drum of about 4ft in diameter and 5ft long and half filled with water. Inside was a drum of tin which was divided into compartments from which the flow of gas displaced water making the drum rotate. The rotation of the drum was counted allowing the meter to be interpreted.

A station governor was included to maintain a constant pressure of the gas coming from the holder.

Figure 13. A Station Governor - design by George Bower.



Potential Waste/By-products associated with the process.

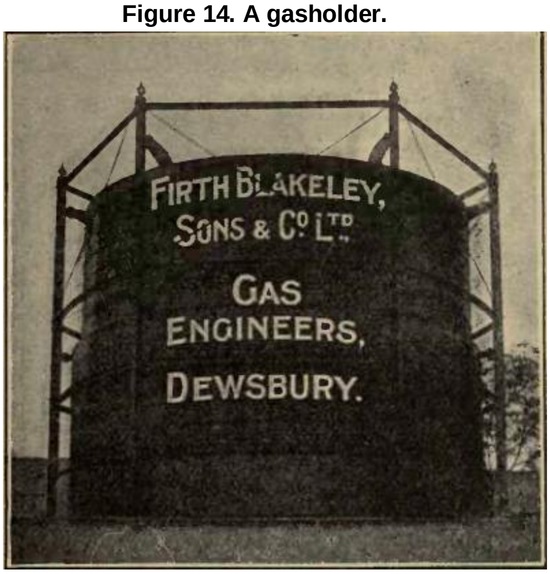
- No specific waste associated with process.

The Gas Holders

The purified and metered gas was stored in a gasholder, the large circular objects associated with gasworks. The weight of the tank pushing on the gas provided the pressure in the gas mains to distribute gas around the local distribution system. Until the development of spirally guided gasholders in 1888 all gas holders required the construction of an underground tank. The first holders were of single lift construction, column guided with a water filled brick tank, made water tight with puddle clay. Early gasholders and those at country house works were only single lift. The gasholders generally held up to 24 to 36 hours supply of gas.

The gas was then distributed to the local supply network through the Station Governor and had a quality of about between 450 and 500 British Thermal Units cu. ft (Natural gas is about 1000 BTh U per cu. ft).and a general composition of the

Figure 14. A gasholder.



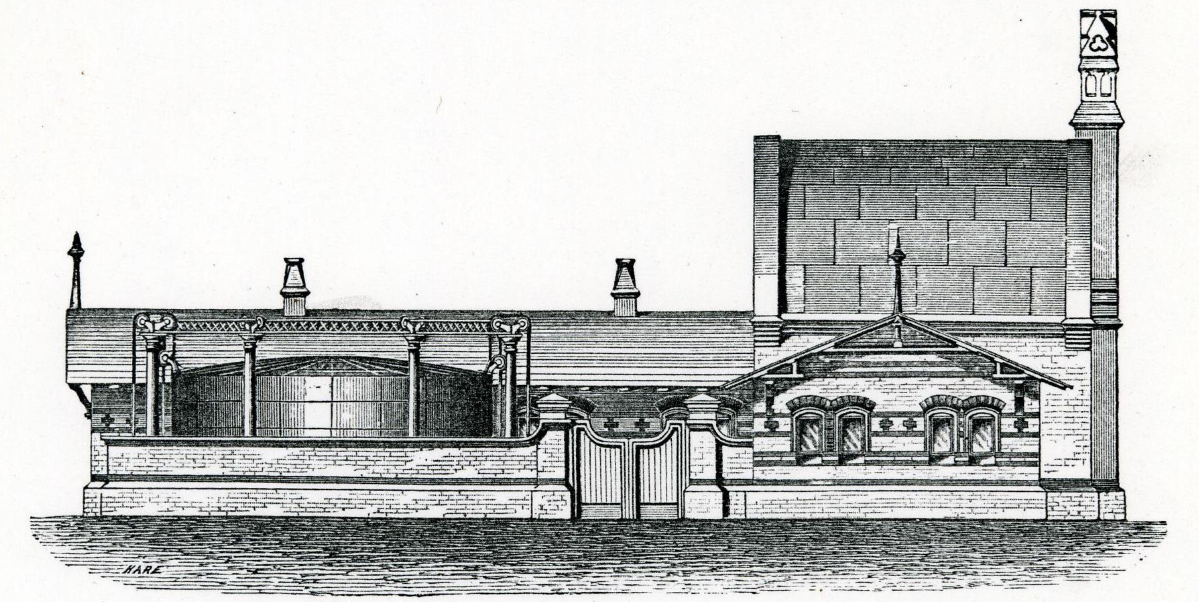
gas is shown below

- Hydrogen 52%
- Hydrocarbons predominantly methane 34%
- Carbon monoxide 8%
- Oxygen (1%), carbon dioxide (2%) & nitrogen (4%) 7%.

Potential Waste/By-products associated with the plant.

- Contaminated water
- Light oils
- Lead paint

Figure 15. A drawing of a small country house gasworks as designed by WC Holmes.
Figure courtesy HGT archive'



<u>**The Composition of the Products/Wastes Produced During the Gasification Process**</u>

A number of products/wastes from the gasification process are mentioned above, the composition of these are discussed in more detail below:

Coal tars.

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

In terms of elemental composition, coal tar is approximately 86% Carbon, 6.2% Hydrogen, 1.8% Nitrogen, 1% sulphur with the remaining 5% being composed of oxygen and ash. In terms of the types of compounds present, the composition is given below.

Saturates 15%
Aromatics 37%
Resins 42%
Asphaltenes 5%
The most predominant fraction of coal tar is medium pitch a solid at room temperature (approximately 67%), this material is relatively inert. The US EPA 16 Polycyclic Aromatic Hydrocarbons compose approximately 17% of the coal tar. There is also entrained free carbon within the tar (up to 22%).

The Main Contaminants of Concern are

- Polycyclic aromatic hydrocarbons (PAH),
- Phenolic compounds (e.g. Phenol, cresol, xylenol etc),
- Benzene, Toluene, Ethyl Benzene and Xylene (BTEX) compounds,
- Aromatic and aliphatic Petroleum hydrocarbons.
- Ammonia, Styrene, Carbazole and Dibenzofuran, also present.

As mentioned above a majority of coal tar is inert medium pitch, so it should be remembered that these CoC's do not form a majority of the composition of coal tar.

Coal Tar may be found in the ground around buildings, condensers, scrubbers/washers, tar wells/tanks and the pipes connecting the aforementioned. Coal tar may also be found in the base of tar tanks and gas holders. Coal Tars are predominantly Dense Non Aqueous Phase Liquids (DNAPLS), although Light Non Aqueous Phase Liquids were also produced.

Ammoniacal Liquors

Ammoniacal liquors were formed both in the hydraulic main also produced by spraying the gas with water in the scrubber. This dissolved the soluble ammonia and phenolic compounds in water. The ammoniacal liquor consisted of up to 1% ammonium and a much lower concentration of phenol, ferrocyanide and thiocyanate.

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

Foul Lime Spent Oxide

Sulphur and cyanide compounds were precipitated originally by precipitation with lime within a metal box called a purifier. Both wet and dry lime processes were used and the lime was used until saturated with sulphur, this was material was termed "foul" or "spent" lime. It was usually left to weather by exposure to the atmosphere for a long period after which it could be used as a valuable fertiliser. Later developments gave rise to the introduction of purification by iron ore. Similarly to lime the iron ore removed the hydrogen sulphide and hydrogen cyanide from the gas precipitating it as iron sulphide and iron ferricyanide. The lime or bog ore would be laid on oak grids inside the boxes in layers 12 inch to 18 inch deep, sometimes with lime mixed in with the oxide. On the large estate gasworks it is possible that if the oxide could be 'worked-up' to contain about 50% sulphur, after revivification and two or three exposures, it was then possible to sell it off to make sulphuric acid, otherwise it was a waste that required disposal.. The cyanide present in spent oxide forms up to 6% of the total weight and is predominantly in the form of thiocyanate and complex metal cyanides. Spent oxide also consists of about 3-9% iron, 0.08-0.36% manganese, 2-3% sulphate and 36-60% free sulphur. Unlike the foul lime, spent oxide was often used as a weed killer.

Foul Lime and Spent Oxide may be found in the ground near the purifiers and land used to revivifying the spent material. They may also be found anywhere that ground levels have been made up. Its' presence may be detected by blue staining on walls and paving and the presence of stunted growth in vegetation.

Ash/coal Dust

Ash was the waste material remaining after the burning of the coal or coke in the furnace; it contained heavy metals (e.g. As, Pb, Cu, Cd, Ni, Zn) though generally only at low concentrations. Ashes were often used for raising ground levels or for use on cinder paths. Coal dust although not a significant contaminant from a gasworks would have elevated concentrations of PAH including Benzo(a)pyrene.

Ash/Coal Dust may be found in the ground around the retort house/coal store and could be found anywhere that ground levels have been made up.

Coke

Coke was the useful solid remaining after gasification; it is a pure form of carbon. It was used for burning in fires for heating in domestic properties. Hard coke was produced in horizontal retorts and was most suitable for use on blacksmith's hearths and enclosed stoves.

The Fate of Country House gasworks	

There were a large number of Country House gasworks by the late 1800s, after which they were gradually replaced by being connected to the local gas mains or by installing alternative gas making apparatus, such as acetylene, petrol gas or by switching to electricity. The capital costs of Acetylene or air-petro gas plants were considerably cheaper and took up less space and as a result could be located within or close to the main buildings.

The petrol gas systems made gas by mixing air with petrol, which had been vaporised on a heated surface, this was then transferred to a small gasholder which provided the necessary pressure to distribute the to the lights. As other suitable fuels became available they were also used in these types of gas generation systems.

Acetylene gas systems made acetylene gas by dripping water on to calcium carbide. The simple process did not require any means of gas purification, however a major drawback with acetylene is its' very low flashpoint and ability to explode violently, making gas leaks very problematic.

These new gas producing systems became preferable to owners of country houses unable to obtain their own mains gas supply, as a result coal gasworks were gradually phased out.
The new systems although less polluting than coal gas still had the potential to pollute especially through leaks from the fuel tanks or pipes.

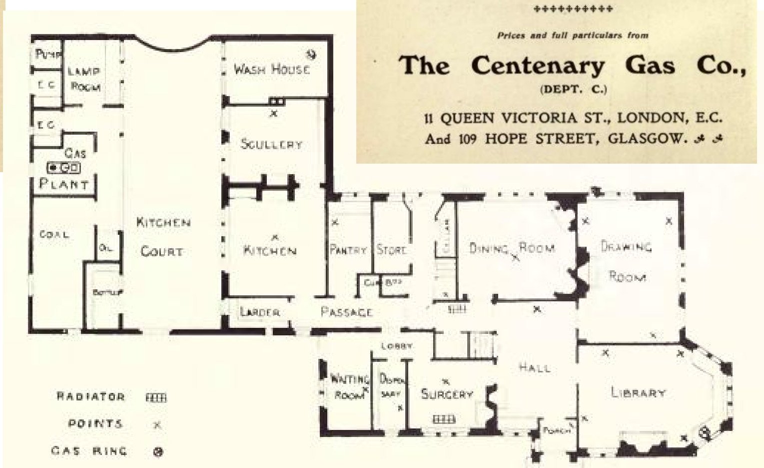


Figure 16. A proposed plan of a country house showing the location of the gas plant and associate equipment (top) and adverts for alternative gas systems for a country houses (bottom).

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