# Gasholders and their tanks

A profile of the construction of different types of gasholders, their tanks and their occurrence on former gasworks sites.

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## Introduction

This profile aims to give a simple insight into the construction and operation of gasholders and their tanks, for those who investigate former gasworks sites. Although gasholders seem simplistic, the complexity and ingenuity of these structures should not be underestimated; they have been the result of complex engineering design which has been well documented in many texts. This profile is limited to a brief description of the various types of gasholders, their operation and importantly their tanks.

Gasholders are generally the only feature of a gasworks to still remain visible today, characterised by a series of large interconnected (telescopic) cylindrical vessels (lifts) which rise and fall depending on the volume of the gas stored. The number of operational gasholders has gradually decreased due to the improved storage capacity of gas within the gas mains, but a few still remain today. Despite this, the tanks of former gasholders are often still present on many former gasworks sites hidden beneath the ground. During demolition they formed ready made repositories for wastes and as such can potentially pose a risk to human health and controlled waters.

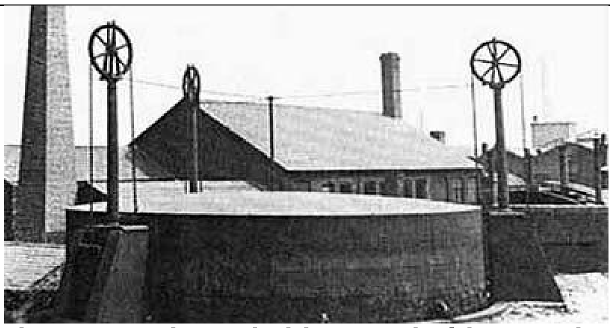


**Figure 1. The primitive gasholder at the first small gasworks at the Soho Factory of Boulton and Watt.**

**Figure 2. A two lift frame guided gasholder with concrete tank, Southern England**

Gasholders have been a feature of gasworks ever since gasworks were first constructed, an example of such an early gasholder can be seen in Figure 1. The purpose of the gasholder was more than just store the purified and metered gas, it acted as a regulator between production rates and the more erratic consumption rates, and provided the pressure for the distribution before boosters were introduced. The gasholder operated on a basic principal of a gas filled floating vessel, rising and falling in a seal of water.

The function of the water was primarily that of providing an elastic gas-tight seal in which the vessel may rise or fall. The water also received the whole of the pressure thrown by the weight of the vessel and in this way the water formed the necessary resistance by means of which the vessel is raised or the gas expelled. Their simplicity and reliability has lead to their longevity of over 200 years.

Gasholders all worked on the same principal of the vessels or piston, rising and falling, but it was the method employed to guide the movement of the vessel or piston that differed as the gasholder technology developed.

Originally gasholders only contained a single vessel (lift) floating within the tank, later multiple lift (telescopic) gasholders were developed. Telescopic gasholders allowed a much greater volume of gas to be stored in roughly the same footprint of land.

Gasholders could generally by classified under 5 main headings, which were:

- Gasholders guided by wire cables (early system);
- Gasholders guided by columns, which could be single lift or telescopic, with or without “flying lifts.";
- Gasholders with vertical guide-framing, which could be single lift or telescopic with or without “flying lifts";
- Spirally guided holders (multiple lift), the guides could be left or right hand or both and either internal or external; and
- Holders with a floating roof (piston).

Another form of gas storage was later developed, this was High Pressure bullet tanks, which stored gas at much higher pressure than those listed above.

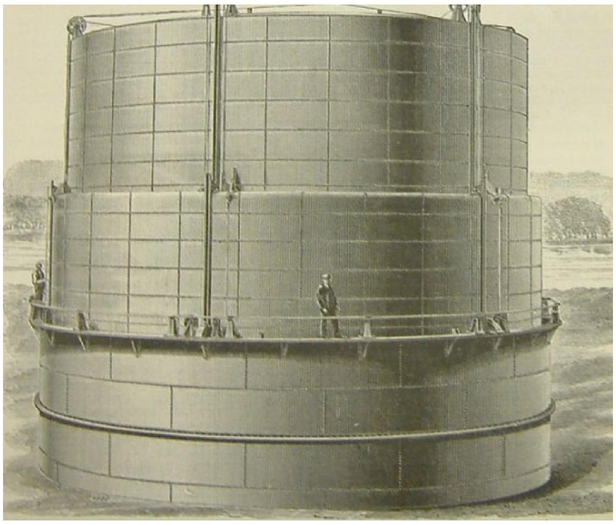


**Figure 3. A cable guided gasholder in a cast iron tank.**

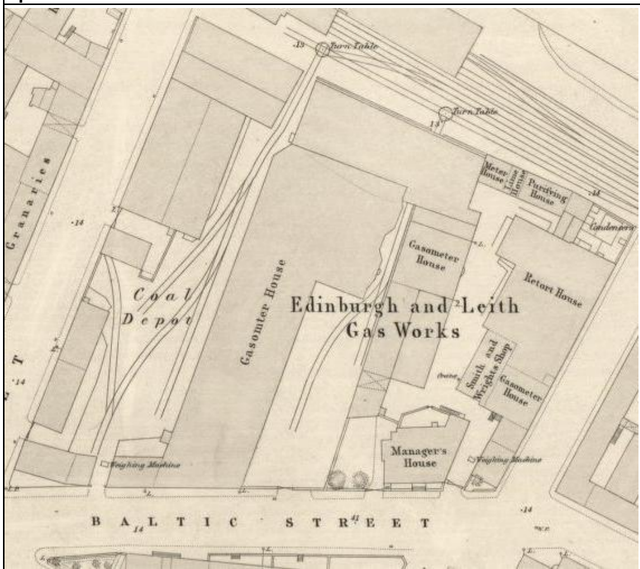



**Figure 4. A map of the Leith Gasworks, showing the gasometer houses.**

**The housing of gasholders**

The early concerns over the safety of gasholders lead by Sir Joseph Banks and other members of the Royal Society, lead to gasholder having to be constructed in strengthened buildings, often refered to as gasometer houses. This was a separate superstructure built around the gasholder with the intention of making it safer. The logic behind this was not entirely sound as small gas leaks from the gasholder into the gasometer house could easily lead to the build up of potentially explosive combinations of gas and air. In the UK these gasometer houses were phased out, but in Europe where extreme cold weather was a risk, huge ornate brickbuilt gasometer houses were used for many years, for example in Berlin and Vienna.

**Cable guided gasholders**

Cable guided gasholders used a complex arrangement of at least three separate cables for a single lift gasholder which stretched via a series of pulleys from the top of the gasholder tank to the top of the gasholder vessel and back, which would keep the cables taut and the floating vessel in position.

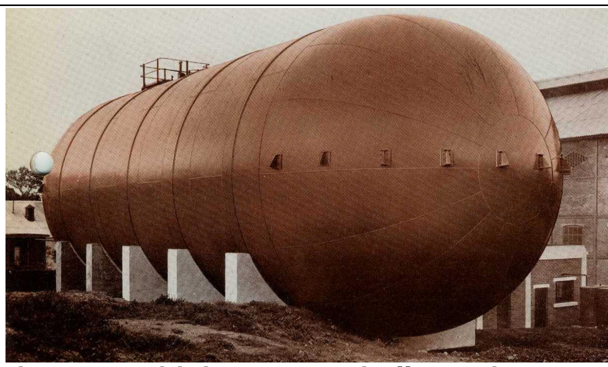


**Figure 5. A high pressure bullet tank.**

**Column guided gasholders**

Column guided gasholders were more simplistic and reliable systems, they consisted of wheels attached to arms extending from the corners of the top of the vessel. The wheels would run up and down within a guide rail set in the columns.

Originally these guide rails would have been set in massive cast-iron columns which ensured the rigid guiding of the holder. These columns would be attached to one another via heavy cast-iron or wrought-iron trellis cross girders and bolted on to the piers of the gasholder tank. These cast iron constructions were later superseded by structures composed of comparatively light rolled mild-steel. Some early gasholders used counter weights (Figure 1 and 6) but these were largely phased out (apart from specialist situations). Whilst the counter balances reduced the resistance to gas entering the gasholder, they also reduced the pressure of gas leaving the gasholder.

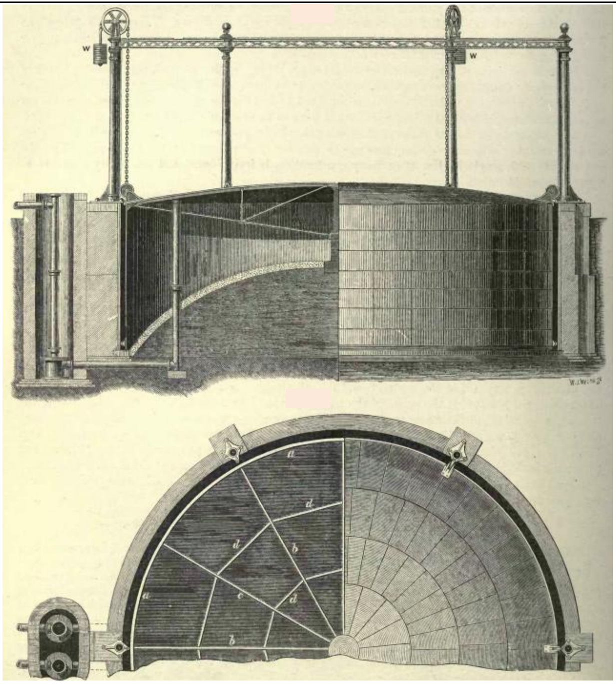
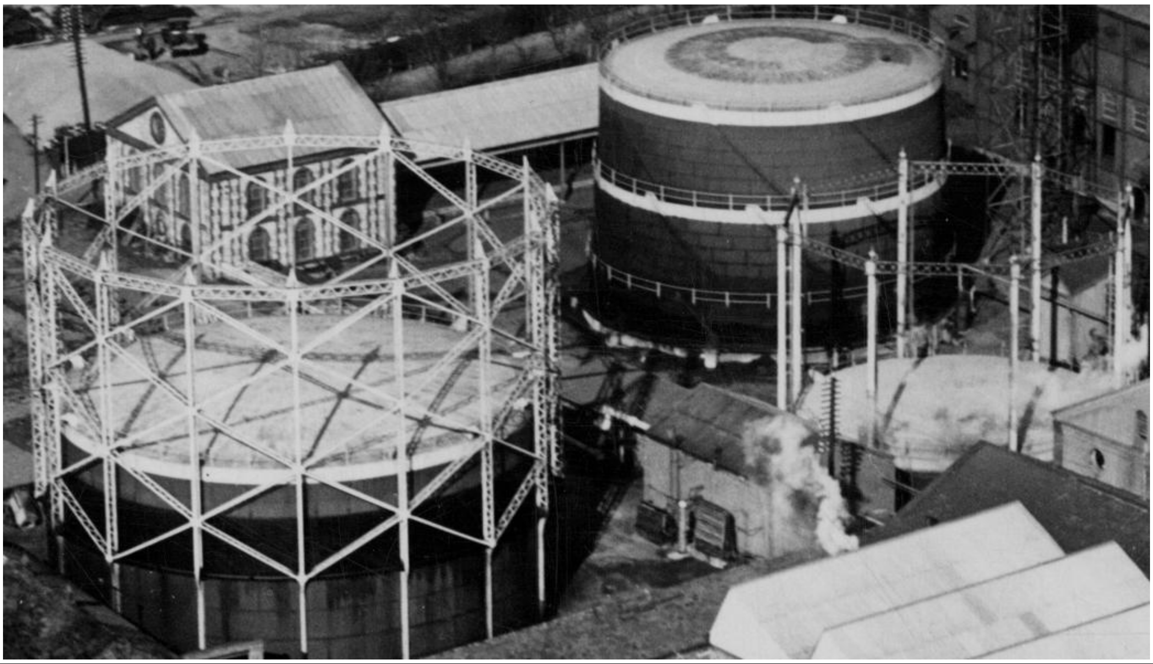


**Figure 6. A drawing of an early single lift gasholder with counterweights and a brick tank. From "A Practical Treatise on the manufacture and distribution of coal gas. Richards Williams 1877.**

**Figure 7. Evolution of gasholders on a former gasworks, Bottom right – Column guided, Bottom Left – Guide framed and Top – Spiral guided.**



**Guide framed gasholders**

Guide framed gasholders were similar to the column guided design, except that a more extensive framework was built around the gasholder effectively forming an outer cylinder of structural steel or iron work. The guide frame was attached to the outside of the above ground tank or to the top of a below ground tank by bolts on to the piers. The vertical girders (known as standards) were intersected by horizontal girders and braced for extra strength. Some tanks just had diagonal triangulated framing rather than horizontal girders. In general the more modern the gasholder the lighter the material used to construct of the guide framing would be. The gasholders moved up and down the guide rails on wheels in a similar fashion to the column guided gasholders, with the guide rails on the standards as opposed to on the columns.

**Flying lifts**

Both column guided and guide framed gasholders could be extended by the insertion of a flying lift. A flying lift was an additional vessel which could be inserted into the centre of the gasholder, but instead of running within the set columns or rails the flying lift was set above these and attached to the rest of the gasholder via cables and pulleys. This was a common practice for number years to quickly increase capacity on gasworks, but was later phased out.

**Spiral guided gasholders**

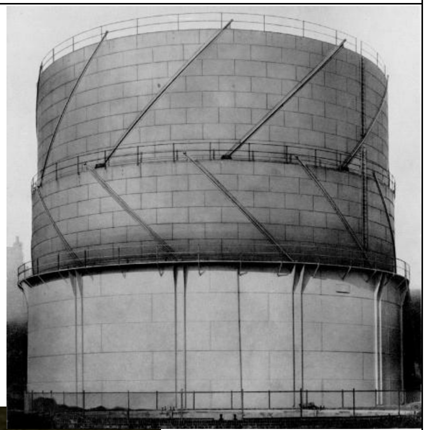
The spirally guided gasholder was proposed by Mr. W. Webber and the invention of Mr. W. Gadd, they were first seen in the UK in 1888.

They operated based on spiral guided rails affixed to the side of the gasholder vessels. The spiral rails engage with rollers on the edge of the tank in such a manner that the bell moved up and down in a screw like fashion. The vessels could be all left-handed, all right-handed, or successive combinations of both.

The rails on the outer lift were always affixed to the exterior of the vessel, but those on succeeding lifts could be either interior or exterior, although the latter were invariably used.

Spiral guided holders required more precise engineering and as a result the rollers were at a greater risk of jamming of than the other types of gasholders.

**Figure 8a. Spiral guided gasholder with 2 lifts in a steel tank.**



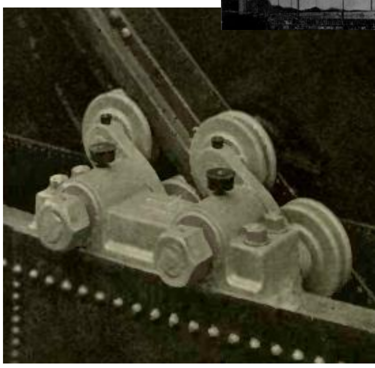


**Figure 8b. Multiple Roller Carriage which guide the upwards and downwards movement of the gasholder.**

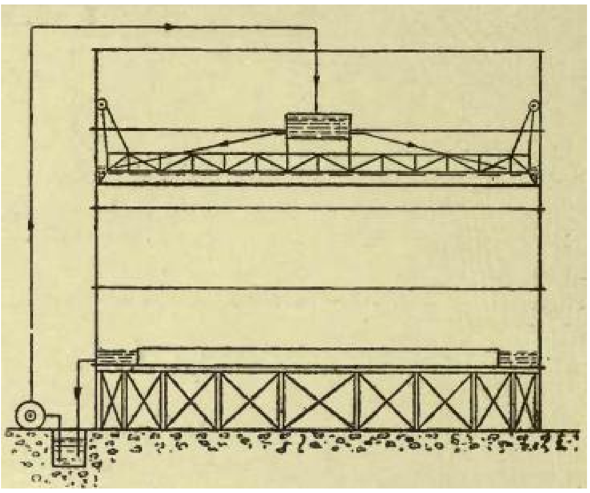


**Figure 9. An early type of floating roof gasholder.**

**Floating Roof Holders**

The floating roof gasholder allowed for a very simplified system, where by which the only moving part was the piston. The piston was able to rise and fall by means of guide rollers. The outer cylindrical shell was similar in appearance to other gasholders, although these gasholders were taller and thinner. It was also evident that the outer shell remained the same size and the roof of the structure was permenantly fixed. Early systems still had a water seal and a small water resevoir in the annulus at the base, but later systems such as the M.A.N. or Klonne waterless gasholders had tar and oil seals respectively.

These gasholders allowed the large water tanks required on previous gasholders to be dispensed with.

**Crowns, Cups and grips.**

Due to the relative weakness of the dome (crown) of the gasholder vessel, it required support when all the lifts were down and there was no gas pressure within the holder to prevent the crown from buckling. In these cases the crown required either its own internal frame (akin to the supports in an umbrella) to provide strength or it required support from underneath to maintain its shape (a crown rest). Where an internal frame was used this was still supported on a central column or pier, trussing was generally limited to gasholders of a diameter of 170 feet or less due to the technical limitations of the method. The crown rest consisted of a series of radiating rafters carried on columns erected in the tank and connected together by purlins to form a skeleton framework of the same camber as the dome.

The cups and the grips were the semi-circular or square features which interlocked to form the seals at the edges of each lift and between the outer lift and the tank. As the inner lift raised to its maximum the cups and grips interlocked, the cup being of sufficient depth to be filled with enough water so that an air tight seal was formed. The cups and grips were of similar size and ranged from 8 to 12 inches wide and 16 to 24 inches deep depending on the size of the gasholder.

**Gasholder tanks**

The gasholder tank was the part of the gasholder which would house the lifts when down and contain the water in which the holder raised and descended depending on gas flow. The water functioned primarily as an elastic gas-tight seal. The tank was waterproofed to prevent water leakage.

The Gasholder tank could be below the ground level, partially below the ground level, or entirely above the ground level, depending on the type of gasholder employed and the ground conditions.

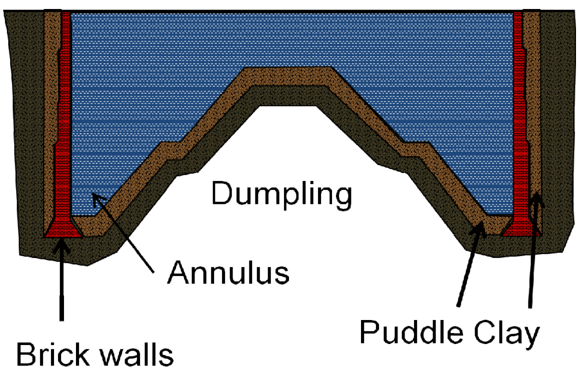



**Figure 10. Schematic of a gasholder tank with a dumpling and annulus.**

**Figure 11. Excavation of a backfilled concrete gasholder tank with dumpling.**

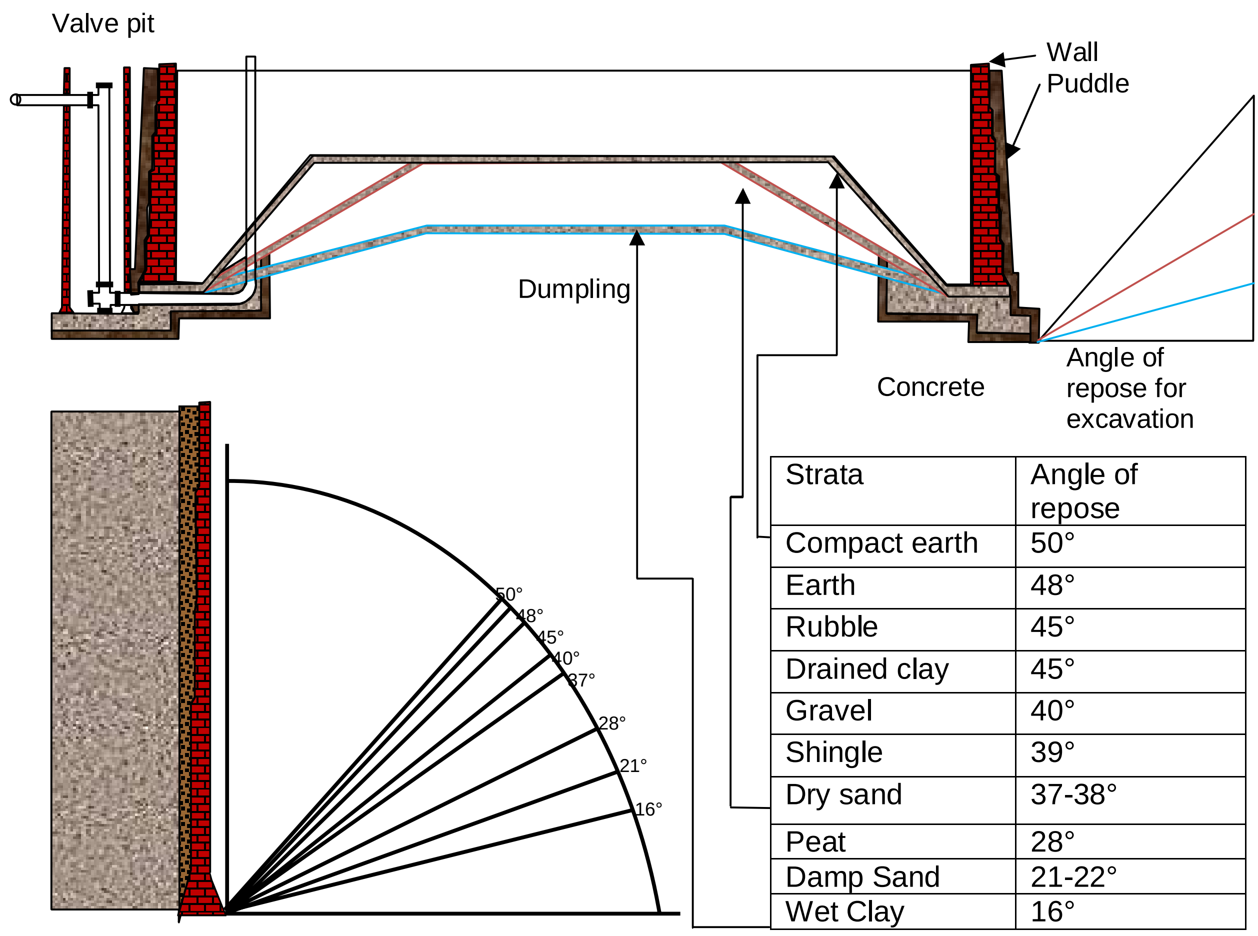
The material which a gasholder tank would have been constructed from would be dependent on the available local building materials and the ground conditions at the gasworks. Where a local source of good quality stone for building was available then this would often have been used. The most commonly used material for building gasholder tanks was brick (preferably hard burnt bricks of a lower porosity). The full range of building materials for gasholder tanks were:

- Stone
- Brick
- Concrete
- Cast or Wrought Iron
- Steel
- Hewn from the bedrock
- A combination of the above (composite).

Brick or stone tanks were porous and for this reason the walls and base of the tanks were usually backed with puddle clay. The puddle could be pure clay, but often thought preferable to mix it with one-third sand, silt, or soil free from vegetable fibre, as it was firmer in texture, and less liable to crack when dry. The puddle would be prepared outside of the trench and built up in thin layers as the wall of the tank was built, kept moistened, punned well and backed up with carefully pounded earth.

An alternative method of water proofing was through the application of an inch render of Portland cement to the internal face of the tank. If this was applied successfully then it could make the puddle redundant and on such tanks puddle was not generally used. The use of 4 $^{1}/_{3}$ inch bricks with a cement lining could also serve this purpose. Tanks built from water proof concrete did not require rendering or puddle.

The excavations required for the construction of a gas holder tank were dependent on ground conditions. As can be see in Figure 12 the safe angles of repose which could be used varied dependent on the strata, with compact earth offering the steepest and wet clay the shallowest.



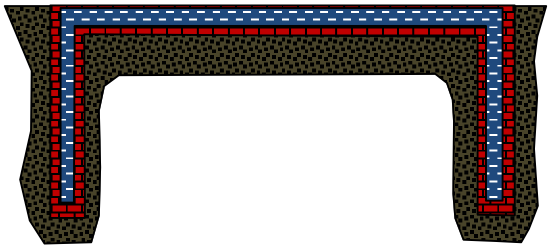

| Strata | Angle of repose |
|---|---|
| Compact earth | 50° |
| Earth | 48° |
| Rubble | 45° |
| Drained clay | 45° |
| Gravel | 40° |
| Shingle | 39° |
| Dry sand | 37-38° |
| Peat | 28° |
| Damp Sand | 21-22° |
| Wet Clay | 16° |

**Figure 12. The effect of ground conditions on the angle of repose when constructing an underground gasholder tank. Showing angles of repose for different Strata.**

A few examples existed where gasholder tanks were hewn out of bedrock, gasholders at the Chester gasworks were constructed this way, and these tanks still required water proofing. Where the ground conditions were favourable it was more economical to leave a conical mound within the centre of the gasholder tank, this was called a cone or dumpling. In tanks, whose diameters did not exceed 55 to 60 feet, it would be more economical to remove all the material if it required waterproofing. In rock, stiff clay or chalk, it would be more economical to leave a dumpling for much smaller diameter tanks.

Occasionally tanks were built by making a circular cutting in the ground and constructing an iron or brick annular channel to contain the water with the intervening central space being also covered with a shallow layer of water. These were termed annular tanks.

**Figure 13. A schematic representation of an annular gasholder tank.**



The weakest point on a circular masonry tank was always the point at which the gas pipes entered and exited the gasholder from outside. This was generally situated within a recess in the tank walls; however, by breaking the circle of the wall it weakened the tank and made it more likely to fail. Methods which were used to reduce the stress in the tank wall included the installation of iron struts or square pipes built into the wall.

Large gasholder tanks required methods of strengthening the walls which included at 2-3ft intervals layers of thick Portland cement into which the brick or stone was placed or hooped iron or flat iron rings were built at intervals into the wall.

If the ground conditions made it very expensive to construct good foundations to build a tank or there was a high water table in a porous strata (e.g. sand) then an above ground tank would be used. Above ground tanks were generally constructed of cast or wrought iron or later on steel plates, they were bolted or riveted together and built on a reinforced concrete slab. If ground conditions were unstable even for an above ground tank then the concrete slab would require piled foundations. These above ground tanks were more expensive than an underground tank and therefore were often seen as an option of last resort.

## Calculating the size of gasholder tanks.

First stage would be to work out whether the gasholder had an above ground tank, partially below ground or below ground gasholder tank. This can be worked out from the information available for the gasholder from plans and records, which may say whether the tank was above or below ground and if you are lucky give you the depth of the tank, capacity and number of lifts. If this is not available then the construction material will give you an indication, brick, stone and concrete tanks were normally only used to construct tanks which were totally or predominantly below ground. Iron and steel tanks were generally used for tanks which were above or predominantly above ground, however, they were also used for below ground tanks.

Photographs provide a vital source of information as they can show the type of gasholder and the position of the tank. All types of gasholder except floating roof types could have an above ground (Figures 3, 7, 8a and 15) or below ground gasholder tank (Figures 1, 2, 6 and 11). If a tank is not visible on the photograph then it can be assumed the gasholder has a below ground tank. One important point to remember is that even above ground tanks have concrete slabs which can be buried on redeveloped sites significantly below ground level (approximately 1-1.5 mbgl) due to ground raising activities.

Annular trench

For tanks which contained a dumpling, they also contained an annular trench or annulus; this was located just inside of the tank wall. The annulus would provide a flattened circular trench for the lifts to rest when the gasholder was deflated. It varied in size but from reviewing numerous records it would appear that the size was generally between 3ft (0.91m) and 6ft (1.82m) wide. Where these were encountered in infilled gasholders they are generally found to contain a depth of 200-300mm of gasholder sludge.

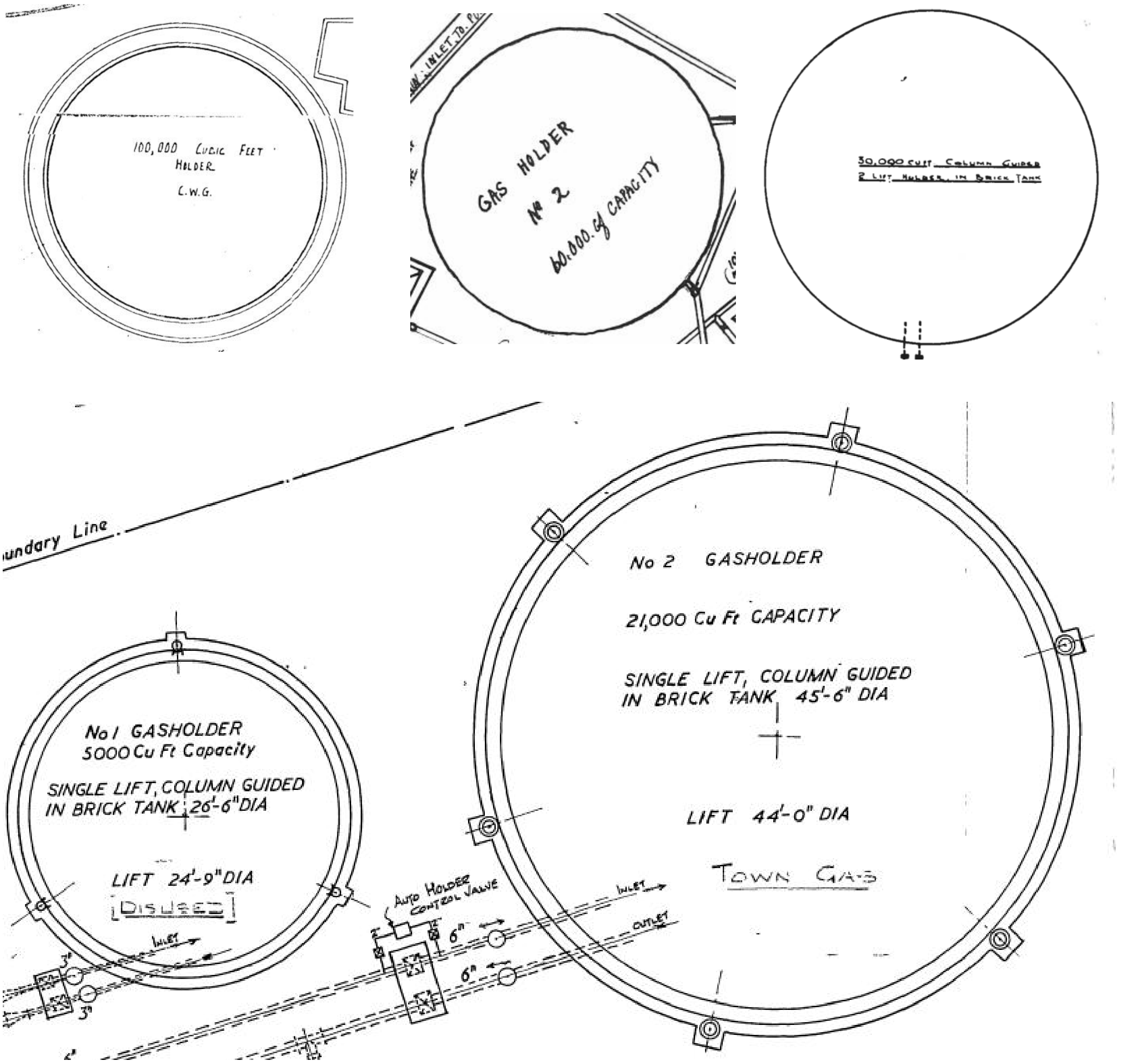



**Figure 14. Examples of Gasholder on the plans of former gasworks, with varying information.**

**Methods for estimating the depth of the gasholder tank with limited information**

**<u>Single lift holders</u>**

<u>Simple ratio for Single lift holders</u>

For single-lift holders the height of the vessel varied from 0.3 to 0.4 of the diameter of the tank. The height of the vessel was usually about a foot (0.304m) shorter than the depth of the tank.

For example a 20m diameter gasholder would have a tank depth of between 6 and 8m.

<u>Calculation for single lift holders based on diameter and capacity</u>

If you know the capacity of the gasholder and the diameter of the tank then you can roughly calculate the depth of the tank using.

(Capacity in cubic feet/(0.7854 X (diameter)$^2$))/10 = depth of tank (approximately).

This is a rough estimation for the tank depth which works better with single lift tanks, but it can be used with multilift tanks also, it should be used with other measures to calculate the potential tank depth. An assumption can also be made based on the data in the graph in Figure 14.

**<u>Multiple lift holders</u>**

Each lift will be approximately of similar depth; i.e. the depth of each lift is approximately equal to the total height of the bell divided by the proposed number of lifts, due allowance being made for the depth of cups and grips. The depth of the tank will be roughly equal to the depth of the average lift height

<u>Simple ratio for multiple lift holders</u>

For telescopic holders the normal proportion varied between 0.5 and 1.0 of the mean diameter. Modern gasworks practice suggests that 0.64 can be used as a ratio between total height and diameter of a four lift gasholder. It also suggests that 0.5 can be used as a ratio between total height and diameter of a three lift gasholder. On this basis it would be assumed that for a 2 lift holder the ratio would be about 0.4. The depth of the tank was usually just longer than each of the individual vessels (lifts) of the gasholder (they were roughly the same length, inner vessels being slightly taller than the outer vessel).

<u>Calculation for multiple lift holders based on diameter and capacity</u>

The same equation can be used as highlighted above.

An assumption can also be made based on the data in the graph in Figure 14.

**Methods for estimating the volume of the gasholder tank with a dumpling present**

Firstly it should be remembered that only below ground tanks had a dumpling. Many underground tanks did not have dumplings, those tanks less than 55 to 60 feet and required waterproofing did not generally have dumplings unless built in rock, stiff clay or chalk.

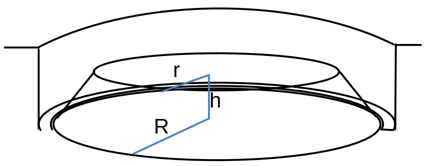
The dumpling was a mound of earth left within the gasholder tanks for economical reasons (i.e. it was cheaper to leave the material *in-situ* than excavate it. It was often covered in a layer of cement or puddle covered with stone or brick.

The dumpling was not a uniform structure and its shape as highlighted in Figure 12 would be highly dependent on the strata the tank was constructed in. An annular channel was built between the edge of the tank wall and start of the dumpling which was roughly 3ft (0.91m) and 6ft (1.82m) wide.

The dumpling was generally cone shaped with a flat top (e.g. Figure 12) although dumplings which were more dome shaped were also encountered. On this basis calculating the volume of a dumpling cannot be easily presented here, it would need to be made on a case by case basis.

The simple calculation for working out the volume of a cone can be used to roughly estimate its size. This calculation is the volume of a cone = $(^1/_3)$ x p x Radius$^2$ x height. This calculation does not take into account that the dumpling was often a wide short cone with a flat top (a lustrum of a cone), with the angles dependent on the strata. A more accurate approach would therefore be to work out the area of a frustum of a cone as below.

$$V = \frac{(p \times h)}{3} (R^2+r^2+Rr)$$




v= volume

h = height

R = radius of the base of cone,

r = radius of the top of the cone

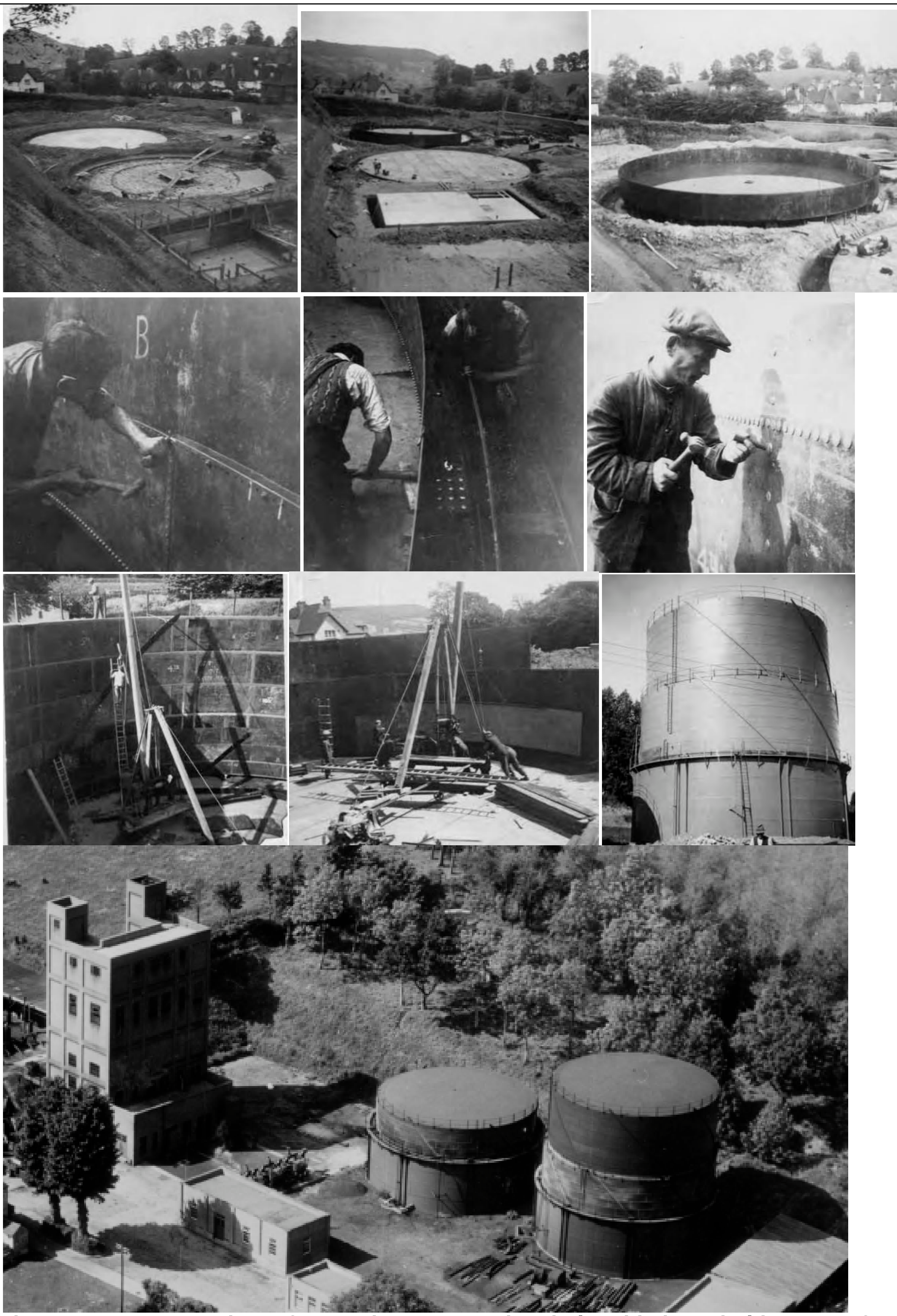


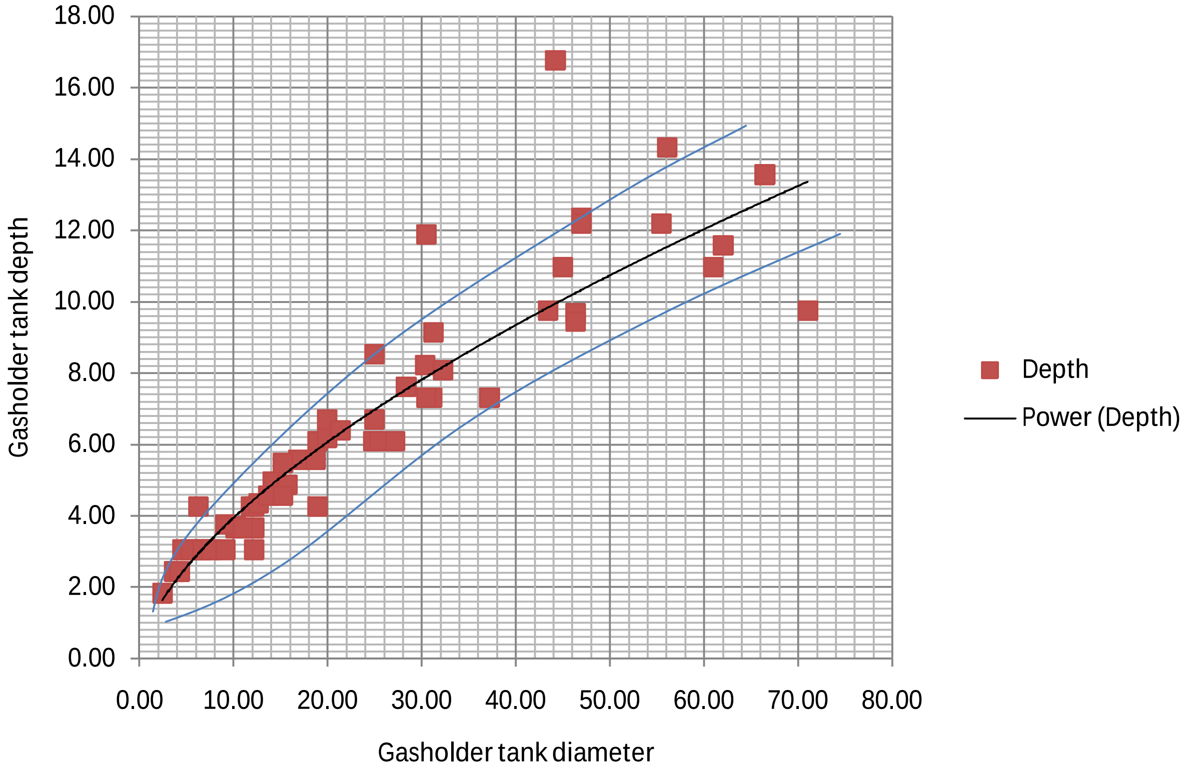
**Figure 15. Construction of two above ground spiral guided gasholder at a former gasworks in South West England.**

Ideally you need to know the height of the dumpling, this can be found during investigation of the gasholder tank if you place a borehole in the correct position, you would be very lucky to have that information from site plans or gasholder records for infilled tanks. Old gasholder records did provide a lot of detail on gasholders tanks; however these are rarely encountered as they were generally disposed of when the gasholder was decommissioned. Where you don't have site investigation details you will have to rely on previous experience of investigating gasholder tanks of reference texts.

Alternatively you can make assumptions based on a standard rule of thumb, which is the volume of the dumpling is 30% of the tank. As with most rules of thumb this does not taken into account the significant variation encountered based on ground conditions. It would be more accurate to calculate the size of the dumpling based on the angle of repose which would be used in the strata the tank is built and use this to guide the size of the upper flat surface of the cone.

Despite these problems, the presence of a dumpling is very important to take into account when investigating a tank and the volume of the dumpling is very important when working out the volume of infilled material present within the tank and remediation volumes. Subtracting the volume of the dumpling from the cylindrical volume of the tank will give you the volume of potentially infilled material within the tank.

Figure 16. A plot of the Gasholder tank diameter against depth for brick, stone , concrete and composite tanks




## Gasholder or Gasometer.

The gas engineer would never use the term gasometer, a term printed on Ordnance Survey maps and used by the lay person. A gasometer is an incorrect term as they do not measure gas (that was the role of the meter), but only acted as a vessel to store gas (gasholder). Having said this, it was used by Samuel Clegg Jnr extensively in his Practical Treatise on the Manufacture and Distribution of Coal Gas, but not in later gas engineering texts.

**Gasholder site or Gasworks**

Not all sites containing gasholders were active gasworks. During the expansion and development of the gas industry and its distribution network, some new sites were developed purely for the storage of gas; these were referred to as gasholder stations. These gasholder stations were developed because either there was insufficient room for the construction of new gasholders on the gasworks site or new areas of supply had been developed and a new remote gasholder was required to store and distribute (via pressure of the holder) to this area.

These gasholders would have been supplied with gas under a greater pressure than used for local distribution from large centralised gasworks on the distribution network. Depending on the purpose of gas mains they supplied (and still supply) gas at varying pressures generally regarded as low, medium or high pressure. The low pressure being used for local distribution to properties and the higher pressures for distribution over greater distances. Pressure reduction station being used reduce the pressure down between the various gas mains. Although new gasholder stations were built, additional gas storage was generally held within the gasholders which had been retained on the many former gasworks sites where gas production had ceased. Most gasholders on former gasworks sites were retained for some period of time after closure for this purpose.

**Figure 17. Repairing the gas mains in Victorian times.**

Many old sites marked as ‘gasometers’ adjacent to mills, factories, hospitals and country houses were associated with small gasworks which were often not marked on maps. If you find such as ‘gasometer’ site then it is likely that you have found a gasworks and the production plant would have been located in a nearby building. More details on this subject can be found in the previous Profile on “Country House Gasworks”.

Many of the factory and mill gasworks date back to 1805-1830 when the gas industry was in its infancy. At this time the likes of Murdoch and Clegg were providing small works to factory owners, following the success of gas installation at the mills of Philips and Lee (Salford) and Henry Lodge (Sowerby Bridge) in 1805. This philosophy was successful for a while until these small works related gasworks gradually lost favour when the likes of the German Fredrich Winsor promoted the concept of centralised gasworks distributing gas through mains to a larger number of local customers. Whilst many of these factory/mill gasworks appeared small, they often produced more gas than many of the smaller village and town gasworks.

This was because an adequately lit mill using the simple burners available at the time could have been operating many hundreds of burners throughout the mill and associated properties, compared to a village gasworks with 20-30 street lamps and 30-40 customers. These mill and factory gasworks disappeared because of economic rather than technical reasons. The larger town gasworks established in the industrial towns could supply many mills at a much cheaper price than they could achieve independently. The isolated mills, hospitals and country houses (away from a mains supply) kept their gasworks much longer, but would later transfer to gas producers and/or electricity. A few of the mill works did evolve into the town gasworks and a few provided a public supply, which was often absorbed later by the local gas company.