Low-pressure gas storage

by Brian Sturt

There are perhaps 1600 to 2000 gas holders surviving in this country, located in 850 holder stations; this compares with 3000 holders twenty years ago. After Nationalisation in 1949 many small holders were scrapped due to the rationalisation of supplies. However the popular rumour that all holders would disappear after the change over to natural gas is far from the truth. Although the gas holder developed with the carbonizing era of the industry, it still competes effectively with more modern forms of storage. Of the 120 holders in the South Eastern Region, the oldest is 110 years old, at least ten are 100 years old, and a good 50% are over 50 years old, which says much for the original design and workmanship.

While the gas industry is of interest to the industrial archaeologist, gas works are not normally accessible to the public; the gas holder, however, can usually be observed from outside. This article describes the history and development of the various types of low pressure holders in use today.

The need for storage

The gas industry initially consisted of small units supplying a few customers, who contracted to burn a light for a certain period of time only. The gas companies spent considerable money employing surveyors to detect infringements of contract.

A works would run thus for only a short period and the requirement for storage would be small. With expansion of the industry and the development of the gas meter (c.1816), service to the customer became 'as and when required'. At a manufacturing station, storage was provided to cover any sudden variation in demand, or mechanical breakdown, the optimum being storage for 24 hours supply.

In the manufacture of 'towns' gas by the destructive distillation of coal, the retort house ran best at constant load. Even with the introduction of carburreted water gas in the 1890s, with a start-up time of hours rather than days, flexibility remained a problem. New processes of the oil era in the 1950s improved flexibility, but rapidly increasing demand in the last 20 years has offset these benefits. Today the South Eastern region takes gas from the National Grid at a constant rate, and short term variation in demand cannot be passed back onto the national system. Thus on a typical day, with a 0600 hours start, by 2200 hours the consumer has taken between 77 and 83% of the daily demand, yet only 67% would have been taken at a constant rate; the difference is withdrawn from storage. The South Eastern Region had a peak load of 250 million cubic foot per day (Mcfd) of towns gas; today it is normal to exceed 600 Mcfd of natural gas in winter. Since the calorific value of natural gas is approximately twice that of towns gas, this is equivalent to 1200 Mcfd of towns gas, with about the same number of consumers as in 1949.

The storage requirement is thus about 15% of the 'sendout' on a normal day, and also a reserve has to be provided for the sudden deterioration in weather. Although today high pressure storage is used either from vessels or linepack (depressurisation of high pressure grid mains), low-pressure gas holders still have a very important part to play in ensuring continuity of supply to the consumer.

The history of gas holders

The first effective form of gas holder was the water sealed type, which consisted of 2 tanks. The smaller tank, or bell, containing the gas, was inverted over and inside the larger tank, which contained water; the bell was supported by chains, pulleys and counterbalance weights. Holders of this type were first used by Lavoisier in 1782 whilst studying the properties of various gases. They were developed by William Murdoch when constructing plant for the lighting of Boulton & Watt's Soho works in about 1800. It is said that Samuel Clegg (see Appendix 1), in the early 19th century, copied and developed this holder to its present form for the Gas Light & Coke Company.[1] Clegg also invented some short lived variations, one of which, the rotating holder, led to the development of the gas meter. Prior to the introduction of meters, small calibrated gas holders were used to measure the gas used. They were known as gasometers, and the term is still in popular use, although the Industry always refers to 'gas holders.' One curiosity in early times was the naming of holders: the City Gas Company had a holder built in 1816 for £737 4s 9d called the 'Good Intent', and Bristol's first holder of the same year was a Clegg design named 'Aladdin'.[2]

Much public concern was expressed over the safety of gas holders, and in 1813 the Royal Society recommended that holders should not exceed 6000 cubic feet in capacity and that they should be housed in strong buildings; however lack of proper ventilation was the cause of a holder explosion in Manchester in 1819. The Royal Society inspected Great Peter Street works (Westminster) and discussed, in the presence of Clegg, the danger of leakages. Clegg stuck a pickaxe into the holder and lit the escaping gas with a candle. The members of the Royal Society retreated, but the expected explosion did not take place.[3] By 1823 forty seven gas holders were in use in London alone.

Early holders were often rectangular or square (in plan), the infamous Manchester holder being of this type; the more familiar circular holder apeared after developments by John Malham, who improved the counterbalance system and enabled a lighter construction to be used.

William Nicholson patented a telescopic holder, with two or more lifts, in 1827, but gave up the patent in 1836 due to the unpatented design of Tait (1824).[4] The first telescopic holder was build in Leeds in 1826, and early examples were also constructed at Mile End. The telescopic holder used less ground space for a given volume of gas and was cheaper to construct than two separate holders; however the pressure increased with the number of lifts raised. In 1852 an unsuccessful attempt was made to build a three lift holder at Rotherhithe, followed, in 1861, by the first successful example built by the City Gas Company at Blackfriars. After demolition the guide framing of this holder was exported and re-erected in Calcutta.[5] A four lift

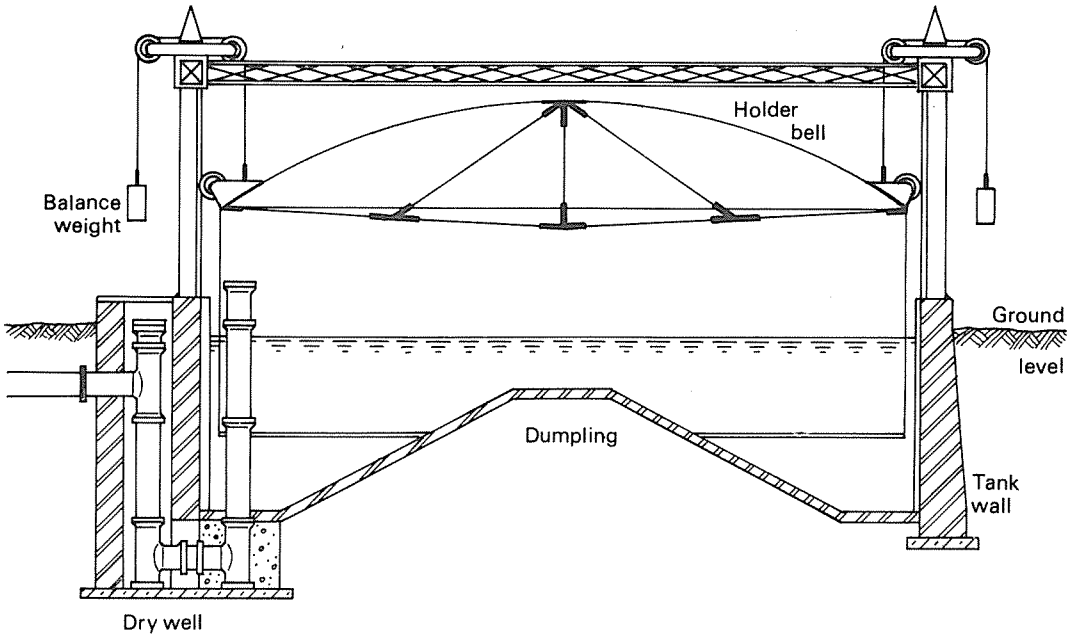

Fig.1. *Typical cross-section of small water-sealed buried gas holder; not to scale but diameter usually less than 100ft.*

holder was built by the South Metropolitian Gas Company at East Greenwich in 1886.

During the 1880s the spirally guided holder, with no guide columns, was developed, and has since become quite common. The waterless holder was developed in Germany in about 1914 and the first was built in Britain in the 1920s. They are less popular here than in many other parts of the world. The Wiggins Holder, developed by the American oil industry in the 1940s, has been used to a limited extent in Britain since the 1950s.

Column guided holders

Holder tanks. One of the main difficulties in the early days of holder construction was the building of the tank. An early solution to this problem was to use second-hand brewers vats. However the water used in the holder dissolved any residual ammonia and hydrogen sulphide in the gas, and the iron hoops corroded. The resulting collapse of the vat not only interrupted supplies but also left the malodorous contents of the vat to be disposed of! Despite these occurances the last vat did not go out of use until 1843.

By 1818 the standard methods of construction had been evolved for holder tanks. Three basic types are used; buried, semi-buried and above ground tanks. In the buried type shown in Fig.1, a circular trench is excavated in which the tank wall is built. The wall, built of well burnt brick, is waterproofed with a cement rendering on the inside or by being surrounded by puddled clay. The interior is excavated to the full depth providing room for the bell of the holder, but the central section is only partially excavated, leaving the 'dumpling', which reduces the volume of water required and provides a foundation for the wooden framework to support the crown of an untrussed holder when deflated. Without the dumpling the volume of water required to fill the tank is very large; the tank of No.2 holder at Greenwich needs 12 to 13 million gallons. The dumpling was either faced with brick and rendered, or, where suitable clay was available, was left as puddled clay. Inlet and outlet pipes are built into the tank through a shaft excavated outside the tank wall, known as the dry well. Provision is made for pumping water. If the pipework is large enough an airlock is placed at the top of the dry well giving accesss to the interior of the holder for maintenance when the holder is decommissioned.

In 1871 George Livesey (see Appendix 1) built the tank for No.11 holder at the Old Kent Road using Portland cement to replace the outer layer of brickwork. The cost of this hybrid tank was £1700 less than one of normal construction. In 1875 the tank for No.12 holder was built using mass concrete alone (Fig.2a). Water was encountered at a depth of 11ft and the working had to be pumped at the rate of 60 to 70 thousand gallons per hour; nevertheless the tank was completed at a saving of £5000. The tank developed vertical cracks allowing the water to leak out. To prevent this happening subsequently, the three holders built by the South Metropolitan incorporated iron bands in the walls. It was not unusual for tanks to leak slightly, and dung or spent hops from the local brewery thrown into the holder tank were time honoured methods of controlling the problem.

In poor ground conditions a semi-buried tank could be built, as at East Greenwich. In 1886 the depth of the tank for No.1 holder had to be reduced from 60ft to 45ft, with the top 13ft above ground level, but it was still necessary to pump out 240 thousand gallons of water per hour (the holder being near the Thames). To keep the holder capacity the same as designed the number of lifts was increased from 3 to 4, resulting in the first four-lift holder in the world.[6] In 1892 the base of the tank for No.2 holder was built at water table level, 13 ft below the original ground level. This tank has no dumpling because the peat subsoil was unsuitable for lining with concrete and was removed.[7] (Fig.2b)

Above-ground tanks were constructed from flanged cast- or wrought-iron plates, each tier of plates being strapped with a wrought-iron band. The holder standards stood on brick or stone piers, or, sometimes, cast-iron boxes. These tanks were relatively light in weight and could, with proper precautions, be built on soils with poor load-bearing properties. The cost was, however, three to four times that of a conventional tank, and the average size of this form of tank was restricted to about 60ft

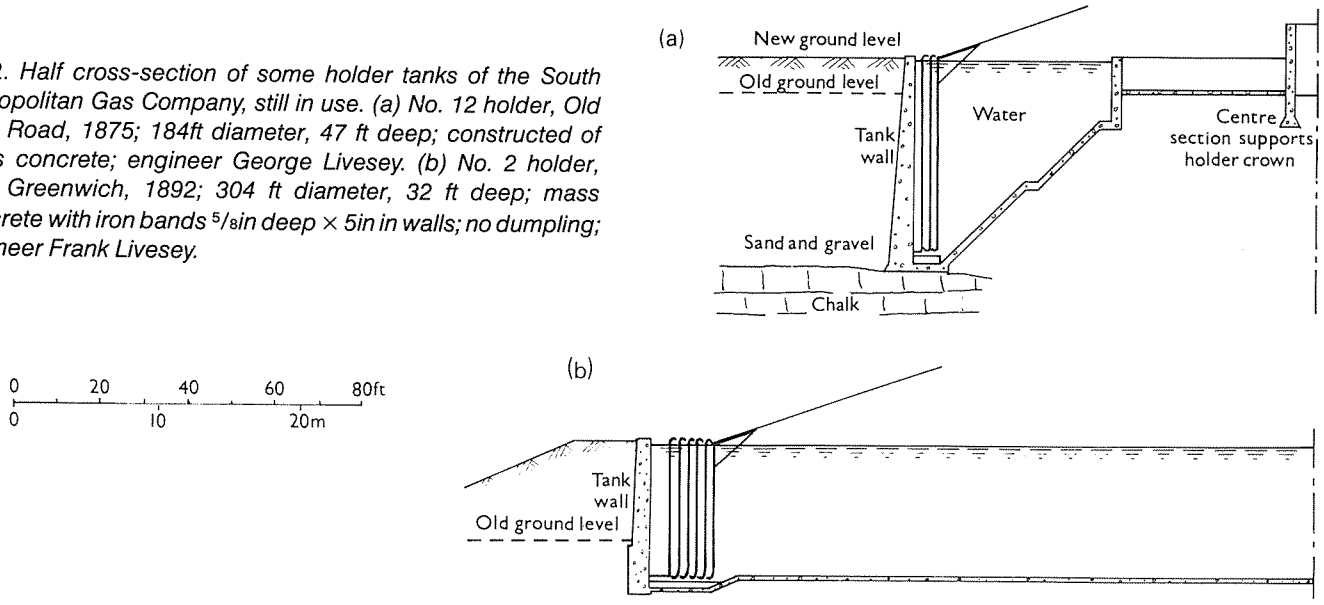

Fig.2. *Half cross-section of some holder tanks of the South Metropolitan Gas Company, still in use. (a) No. 12 holder, Old Kent Road, 1875; 184ft diameter, 47 ft deep; constructed of mass concrete; engineer George Livesey. (b) No. 2 holder, East Greenwich, 1892; 304 ft diameter, 32 ft deep; mass concrete with iron bands 5/8in deep × 5in in walls; no dumpling; engineer Frank Livesey.*

diameter. As techniques improved and with the better availability of steel plate, the new material was used increasingly, especially with spirally guided holders. These tanks have the advantages of lower cost, easier overall maintenance and lighter weight, but have the visual disadvantage of increasing the height of the holder.

Column guides and standards. Column guides, which are embedded in the foundations of the holder, provide a vertical guide and support for the bell, which is unstable when high in the framing. They also absorb stresses on the holder due to wind and uneven snow loading. When the holder is deflated, the column guides are themselves subjected to direct wind loading and, to give extra rigidity on tall holders, Paddon's ties are added (Fig.3). These bracing ties were first used by John Paddon at Hove in the 1870s.[8]

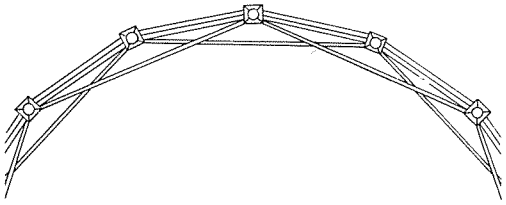

Fig.3. *John Paddon's wind ties*

The earliest holders were housed in buildings, the roof trusses of which were used to support the pulleys of the counterbalance system. Support was later provided by tripods, and when a number of tripods were used these were tied together giving the column guided holder we know today. The first type of column guided holder was the work of John Mallam. This relied on a central cast-iron column with guide rollers at the top and bottom of the bell, rails being fitted to the column on which rollers could run. The first holder at Old Kent Road (1832) was of this type and was protected from the wind by a brick wall.[9] Some holders built in the 1840s are shown in Figs. 4 and 5.

The multi-column holder, often with massive cast- or wrought-iron uprights tied together at the top with girders and cross braces, developed from this. The columns were designed to react individually to the forces on them. A group of six holders, built by Thomas Kirkham for the Imperial Gas Company in 1870-5, provides a good example of this type and is still to be seen at Bromley-by-Bow (TQ 385826).

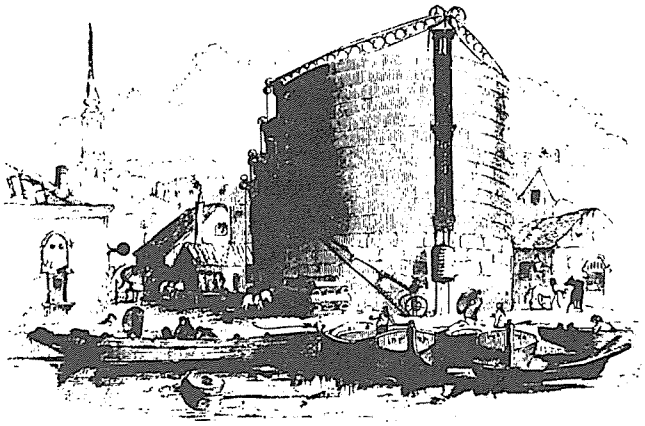

Fig.4. *Early column holders at the City of London gas works, Blackfriars, c.1840. The holders were demolished c.1865 and Unilever House is now on the site.* (*Source:* Discoveries & Inventions of the 19th Century, *13th edition, Routledge, 1900*).

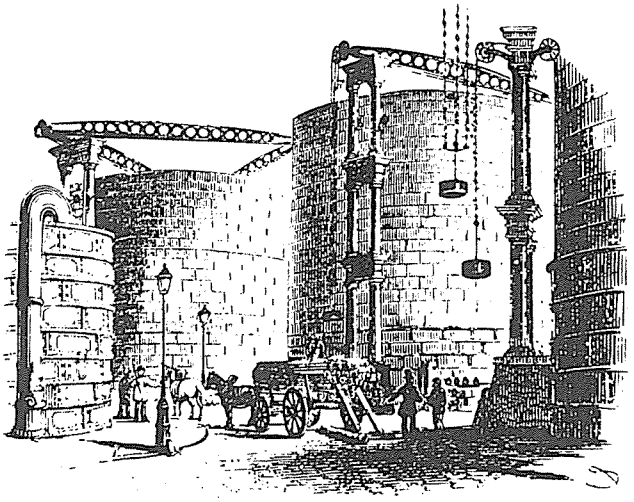

Fig.5. *Column gasometers and early scrubber at Great Peter Street works, Westminster, c.1840.* (*Source:* Useful Arts & Manufactures of Great Britain [1848], *second part* 'The manufacture of Gas'.)

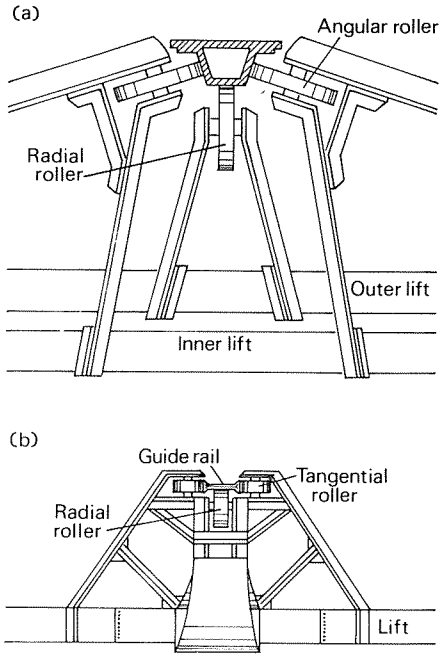

Fig.6. *Holder carriage rollers. To enable carriages to pack together when the holder is deflated, rollers of different types are fitted to different lifts. (a) Combination of angular and radial rollers on holder at East Greenwich. (b) Combined tangential and radial rollers on holder in Manchester.*

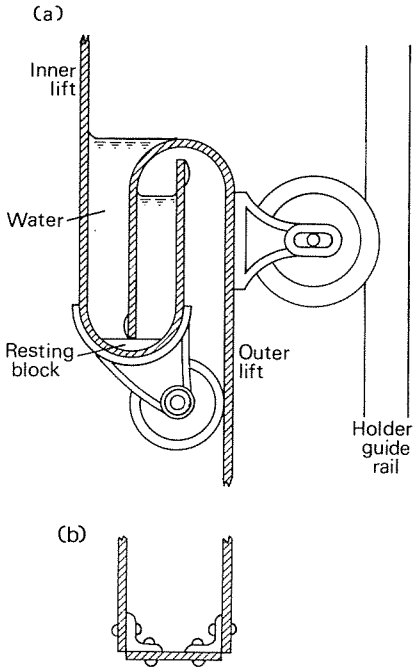

Fig.7. *Gas-tight seal used in telescopic holders. (a) cup and grip, with lift inflated, introduced by George Piggot, 1862. (b) rivetted cup used before this.*

Cast-iron columns were superseded in the 1880s by standards fabricated from rolled sections or lattice girders, on which were mounted the guide rails for the carriage rollers. The standards were tied together by deep girders at the top, and by cross-braces under tension forming in effect a cylindrical shell, which distributed the imposed forces round the structure. This development followed from the work of Sir Benjamin Baker and Frederic Southwell Cripps[10], and led to the building of larger gas holders, pioneered by George Livesey.

The Bell. The first rectangular holders were built by covering a wooden framework with iron sheet. The circular holder is constructed from rivetted iron or steel plate of a nominal 1/8in thickness. Thicker plate or a double layer of plate is used — up to 1 in thick on larger holders — where extra stiffness is required, especially on the edge of the crown. The crown is usually a section of a sphere, trussed on the underside to prevent collapse when the holder is deflated (Fig.1). Later holders were untrussed and used a wooden framework constructed on the dumpling to support the crown when deflated. Wheeled guides at the edge of the crown and at the base of the bell were set radically or tangentially to run on the standards or guides (Fig.6).

With the introduction of the telescopic holder the construction became more complex. The top edge of the outer lift is rolled over inwards to make an inverted U-shape to form the grip, and the bottom edge of the upper lift is rolled outwards and upwards to form the cup (Fig.7a). When the holder is filled the inner lift rises until it reaches its maximum height when the cup and grip engage with each other and both lifts rise together. The cup is full of water as it comes from the tank and this forms a gas tight seal. Cups are nominally 8in wide and 16in deep, but the size on larger holders is a maximum of 12in wide by 24in deep. The bent section of the cup was introduced by George Piggot in 1862, and first used on a holder at Old Kent Road.[11] Prior to this, rivetted sections were used (Fig.7b), which led to leakage and repair difficulties. Even today the cup and grip can be a maintenance problem. In cold weather when the water in the cup can freeze with risk of serious damage to the holder, electrical or steam anti-freeze systems are provided. The complex carriage rollers on multi-lifted holders are required to pack together when the holder is deflated (Fig.8), and on the six-lift holder at East Greenwich it was necessary to fit different types of carriage rollers on different lifts (Fig. 6a).[12,13] Rollers at the bottom of the inner lifts are mounted under the cap and run on stiffened sections on the inside of the next outer lift. These are inaccessible for maintenance except when the holder is decommissioned. A further development of the telescopic holder is the flying lift. In this case the top lift can pass out through the top of the standards. In 1888 George Livesey inflated a holder at Rotherhithe which had three lifts with one passing out of the guide framing. This may have been another

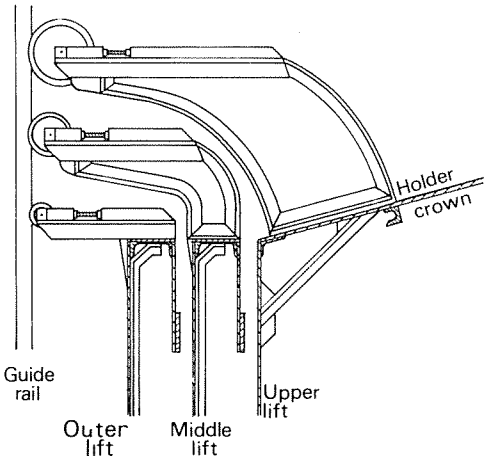

Fig.8. *Typical arrangement of carriage rollers on a three-lift holder*

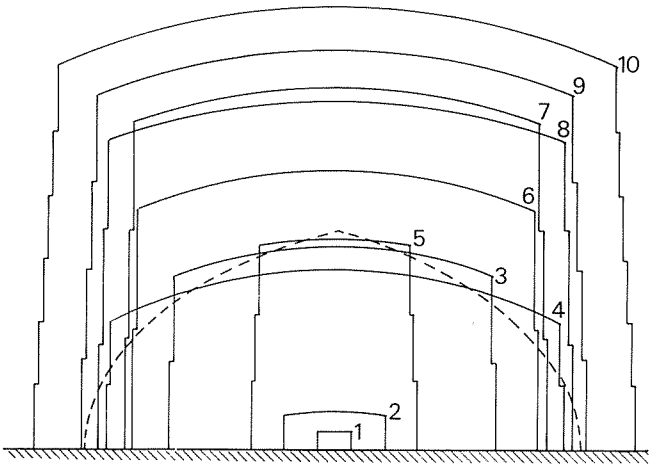

Fig.9. *Growth of the gas holder from 1200 to 12,000,000 cubic foot capacity, from a diagram by George Livesey, 1905.*

1.	Typical chartered single holder	1200 cu ft	1812
2.	First South Metropolitan single holder	30,000 cut ft	1832
3.	William Innis's Kennington double holder	1,400,000 cu ft	1854
4.	Robert Jones's Stepney and Nine Elms double holders	2,000,000 cu ft	1860
5.	William Mann's Blackfriars three lift holder	500,000 cu ft	1861
6.	Corbet Woodall's Kennington double holder	3,100,000 cu ft	1878
7.	Old Kent Road three lift holder	5,500,000 cu ft	1881
8.	Charles Hunt's Birmingham three lift holders	6,00,000 cu ft	1883
9.	East Greenwich four lift holder	8,000,000 cu ft	1887
10.	East Greenwich six lift holder	12,000,000 cu ft	1892

To indicate scale, the dashed line represents the roof span of Midlands Railway's St. Pancras station, London.

first for the South Metropolitan. Rotherhithe possessed an unusual collection of holders, which suggests some experimentation: all three holders had a total capacity of less than 2½ million cubic feet, yet No.1 had three lifts, one of which was a flyer, and No.2 and No.3 (1897) each had five lifts, two of which were flyers.[14] The South Metropolitan produced the ultimate in flying lifts, when in 1892 the giant No.2 holder at East Greenwich was built with two flying lifts rising 60ft above the 126ft high standards (Plate 1.)[15] These flying lifts were destroyed in the Silvertown explosion of 1917 (an armament factory about 1½ miles away).[16] Flying lifts placed extra stress on the guide system, resulting in heavier wear; also in high winds there was a risk that the carriages would foul the guide system on deflation. Despite these disadvantages flying lifts were added to existing holders and new holders were sometimes designed to have an extra lift as a later development. The South Metropolitan altered a number of their holders by adding flying lifts, No.1 holder at Kennington being an example. Built in 1878 by the Phoenix Gas Co. (Plate 4), its capacity was doubled to 6 million cubic feet in the 1890s by the addition of two extra lifts, one flying.[17] The use of the flying lift allows a lower less expensive guide framing to be built which is also less obtrusive. An example of this can be seen at East Greenwich where the holder with the lower framing has the larger capacity.

Cost can be further reduced by using more shallower lifts thereby reducing the depth of the tank: the No.2 holder at East Greenwich, cost £8000 less to build but gave a 50% increase in capacity compared with the No.1 holder. If space is at a premium a telescopic holder provides the greatest storage capacity for a given ground area, as with William Mann's three-lift holder at Blackfriars (now demolished); 84ft in diameter and 100ft high it occupied a space less than 100ft square.[20] One disadvantage of the telescopic holder which restricted its initial development is that each lift 'throws' a different pressure. The top lift inflated alone could be less than the district pressure and lower lifts could be more; some early telescopic holders had counterbalance systems on the lower lifts to overcome this. Today the gas is pumped out of the holder onto the district system but difficulties can still be experienced at multi-holder stations in filling and emptying the holders due to variation in pressure. The telescopic holder reached its zenith in the late 1890s and Fig.9 based on a drawing by Sir George Livesey indicates this development.

Spiral guided holders

In 1887, W. Gadd and W.F. Mason patented the spiral guided holder, and the first was built in 1889-90 at Northwich, Cheshire[21]. This dispenses with guide framing and is designed to withstand wind and uneven snow loadings without additional support. The guiding system consists of rails fitted externally to the lifts at 45°. The extra plates used to support the guide rails also act as stiffeners to the lifts, and the bottom lift often has double the number of guide rails for extra strength. Carriage guides are of the four roller type with two rollers above and below the guide rail (Fig.10), and are fitted to the grip of each lift. The carriage rollers, unlike those of telescopic holders, are easily accessible, especially when the holder is deflated, but do require greater expertise in adjustment to prevent jamming. The cup and grip system is the same as used on column guided holders. However the risk of damage from water freezing in the cups is higher: the rotating motion of the holder could sheer the inlet and outlet pipes with very serious results and an anti-freeze system is needed.

Although slow to be accepted, a considerable number of these holders have been built: they are cheaper than the column guided holder, especially if a steel tank is used. Spiral guided holders were often added to a works, or replaced a scrapped holder, sometimes with the reuse of an old holder tank, an example of which is at Bromley, Kent.

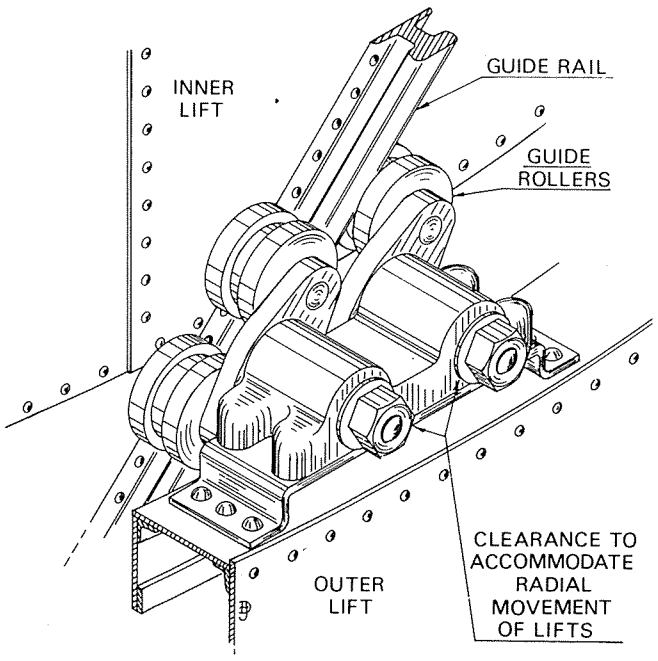

Fig.10. *Carriage rollers on spiral guided holder*

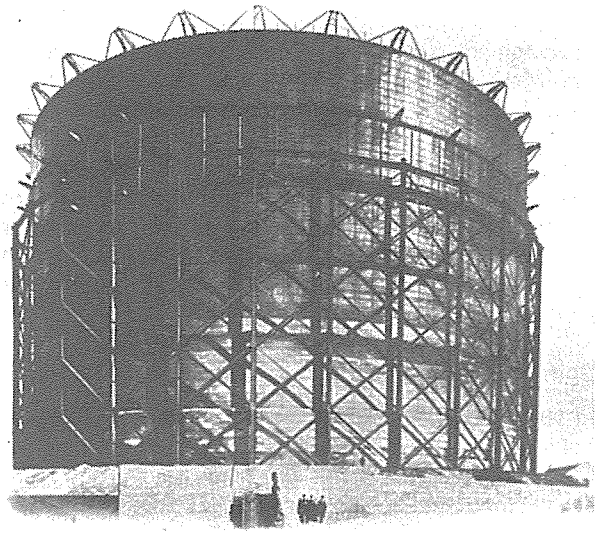

Plate 1. *No. 2 holder at East Greenwich Works c.1900, showing the two flying lifts which were lost in the Silvertown explosion of 1917.*

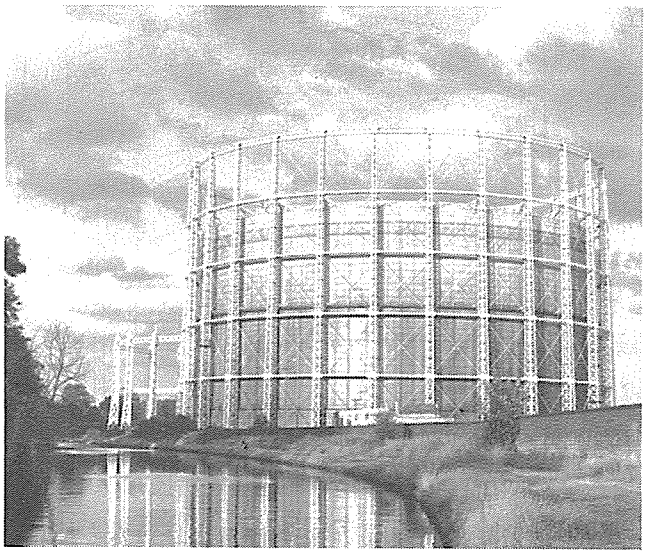

Plate 2. *Kensal Green:* The Colonel *four-lift holder, 1891, 7,500,000 cu ft; earlier cast-iron column holder behind (photo David Hamilton, 1980)*

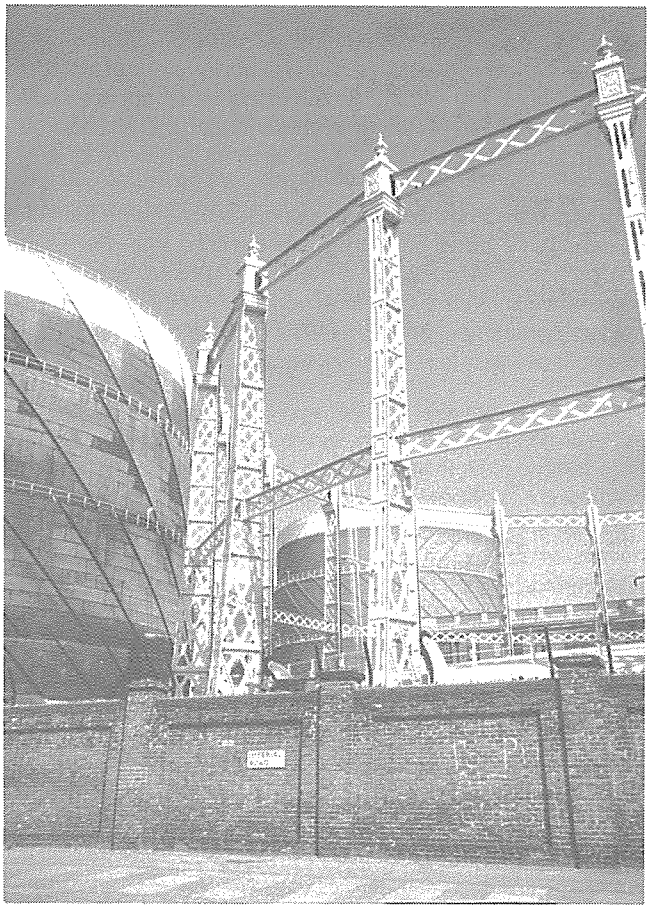

Plate 3. *Fulham: frame of No.3 cast-iron column holder, 1871; two later spiral guided holders (left and behind) (photo David Hamilton, 1980)*

Plate 4. *Detail of No. 1 holder at Kennington showing Phoenix Company crest (photo David Hamilton, 1980)*

Waterless holders

Two similar types of waterless piston holder (the M.A.N. and Klönne) were developed in Germany. These consist of an upright steel cylinder with a height to diameter ratio of 1.6-1.5:1, the outer shell built from rivetted, or later welded steel plate. Upright stanchions of channel section, bolted to the foundations, are provided and the whole structure is stiffened by access galleries placed at 40-50ft intervals. Gas is stored under a piston with a gas tight seal at the periphery. Access to the interior of the holder for maintenance and inspection of the seal is via the roof and ladder, or in larger holders a lift. In the building of these holders the piston is used as a floating construction platform, and is raised as the holder is built, finally being used as a temporary support for the roof staging.

Piston holders have a number of advantages over water sealed holders. They are approximately 40% lighter in weight, and the provision of suitable foundations, even in poor soil conditions, is comparatively easy; if subsidence occurs the holder can be re-levelled. Gas is stored at a constant pressure, and, by weighting the piston with concrete blocks, the booster pump can be eliminated: also anti-freeze systems are not required.

Holders of this type have been built all over the world, some in Germany and America up to 20 million cubic feet in capacity: one in Chicago (1927) was 280ft in diameter and 373ft high. Although some piston holders were built in Britain between the Wars, this type has not found great favour within the British gas industry, and the spiral guided holder seemed to become the most popular. The reasons are difficult to assess; certainly the piston holders are visually unattractive and also present a greater fire risk, or so it was thought. In service, however, they have proved no more hazardous than a conventional holder and wartime experience in Germany under extreme conditions demonstrated this. The North Thames Gas Region has several piston holders (thought to be M.A.N. types) in the London area, examples being at Battersea and at Harrow (Plate 6).

The M.A.N. holder. The first M.A.N. holder was built in Germany in 1915-16 and the first in this country was built at Ipswich in 1927.[22] These holders are polygonal with stanchions inside the shell. The piston is also polygonal in plan to match the outer shell, with radial and tangential rollers running in the stanchions at piston level, and a second set at higher level to give extra stability. The seal (Fig.11) is made from rubbing plates fitted to the sides of the piston and pressed into place by balance weights on fulcrum brackets. Under the rubbing plates folds of rubberised canvas are fitted forming a trough which is filled with tar. As the piston rises, tar runs down the walls to the base to be recirculated to the feed tank at the top of the holder. Selecting a suitable tar presented problems, since it had to be free from water and retain a reasonable viscosity over the full range of operating temperatures; oil seals are now used. Holders upto 7.5 million cubic feet capacity have been built in this country, and this is the only type of waterless holder to be built in any number by the British gas industry. The two 5 million cubic feet holders at Ford's Dagenham plant, which were demolished in 1979 (Plate 5), were presumably M.A.N. types as they contained tar.

The Klönne holder. Patents for the Klönne holder were taken out in 1882, but the first was not built until 1927 in Dortmund. Four years later the first was built in this country at York[23]. The shell of

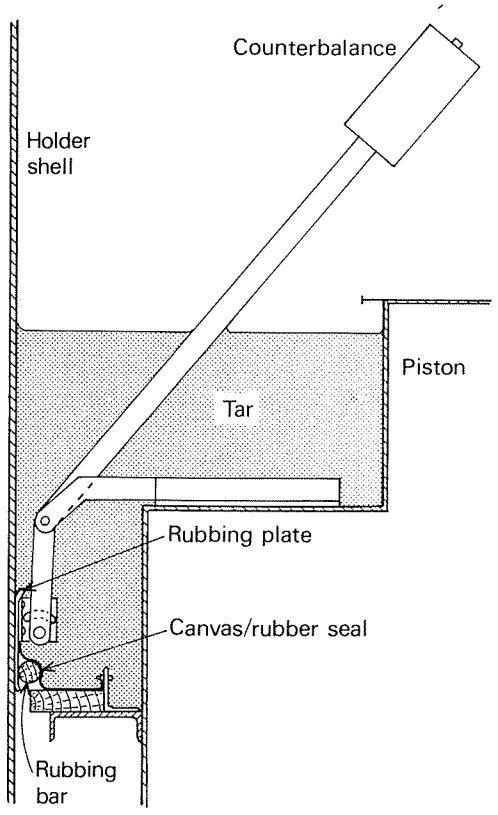

Fig.11. *Tar seal on M.A.N. holder; counterbalance keeps rubbing plate under pressure against shell.*

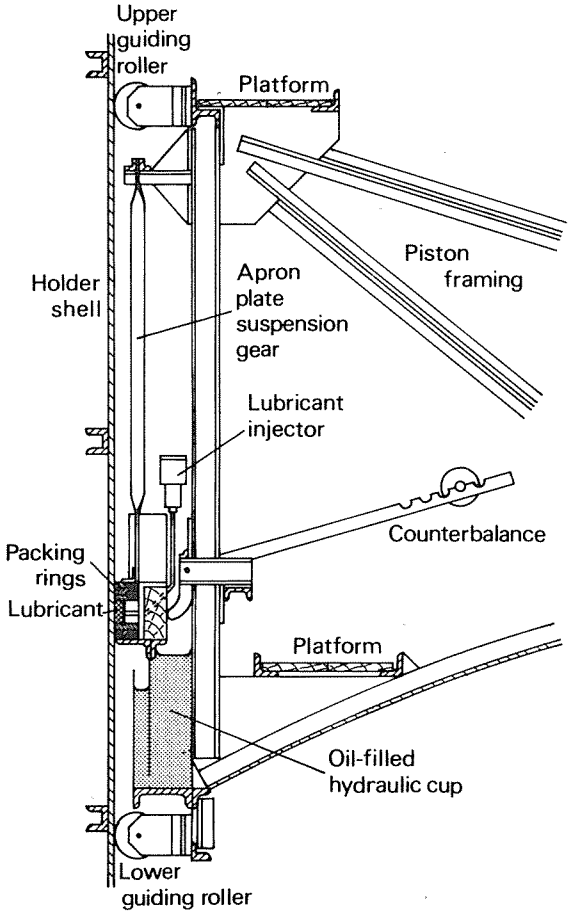

Fig.12. *Section of seal on Klönne holder; hydraulic cup allows movement of suspended packing; continuous platforms are for access.*

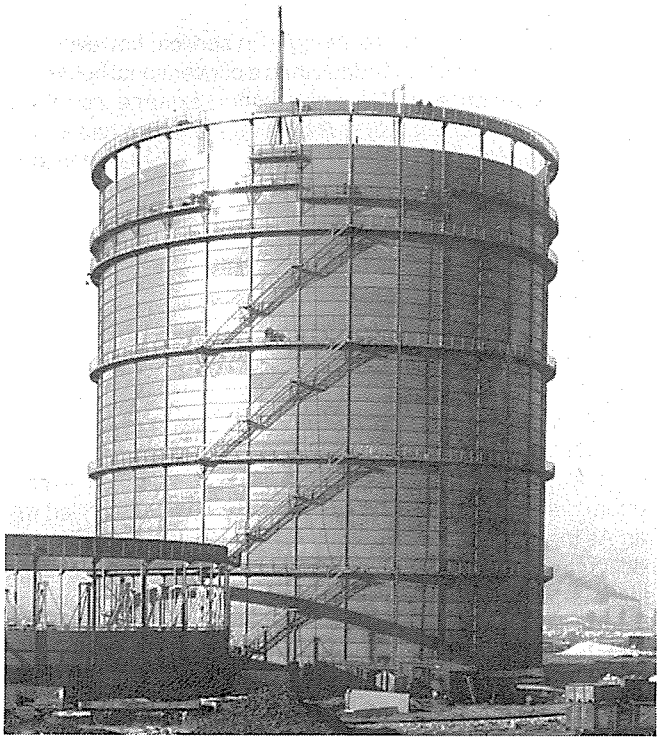

Plate 5. *Piston holders at Ford's Dagenham plant being erected c.1946 (copyright Ford Motor Company Ltd)*

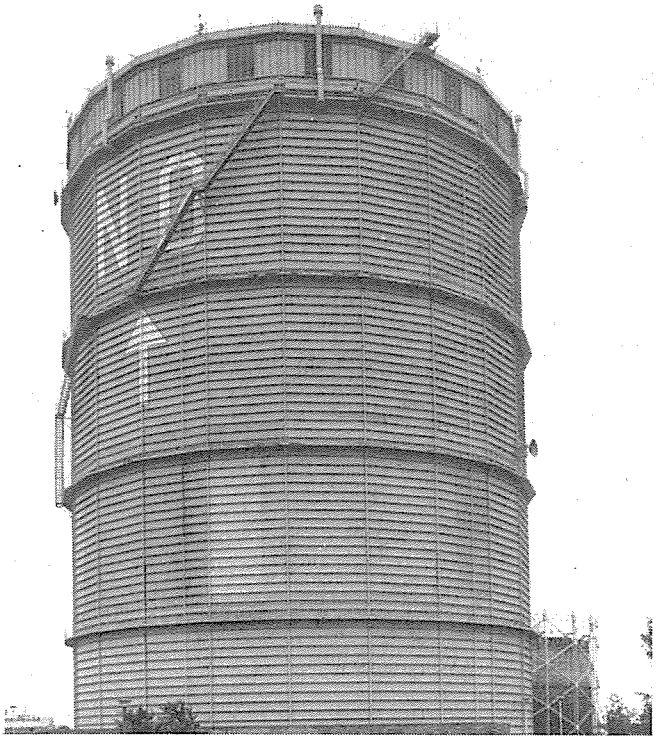

Plate 6. *Piston holder at Harrow, and earlier two-lift holder behind (the sign to Northolt is for aircraft navigation; a similar holder at Southall indicates the direction to Heathrow) (photo David Hamilton, 1980)*

the holder is a cylinder with a smooth interior surface, the stanchions are placed outside. All seams are caulked with lead and rivets are countersunk. As in the M.A.N. holder the piston is guided by two sets of rollers set radially, one above the seal, the other at the top of the bracing from the piston deck. The rollers are made of elm, slightly curved to match the shell: bakelite has also been used. Tangential rollers are not used, so the pison is free to rotate when it moves. In practice the rotary movement is only 2 or 3 feet, the piston returning by the same path. The seal (Fig.12) consists of several layers of rubberised textile, alternating with wooden packing pieces and lubricated with graphited grease, which was applied manually on the early holders. High operating speeds do not affect the working of the seal, or induce excessive wear. The seal on the holder at York lasted for more than 30 years. The Klönne holder is used in the steel industry in conjunction with blast furnace plant; none are operated by British Gas.

The Wiggins holder. A tank with a flexible seal was designed by John Wiggins in 1936 and first used in a tank with a floating roof in oil refineries. The first Wiggins gas holder was built in 1940 in America, and proved so successful that it is claimed that 75% of holders in the States are of this type.[24]

The holder is a welded cylindrical shell, with a height to diameter ratio of 0.8-1.2:1 having a flat floor and a slightly domed, trussed roof. Gas is stored under a nylon reinforced neoprene rubber diaphragm, which is sealed to the shell of the holder and the piston. The piston is in two sections (Fig.13), which simulates the action of a multi-lift holder. The outside section, a telescoping fender, is connected to the inner section by the diaphragm. When the holder fills the inner section or piston, half the height of the fender, rises until the holder is one-third full, where it engages the fender and both rise together. The piston is in two sections to reduce the 'fullness' of the diaphragm where there is long piston travel. To guide the piston, and also keep it level, a counterbalance system is provided with cables, pulleys and weights, reminiscent of the system introduced 170 years ago. The counterbalance weights run down the outside of the shell of the holder, providing an indication of stock level.

Wiggins holders have the advantage that apart from the pulley sheaves there are no moving parts that can wear, and no metal-to-metal contacts, except between the piston and the telescoping fender. Also the fender has at least 12in clearance reducing any tendancy to jam or foul. The all-welded construction gives the same advantages as the Klönne and M.A.N. holders, and the Wiggins type is claimed to require less maintenance. Since there is no need for an antifreeze system this is an ideal small holder for remote districts. The South Eastern Region has five of these holders dating from the late 1950s to the early 1960s, but none are in the London area.

Automatic operation of gas holders

Most gas holders, especially in remote districts, are automatically operated, filling and emptying under the control of a clock mechanism. There are many configurations of pipework, all performing a similar function; a typical layout is shown in Fig.14. Gas from a medium pressure main passes to the district via a safety governor; a tee before this governor feeds gas to the holder via the volumetric governor. Gas is pumped via a booster from the holder to the booster governor and the district main, downstream of the safety governor. In a day's cycle, with a full holder at 07.30 a.m., the booster starts, opening the booster governor and shutting off the safety governor, and gas is pumped from the holder until 09.30. The booster then shuts down, closing the booster governor and opening the safety governor. At 16.30 the booster restarts to cover the evening load, using the same procedure as in the morning, running until

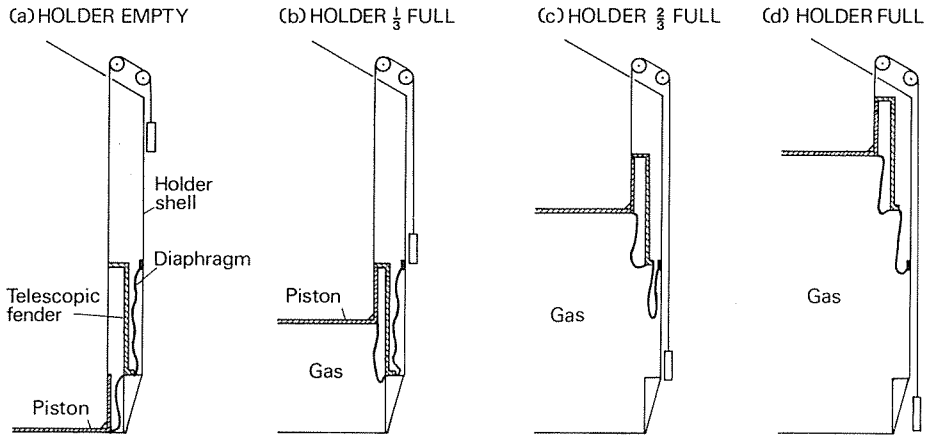

Fig.13. *Filling the Wiggins holder (diagramatic). (a) holder empty; (b) holder one-third full (piston couples with telescopic fender); (c) holder two-thirds full; (d) holder full.*

23.00 or earlier if the holder is empty. At 23.00 the volumetric governor opens and enough gas is passed into the holder so that it is full by 06.00. When the holder is full the volumetric governor closes, and the holder is ready for the next day's cycle. A recent development is to monitor holders by a computer-driven telemetry system from a regional control room, with the facility to override the normal operation of the volumetric governor and the booster. This enables a more efficient regional stock control to match any major variation in demand: also at periods of low demand, boosters can be shut down to save power.

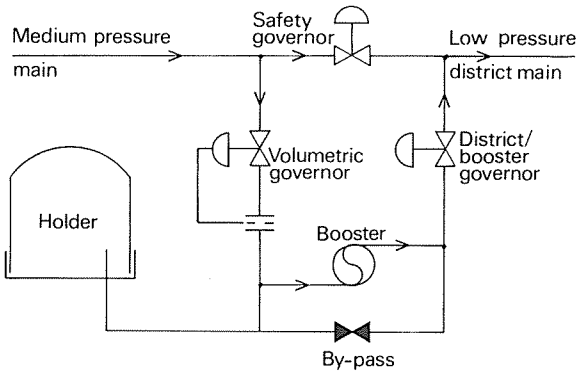

Fig.14. *Typical arrangement of automatic operation of low-pressure gas holders.*

Appendix 1: Brief biographies of some engineers

George Thomas Livesey was born 8th April 1834, and died 4th October 1908. He was born in Islington, son of Thomas Livesey (who was employed by Gas Light & Coke Company from 1821). In 1839 Thomas Livesey became Secretary and Manager of the South Metropolitan Gas Company (SMGC) and lived close to their works in the Old Kent Road. George started work for the SMGC in 1848, became his father's assistant, and in 1862 was made engineer to the Company. On his father's death in 1871 he also became secretary of the Company. As part of the amalgamations of 1882 he was elected a member of the Board, and in 1885 Chairman of the Company, a position which he held until his death. He was knighted in 1902. The Liveseys built up the SMGC to what was to become the second largest gas undertaking in the country, providing consumers with supplies of the highest standards.

George Livesey effected improvements in almost every branch of the industry, and with his ability to utilize better and more economical methods of construction, he saw the development of the water sealed holder brought to its zenith. Of his many achievements there is space to mention only two. In 1883 work started on Greenwich Works, a purpose built station, designed with room for development; this was to become the world's largest works in the oil era. Secondly, he introduced a profit sharing scheme, with provision for employees to invest in the Company. Copartnership, as it was to be known, was a pioneering development in industrial relations with far reaching effects throughout the Industry.

Fuller biographical details of George Livesey are to be found in the *Proceedings of the Institute of Gas Engineers*, 1908, p. 348-59, and in the *Journal of Gas Lighting*, 6th October 1908. Further details of the history of the SMGC are given in *A Century of Gas in South London* published by the SMGC.

Samuel Clegg was born 2nd March 1781 and died 8th January 1861. Born in Manchester, he was educated under Dr Dalton, and apprenticed to Boulton & Watt either in 1802-3 or 1805. In 1805 he lit Henry Lodges Mill at Sowerby Bridge, Halifax and in 1809 installed lighting in Mr Harris's factory at Coventry, using lime in the holder for purification. Either in 1807-8 or 1811 he lit Stonyhurst College, and for the first time removed hydrogen sulphide in separate vessels. Frederic Winsor's work attracted him to London in 1812 and he gained prominence by constructing gas making plant for Rudolf Ackerman's print shop at 101 Strand. In 1813 (there are many dates given) he became Chief Engineer to the Gas Light & Coke Company, and undertook reconstruction of the Great Peter Street works, re-running mains, and generally putting the Company on a sound practical footing. He left the Company's service in 1817, possibly over a question of salary.

Samuel Clegg was responsible for a large number of inventions and for the development of gas making plant in various parts of the country. He lost money on an enterprise in Liverpool, went to Portugal, rebuilt the Mint and engaged in various public works there. In the 1830s he became involved with the Samuda brothers in the development of atmospheric railways. After their failure he gave up active engineering and became a Survey Officer for the government vetting new Gas Bills coming before Parliament. He spent his spare time writing a comprehensive treatise on gas

lighting, with his son (Samuel Clegg jun.). He died at Haverstock Hill.

Further details can be found in the Murdoch Centenary Lecture, given by Dr E.F. Armstrong, *Proc. Inst. Gas Eng.* **88**, 1939, p. 939, and *The Rise of the Gas Industry in Britain*, Chapter 5.

Appendix 2: Gazetteer

Note that all holders are in use and are column guided unless otherwise stated.
The following sites are some of particular interest; being within the South Eastern Region they are familiar to the author.

Old Kent Road **TQ 347776**

The inaugural works of the South Metropolitan Gas Company. The site was acquired in 1832, and production ceased in 1953. Four holders remain on site, only No. 13 can easily be seen from the road.

No. 10	2 lifts	1867
No. 11	2 lifts	1872
No. 12	2 lifts	1875

—This holder has a mass concrete tank. A third, flying lift was added c.1895, and remained in use till 1952.

No. 13	3 lifts	1881

—This holder has a concrete tank reinforced with iron bands, 53 feet deep.

East Greenwich **TQ 393794**

The site was a purpose built works started by the South Metropolitan Gas Company in 1886, production ceased in 1975.

No. 1	4 lifts	1886

—The world's first four lift holder.

No. 2	4 lifts	1892

—The holder was originally built with six lifts; the two flying lifts (Plate 1) were destroyed by the Silvertown explosion in 1917.

Kennington **TQ 310779**

Site acquired by the Phoenix Company c.1850 from the Southwark and Vauxhall Water Company as a holder station for Bankside and Vauxhall Works. Four holders remain on site.

No. 1	4 lifts (1 flying)	

—This was originally built by Sir Corbett Woodall in 1877 as a two lift holder, and was rebuilt c.1890 by G. Livesey with four lifts, one flying, doubling the capacity of the holder (Plate 4).

No. 2	3 lifts, spiral	1950
No. 4	2 lifts	1955
No. 5	2 lifts	1955

Sydenham **TQ 368720**

Site acquired by the Crystal Palace Company in 1854, and production ceased in 1969. Four holders remain on site, only two, Nos. 7 and 8, can be seen from the road.

No. 4	2 lifts	1864, rebuilt 1901
No. 5	2 lifts	1865, rebuilt 1930
No. 7	4 lifts (1 flying)	1881
No. 8	4 lifts (1 flying)	1890

The following sites (within the South Eastern Region) are mentioned in the text.

Bromley, Kent **TQ 415688**

Site acquired by the Bromley Gas Consumers c.1860, and production ceased in 1954. Two holders remain on site.

No. 2	3 lifts	1889
No. 4	3 lifts, spiral	1969

Rotherhithe **TQ 356800**

Site acquired by the Surrey Consumers Gas Company c.1850. One holder remains on site; production ceased 1959.

No. 3	4 lifts	rebuilt 1955

—The original holder was built in 1897 with five lifts.

The following list of sites (now in the North Thames Region) has been compiled from information provided by GLIAS members and from the book Historical Index of Gasworks *by E.G. Stewart (North Thames Gas Board, 1957). The author of the present article would be glad to receive corrections and additions which could be included in a comprehensive gazetteer.*

Battersea **TQ 288772**

The four holders of differing dates are best viewed from the railway between Battersea Park and Victoria. The holder station site was acquired by London Gas Light Co in 1873. In 1869, R. Morton, engineer of Nine Elms gasworks, invented the self-sealing retort; his initials are cast on the two oldest holders.

One two-lift, dated 1876 (?)
One two-lift, dated 1882
One spiral
One piston

Bethnal Green **TQ 348833**

Oldest of four holders has attractive multi-column guide frame wholly of cast iron; probably 1860s; Imperial Gas Light & Coke Co.

Brentford **TQ 186780**

This is the oldest established works of North Thames and first produced gas in 1821.

One two-lift (?), dated 1864
One piston (built early 1930s ?)

Bromley-by-Bow **TQ 386826**

This was the Imperial Gas Light & Coke Co's largest works, opened in 1870, and aquired by the Gas Light and Coke Co in 1876. The very fine group of eight large-diameter multi-column holders was built between 1873 and 1876; geographically in West Ham.

Fulham **TQ 260768**

The Imperial Gas Light & Coke Co produced gas here from 1824 until the 1876 merger, when the site was operated by the Gas Light & Coke Co. The Victorian holders when built were the largest existing (Plate 3).

No.2, 1830 single-lift wrought-iron holder, guided by attractive cast-iron A-frames; 100ft diameter; 234,000 cu ft; disused; listed building, reputed to be the oldest holder in the world; not visible from outside works.
No.3, two lift, cast-iron columns, 1871; 1541,000 cu ft.
Four spiral

Harrow (Plate 6) **TQ 143867**

One two-lift
One piston

Kensal Green **TQ 235824**

Western (Cannel) Gas Light Co produced gas here in 1845; the works was taken over in 1872 by the Gas Light & Coke Co. The holders (Plate 2) were of unusual construction, having flat crowns.

One two-lift (?), cast-iron columns, 1870s (?), similar design to Fulham No.3

One four-lift, 1891; 7500,000 cu ft; called the *Colonel*; one of the largest frame-guided holders.

St Pancras **TQ 300833**

This was the Imperial Gas Light & Coke Co's oldest works and produced gas 1822 – 1904. In 1869 it was the largest works in London.

Set of multi-column holders, 1861, 1864, 1867 and 1883; some frames 'Siamese triplets'; 20th century unbraced lattice steel frames also of visual interest.

Southall **TQ 119797**

One piston

Note: British Gas officials are very conscious of security and may be worried by industrial archaeologists with binoculars and cameras. Please comply with any requests they make.

Acknowledgements

I would like to thank all the members of GLIAS who provided advice and assistance with the illustrations. Without this help the article would not have seen the light of day.

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