

# Producer Gas Plants.

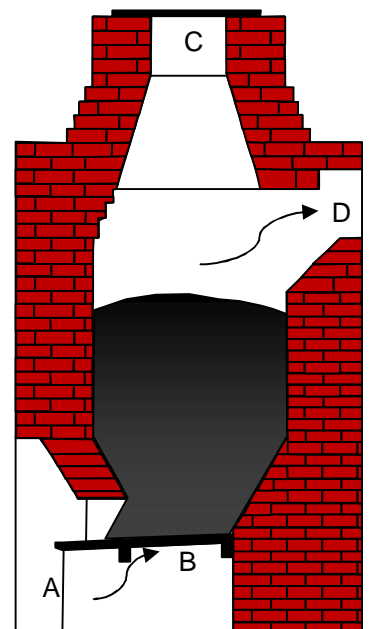
A profile of the sites, the processes undertaken and type of contaminants present.

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## Introduction

William Murdock used coal gas to light his house and office in Redruth in 1792; this was the first commercial application of gas in the world. Gas has been used ever since for commercial, industrial and domestic applications. Gas was first produced from coal and later on from oil until its replacement by natural gas in the mid 1970s. The conventional production of gas from coal is well documented; however, there was also another method of gas production which is less well known, this was called "producer gas".

Producer gas plants started to become popular in the early 1880 and were in extensive use by 1910. As producer gas plants evolved from the first plant built by Bischof (figure 1) through to their demise in competition in the mid 20<sup>th</sup> century, many varied types evolved. Following Bischof's early development of the gas producer the next major development was that of Fredrick Siemens who developed a combined gas producer and regenerative furnace in 1857. This system was gradually improved and introduced to the UK through William Siemens. Producer gas plants provided a great benefit to those industries requiring high and uniform temperatures. This greatly aided those industrial processes which were unable or found it very difficult to use directly fired solid fuel furnaces, it also saved fuel as the gas could be burnt at the exact point required.



**Fig. 1. Bischof Gas Producer.** Air is drawn in (A) through the fire bars (B) and fuel, existing via the vent (D), fuel enters the producer via C.

## Scenarios where producer Gas Plant were likely to have been used.

Gas producers were employed in many and varied industrial, commercial and domestic settings from 1880 to the mid 20<sup>th</sup> Century.

Gas producers in industrial setting were likely to be found in:

1. Gasworks, as the method of producing gas process or just to heat the retorts;
2. Steel works;
3. Ore roasting plants;
4. Power Stations;
5. Factories and Mills;
6. Glass Works;
7. Potteries and Kilns;
8. Muffle furnaces; and
9. Chemical works (Mond Process).

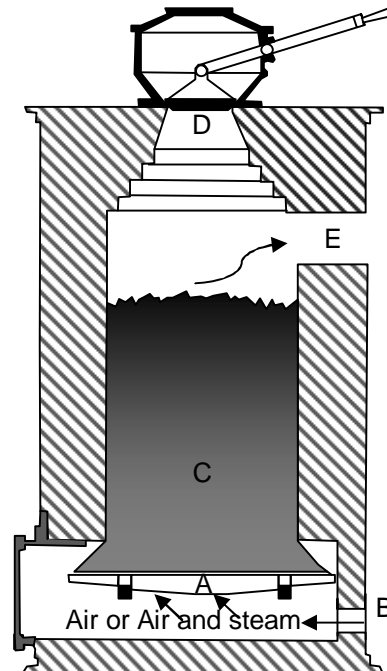
Gas Producers in commercial or domestic setting would be found in:

1. Associated with country houses or estates to power gas engines for generator and to directly drive plant such as saw mills; and
2. Large schools, hospitals or other public institutions to power gas engines for generators and to directly drive plant.

For industrial applications such as furnaces the gas was not cooled or cleaned as per a conventional gasworks of the time. Where gas was used on a smaller scale or for more sensitive purposes it had to be specially treated after production and prior to use. A simple drawing of a gas producer working using just air or air and steam is shown in Figure 2. In this figure A represents the fire bars or grate, B is the air inlet, C is the column of fuel, D is a hopper with close-fitting valve through which the fuel is introduced, and E is the gas outlet.

The next major advance in the application of gas producers came in 1878 when Dowson developed the Dowson complete gas plant. This plant could be used both industrially and domestically. Dowson went on to demonstrate the effectiveness of gas engines (developed by Otto circa 1876) when in 1881 he combined one of his producer gas plants with a 3 Horse Power (H.P) Otto gas engine. Whilst these early gas engines were only a maximum of 20 H.P, gas engines by 1910 had reached 2000 H.P.

Circa 1900 suction gas plants and engines were introduced, these plants were able to make more effective use of the lower quality producer gas and became a popular system in their own right.



**Fig. 2 Gas Producer working with air or air and steam.**

### Principals of Producer Gas

Producer gas manufacture varied from traditional gas production through the way and conditions the gas was made. A traditional gasworks would manufacture gas by heating coal in an oxygen free retort indirectly through a separate furnace located beneath the retort. In simplistic terms a producer gas plant made gas by forcing or drawing air, with or without the addition of steam or water-vapour, through a deep bed of fuel in a closed producer vessel.

The fuel was gradually consumed during the process and the gas made piped to where it was required. An important characteristic of the producer gas process was that no external heat was applied to the producer; the producer was heated by the combustion within the producer itself. Once the burning of the fuel inside the producer had started, the air supplied to the producer allowed a continuous process of combustion, and a sufficiently high temperature was maintained to decompose the steam and enable other necessary reactions.

Producer gas was a mixture in varying proportions of carbon monoxide, hydrogen, gaseous hydrocarbons (chiefly methane), carbon dioxide, and nitrogen. The carbon monoxide, hydrogen, gaseous hydrocarbons were combustible (40-45% of the gas composition), and the calorific value of the gas was dependent on the relative proportions in which they were present; the carbon dioxide and nitrogen were diluents which lowered the flame temperature of the combustible gases when burnt.

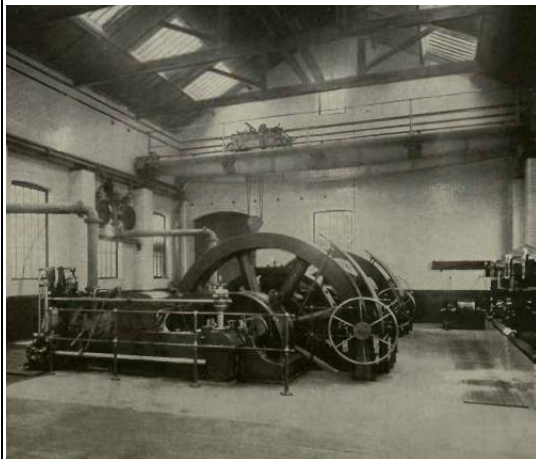
Producer gas varied depending on its use, where it was used in furnaces the producer was operated so that its carbon monoxide content was maximised and the hydrogen content was less than 14%.

**Fig 3. Advert for a Gas Producer**

150 B.H.P. SUCTION GAS PLANT FOR ANTHRACITE.  
Provided with Duplicate Producer.

**"CAMPBELL"**  
**Suction Gas Plants**  
FOR ANTHRACITE, COKE, CHARCOAL, Etc.

**THE CAMPBELL GAS ENGINE CO., Ltd.,**  
HALIFAX, ENGLAND.  
LONDON: 114, Tooley Street, S.E. GLASGOW: 104, Bath Street.



**Fig 4. Two 250 H.P. Premier gas engines**

Where it was used for gas engines the gas composition was not as important but it had to be cleaned of impurities, in particular ammonia and tarry residues. The gas was cleaned with the use of a scrubber. Producer gas could be obtained from almost any carbonaceous fuel. The type of fuel used depended, not only on the purpose for which the gas is to be used, but on its cost and the ease with which each fuel could be purchased locally. Producer gas was predominantly made from anthracite or coke especially where the gas use was sensitive. Where the end use of the gas was not sensitive, bituminous or semi-bituminous coal could be used and in some circumstances it was also possible to use brown coal, lignite, peat or charcoal. The composition of the gas was largely influenced by the nature of the fuel used as a feedstock.

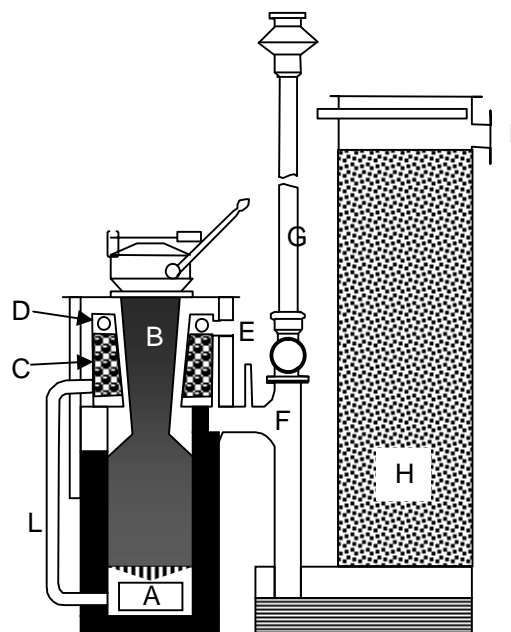
The skill to effectively operating a producer was to ensure that the fuel was neither too shallow or the air supply too great as to allow complete combustion of the fuel to carbon dioxide, as carbon dioxide has no calorific value as the carbon is fully oxidised. The producer gas process aimed at the incomplete combustion of carbon so that carbon monoxide was produced instead.

This was achieved through two main processes: i) the complete combustion of carbon at the base of the producer leading to carbon dioxide generation which then reacted with carbon further up the fuel pile to form carbon monoxide; and the direct effect of heating the carbon in the producer under oxygen limited conditions generating carbon monoxide gas.

Hydrogen could also be generated in the process through the addition of water preferably as steam to the process. When steam ( $H_2O$ ) interacts with carbon at a high temperature it is decomposed and an equal volume of hydrogen is produced. The oxygen released from the reaction of the steam could, dependent on the conditions combine with carbon to form carbon monoxide or carbon dioxide. Similarly to coal gas producer in a retort, complex hydrocarbons within coal would decompose within the producer leading to the generation of gaseous hydrocarbons within the producer gas. Where coke or anthracite were used very little volatile hydrocarbon would be generated in the gas as these feedstock were largely devoid of such components.

### Suction Gas

Early gas producers operated using the suction of gas through the fuel, however, this was later disregarded in preference to pressurised gas injection. Developments in the 1860's gradually lead to the construction of effective suction gas plants namely based on the design of Dowson (Figure 5). These were very effectively employed in combination with gas engines optimised for suction gas producers. The operation of the system can be explained in Fig. 5, where A was the grate on which the fuel was placed; B was the container holding the store of fuel, which entered through the hopper and valve at the top; C was a circular chamber filled with broken firebrick; D was a circular pipe which sprayed water into the system; E was the air inlet, and F the gas outlet, G was the chimney; H was the scrubber with water-seal at the bottom; and I was the gas outlet.

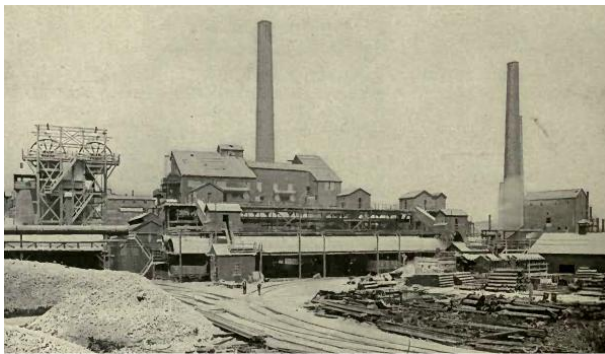


**Fig. 5. A Suction Gas plant of the Dowson Design.**

To start the producers some oil waste and wood were placed on the grate and the producer was filled with anthracite or coke in small pieces. The feeding hopper was closed and the fire then lighted. The fan (not shown in Fig 5) was set in motion, and the exiting gases from the producer were initially allowed to escape through the chimney. Once combustion was effective the water-supply would be turned on and as soon the gas produced was burning effectively it was connected to the gas engine. The engine would be started and the fan stopped. From this time the engine itself would suck the air required into the producer. Before entering the engine the gases passed into the coke scrubber, where they ascended through a column of coke, kept wet by a suitably arranged sprinkler. The role of the scrubber was to purify the gas, removing ammonia and tarry residues in particular. The gases then passed along the pipe main, and into an expansion box, which was in direct communication with the engine cylinder.

### **Mond Gas**

The first plant designed for the simultaneous conversion into combustible gas of bituminous small coal (slack) and the simultaneous recovery of ammonium sulphate was the Mond gas system. This was producer gas plant developed by Dr. Ludwig Mond, with the first plant put into operation at the Brunner, Mond & Co.'s Works at Northwich, Cheshire. The Mond gas producer was designed to produce gas which was hydrogen rich and carbon monoxide poor, which did not make it suitable for furnace work. Mond Gas plants required a massive capital outlay in order for them to be profitable, they had to use over 180 tons of coal per week for the ammonia recovery to be profitable, however they did later evolve to use more cost effective plant from the iron/steel industry for washing and scrubbing the gas.



**Fig. 6. The Mond Gas Plant at the Brunner and Mond works, Northwich, Cheshire.**

In the Mond plant a low working temperature (250°C) was used to enable ammonia to be obtained from the nitrogen entrained in the bituminous coal. The efficiency of the Mond plant was as high as 80 per cent, but in order to achieve this a large excess of steam was required so that the small proportion of it which was decomposed (about one third) was sufficient to absorb the heat evolved in the formation of carbon dioxide and carbon monoxide from air and carbon. A large plant was required to condense the undecomposed steam in the gas, and use a far as practical the heat by means of a heat exchanger to generate further steam for the producer.

The hydrocarbon rich vapours given off by the distillation of the bituminous coal in the upper part of the producer were partially converted into fixed gases before they entered the system of mechanical washers, acid tower, gas cooling tower and air saturation tower where they were removed. Each of these separate pieces of plant drained the tarry liquor into separate settling tanks. The tar being removed and processed elsewhere.

### **Contaminants Associated with Producer Gas Plants**

Producer gas plants were not as contaminating as traditional gasworks which used retorts to produce gas. This was primarily because the feedstock fuel used within a producer was predominantly either coke or anthracite (a coal with a low concentration of volatile hydrocarbons). In some circumstances however, other feedstock were used which would have a higher concentration of volatile hydrocarbons such as coal. The Mond Gas process also generated additional contaminants which were not associated with the other processes, these included sulphuric acid and lead.

#### ***Ash/coal Dust***

Ash was the waste material remaining after the burning of the coal or coke in the producer; it contained heavy metals (e.g. As, Pb, Cu, Cd, Ni, Zn) though generally only at low concentrations. Ashes were often used for raising ground levels or for use on cinder paths.

### **Ammonia rich liquors**

Ammonia rich liquors were formed in the scrubber, acid tower by spraying the gas with water or a weak sulphuric acid solution. 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 may also be present.

Ammoniacal liquors may be found in the ground around scrubbers, washers and settling tanks and the pipes connecting the aforementioned.

### **Coal tars.**

Significant concentrations of coal tars were generally not produced by producer gas plants, however those plants designed to be operated using bituminous coal (Mond gas) did produce coal tars. The exact composition of coal tar produced was dependent on many factors the most important being the type of gas producer being operated and type of coal or other fuel 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 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.

### **Lead**

Lead was used to line the acid towers of the Mond gas plant. Lead may be found associated with the site of the former scrubbers on Mond gas plants.

### **Sulphuric Acid**

Sulphuric acid was used within the acid towers in the Mond gas process to remove ammonia from the gas.

### **Case Studies**

#### ***Small Scale Gas Producer Plants - Canwell Estate***

Canwell was typical of many country estates; the house was substantial containing forty three rooms. The estate also including stables, garages and farms with associated tenanted cottages. The estate was powered by a conventional coal gasworks until 1905. The gasworks provided light and power to the whole estate. Power came from two gas engines powered by the gasworks which was used for both pumping and the farm machinery. Where the tenants used gas it was charged to them at the cost of production.



**Fig. 7. Suction Gas Producers at Canwell.**

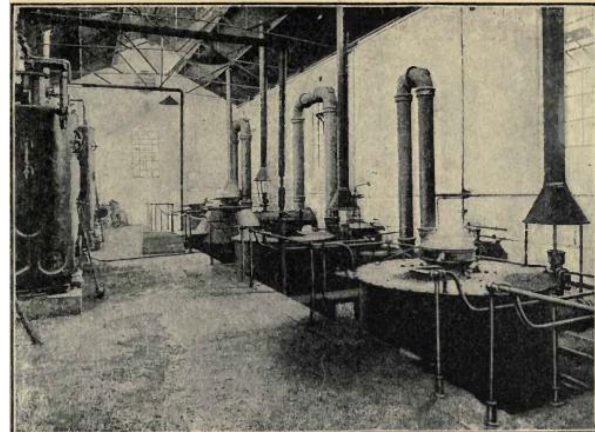
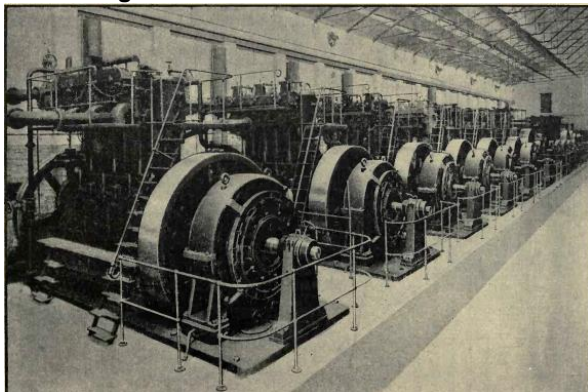
In 1905 an electric plant was installed to replace the gasworks. The plant consisted of two 30 h.p. gas engines, each of with suction-gas producers and two generators, also an accumulator (battery) capable of maintaining all the lights that were required for 9 hours. The plant powered a maximum of 720 lights plus two 15 H.P motors running various pieces of plant such as a saw mill and laundry. The conversion to the producer gas system was approximately 10 to 15% cheaper than the previous energy provided by the gasworks.

*Medium Scale Gas Producer Plants - Walthamstow*

There was a medium sized gas power installation At the electricity generating station of the Urban District Council of Walthamstow, at Walthamstow. The station generated electricity for the electric lighting of the town and also for powering the electric tramway service.

The gas engines were built by Westinghouse (Fig. 8) and the producer gas plant used was a Dowson steam-jet type producer (Figs.7). The works had an aggregate power of 3000 B.H.P. in 1905.

**Fig. 8. Generators at the former Walthamstow Generating station.**

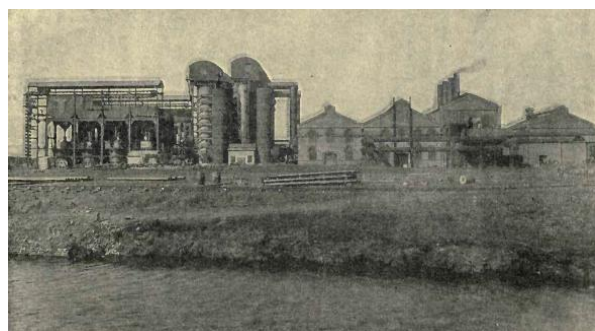


**Fig 9. Producers at the former Walthamstow Generating station.**

The gas from the producers was cleaned using gas scrubbers of a similar design to those shown in Fig 5. But on a much larger scale. Two gas scrubbers were used in combination with the three main Dowson gas producers, these in turn operated via pressurised mains up to thirteen generators.

*Large Scale Gas Producer Plants - Tipton*

The largest example of a producer gas plant in the UK was that built at Dudley Port, Tipton. This plant was built South Staffordshire Mond Gas Company circa 1902 after it had obtained the parliamentary powers to distribute producer gas in South Staffordshire via a gas distribution network. The plant was designed to be able to house 32 producers, capable of gasifying over 600 tons of coal per day. To ensure a supply of gas could be maintained the plant was designed in duplicate, this included the producers, ammonia recovery, gas washing and cooling apparatus.



**Fig.10. The South Staffordshire Mond Gas Company works.**

The gas was distributed from the plant through the use of compressors at a pressure of 10lb per square inch, the mains were manufactured as specialised asphalt covered steel mains. The works provided gas to a large area of South Staffordshire in competition with other gas companies.

When the Mond gas plant switched to coke as a feedstock, the resulting gas was of a lower calorific value. Gas from the plant therefore had to be mixed with conventional coal gas from a nearby gasworks to enrich its calorific value.

### Known Producer Gas Plants

The sites listed below are examples of known sites or companies in the UK where producer gas plants were previously installed. This is not an exhaustive list and many other sites were also known to have existed, especially small producer gas plants such as that described at Canwell.

- Brunner, Mond & Co., Ltd., Northwich.
- The Castner-Kellner Alkali Co., Ltd., Runcorn.
- Albright & Wilson, Ltd., Oldbury.
- Ashmore, Benson, Pease & Co., Ltd., Stockton-on-Tees
- Gloucester Asylum, Coney Hill
- The Railway and General Eng. Co., Ltd., Nottingham
- Birmingham Small Arms Factory, Smallheath.
- The Salt Union, Ltd., Liverpool
- The South Staffordshire Mond Gas Co.
- Cadbury Bros., Ltd., Birmingham
- D. & W. Henderson & Co., Ltd., Glasgow
- The Premier Gas Engine Co., Ltd., Nottingham
- J.&E. Wright of Millwall
- The Trafford Power and Light Co., Ltd., Manchester.
- Walthamstow District Isolation Hospital
- The Farnley Iron Co., Ltd., Leeds

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