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GAS INDUSTRY

Step 1 Report

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The Gas Industry

Step 1 Report

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1. INTRODUCTION

1 1 Throughout the nineteenth and twentieth centuries, the gas industry has been concerned with supplying gas to customers for lighting, heating, cooking, and a range of industrial uses. It effectively began with the work of William Murdoch and Phillip LeBon in the 1790s Gas plant was subsequently sold to provide private factory installations, but the industry came to be dominated by the system of centralised stations serving many customers through a distribution system The spread of the industry to most parts of Britain occurred prior to about 1850, and subsequent growth was in terms of increasing numbers of customers and consumption The gas industry also had an important effect on other industries, particularly the coal industry, which provided the raw material, the iron industry, m terms of demand for plant manufacture and as a customer for coke; railways, as a major transporter of coal and other materials; the chemical industries, which utilised by-products; and the coking industry, from which surplus gas was purchased (see Falkus 1967, 504) In historical terms, studies of the gas industry of the early nineteenth century have been an important element in a debate over the role of state intervention in industry at that period (see for example Matthews 1986) The major twentieth-century change has been the conversion to natural gas between 1967 and 1977, which inevitably meant the loss of many early remains As with the later electricity industry, developments took place on an international stage with Britain, the USA, Germany and France all playing important roles Remains in England must be viewed in this context and are of major importance

1 2 There is a considerable literature on the history of the gas industry. This has focused mainly on technological and business history Limited outline studies of field remains have been undertaken in certain areas and varying observations on individual sites have been reported in a wide variety of local journals and other publications It must be stressed that in studying the gas industry, we are dealing with a product of the industrial revolution Its broad history, particularly technological, is fairly well documented. This is supplemented by museum preservation of examples of equipment and machinery from its early development. Surviving archaeological remains are mainly buildings and gasholders, often of considerable scale. Their value lies in the potential to explain the specific architecture of the industry, its regional and company variation and the way in which gas technology was put into practice Surviving *in situ* machinery is rare and, where it occurs, considerably enhances the value of remains Conservation of remains of the later industry, with the development of more complex plant on ever larger sites is problematical. To the authors knowledge, no overview of the archaeology of the industry has previously been compiled.

1 3 The purpose of this report is to set a framework for the gas industry in the identification, recording and evaluation of industrial monuments and, where applicable, their selection for statutory protection under existing legislation, in accordance with the approach set down by English Heritage Archaeology Division (1992) Specifically the framework includes· a technical and historical outline, a breakdown of the archaeological components one would expect to encounter; an attempt to specify sources for identifying sites, and a statement of anticipated priorities for the mdustry In achieving this, and in view of the dispersed nature of accessible

source material, it has been useful to partially pre-empt the data gathering process of Step 2 by circulating a questionnaire to potential contacts. The responses to this have formed a valuable source in compiling this report.

1 4 Following English Heritage guidance, the report deals specifically with the production of gas from coal and other raw materials (including methane gas drainage), together with the storage and distribution of gas, and the conversion to natural gas. It does not deal with the transport of fuel, customer consumption or the manufacture of gas plant These subjects, together with related industries, in particular those using the by-products, should be considered in separate reports It should be noted that the report has been written in tandem with the step 1 report for the oil industry

1 5 Although, the industry grew as a *British* industry, and was operated as such within the nationalised and re-privatised sectors, this report is geographically limited to England. It does not attempt to cover the industries of Wales and Scotland Nevertheless, as an industry that grew from international efforts and in order to allow informed judgements to be made, it has been deemed necessary to make reference to the industry of these and other countries

2. GEOLOGY AND RAW MATERIALS

2.1 Prior to the 1960s conversion to natural gas, coal was the basic raw material of England's gas industry. Coal is a sedimentary rock, consisting essentially of carbonized vegetable matter formed under compression. It varies in flammability, bitumen content and its ability to be coked (see Buchanan 1972, 69-71; Gould & Cranstone 1992, 1-2, Trueman 1954). In order of decreasing hardness and increasing volatility, coals are graded as follows. *anthracite* (a clean burning hard coal of almost pure carbon); *bituminous coals* (which burn with a smoky flame - through cannel coal, steam coal, coking coal, and gas coal), to *lignite* or brown coal (which has strong traces of plant structure and is part way between bituminous coals and peat).

2.2 *Coking coals* formed the basis of the English gas industry. They produce a good quality coke and gas, and are found in Durham, Northumberland, Lancashire, Yorkshire, the Midlands, Somerset, and Kent. *Cannel Coal* had a particular value for the coal gas industry (it also played an important role in the coal-oil industry) as it produces a rich gas, although conversely a poor coke, and it provided the foundation of the early Scottish industry. In England, there are large deposits in South Lancashire.

2.3 Early gasworks could not transmit gas over large distances and as such needed to be near their customers, rather than the coal source. The transport of raw materials was therefore a fundamental concern, so that gasworks are generally located adjacent to a canal, river, or railway. For example, most of London's coal came by sea from the Durham coalfields, in contrast, most Yorkshire towns got coal from neighbouring pits, by rail or canal (Stewart 1958, 1, 4)

2.4 Throughout most of the nineteenth century the industry was essentially providing gas-light, utilising the *illuminating power* of the burning gas. This illuminating quality was measured in *candle power* (cp). Hence, for example, the early Scottish industry supplied gas with a high illuminating power of about 25cp, resulting from its heavy use of cannel coal. By contrast, the English industry used coking coal, which produced a gas with a typical illuminating power of 16 cp. In the late nineteenth-century two factors (both partly spurred by competition with the emerging electricity industry) led to a fundamental change from the *illuminating standard* to the *thermal standard*. The first development was that of the incandescent mantle burner, which provided light indirectly by using the heat of the burning gas to cause a solid to fluoresce. The second development, was a move to using gas for heating and cooking appliances. Formal change to the thermal standard was by act of parliament in 1920. From this date the *calorific value* of gas (ie the amount of heat released when fully burned) was measured in *British Thermal Units* (100,000 Btu =1 therm). In broad terms, town gas had a calorific value of 500 Btu; natural gas is about 1000 Btu

3. TECHNICAL OUTLINE

This section summarises the processes involved in the gas industry The purpose is to identify the function of <u>components</u> (including ***plant***) which are to be used in the site assessments, together with other *important terms* Items are described under class headings GASWORKS, covering both the production of town gas by carbonization of goal and the gasification of other materials; **DISTRIBUTION**, and NATURAL GAS INSTALLATION, covering remains of the use of natural gas, mainly from the 1960s The bulk of this section is based on Cossons 1987, Cotterill 1981, Elton 1958, Bracegirdle 1973, Stewart 1958, Sturt 1980, Wilson 1976.

3.1 DEFINITIONS

3.1.1 For the purposes of this report a distinction is drawn between *town gas* and *natural gas* From its origins at the beginning of the nineteenth century up to the British adoption of natural gas in the 1960s, manufactured gas formed the basis of the British gas supply industry Throughout that era, the term *town gas* was used to refer to any combination of combustible gases distributed through mains for domestic, commercial and industrial use Town gas was largely produced by heating fossil fuels Coal gas was the principal form, produced by the carbonization of coal Cannel coal also used, particularly in Scotland - yielding a richer gas (20-28 candle power compared to 12-18cp of coal) but poorer coke In London, in 1844, several companies sold gas from cannel coal, others supplied both coal gas and cannel coal gas in separate mains, whilst others mixed the two (Stewart 1958, 18-19)

3.1.2 Other fuels used including brown coal, coke, mineral oil, animal oils and wood, and in these cases the heating process was termed 'gasification' Coke, resulting from the carbonisation process, became commonly used to produce 'water gas' (by passing steam over the heated coke) and 'producer gas' (by passing air over it) - the end products generally being blended with the town gas mix In the case of 'oil gas', gasification was achieved by spraying the oil onto coke or heated brick, a process known as 'cracking'. Coal gas production required a considerable time (measured in weeks) to go from cold start to effective production, in contrast both water gas and oil gas could be brought into and out of production rapidly and as such became important for covering demand fluctuations In addition to the manufactured gases, some natural gas was used, in the form of methane, which was abstracted from coal mines in a process known as 'methane gas drainage'

3.1.3 Hence, the main forms of town gas were

Coal gas: mixture of hydrogen, methane and carbon dioxide (typically 55%, 30%,10%) produced (with impurities including tar, ammonia and hydrogen sulphide) by destructive distillation of coal.

Producer gas mixture of carbon monoxide and nitrogen formed by passing air through red hot coke. Cheaply made in gasworks where used for heating retorts

Water gas: mixture of hydrogen, carbon monoxide, carbon dioxide produced by passing steam through incandescent coke.

Oil gas: gas produced by the 'cracking' of oil (spraying onto heated coke or bricks).

Methane: highly flammable gas. mam component of natural gas. Occurs commonly in mines

3 1 4 *Natural gas* is gas found under pressure in the earth either alone or in association with cmde oil and has quite different properties to the various town gases It is a mixture of hydrocarbon gases, mainly methane, ethane, propane and butane - methane being the largest component. These gases have a high calorific value, that is a given volume of gas, when bumt, yields a large amount of heat (consequently half the volume of natural gas to coal gas is needed to achieve the same heat, hence natural gas is cheaper to store). The domestic bumers developed for Britain's coal gas industry could not bum natural gas - basically because the higher calorific value of natural gas meant that, in order to bum, it required a higher quantity of air mixed in at the bumer. The decision to switch to natural gas supplies in the 1960s therefore necessitated a major conversion programme for gas appliances

3.2 GASWORKS

3 2 1 The essential stages in the manufacture of town gas were developed in Britain in the early nineteenth century. Whilst individual processes were refined and changed over the next 160 years, these essential stages remained and are summarised below.

Raw Materials & Preparation
- This stage covered the preparation and handling of raw materials, for example storing and crushing coal.

Heat Treatment
- The basic process to manufacture gas took two forms
- *Carbonization* - heating of coal (at a temperature of over 500C, 'low temperature carbonization' was below 600C, 'high temperature carbonization' was up to 1000C.
- *Gasification* - heating of brown coal, coke and oil
- The output from this process was a crude gas, at a temperature of about 80°C. It appeared as a yellow-brown smoke, made up of a cocktail of permanent gases (varying mixtures ofi hydrogen, oxygen, carbon dioxide, carbon monoxide, nitrogen, ammonia, naphthalene, sulphuretted hydrogen, organic sulphur compounds, cyanogen compounds, nitric oxide compounds, benzole) together with tar and water vapour.

Purification

- Certain constituents of the cmde gas impeded its usefulness, and hence were regarded as 'impurities'. Hence a large part of a gasworks was taken up by a variety of *purification* processes for extracting these impurities These processes divided into three
- *Condensation* - reduced the temperature of the gas, and condensed out tar and water vapour
- *Washing* and *Scrubbing* - removal of impurities by absorption in a liquid. Pre c1870, a *washer* was used to bubble gas through the liquid; a *scrubber* was used to pass gas over wetted surfaces. Post c1870, these distinctions lost.
- *Dry purification* - process for removing sulphuretted hydrogen by passing gas over solid granules of lime or iron oxide held in purifier boxes.

Pumping, Metering and Storage

- A pump or exhauster was used to cause gas to flow through the various processes.
- Meters - recorded the quantity of gas manufactured
- Gasholders - stored the gas ready for distribution

3 2 2 In addition to this, waste products were collected and disposed of (wherever possible by sale) - specifically these were coke, ash clinker, waste heat steam, tar, ammoniacal liquor, and purifier wastes. The ammoniacal liquor of the early industry had no re-use value and was often dumped m canals, rivers and sea, or on waste ground around the works Alongside this, the early wet purification process yielded a noxious sludge known as 'billy blue', which was often dumped with the ammoniacal liquor These wastes and the smoke and dust from the fumace and the steam from quenching coke all contributed to the gas industry's well-eamed reputation for filth.

RAW MATERIALS AND TRANSPORT

3 2.3 All coal GASWORKS required a coal store (Cotterill 1981, 31, Wilson 1976, 34) This could be covered or in the form of open stacks, although wet coal reduced the gas yield (the temperature of the coal needed to be monitored against the possibility of spontaneous combustion, and the heaps were apparently often sprayed with whitewash as a guard against pilfering) Similarly there was a requirement for a coke store, a lime shed, and a refuse lime heap Later works incorporated *coal handling plant* and *coke handling plant*, and an oxide shed. A weighbridge would be used to monitor quantities As gasworks needed to be sited close to centres of use, transport features were an important part of the site: for early works location next to a canal was common, a canal or riverside jetty would have provided unloading facilities. From the mid-nineteenth century, railway sidings were a common feature

CARBONIZATION

3 2 4 The core of a gasworks was the retort house, incorporating a *chimney* for the furnace exhaust. Most early retort houses for *horizontal retorts*, had characteristically low profiles and are rare survivals The later move to *vertical retorts* saw much taller buildings with characteristic wall ventilation Inclined and vertical retorts occupied less space, allowing greater production capacity on a smaller area.

3 2 5 Coal was held and carbonised in *retorts*, heated by a *furnace* Several retorts heated by the same furnace were known as an *oven*, and a row of adjoining ovens was known as the *retort bench*. (Cotterill 1981, 25; Stewart 1958, 12, 13) The particular pattern of retorts and furnaces was known as the retort bench *setting* The gas/impurity mixture rose from each retort through an *ascension pipe* into an *hydraulic main*, essentially a large closed trough half filled with water (devised by Clegg in 1811) From the 1930s, individual *ascension pipes* gave way to a *standpipe* serving several retorts. The hydraulic main served as a seal and collected hot tar and ammonia which dissolved in the water and was continuously drawn off through a *tar tower* and thence to a liquor tank and tar well The gas passed to a large pipe called the *foul main*, which cooled the gas and conveyed it to the first of various purification plants. A series of underground pipes then conveyed the gas between the different *purifier plant* and into the gasholders

3 2 6 By 1805, Murdoch had devised both vertical and horizontal retorts. Many different forms and arrangements were tried out (eg Clegg's horizontal rotary retort of 1817). However, the essential development was from *horizontal cast iron retort* to the *fireclay retort* of the mid-nineteenth century to the *inclined* and *vertical retorts* of the late nineteenth and early twentieth centuries (although in 1956 one quarter of the capacity of the industry still came from horizontal retorts).

3 2 7 Key dates in the development the *horizontal retort* in relation to the English industry are as follows (Stewart 1958, 12-15):

1810s Clegg set standard arrangement for *iron retorts* (200 day lifetime).

1831 George Lowe devised *through retort*

1853 Wide adoption of moulded *fireclay retorts* (1000 days).

1920s Introduction of *silica retorts,* moulded or as shaped bricks/sections (3000-4000 days)

3.2.8 Clegg's early standard used cast iron with a D-section, measuring 12 inches x 12 inches or 20 inches x 14 inches and 7 feet long Iron retorts had good conductivity (keeping down fuel consumption) and were non-porous (allowing production of gas at a high pressure, which carried it through the purification plant). However they had a short lifetime, as they easily expanded, disturbing the brickwork they were set in and, once cracked, they could not be repaired Fireclay linings were developed by Grafton in Edinburgh in 1818, followed by retorts entirely of fireclay in 1820 (Cotterill 1981, 25-6) These were first used in England at Wolverhampton in 1822, but only came into general use from 1853 The advantages of fireclay were the greater lifetime, the lower distortion and the ability to withstand higher temperatures, although their porosity created the need for *exhauster* pumps to drive gas through the purification processes Silica as the material for retorts was introduced in 1920 in larger gasworks

3 2 9 Many settings were used For example with cast iron retorts, Clegg devised an early common arrangement of five retorts around a furnace When clay retorts were introduced, mixed settings were initially used with the heat from clay retorts rising around iron retorts, but improved settings led to cast iron being dropped. An example is the 'Methuen' setting of ten retorts in two vertical rows of five (Stewart 1958, 12, 13)

3 2.10 The essential developments in relation to the *furnace* are concerned with the fuel used (Stewart 1958, 12, 13-14, 18-19; Wilson 1976, 35) Coal was the basic fuel at the earliest gasworks, with some later use of tar (used a lot in Scotland from 1826, but only occasionally in England from 1838, see Cotterill 1981, 25) The use of coke drawn from the retort was an important change (in 1839 by Alexander Cross according to Stewart 1958, 12, in 1819-23 by Croll in London according to Cotterill 1981, 25), and this became the normal fuel Heat was by direct contact of flames from furnace to retorts, which was known as 'direct fired setting' Cotterill (1981, 25) states that Rackhouse introduced indirect heating of several retorts in an oven in 1817.

3 2 11 In 1861 Siemens invented the *gas producer*, and producer gas was rapidly adopted as the fuel for large gasworks The 'Generator setting' was used from 1865 to the 1930s in smaller works, whereby producer gas rose around the retorts and burned with injected air in a combustion chamber. In 1885 the Klonne recuperator was invented whereby outgoing spent producer gas was used to heat incoming air supplies; this was the 'regenerator setting' which remained in use up until conversion to natural gas.

3 2 12 The charging and drawing of retorts evolved from a manual to a mechanical operation, the latter being the norm after 1885 (Stewart 1958, 12, 13-14, Wilson 1976, 37) This change occurred as a complex series of technical improvements One of the most basic was the change from the early retort iron lid with clay 'lute' seal, to Robert Morton's mechanical self-sealing lid of 1869 Initially retorts were charged by shovel with the spent coke raked out, quenched and stored for sale The development of a *raised retort bench* allowed withdrawn coke to be dropped into an arched cellar for quenching and the U-shaped *scoop* (9 feet long, operated by three men) was developed for charging the long *through retort* of 1831

3 2 13 Although there were early efforts at mechanical charging, including Clegg's 'rotary retort' of 1815, and further efforts in the 1830s (using conveyors, worm-drives and wagon chargers), the main development of *mechanical scoops* came after 1868 (Best, 1868, Holden & Mann, 1868; West, 1873, Taylor, 1878: Richards, 1878, Ross, 1881, Somerville, 1883). Subsequently other types of charger were devised, for example the *shot charger*, *projection charger* (using rotating wheel), and the *conveyor chain* (which also allowed retorts to be fully filled rather than the previous two-thirds) Discharging was also mechanised, for example by ram and conveyor

shot:	• Arrol-Foulis	1891
	• Guest Gibbons	
conveyor:	• Green	1892

- Fiddes-Aldridge 1900s (and discharged)

projection:
- Brouwer 1900
- Drake
- Jenkins
- Ride & Bell

3 2 14 *Inclined retorts* were devised to utilise gravity in charging and discharging (Stewart 1958. 15) In 1869 Carpenter used a short-lived system of 8 inclined retorts fed by worm-drive. However, the main development was by Coze (1885 in Rheims). taken up in England by Morris at Brentford, using retorts at 32° to the horizontal with coal fed from overhead hoppers, and an iron stop releasing spent coke. The system was in wide use between 1890 and 1930. Although intermittent *vertical retorts* had been used very early on in the gas industry (Murdoch tried them in 1805. and Brinton designed one in 1828), their practical development was as an improvement on *inclined retorts* (Stewart 1958, 16-17) Rowan attempted an early version in 1885, but the first successful, and widely adopted, design was by Bueb (in Dessau, Germany) in 1902, using retorts grouped in threes with up to eighteen in a setting. Later designs built the three retorts as a single unit or *chamber*.

3 2 15 More importantly, continuous *vertical retorts* were developed in the early twentieth century (Cotterill 1981. 29, Stewart 1958, 16-17) Various experimental plant was built (1854 - Young, 1874 - Scott, 1902 - Settle and Padfield), but two designs were particularly successful. 'Woodall-Duckham' retorts were developed by W H Woodall at Bournemouth 1903: and 'Glover-West' retorts derived from a 1905 prototype at St Helens by S & T Glover and W Young. The retorts were heated via surrounding flues using producer gas (often from a separate *producer gas plant*), sometimes with recuperation and usually with waste heat boilers Coal was fed at two-hourly intervals from overhead *hoppers* to a *charging pouch* above each retort. Continuous carbonisation took place over a seven hour period. with coke being removed in small amounts via a helicoidal *extractor* into a *coke box* The latter was emptied at two-hourly intervals through gas-tight doors.

3 2 16 The significant advantages of these retorts, given below, led to their wide adoption:

- part of process was to introduce steam to retort base, this had the effect of allowing coke to be discharged without smoke, dust and steam.
- there was a saving in ground space
- efficiency of operation in mechanisation and fuel saving
- high quality of coke produced - good for resale as domestic smokeless fuel

3 2.17 *Coke ovens* were mainly developed in the eighteenth century for the iron industry (Mott 1936, Stewart 1958, 17-18; Trinder 1981, 165). The earliest systems used coke heaps and, in north-east, beehive ovens. The latter increased in use and by the mid-nineteenth century were a standard feature of ironworks. European developments of coke ovens included elliptical ovens and vertical flues and the important *By-product recovery oven* dates from 1866 The first Simon-Carves recovery ovens in England were built at Crook, County Durham, in 1882 This technology appears to have made little direct contribution to gas industry technology until the twentieth century

However, the coking industry and gas industry have interacted in the sense of sales of materials to each other The purchase of coke oven gas was effectively restricted to undertakings in iron and steel areas, but this was widely done in the early twentieth century (the earliest at Lanchester in 1906, Little Hulton in Lancashire, 1910, Middlesborough, 1914, Leeds, Wath, Swinton, & Mexborough, 1918, and subsequently many more) Coke oven designs with their large chambers were adopted on a few large gasworks, the main advantage being their long working lifetime (typically 25 years) The first English gasworks to use them was in Birmingham in 1912 and in 1930, the massive Beckton works built a set of 'Koppers' ovens (Mott 1936, 104).

GASIFICATION

3 2 18 *Carburetted water gas plant* was used to generate *carburetted water gas*, a mixture of gases from two processes - *water gas* from passing steam over hot coke, and *oil gas* from cracking of oil on hot coke or brick (see Cotterill 1976, Elton 1958, 272, Mills 1995, Nabb 1997, Stewart 1958, 11, 20-22, Williams 1981, 29-30, 60-62).

3 2 19 *Water gas* is produced in retorts, passing steam through white hot coke (developed by Ibbetson, 1824, Donovan, 1830, Val Marino, 1839, White, 1847) The cupola *generator*, from 1849, used an air blast to heat coke alternated with the gas making steam blasts (developed by Gillard, 1849, White, 1849, Kirkham, 1854, Spice, 1875, Lowe in USA) In 1874 Strong patented a system for preheating the steam

3 2 20 The gasification of non-mineral oil in retorts was earried out in the 1820s (patented by Taylor and devised in relation to whale oil), but was abandoned by 1830 as uncommercial. Related to this, in 1819, Gordon and Heard patented a process for compressing oil gas into cylinders as the basis of a proposed portable gas industry. This was also short-lived, although it was revived for lighting railway carriages in Germany, in 1871, and adopted in England in 1876, being supplied by Pintsch & Co and Pope & Son.

3 2 21 In 1874 Lowe devised a system for gas enrichment by spraying oil onto the hot coke inside a *water gas generator*, and in 1882 by spraying oil onto heated brick in a separate chamber (a *carburettor*) adjacent to a *water gas generator* This result was the basic *carburetted water gas plant*, introduced to England in the 1890s and continued in use (with refinements) until the introduction of natural gas in the 1960s In the twentieth century, some plant was also developed that used oil as the sole raw material

3 2.22 The *complete gasification of coal* was developed from Siemens' gas producer technology, that is passing a mix of steam and air through a fuel bed Part of the spur for this development was a growing shortage of coal suitable for carbonization and it was used initially for non-coking bituminous coals The technology saw many refinements in the period 1890-1920, about 150 small complete gasification plants were built in Britain in 1918-21 (by Tully), and it was revived in the 1930s and after the second world war A particular development was that of Mond in 1889, to allow the use of coking coals, a system improved by Lymn in 1920 and subsequently used in Staffordshire for industrial heating *Complete gasification* technology was mainly used

and developed in the USA (for anthracite) and Europe (for Lignite). hence in the 1930s. the *Lurgi process* was developed in Germany, using oxygen and superheated steam in a continuous process that produced gas at high pressure (see Stewart 1958. 21-2. Williams 1981. 123-5) Lurgi plant was built at Westfield. in Scotland (in 1958-60). and at Coleshill. in Birmingham (closed in 1969)

PURIFICATION

3 2 23 The degree to which purifying processes changed through the nineteenth and twentieth centuries was affected in part by the development of understanding of these processes. and in part by discoveries of uses for the impurities The processes are described here from the point of view of a coal gasworks. In broad terms. the processes were equally applicable to water gas and oil gas. although these do not contain ammonia (Cotterill 1981, 32-4. 35, Stewart 1958, 23-9)

3 2 24 In the early industry. the chemistry behind purification was poorly understood. The basic need was to remove tar; and to reduce the content of those constituent gases that were of no use for lighting (CO_2. O_2 and N_2); and to remove gases that left an unpleasant effect when burnt (particularly ammonia. hydrogen sulphur and sulphur compounds) In all cases, tar would have been washed into a <u>tar pit</u> and 'ammoniacal liquor' was drained into a <u>liquor tank</u>

3 2 25 The very earliest purification, beyond simply cooling and washing in water. was a *wet process*, based on the discovery (by Henry in 1805) that washing gas with a suspension of slaked lime appeared to remove the impurities (the process was generally referred to as 'cream of lime') Clegg originally put lime in the gasholders. However *<u>lime washers</u>* were quickly developed (various plant devised mainly by Richards. Clegg and Malam) and were standard up to c1845 in spite of the problem of 'billy blue' waste (Chandler & Lacy 1949, 60-67). They incorporated *agitators*, initially manually operated, later mechanically driven In addition. purification plants would have had a <u>lime shed</u>, and a <u>refuse lime heap</u>

3 2 26 The *<u>Condenser</u>* was essentially a long run of piping which allowed the gas to be cooled (by air or water), in order to condense out more tar and ammonia Murdoch had used a *vertical cylindrical condenser* which used a water jet to precipitate out the tar. In 1817, John Perks designed a *multiple inverted U-tube air-cooled condenser* design. which became common. Improved designs were spurred in 1860 and 1870 by legislation over allowed levels of impurities. Types devised were *annular condensers* (Kirkham 1860, Wright Walker & Padham 1865). the *zigzag condenser* (Graham 1867), and *water-cooled condensers* (Livesey 1870. Cleland 1873. Morris and Cutler 1874, Clapham 1884). *<u>Electro-detarrers</u>* were introduced in the twentieth century. placed after the condenser.

3 2 27 *<u>Washers</u>* and *<u>scrubbers</u>* were other distinct plant types devised to further reduce residual tar and ammonia by absorption in water, and were placed after the condenser. Both techniques were improved as the use of by-products grew. The *<u>washer</u>* was devised by Wilson in 1817; it consisted of a gas-tight box in which gas was passed through perforated wooden boards running with water. This was improved by Cathels (bubbler washer of 1868), Livesey (using perforated metal tubes, 1870) and Walker

(using fine slots in metal tubes, 1872) The ***washer*** mainly removed tar, but also some ammonia The more efficient ***tower scrubber*** was devised by George Lowe in 1846 to remove the remaining ammonia: it employed shelving and a water spray from the summit of the tower It was improved by Mann and Walker in 1871 The alternative ***rotary washer***, devised by Hills in 1848, sprayed water onto brushwood in a rotating cylinder

3 2 28 Up to the 1840s the *wet process* was the dominant means of removing hydrogen sulphide and sulphur compounds The expansion of the industry and increasing size of gasworks over this time inevitably meant increasing amounts of lime waste from this process An alternative process, *dry lime purification*, avoided the problem This method was originally devised by Reuben Phillips in Exeter in 1817, and involved passing the gas over slats which held damp burnt lime It was gradually adopted from the 1840s, and was particularly taken up after the 1860 and 1871 acts that introduced stringent controls and independent testing at gasworks In addition, there were experiments with the use of various metal oxides in place of the dry lime: manganese oxide by Croll in 1840, and iron oxide by Evans in 1842, Langmaid in 1848, and Laming and Hills in 1849 Hills patented a process for *revivifying* iron oxide that led to its wide use The spent oxide was spread out in an open oxide shed to allow oxygen to react with the iron sulphide, so releasing sulphur and reforming the iron oxide However, iron oxide only removed hydrogen sulphide from the gas so that lime continued to be used alongside it until the early twentieth century when the legal requirement to remove sulphur compounds was dropped In fact, because of the resale value of the lime as agricultural fertilizer many sites continued to use dry lime by itself (55% in 1901) In all cases, ***purifiers*** were the basic component - consisting of a series of large cast iron boxes, holding the trays of dry lime or iron oxide, with piping and *valves* to control the cycle of use of the boxes From 1921 some sites used reinforced concrete instead of cast iron In 1930, the ***tower purifier***, with removable trays operated by crane, was introduced from Germany and became popular for large sites.

3 2 29 Beyond these basic processes, further refining took place in the later stages of the industry's history, either to improve gas quality or to extract a useful by-product. ***Cyanogen plant*** was employed on some large sites between 1885 and 1922, the Cyanogen liquor being of use in printing and dyeing (for example to make 'Prussian blue') It was eventually abandoned as uneconomical ***Naphthalene plant*** was used from c1912 to remove naphthalene, a hydrocarbon which higher carbonising temperatures caused to create a flaky deposit in the gas plant. ***Benzole plant*** was adopted during the First World War to boost explosives manufacture and subsequently was maintained for resale to the chemical industry for dyestuffs, plastics and as motor spirit. The basic process was either by washing with gas oil or by passing gas through chambers with carbon pellets. From 1930 ***gas drying plant*** was used to reduce water vapour in the gas, and so reduce the problem of water deposition in the mains

PUMPING

3 2 30 The purpose of pumping at a gasworks was to draw gas through the purifying processes and to provide energy to lift the bells in the gasholders, which in turn pressurised the mains (Elton 1958, 271; Stewart 1958, 34-5) In 1825 Broadmeadow

identified purifiers as slowing the gas flow resulting in so-called 'back pressure' in the condenser which in turn reduced the amount of gas leaving the retorts. In spite of the high pressure possible with iron retorts, this limited the amount of purification that could be carried out, resulting in ammonia reaching the mains and causing corrosion. To combat this, Broadmeadow invented the *exhauster*, a one way pump placed after the condensers However, only with the widespread use of clay retorts from the 1850s, with their lower pressures, did exhausters become a standard component of gas plant Many developments of the *exhauster* took place John Grafton's efficient version was widely used, as was Beale's rotary steam exhauster and subsequently the Rateau turbo exhauster

1830	*2-bell*	(Broadmeadow)
1840	*reversed wet drum*	(Malam)
1841	*3-bell*	(Grafton)
1841	*piston-type*	(Anderson)
1843	*3 bell with flap valves*	(Methuen)
1847	*double-lobed*	(Jones)
1848	*rotary steam type*	(Beale)
1850	*steam ejector type*	(Cleland)
1910	*turbo*	(Rateau)

3 2 31 *Exhausters* were initially driven by *steam engine*, later by *gas engine* (common on small rural works), *steam turbine* or *electric pump* Common practice was for each pump to be driven by its own steam engine, but line shafting was also employed (and was essential for gas engines, with their higher speeds). To ensure an even 'pull' on the gas by the exhauster, a small *governor* alongside it controlled flow between the inlet and outlet. These components could be housed in an exhauster house and there may have been a separate engine house, with *boiler* and *chimney* (see Watkins 1978, 108-13) From the early twentieth century, a gasworks often had its own power house to provide electricity

STORAGE

3 2 32 The purpose of a gasholder is to provide a storage buffer between the production processes and the distribution of gas to customers (Miele 1996, Stewart 1958, 32-4; Sturt 1980) It also provides the *mains* pressure. In 1782 Lavoisier devised the forerunner of the gasholder, and the earliest practical holders followed his design: a cubical wooden framework covered with sheet iron, with the bottom end open and submerged in water However, by 1816, the normal arrangement was for a cylindrical *bell*, supported by a central chain and counterbalance system, lifted by gas pressure and sealed at its base in a *water tank* There were many short-lived variations on this and one, Clegg's *rotating gasholder* of 1815, led to the early *meter* design (see below)

3 2 33 During the first quarter of the nineteenth century gasholders were frequently encased in brick built gasholder houses This practice based partly on the erroneous belief that

gas storage held a major danger of explosion and partly with the intention of protecting the holder from wind and rain.

3 2 34 The very earliest *water tanks* were made from second-hand wooden brewers vats (a use that survived to 1843) However, the basic designs that became standard, were in place by 1818.- *buried* (with brick walls, cement or puddled clay waterproofing and a central 'dumpling' to reduce the water needed), *semi-buried* (with an earth bank built against the tank walls that could be used on poor ground) and *above ground* (of expensive cast or wrought iron plates but which could be used on a wide range of locations).

3 2 35 The central chain support of the earliest holders gave way to more complex *guide framing* The earliest *column guide* used a single central cast iron column, designed by Malam. Guide rollers at the top and bottom of the bell ran on rails fixed to the column. The next development, for bigger bells, to use a series of independent cast iron lattice girder tripods placed around the circumference of the water tank (the 1830 Fulham no 2 gasholder is a unique survival of this type) With the use of *telescopic holders*, there was a need for greater stability, so banded framework of cast and wrought iron ties was added to the top and bottom of the guide frame, and the tripods were replaced by cast iron columns Paddon ties were used from 1870 From the 1880s sfill bigger holders were built using rolled section steel or lattice girders in place of the columns and diagonal tension rods m the frame, this followed work by Cripps and Baker and was pioneered by Livesey.

3 2 36 To the middle of the mneteenth century, most gasholders were single lift, with the *bell* of riveted iron or steel plate, and *carriage rollers*, at the edge of its spherical crown and base, rimming against the column guides A *telescopic holder* was designed in England by Tait in 1824 and were first used in 1826 in Leeds (the first patent was in 1827 by Nicholson, who abandoned it due to Tait's eariier published design) This design allowed more gas to be stored on a given area of land, and proved cheaper to build than two single lift holders (although the increased pressure had to be dealt with) It consisted of an inner bell with a U-shaped base rim (the *cup*), and a *lift* running around it with an inverted U-shaped upper rim (the *grip*). As the *bell* rose under pressure the water-filled *cup* linked in to the *grip* and earried the *lift* with it. The cup and grip of early designs were of riveted sections, which caused leakage problems, but from 1862 bent sections became the common practice The further problem of freezing in the winter necessitated electrical and steam-based *antifreeze systems* The first successful 3-lift holder followed in 1861 at Blackfriars, with the first 4-lift in 1886 at East Greenwich. The 1880s also saw the *flying lift* (pioneered by Livesey at Rotherhithe in 1888), where a top lift rises above the supporting standards Broadly, until the 1880s, small gasworks had *single lift holders* and larger works had the *telescopic* type.

3 2 27 A *cable-guided holder* designed by Pease in 1887, replaced the guide frame with a system of wire cables This had limited use to c1910, but became obsolete. More importantly, the *spirally guided holder* was patented by Gadd and Mason in 1887 and the first was built in Northwich, Cheshire in 1889-90. In place of a guide frame, there was a system of rails fitted to the exterior of each lift running at an angle of 45°. Carriage rollers on the water tank and on the top of each lift ran against these rails.

Water seals were provided by the *cup* and *grıp* system of telescopıc holders Inıtıal nveted constmctıon was replaced by welding ın the twentieth century. These holders were cheaper to buıld than column-guıded holders. and became common addıtıons and replacements at gasworks, by the mıd-twentıeth century they were the domınant form m Brıtaın

3 2 38 *Dry holders* were adopted from German and USA developments in the twentieth century. although the concept was devısed ın England by Caslon ın 1823 and developed by Knapton in 1849. Essentıally these are *waterless pıston holders*, which avoıd the constmctıon problems of the water tank (requırıng lighter foundations), re-wettıng the gas and the needs for antı-freeze systems of wet holders; they also provide a constant pressure irrespectıve of the amount of gas ın them Theır dısadvantage ıs the need for greater maıntenance. Relatively few were built in Brıtain There are three mam types The *M A N holder* was developed in Germany ın 1915-16. and the first example buılt in Brıtaın dates to 1927. It has a polygonal shell of steel plate with inner stanchions The steel *pıston*, with radıal and tangentıal rollers which mn in the stanchıons. is sealed by counterbalanced mbbıng plates in a tar- (later oıl-) filled channel. The *Klonne holder* was patented in Germany in 1882, but only built in 1927 The first Brıtısh holder was buılt in 1931 It has a cylındrıcal steel shell with outer stanchıons and a *pıston* wıth two sets of radıal rollers (which allow ıt to rotate) and a seal of lubricated mbberised textıle The *Wıggins holder* was effectively an American development of the Caslon/Knapton designs, used inıtıally in the oil industry. Desıgned by John Wiggins in 1936. ıt was first built in 1940. and was used for gas m Brıtaın from the 1950s It has a welded cylındrıcal shell wıth a slightly domed roof An ınner *pıston* has a flexıble seal wıth an outer telescopıc *fender* and a further seal to the shell. As the pıston rıses, ıt pıcks up the fender. guided by a counterbalance system

3 2.39 The *pressure holder* was developed from the 1930s, and consısts of a sphere or a horizontal cylınder with dıshed ends. It holds gas at hıgh pressure, releasing it to dıstrıbutıon systems through pressure-reducing *governors.*

METERING AND PRESSURE

3 2 40 Gasworks staff monıtored the quantity and quality of gas produced with a station meter The *wet meter* was devised by Clegg ın 1817, following the principle of his earlıer *rotatıng gasholder*, and improved by his son-m-law. John Malam. gas dısplaced water in the chambers of a paddle wheel or dmm causing it to rotate, this actıon operatıng a dıal. A station governor maintaıned constant pressure into the mams. This was again devised by Clegg. in 1815, and resembled a small gasholder set over the mains pipe, wıth a self-regulating valve sıtting wıthin the gas flow, and the pressure set by placing weights on its floating bell Further developments by Hunt. Cowan, Parkınson and Braddock ıncreased the precısıon of this device, and an altemative design used a flexıble diaphragm in place of the bell An 1879 design by Stott used a mercury seal A meter house commonly held these components, although the governor could be located separately in a valve house, from where gas flow into and out of the gasholders was controlled (see Cotterill 1981, 31, Elton 1958, 270. Stewart 1958. 389, Wıllıams 1981, 20, Wilson 1976. 39-40)

ADMINISTRATION

3.2.41 In addition to these major components, a range of ancillary features were present at a coal gasworks. These included a boundary fence and a gateway into the works, a workshop and a smithy for the many running repairs, a stable, a stores, a laboratory, offices, gas showroom, and a manager's house. Large, later works had an administrative block, with *offices*, *canteen* and *toilets*, and generally a *car park*.

3.3 DISTRIBUTION

3.3.1 The purpose of a gas distribution system was to send gas to customers at an even pressure and volume at any time of day and at whatever distance from the place of storage, such that it would fuel appliances (Cotterill 1981, 36-7, Elton 1958, 271, Stewart 1958, 37-42, Wilson 1976, 40-42). In the early industry, there was a great deal of variation in the ability to achieve this. The pressure in the system came from the falling weight of gasholder bells, controlled by the station governor. Early systems, and later small systems, were based on *low pressure* mains laid through the supply area, decreasing in size with distance from holders. *Street mains* branched off this, with further branching of *service pipes* to individual customers, where a *meter* measured the amount of gas consumed. Piping in the house was known as *carcassing*. Such simple systems only worked for small areas and more complex systems evolved to deal with increased overall demand, peak demands, multiple gas station supplies, and bigger areas (especially towns). Four elements to these system are described by Stewart (1958, 38).

Low pressure network

Medium pressure feeder mains
- fed by *pumping plant*
- fed from gasworks to *governors* at strategic points on low pressure network
- fed gasholder stations on the edge of the system, which in turn fed a low pressure network via *governors*

High pressure grid
- linked gasworks and gasholder stations
- fed from gasworks to *governors* at strategic points on a low pressure network

Boosters
- to boost pressure at times of low gasholder levels or during heavy demand

3.3.2 *Boosters* were pumps similar to exhausters, situated in a booster house at gasworks or gasholder stations, and driven either by steam, gas engine or electric motor. Turbine-driven fan-type boosters became common in the twentieth century (see Watkins 1978, 108).

3.3.3 In addition to this, some rural systems used small diameter high pressure steel mains to deliver gas direct to each customer, with pressure-reducing valves bringing the gas to the correct pressure for burning. In addition some mains were for delivering raw 'coke oven' gas, from ironworks and collieries, to a gasworks for purifying. In 1931, the Sheffield Gas Company gained permission to build a high pressure grid for this purpose The general progress was to larger systems, culminating in nationalisation of the industry, when a high pressure *backbone mams* was built.

3 3 4 House *meters* were originally wet meters, with dry meter designs being used from the 1850s and com in the slot meters from 1889 (Bracegirdle 1973, 144, Elton 1958, 272, Stewart 1958, 44)

3 3 5 For <u>mains</u> construction, lead, wood and stone were tried by the early industry. Howeger, cast iron rapidly became the norm (originally introduced for water m 1810) In 1919 spun-cast replaced pit-cast manufacture and allowed longer sections of pipe (from 9 feet - 12 feet to 12 feet - 18 feet). Lengths were joined by flanges or lead-filled sockets or, from 1826, socket and spigot joints. These were improved in 1921 by the use of a rubber ring, and from 1928 by a lead ring Control valves at points on the mains were used by the early industry as a precaution against repair needs, although this was discontinued m favour of the practice of inserting pigs bladders (later rubberised canvas) during the repair process[1] After the second world war, valves were adopted again From 1840, lengths of wrought iron, and later steel, were used (for greater tensile strength) where ruains crossed bridges or m tunnelling From 1900 seamless steel tubes were increasingly used for mains and from 1933, there was occasional use of reinforced asbestos cement.

3 3 6 *Service pipes* were small diameter 'barrels' (made in the same way as gun barrels and in period following the Napoleonic wars, actually ruade of old gun barrels) The were replaced by wrought iron In 1813 Russell devised a system of screwed and socketed wrought pipes; in 1825, Whitehouse patented a butt welding process which allowed manufacture of longer lengths, and in 1840 the lap welding process was devised From 1940, steel replaced wrought iron. Corrosion protection was provided by wrapping the pipes in bitumenised hessian or laying m wooden troughs filled with pitch.

3 3 7 *House carcassing* was originally in lead and copper However copper reacted with ammonia and could cause blockages and was replaced by iron tubing Lead piping was replaced by 'compo pipe', a thin lead coated with tin In the twentieth century, iron or steel tubing has been used

3.4 NATURAL GAS INSTALLATION

3.4 1 The components in this section refer entirely to the natural gas industry of the 1950s and later (Williams 1974) The main component relevant to this report is the <u>shore terminal</u> (or *beach* or *reception terminal*). These are large complex sites, and an entirely twentieth-century feature, characterised by large amounts of specialised plant and pipework, above and below ground, which is spread over large areas. In terms of the MPP it is the terminal as a whole that is of interest. Different parts of a terminal are run by different organisations

3 4 2 The technical structure of industry as it stands m 1997 is as follows (see TransCo's *Beach to Meter* booklet, available from TransCo Public Relations, and BP 1972, 170-

248). Companies known as *gas producers* extract *natural gas* via *rigs* in undersea *gas fields* around Britain, and deliver it, via *undersea pipeline*, to one of six shore terminals (Bacton, Theddlethorpe, Easington, Teeside, Barrow and St Fergus), where the gas is refined (this includes reduction of water and hydrocarbon content, sulphur purification and odorizing) Gas is then transported, via pumping in 20 *compressor stations* (using gas-fuelled jet engines) through the pipeline or *high pressure main* of the *National Transmission System* (either directly or via the large capacity *Storage Network*) to 120 *off-take stations*, from where it is delivered to 14 power stations, 8 large industrial users, and 4 *area transmission systems*, which further divide into 13 *Local Distribution Zones*. The latter includes *low pressure storage* and *low pressure mains* that deliver to customers. There are also *interconnector* pipelines to Ireland and the continent Within this system, the *Storage Network* includes *Liquid Natural Gas storage* (English sites at Avonmouth, Partington, Isle of Grain), *Salt Cavity Storage* at Homsea, and *Rough Storage* in the now depleted Rough gas field Management of gas flow and delivery is via a *System Control Centre* and *Area Control Centres* About 40 companies, referred to as gas *Shippers*, buy the stored gas and sell it to customers

4. HISTORICAL OUTLINE

4.1 BACKGROUND

4 1 1 The technological history of gas manufacture is essentially one of refinement and increase in scale of that process. A considerable literature exists on the history of the industry, although there has been relatively little mainstream archaeological investigation of physical remains The history of the gas industry does appear to break down into a series of periods of development that may be reflected in the surviving remains

4.2 SCIENTIFIC INVESTIGATION AND EXPERIMENTATION, TO 1805

4 2 1 Natural gas was encountered and utilised in various parts of world at very early dates, but consideration of this is beyond the scope of this study (Williams 1981, 3) In Europe, curiosity about inflammable airs may be traced from the late sixteenth century, with the seventeenth and eighteenth centuries characterised by scientific investigation of the phenomenon and experimentation in its manufacture This history is described by (amongst others) Elton (1958, 258-63) and Stewart (1958, 5-6) Some of the notable steps are as follows

1688	Rev John Clayton communicated to Royal Soc. that gas could be extracted from a fuel and used as an illuminant
1764	Gabrield Jars suggested using mine gas for lighting
1765	James Spedding collected pit gases and used them to light works office at Whitehaven colliery
1770	Coke ovens built at Sulzbach which carbonised coal m closed retorts trom which gas was piped away as waste
1779	George Dixon founded works for extracting tar from coal at Cockfield Durham
1782	Lavoisier devised forerunner of gasholder
1782	Archibald Cochrane (Lord Dundonald) collected gas from tar ovens at Culross, and experimented with it for lighting
1783 on	Jean Pierre Minkelers reputed to have lit his lecture room in Louvain with coal gas
1792	William Murdoch lit his office in Redruth, Cornwall with gas distilled from coal
1797	Pillipe LeBon produced gas from wood in an iron retort (patented m 1799)
1802	Murdoch's gas plant used to illuminate Boulton & Watt's Soho factory

4 2 2 The origin of the gas industry may be seen in the coming together of two strands - an increasing understanding of chemistry and demand for artificial lighting. By the end of the eighteenth century, a reasonable grasp had been attained of the chemistry behind gas manufacture In addition, the practice of carbonizing coal to produce coke became well established following Abraham Darby's hugely important development of the

coke-smelting of iron in 1709. Prior to the emergence of gaslight, dependence for artificial light was on tallow and wax candles and on oil lamps. The drive for better lighting grew in the late eighteenth century, with increasing numbers of urban streets, public buildings (theatres, assembly rooms, inns, shops) and the needs of developing industry Increasing numbers of factories, particularly in the textile industry, worked long hours throughout year and wanted safer lighting - the snuffing of candles caused dangerous sparks, and there were many resulting mill fires (Falkus 1981, 218-19).

4 2 3 The initial commercial development of the industry may be related to the work of a group of engineers and industrialists (see Elton 1958, Falkus 1981, 220-2; Stewart 1958, 6-9). William Murdoch, an engineer with the firm of Boulton and Watt, began systematic experiments in the production of gas from coal in 1792 Phillipe LeBon worked on gas lighting from the distillation of wood from about the same time LeBon's work was cut short by his murder in 1804, but importantly provided inspiration for the entrepreneurial pursuits of Fredriech Winzer which formed the beginning of the central station system Murdock's work was in part spurred by a sense of competition with LeBon after becomming aware of his work m 1801, but it was also driven by the encouragement of Manchester cotton spinner George Lee (reflecting the textile industry's desperate need for better lighting systems and also the personal contacts of the time - Lee was a major customer of Boulton and Watt and a family friend of the Watt family) By 1802, Murdoch had developed a practical gas plant that was used to illuminate Boulton and Watt's Soho Foundry in Birmingham, and this plant was rapidly developed for commercial sale by Murdoch, aided by his apprentice Samuel Clegg The first commercial Murdoch installation came m 1805-06, not unsurprisingly at George Lee's cotton mill At the same time, having left Boulton and Watts employ in 1805, Clegg set up independently and installed his own gas plant at a cotton mill near Halifax mn by Henry Lodge, apparently ahead of Murdock (see Elton 1958, 268, Stewart 1958, 8).

4.3 Early Private and Central Gasworks, and Innovation, 1805 - 1820

4.3 1 The period to the 1820s saw the establishment of the basic components of gasworks with considerable experimentation and innovation by early gas engineers. It also saw competing systems of private gas plant versus central stations supplying customers through mains. The latter dominated by the end of the period.

4 3 2 The making and selling of private plant was pursued by the Boulton & Watt company from 1805 to 1814 This route was also pursued by Samuel Clegg and Josiah Pemberton as independent gas engineers. With one exception this was the plant was sold to industrial concems (particularly textile mills), predominantly in the North and Midlands Between 1805 and 1812 gasworks erected in factories in England included following (Elton 1958, 268; Falkus 1981, 224; Stewart 1958, 9).

Boulton & Watt

1805-6	Phillips & Lee cotton mill	Salford
1809	Birley & Co mill	Manchester

1809	Kennedy's mill	Manchester
1809	Wormald, Gott & Co	Leeds
1809	McConnel & Kennedy	Manchester
1809	Gillespie & Co mill	Glasgow
1809	Nielson & Co	Kirkland, Fife
1809	Gott's mill	Leeds
1810	Marshall Hives & Co	Leeds
1810	Birley & Hornby	Chorlton
1810	Lister Ellis & Co	Otley
1810	Coupland & Sons	Leeds
1810	Thomas & Lewis	Manchester
1811	Marshall, Hutton & Co	Shrewsbury
1811	Huddart & Co	Limehouse
1811	Benyon, Benyon & Bage	Shrewsbury

Clegg

1805	Lodges cotton mill	Halifax
1806	Borough Reeve of Manchester (experimental street lighting)	Manchester
1807	Knight factory at Longsight	Manchester
1809	Harris Works	Coventry
1811	factory at Delphinstone	Lancaster
1811	Stonyhurst College (with separate liming plant)	Lancashire
1812	Greenaways cotton mill (with first hydraulic main)	Manchester
1812	Ashton & Sons mill	Hyde
1812	Ashton & Sons mill	Stockport
1812	Ackermann lithographers	London (Strand)

Pemberton

pre 1807	Saunders Button factory	Birmingham
pre 1807	Spooner park Mill	Birmingham
pre 1807	Cook's brass works	Birmingham
1807	Golden Lane Brewery	London

4.3 3 The period also saw numerous innovations (many by Clegg) By 1812, the basic plant mcluded single-ended horizontal cast-iron retorts, a hydraulic main, a tar pit, purification by wet liming plant, and cooling by means of a 'worm' in the gasholder water (Elton 1958, 269) In addition, Reuben Phillips devised a dry lime process in 1817, although this was not commonly used until the 1840s.

4 3 4 The central station system aimed to supply customers via street mams and seems to have ongmated with the German entrepreneur Fnederich Winzer (later 'Fredenc Winsor'), possibly adopting the idea from the water industry His interest m gas manufacture was apparently sparked by observation of LeBon's in Paris Subsequently Winzer chose to attempt a promotion of gas-lighting m London, with its large wealthy market and wide relative costs of coal and oil/tallow In spite of strong opposition by Boulton & Watt and others, this led to the formation of the Gas Light and Coke Co by charter of 1812 (following a parliamentary act of 1810), permitted to supply gas in London After its formation, Winsor m fact had a very strained relationship with the company and retumed to Parrs in 1815 Initial technical problems were overcome following the appointment of Samuel Clegg as its chief engineer late m 1812. Between then and his departure in 1817, Clegg set up the technical infrastmcture of the company, with gasworks at St Peter's Street (Westminster), Norton Folgate and Brick Lane.

4 3 5 The company consequently had huge financial success, and provided the inspiration and model for companies to follow (see Falkus 1981, 225-31) Between 1814-19 other companies were formed m London The first gas companies outside London were established in Preston in 1816 with a company of subscnbers who engaged London engineer John Grafton, and Liverpool, with a similar set up with another London engineer James Hargreaves (Falkus 1967, 494, 505) By 1820, there were 15 towns in England and Scotland with a gas undertakings, each formed under an act of parliament, which authonsed the building of works and the breaking up of streets to lay mains, and specified gas quality and level of dividends The arrangement generally involved an initial contract with the local authonty to supply public lighting at a very cheap rate as a pay-off for being allowed to dig up paving Profits came instead from supplying pnvate customers.

4 3 6 The early gas supplies were for lighting and the mains was tumed off in daytime. Intenor lighting was initially in non-domestic settings, public houses, shops, warehouses, theatres and public halls. The earliest bumers used for this lighting were formed as holes in pipe caps, and were referred to by the shape of flame produced (rat-tail, cockspur, cockscomb). The improvement of using a sawcut rather than holes was led to the batswing bumer of 1816 and the similar fishtail bumer of 1820. After 1820 an adaptation of the Argand bumer (originally devised for oil lighting) came into common use (the adaptation had been made by Clegg in 1809)

4.4 EXPANSION, 1820 - 1850

4 4 1 This period saw a huge expansion of the industry. Although some pnvate installations continued to be built, particularly at factorres, the bulk of the growth was in terms of companies using central stations to supply non-domestic lighting: for streets, factories,

shops, inns, railway stations, and institutions. The period saw a chronological pattern of new supply to progressively smaller towns. The 1820s saw most gas undertakings established at towns with populations of 10,000 or more, the 1830s towns of 4-10,000, and the 1840s towns of 2,500-4,000, this construction activity matching economic development (see Falkus 1967, 494, 498) The undertakings ranged from large incorporated companies, through smaller non-incorporated companies to numerous small private companies They all needed technical expertise and this was thus also the heyday of the *contract system* for specialist gas engineers (such as Clegg, the Malam bros, Peckston, Stears and others) and for speculators with interests in wide areas (for example the Barlow brothers and John Gosling).

4 4 2 The formation of gas undertakings continued to be by individual act of parliament, although there were occasional general acts, as in the Gasworks Clauses Act of 1847, which codified the terms of operation By 1830, 200 towns in England and Scotland had gas undertakings formed in this way; by 1849 - there were a least 760 towns. In addition village works were often formed without a statutory basis, and eventually there were about 600 of these small works (Falkus 1967, 500, Stewart 1958, 43).

4 4 3 Horizontal cast iron retorts remained the norm in this period, and to c1845, the more or less standard purification plant consisted of a hydraulic main, a foul main, a condenser, a breeze box, and lime washers (Stewart 1958, 23-4) Although the telescopic gasholder was patented by Tait in 1824, the majority of gasholders were single lift

4 4 4 Although the early industry was dominated by coal gas, there was some competition from oil gas companies In 1815 John Taylor, the mining engineer, obtained a patent for an oil cracking process devised by his brother Philip and established an oil gasworks at Bow in London. Taylor and Martineau also manufactured oil gas plant at a London works and franchised it to companies that set up in whaling areas (Edinburgh, Hull, Bristol, Liverpool and others). In 1824 Taylor and Martineau further attempted to set up an oil gasworks to supply Westminster; which brought strong opposition from coal gas concerns and a public enquiry went against the scheme. Alongside this, in 1819, Gordon and Heard patented a process for compressing oil gas into cylinders, which led to the establishment of the Portable Gas Company of 1825, operated until 1834 This early oil gas industry seems to have failed to overcome technical problems and its higher costs compared to coal gas led to closure of all concerns by 1830 (see Cotterill 1976, 20, Elton 1958, 272, Mills 1995; Nabb 1997; Stewart 1958, 11, Williams 1981, 29-30)

4 4 5 Although the gas supply at this time was predominantly for non-domestic lighting, by 1840, there was some domestic lighting in wealthier (ie upper and middle class) homes This advance followed improvements to the quality of gas together with price reductions, better lamp and burner design and improved ventilation, but mostly by the introduction of metering The 1820s saw the first use of credit meters on customer's premises (in place of charging by the time for which gas was supplied) By the 1830s, meters were in wide use Initially these were wet meters, replaced by dry meters from the 1840s, which enhanced domestic popularity (Falkus 1967, 501). The 1840s also saw successful mixing of air with gas to achieve more efficient combustion The use of

meters combined with the appearance of non-lighting appliance (such as the first gas stoves in the 1830s) also led to mains being kept on through the day.

4.5 ESTABLISHED INDUSTRY, 1850 - 1875

4 5 1 After about 1850, the expansion of the industry was mainly the expansion of existing works or the addition of new works for a company to extend its area supply There was also some new supply to very small settlements and the beginning of amalgamation of companies in bigger towns Private gasworks for industnal concems, were also still occasionally installed in this period, where economically viable.

4 5 2 The 1860 Metropolis Gas Act gave a monopoly of supply for a given area in London and provided for independent testing of quality, punty and pressure of gas sold. This latter clause was extended to the entire country in the 1871 Gasworks Clauses Act More fomal professionalisation of the industry also began with the fomation in 1863 of the Bntish Association of Gas Managers (later the Institution of Gas Engineers)

4 5 3 In tenns of plant, honzontal clay retorts came into common usage, with self-sealing hds from 1869 Between 1845 and 1870 dry punfiers largely replaced the wet process and washers and scmbbers were improved and widely adopted. The first successful 3-hft telescopic gasholder was built at Blackfnars in 1861, although the majority of small gasworks continued to operate *single lift holders* Finally, railway sidings to gasworks became common

4 5 4 In 1852 the House of Commons was installed with gas lighting (which remained unttl 1900) Over the next twenty years, lighting was also brought to many houses and further refinements of domestic and non-domestic bumers followed Sugg and Bray introduced the water-slide chandelier in 1869, Sugg produced Argand bumers suitable for use in large spaces such as shops, and Wenham & Sugg developed a regenerative process for powerful lights (as required for lighthouses) Finally, portable oil gas production was revived and used for lighting railway carnages in Genuany, m 1871, and in England in 1876, the latter being supplied by Pintsch & Co and Pope & Son.

4.5 5 The wider use of gas for non-lighting purposes grew from the 1860s, with more common use of gas cooking and gas engines from the 1870s. This was boosted by the invenfion of the bunsen bumer in 1855, which improved combusfion by combined air with the gas Many cooking appliances were patented between 1850-60, although there adoption was slow, partly due to developing nature of the technology and partly to high costs compared to coal. In 1824 the Aetna iron works (in Liverpool) made gas cookers, in 1841, the chef Alex Soyer began gas coking at the refom Club in London, in the 1860s Wnght & Co. and Leoni & Co sold small cooking and heating appliances, and from 1869, the Crystal Palace District Gas Co began renting out cookers and stoves. Heating appliances were also developed, if slower than for cooking In 1849 Edwards invented pumice balls, in 1851 Smith and Phillips devised an imitation coal fire; in 1852 Goddard devised asbestos fibre; 1859 saw the invenuon of the firebnck back, and 1877 the radiant fire with woven wire. In addifion, water heaters were being made from 1850, and the first water geyser (by Maugham) appeared in 1868 and was subsequently improved by others These new products were readily promoted and in 1879 there was an exhibition of gas appliances in Leeds

4 5 6 A further important development was the invention of the gas engine by Lenoir in 1866 The subsequent development of the Otto cycle for gas engines in 1876 led to the commercial success of the gas engine, with many being produced by the Crossley brothers of Manchester.

4.6 EXPANSION, MODERNISATION, MUNICIPALISATION AND ELECTRICITY, 1875 - 1920

4 6 1 The period 1875-1920 saw considerable growth of the industry, with gas consumption trebling. It was characterised by a significant expansion of non-lighting uses, partly spurred by competition with electricity from the 1880s, further technological developments (including a move to vertical retorts, improved condensing and purifying techniques, and greater mechanisation), the expansion and modernisation of gasworks, and widespread municipalisation in the North and the Midlands.

4 6 2 The first municipal gas undertaking was formed in 1843 by the Manchester Corporation However this was a rarity until the late nineteenth century Although the 1872 Borough Funds Act prevented municipal undertakings from supplying to an area already covered by a statutory company, the 1875 Public Health Act empowered local authorities to purchase local undertaking and by 1882, 148 municipal undertakings had been formed. This had risen to 306 in 1912, mainly in Lancashire, Yorkshire and the Midlands (Williams 1981, 27-8, 43) However this was still less than half the number of private companies In London, several companies amalgamated. In 1870 the Gas Light & Coke Co merged with the Great Central Co and the City of London Company In 1876, the Imperial Company merged with the Equitable, the Western and the Victoria Docks companies (Williams 1981, 27)

4 6 3 There were several major technical advances in this period Inclined retorts were introduced in the 1880s, followed by vertical retorts in the early 1900s, resulting in tall <u>retort houses</u>, with characteristic wall ventilation Carburetted water gas plant was also introduced, at the Beckton works in 1890 Between 1870-1920 the standard sequence of purification plant was. condensers, exhauster, Livesey (or similar) washer, tower scrubber or rotary washer, and dry purifier (with iron oxide and/or lime) The 1905 Act relieved London Companies of the need to remove organic sulphur and this was gradually extended throughout the country. The 1880s and 1890s were also the time when telescopic gasholder construction reached its peak under engineers such as George Livesey This included the first 4-lift holder at East Greenwich in 1886 and the first use of the flying lift In addition the spiral holder was invented (in 1888).

4.6 4 The period 1890-1910 saw a major extension of gas supplies into working class homes. This was a product of several factors and was done in the face of severe competition form the new electricity industry. The gas industry was able to compete with the electricity industry in providing domestic and street lighting (until *c*1930) very largely due to the introduction of the incandescent gas mantle, which came into general use, in its more efficient inverted form, from about 1900 It evolved out of a long line of developments from the 1860s on, based on the principle of using gas combustion to cause a solid body to glow rather than depending on illumination of the gas itself, and culminaung in the Welsbach lamp of 1887 The penny-in-the-slot meter was introduced in 1889 (by Thorp & Marsh), and from 1893 this was a comerstone in the expansion into working class homes (Stewart 1958, 46) Domestic increases were also due to the wide adoption of heating and cooking appliances, partly spuried by competition with electricity and partly due to the availability of better designs (Falkus 1967, 495) These designs included the Leoni gas fire of 1882, Fletcher's 'Afnca' gas fire (a metal basket with fireclay balls) of 1890, Fletcher's improved water geyser m 1890, Pottertons water heater of 1904, a gas fire with columnar radiants in 1905, a gas fire with grid radiants in 1925, and the Ascot water heater in 1932. Industrial use also grew. From 1880, Fletcher and others developed gas for small industrial uses (muffle fumaces, metal working, glue boiling, etc), and during the First World War, there was increased use for fumace-firing.

4 6 5 The penod also saw several important institutions formed. the Gas Companies Protection Association in 1898, the Incorporated Institution of Gas Engineers (IGE) in 1903. (by amalgamation of conflicting mstitutions), the Society of Bntish Gas Industnes m 1905 (to represent makers of plant and apparatus), the British Commercial Gas Association in 1912 (a publicity agency for industry), and the National Gas Council of Great Bntain and Ireland in 1916 From 1907, methodical research was earned out under the umbrella of the IGE and the major gas companies (Williams, 1981, 22)

4 6 6 The adoption of the incandescent gas mantle and the steady move to non-lighting functions also brought about a gradual move from the illuminating standard to a thermal standard as the basis for charging customers, and the 1916 Gas Act empowered undertakings to choose to switch to the thermal standard

4.7 RESTRAINED RATIONALISATION, 1920 - 1949

4 7 1 The 1920 Gas Regulation Act obliged all statutory undertakings to adopt the thennal standard It also allowed gas undertakings to buy gas from each other (Williams 1981, 44, 59) The industry at this point was in the hands of numerous different undertakings, a set-up which now came to be regarded as a 'fragmentary' arrangement for what was now a fundamental utility industry In 1920 there were at least 1300 gas undertakings, of which 780 statutory undertakings provided the bulk of the supply. Changed economics and electricity competition forced some smaller undertakings to be absorbed by large ones, such that the number of statutory undertakings reporting to Board of Trade reduced from 798 in 1920 to 716 in 1935 (for example the GL&C absorbed a further 6 companies between 1922 and 1935) More important was 'Holding Company' movement of the 1930s which saw 242 undertakings enter into joint operation under 18 umbrella companies (covering 9% of gas production) By 1936, half of the gas supplied came from 20 undertakings, of which the biggest was the Gas Light and Coke Company In addition the institutions representing the industry underwent some re-organisation. In 1919 the Federation of Gas Employers was fonned; in 1934 British Gas Federation was set up to represent five exisfing bodies, and in 1939 the Gas Research Board was set up under the IGE and the Society of British Gas Industries, to conduct co-operative research for industry.

4 7 2 The purchase of coke oven gas produced in relation to the iron and steel industry, was effectively restricted to neighbouring undertakings. The possibility of building networks for extending this were examined by a Board of Trade Departmental Committee, which decided it was only feasible in South Yorkshire and in 1931, the Sheffield Gas Co was given permission to build a high pressure grid (which cut prices by 30%)

4 7 3 By the 1930s, continuous vertical retorts were well established, being in use at 250 of the 450 largest undertakings, and accounting for about 60% of the gas made Carburetted water gas generation on many large sites was an important means of dealing with daily demand fluctuation The first dry holders (to German designs) were built in 1927. Further extension of urban and rural systems led to the gas-main mileage rising from 39,000 miles in 1920 to 69,000 miles in 1945(Williams 1981, 57-67).

4 7 4 By-products remained important. The British Sulphate of Ammonia Federation was set up in 1920 to negotiate on behalf of gas companies and the National Benzole Company was et up in 1919 for similar purpose Coal-tar was important as the continuing basis of an expanding organic chemical industry, as well as being used for re-surfacing roads, treating roofs and timbers Finally the domestic sales of coke rose with improved designs of coke boilers

4 7 5 At this time 60-70% of gas sales were domestic, with 90% of these used in heating and cooking. Domestic lighting lost out to electricity, although public lighting remained important to the late 1930s (until then about half of street lighting was by gas, representing about 5% of the gas made) Commercial and industrial use consumed roughly equal amounts (Williams 1981, 69)

4 7 6 The Second World War resulted in damage to many works, and was a period of repairs, with some new gas plant and some producer gas plant installed. There was also the adaptation of a small proportion of plant to produce hydrogen for barrage balloons (Williams 1981, 81-8)

4.8 NATIONALISATION, 1949 - 1967

4 8 1 Nationalisation of the gas industry had been a policy of the Labour party since before the war. The 1948 Gas Act followed nationalisation of the coal industry in 1945, the railways in 1947, and the electricity industry in 1948, and followed the model of the Electricity Act (Elliott 1980, 13-14, Stewart, 1958, 44, Williams 1981, 103-20). A total of 1,050 works were brought under 12 autonomous Area Gas Boards (10 England, 1 Scotland, 1 Wales). The Act excluded 35 'ancillary gas undertakings' which generated gas for their own purposes, this included 13 undertakings that were already nationalised - 6 owned by the Coal Board and 7 by the Transport Commission. Coke ovens (of the coal board and the steel industry - nationalised in 1949) were also excluded.

4 8 2 The Gas Council was also formed 'to promote and assist the efficient exercise and performance by the Area Boards of their functions'. It had a London headquarters and

had 14 members of Council, made up of the 12 Area Board Chainnen (hence very powerful men within the industry), together with its own chainnan and vice chainnan.

4 8 3 The product of nationalisation was a further concentration of generation into larger works, together with the laying of a gnd mams. The number of gasworks was reduced from 1,050 in 1949 to 536 in 1958, and the gas mains was extended from 77,000 miles m 1950/1 to 90,000 in 1956/7 The bulk of the gas came from this nafionalised industnes gasworks, although 14% was purchased from coking industry, and a small amount from oil refinenes. There was also some transported butane gas to remote mral areas, and *methane gas drainage*, for example at Whitehaven where the gasworks was closed on favour of this.

4.8 4 Gasworks employed coal gas supplemented by carburetted water gas for demand flucuiations However the increasing scarcity of suitable coking coals combined with large increases in coal prices prompted the nationalised gas industry to explore moves away from coal (Williams 1981, 122-9). Research was directed specifically at the complete gasificanon of low grade coal, the gasification of oil, and the importation of liquefied natural gas (see below) Four research centres were established. Watson House (originally set up by the GL&C Co in 1926, adjacent to Nine Elms Works in London), the London Research Station (also set up by GL&C Co, in 1928 at Fulham), the Midlands Research Station (1950s, Solihull), and the Engineenng Research Station (in 1964 at Killingworth, Newcastle-upon-Tyne).

4 8 5 Lurgi plant for the complete gasification of coal was built at Westfield, Scotland in 1958-60, and at Coleshill, Binningham (closed in 1969). However, much wider adoption was made of oil gas processes developed by the research labs The catalytic nch gas (CRG) process was first used at Bromley-by-Bow works, and the gas recycle hydrogeneration (GRH) process was first built at Avomouth, Bristol in 1965

4 8 6 Nationalised gas usage in the 1950s divided as follows: domestic, 51%, industnal, 29%, commercial, 15%, public, 5%. One notable feature was the heavy promotion of central heating in the 1960s. By products again remained important, with yearly sales as below (Stewart 1958, 48).

- coke — 11 million tons
- coke breeze — 1 7 million tons
- tar — 370 million gallons
- ammonia products — 250,000 tons
- sulphur — 125,000 tons
- benzole — 29 million gallons

4.9 NATLRAL GAS, 1967 - 1986

4.9 1 Conversion to natural gas between 1967 and 1977 resulted in the elimination of early equipment and traduional gas works in Bntain (see Elliott 1980, 1-12, Williams 1981, 139-223, Wilson 1974) The Gas Council was pursuing the idea of natural gas from the early 1950s, when it examined the Amencan industry (by 1950 90% of the

American gas supply was natural gas) and became involved in exploration. This led in 1959, to the first delivery of liquid methane (using American-developed technology) to the Canvey Island shore terminal, in Essex In 1961, liquid methane was imported from the Sahara (Hassi R'Mel Oasis), and the Canvey Island terminal was expanded (with a new jetty and storage tanks) to cope This storage capacity was increased further in 1966, such that imported natural gas was providing 10% of the British supply Although the gas was too rich to be used directly in existing town gas burners, it could be blended with the town gas supplies A *high pressure main* built from Canvey Island to Leeds allowed this blending, via spurs to eight of the twelve Area Boards.

4.9 2 A series of developments made it possible for the gas industry to consider total conversion to natural gas First, in the 1950s, Britain established oil and gas rights over the western half of the North Sea (by the 1958 'Convention of the Seas' in Geneva, ratified in 1964) Then, in 1959, the discovery of the Groningen Gas Field in Holland waters spurred exploration and in 1965, BP established the *West Sole Field.*

4 9 3 A major problem with conversion was that natural gas could not be used by existing appliances Natural gas has twice the calorific value (or heating content) of manufactured gas so that it requires twice the amount of air mixed with it at the burner in order to burn It was therefore necessary either to convert the natural gas, or to convert the appliances The Gas Council chose the latter option as being cheaper in the long term. A trial conversion run was made in Canvey in 1965 (near the terminal) and the final decision to go for conversion was taken by the Gas Council in 1966. The Conversion Executive was set up, as a department of the Gas Council, to oversee it and the Conversion Programme proper began at Burton-on-Trent in the summer of 1967, reaching completion in 1977 (Elliott 1980, 13-14)

4.9 4 A new shore terminal was built at Easington, Humberside in 1967 to serve the *West Sole Field*, and a new 24-inch main was built to connect this to the Canvey Island-Leeds main at Totley, near Sheffield. In 1966-7 three fields were discovered off the Norfolk coast - *Hewett*, *Leman Bank* and *Indefatigable*; this resulted in a shore terminal at Bacton in 1967-8 The *Viking field* became operational in 1972 (by the NCB and Conoco), with its shore terminal at Theddlethorpe. The *Rough Field* was discovered in 1968, although only developed after 1973, and was linked to the Easington terminal in 1975 In Scotland, the St Fergus terminal opened in 1975/6 in relation to the *Frigg Field* Finally in 1985, a terminal was opened at Barrow to serve the *South Morecambe field.* Hand-in-hand with construction of the new terminals, was a major extension of the high pressure distribution grid, what became termed the *National Transmission System*, which was greatly extended beyond the Canvey Island-Leeds pipeline, from 320 miles in 1966 to 3047 miles in 1978-9 (Williams 1981, 225-30)

4 9 5 Conversion to natural gas also resulted in a major business restructuring, with the twelve area boards and the Gas Council being brought together as the 'British Gas Corporation' on 1 Jan 1973 (from the Gas Act of 1972).

4.10 PRIVATISATION, 1986 ON

4.10.1 Re-privatisation of the gas industry came about in 1986, with the formation of 'British Gas'. The privatisation act also set up the regulatory body OFGAS. Subsequent re-organisations have followed and the industry is currently in the process of de-merging, with two separate parent companies formed in 1997: 'BG plc', which includes 'TransCo' who operate the pipeline and storage system throughout Great Britain, and 'Centrica plc', whose core business is that of supplying gas to customers. In part this re-organisation is in relation to an ongoing process of re-introducing supply competition within industry, (commenced in the South West in 1996)

4.10.2 The companies making up the demergered parent groups are as follows.

BG plc:

- *TransCo* - operates Britain's pipeline
- *BG Storage* - operates gas storage system
- *British Gas International Exploration and Production* - gas and oil exploration and production
- *British Gas International Downstream* - international gas transportation, distribution and power generation
- *Properties* - management of Group's property portfolio
- *Research & Technology* - for the Group and others

Centrica plc

- *British Gas Trading* - markets gas supplies
- *HRL Ltd* (Morecambe) - manages/operates Morecambe gas fields (opened in 1985) in Irish Sea (subsidiary of British Gas Trading)
- *British Gas Services* - installation, repairs and servicing of domestic gas systems and appliances
- *Energy Centres* - retailing of gas and electric appliances.

5. ARCHITECTURAL CONSIDERATIONS

5 1 The buildings and structures of the gas industry are touched upon in general architectural history texts, having a particular relevance to Victorian industrial architecture (Jones 1985, 69-72, 131, Miele 1996, Pevsner volumes) There have been a range of influences on gas industry architecture at different dates which should be catered for in the MPP selection process These include the functional nature of the industry and its need to operate efficiently, its continually increasing scale of production and therefore prominence in urban landscapes, design variation to accommodate changing technologies (notably from horizontal to vertical retorts), the effect of available building materials and structural technology of the day, and the effect of the organisation and ownership of the industry at different dates

5 2 Whilst larger companies and works could afford grander architectural statements, even the smallest gasworks were designed with some aesthetic consideration, and several components were subject to special architectural treatment (reflected in the 58 buildings and structures associated with the gas industry which currently hold listed building status - EH pers comm)

5 3 Retort house designs varied from very plain to the very ornate, in accommodating the change from early low profile buildings housing horizontal retorts to later tall buildings for vertical retort technology, with many stations employing classical features Early noted classical compositions included the Hoxton gasworks, by Francis Edwards in 1823, Canon's Marsh gasworks, in 1819 and the Kendal gasworks, in 1825. The monumental Beckton works of 1869-70, by F R Evans and V Wyatt and built by Sir John Aird, employed classical brick facades for its vertical retort houses, with terracotta detailing for the wall ventilation, the interiors using elliptical-arch iron roofs supported by cast iron columns.

5 4 An early practice of the industry was to enclose gasholders within gasholder houses, which were an obvious opportunity for architectural embellishment A pattern of twin octagonal towers flanking the entrance and offices, with the retort house to the rear, seems to have been used on many sites and is notably represented by the surviving example dated to 1822 in Warwick, with its 'restrained Palladian style'. Similarly, prominent components such as the manager's house, the office and gateway were usually given aesthetic consideration Even station meters could be of ornate design (for example the Bromley Works meter of 1876 - see Williams 1981, 20).

5.5 Innovative engineering design was used in both retort house construction and in the gasholder An example of the former is the exceptional cast and wrought iron roof structure of the 1822 Birmingham gasworks (Williams & Donald 1993) Examples of the latter are the functional cast iron tripod supports of the Fulham no 2 gasholder of 1827-30, and, more noticeably, the extraordinary iron guide frame designs for telescopic gasholders in the late nineteenth-century, as seen in the 1880s St Pancras group, one of the most prominent elements of Victorian engineering architecture (Miele 1996)