Historic Building Recording of Gasholders at the former Wavertree Works Spofforth Road, Liverpool November 2017

Report No. 17/141

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NGR: SJ 3764 8980

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OASIS REPORT FORM

PROJECT DETAILS	*OASIS* molanort1-303916
Project title	Historic Building Recording of gasholders at the former Wavertree Works, Spofforth Road, Liverpool, November 2017
Short description	MOLA (Museum of London Archaeology) carried out a programme of historic building recording of gasholders at the former Wavertree Works, Liverpool. The Works was established in the mid-19th century to a design by Alfred King and was held as a model gasworks by contemporary critics. Recording encompassed two standard-guided gasholders of 1904 and two spiral-guided holders dating to 1929 and 1933. All of the gasholders utilised the existing masonry tanks of earlier column-guided gasholders built in the mid 19th century.
Project type	Historic Building Survey
Previous work	Unknown
Future work	Unknown
Monument type and period	Early to mid 20th-century gasholders
PROJECT LOCATION	
County	Merseyside
Site address	Spofforth Road, Wavertree, Liverpool
NGR	SJ 3764 8980
Area	0.7 ha
PROJECT CREATORS	
Organisation	MOLA Northampton
Project brief originator	Atkins Ltd on behalf of National Grid
Project Design originator	MOLA Northampton
Director/Supervisor	Amir Bassir
Project Manager	Anthony Maull
Sponsor or funding body	Atkins Ltd on behalf of National Grid
PROJECT DATE	
Start date	November 2017
End date	December 2017
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Abstract

MOLA (Museum of London Archaeology) carried out a programme of historic building recording of gasholders at the former Wavertree Works, Liverpool. The Works was established in the mid-19th century to a design by Alfred King and was held as a model gasworks by contemporary critics. Recording encompassed two standard-guided gasholders of 1904 and two spiral-guided holders dating to 1929 and 1933. All of the gasholders utilised the existing masonry tanks of earlier column-guided gasholders built in the mid-19th century.

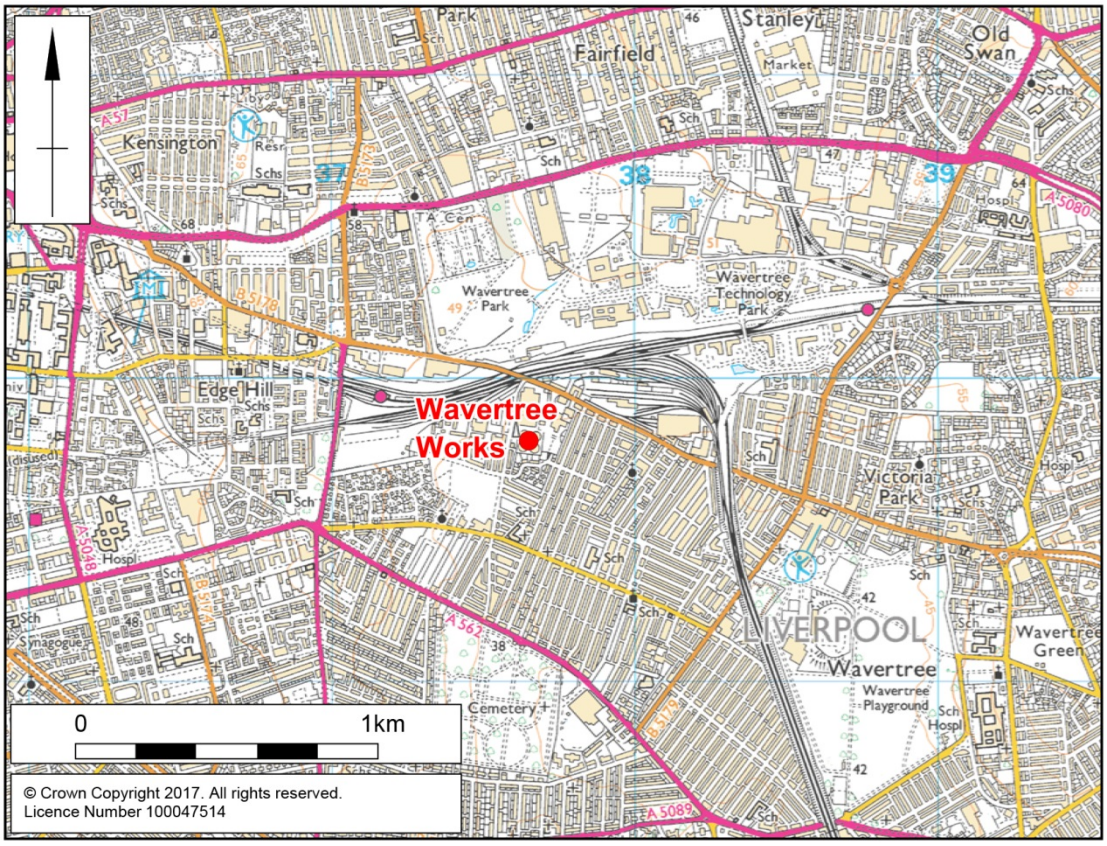
1 INTRODUCTION

MOLA (Museum of London Archaeology) was commissioned in December 2017 by Atkins Ltd, acting on behalf of National Grid, to undertake a programme of historic building recording at the former Wavertree Gasworks, Liverpool (NGR SJ 3764 8980, Figs 1 and 2).

The survey is a voluntary exercise commissioned by National Grid as part of their commitment to the heritage of their broader estate. This report is in accordance with current best archaeological practice as defined in the Chartered Institute for Archaeologists' *Standard and Guidance for the Archaeological Investigation and Recording of Standing Buildings or Structures* (CIfA 2015) and the Historic England procedural document *Management of Research Projects in the Historic Environment* (HE 2015).

The former Wavertree Gasworks is located in the Wavertree area of Liverpool, a short distance to the south of the Wavertree Botanic Gardens and immediately to the south of the London and North Western Railway (LNWR). Edgehill train station is situated a short distance to the north-west of the former gasworks. The site is bound to the north by Wavertree Road, to the west by Spofforth Road, and to the south by Cardogan Street. The northern part of the former gasworks which housed the gas production plant was redeveloped in the late 1960s / early 1970s and at the time of this survey comprised a derelict office unit.

The gasholder compound contained two early 20th-century standard-guided and two early-mid 20th-century spiral-guided gasholders all utilising the pre-existing tanks of former mid 19th-century gasholders.



Site location Fig 1

The recording area (image © Google Earth) Fig 2

2 OBJECTIVES AND METHODOLOGY

The objectives of this survey were to:

- Produce an illustrated, written document detailing the fabric, appearance and form of the gasholders and associated structures and pipework. Due to the safety constraints associated with gasholders, recording was limited to the exterior of the structures;
- Provide historical survey drawings (or sketches) for comparable investigation relating to building form and function, identification of fixtures and fittings where visible or accessible;
- Provide an account of historic fixtures, fittings and architectural features where visible or accessible;
- Provide a photographic record of the structures in context.

The level of recording was specified as enhanced Level 2 for gasholders 1 and 3 and basic Level 2 for gasholders 2 and 4.

Recording was carried out on the 28th November 2017 and encompassed all four gasholders as well as associated infrastructure and miscellaneous buildings.

The site was photographically recorded to include general views of the site and structures, placing them within their wider context, and detailed views of any structural, historic and architectural details that would be lost during demolition. Measured drawings of the standard footings and roller carriages were made and these were also photographically recorded with the aim of producing photogrammatic models of these elements (electronic appendix 1). The photographic survey was to an extent limited by strong and low level sunlight which restricted south-facing views and which cast strong contrasting shadows. Key views were re-photographed during occasional overcast periods.

Photography was carried out using a Nikon D7200 DSLR equipped with Sigma 35-17mm and Nikon 18-70mm lenses. Supplementary photography was carried out using a Panasonic FZ7200.

The National Grid Archive was searched for relevant historic images and documentation relating to the site, and a visit was made to the Liverpool Archives. Documents from both of these sources are referenced in this report.

3 HISTORICAL BACKGROUND

3.1 The Liverpool Gas Company

The Liverpool Gas Light Company was formed and incorporated in 1818 by Jonathan Varty and John Hargreaves, with offices in central Liverpool at the corner of Dale Street and Hatton Garden. After some 30 years rivalry, in 1848, the Liverpool Gas Light Company amalgamated with the Liverpool New Gas and Coke Company (which had begun operating in 1822 as the Liverpool Oil Gas Light Company) under the title of the Liverpool United Gas Company, new offices being built in Newington and later in Duke Street. The company had two works, a coal gasworks at Dale Street and an oil gasworks at Rose Hill.

'The original installations at Dale Street and Rose Hill were discarded at an early period in favour of larger premises in Eccles Street and Athol Street, both conveniently situated on the Leeds and Liverpool Canal for receiving coal by water. In 1847 additional works were erected in Caryl Street (then called Harrington Street)' (Gibson 1927). The first of the company's gasworks to be connected to a railway system was the Wavertree works which was constructed in 1856. This was followed in 1867 by the Linacre Gasworks which utilised both rail and canal links. The Garston Works were opened in 1895 and until 1922 were the only gasworks in Europe in which carburetted gas only was being made.

In 1914, the company changed its name to the Liverpool Gas Company. It continued to expand and in September 1932 announced the takeover of the Huyton and Roby Gas Company, a move which brought the parish of Croxteth Park and the townships of Simonswood, Kirkby, Whitston and Tarbeck as well as a portion of Speke under the control of the Company. By 1934, the company had six works of which that at Garston was the newest. In May of the same year, the Liverpool Gas Company announced a bid for the purchase of land in Bond Street with the intention to clear the site and build show rooms and offices.

3.2 Development of the Wavertree Works

> Liverpool emerged as a modern global city, based around new systems of international trade and capital during the 18th and 19th centuries. Growth and wealth were manifested physically in … the planned development of often pioneering modern urban infrastructure such as railways, parks, docklands and public housing. Liverpool was among the earliest places to face acute social challenges characteristic of the industrial city… Liverpool's core population growth during the 19th century mirrored its strategic and economic prominence, rising from 78,000 in 1801 to 870,000 in the mid-1930s (Sykes *et al* 2013).

The expanding wealth and population of the city were reflected in its evolving urban development. Working classes tended to be housed along the river within easy reach of the docks, whilst the wealthier gravitated uphill to the long ridge overlooking the river (Sykes *et al* 2013). These country estates stretched in a great arc from Anfield to the Mersey at Aigburth (Harris 1958).

> These areas were within the Company's supply limits and were connected by mains to the various gasworks, but the increasing demand, coupled with contour difficulties and distance from the existing gas-making point's created problems which…could be solved only by siting gas production on the reserve slope of the ridge (Harris 1958).

Wavertree Works came into being as the result of a report submitted to the Board of the Liverpool United Gas Light Company in December 1853 by Alfred King its Chief Engineer (Harris 1958). In his report King stressed the difficulties of maintaining gas supply over the elevated topography which separated the core of Liverpool from its eastern townships. King strongly urged the erection of Works on the reverse slope of the ridge, and suggested a site on the south side of the Wavertree Road near the railway bridge to be connected to the railway by a short branch line on which the Cannel and other materials could be conveyed into the Works (Harris 1958). The report was approved by the Board on 18th January 1854 and gas was first sent out from the new works in October 1856. The six works of the Liverpool Gas Company were connected together by high-pressure mains which allowed the company to maintain gas supply during periods of heavy demand. Large exhausters were installed at Linacre and Garston which allowed gas to be pumped north or south as necessary. The Garston and Wavertree Works were connected by mains which allowed the supply of coal gas manufactured at Wavertree by means of the mixture from Garston (Journal of Gas Lighting and Water Supply 1914).

Early Ordnance Survey mapping shows that prior to development, the site lay beyond primary extent of Wavertree and retained much of its rural character though small areas of residential development had begun to encroach (Fig 3). The LNWR lines were already in place by this time, the station at Edge Hill having been opened in 1830. Immediately to the south of Edge Hill Station were engine houses, fitter's workshops and a smithy and brass foundry. Alongside these were two rows of terraced housing named Spekefield Cottages, presumably providing housing to the foundry and rail workers. Urban development rapidly increased and by 1890 the majority of the former rural landscape had been given over to dense terraced housing (Fig 4). There was also a significant expansion of the rail network reflecting the town's rapid growth and increased prosperity.

The Wavertree Works were set out to a compact and efficient design with a separation of production and distribution facilities and were considered model works at the time they were built, and were described and illustrated in ‘King’s Treatise’ (Journal of Gas Lighting and Water Supply 1914) (Fig 6). Raw materials such as coal arrived from the north via rail sidings and were stored at the west and north edges of the site. Retorts and Purifiers occupied the central area of the works, with laboratory, power house and other small building along the edges of the site. The gasholders formed a compact square grouping at the southern end of the site with a small valve house located at the centre of the group (Fig 7).

The Works were subject to modification and improvement in order to keep the plant up to date and in economical and efficient working order. This included the replacement of King’s gas pump exhausters with Donkin exhausters, and the installation of four purifiers on ‘Green’s System’.

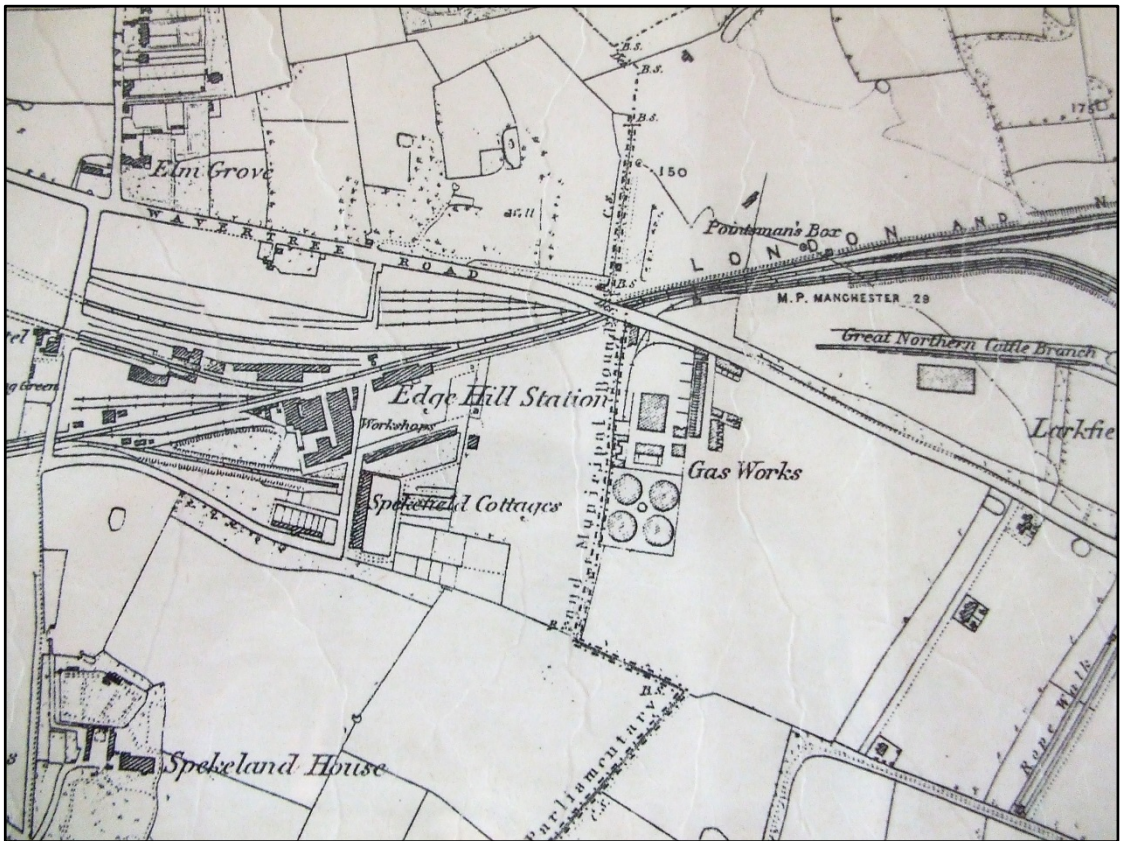
Gas Engineer Walter Mabon described the site’s gasholders as incorporating every improvement in their construction, a fact which rendered them both durable and economical (Mabon 1855). The construction of the original gasholders appears to have been staggered in order to allow at least partial storage capacity until the site was fully operational. Gasholder 4 was constructed by 1855 and Gasholder 2 by 1859. Both were two-lift gasholders, each with a capacity of 639,975 cu. ft. The original two-lift Gasholders 1 and 3 had by 1906 been upgraded to three-lift gasholders. This upgrade required the replacement of the gasholder framing but retained the existing masonry tank. Gasholder 2 was upgraded to a spiral-guided holder in 1929 and Gasholder 4 in 1933.

Following the First World War, there was an increasing attitude in favour of nationalisation and coalescing of the fragmentary gas industry. These plans were temporarily halted by the outbreak of war in 1939, however, in the post-war years the movement gained impetus and plans were put into place for the nationalisation of coal mines, electricity, transport and gas.

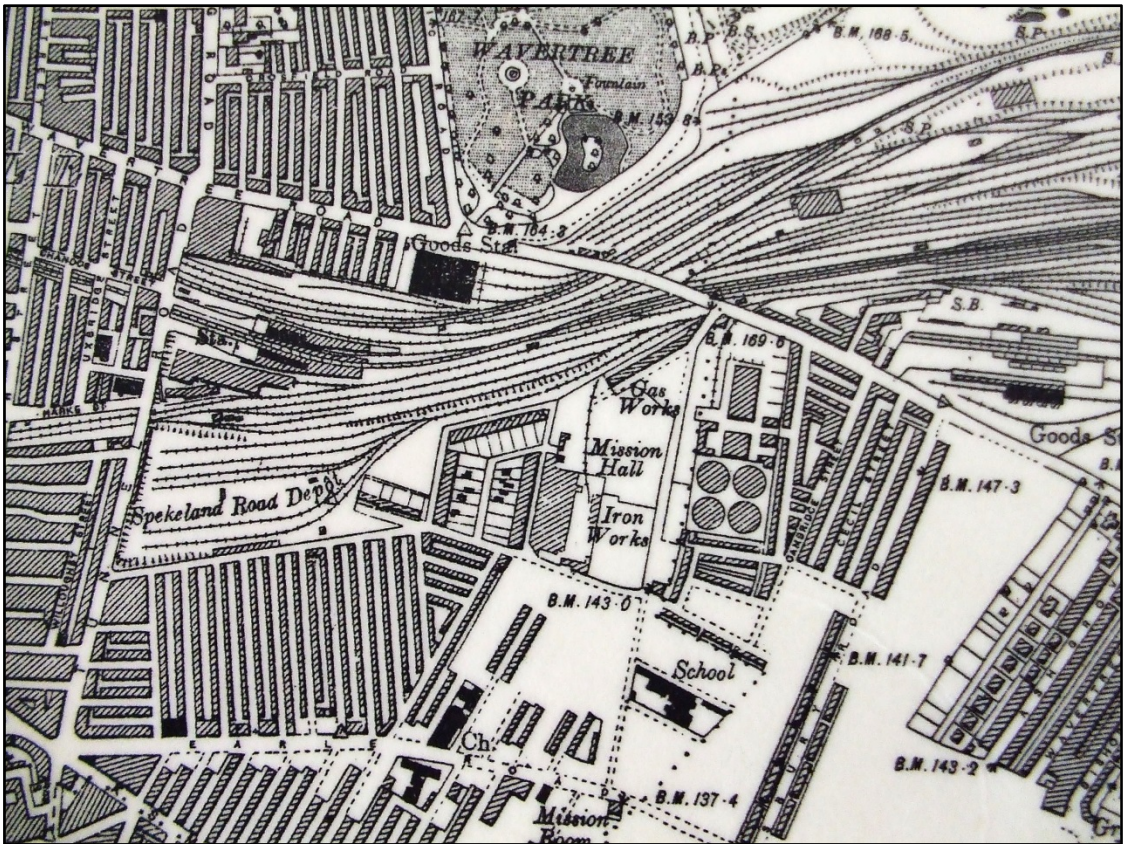
> *Nationalisation was the greatest single event in the history of the gas industry in the first century and a half of its existence…Further; it provided the framework for the remarkable renaissance of the industry that followed the discovery of North Sea gas, a renaissance made possible only by the availability of large and well-organised technological and financial resources* (Williams 1981, 103).

Of the 12 area districts which were set up under the Gas Act of 1948, Liverpool fell into the jurisdiction of the North Western Gas Board. From the 1950s onwards there was an increased drive to prospect for and exploit natural gas resources. The discovery of North Sea gas in the early 1960s triggered a rapid switch to natural gas and a nationwide investment in new distribution plant and appliances which was declared complete by September 1977. The conversion programme was accompanied by the development of a national transmission system of high pressure pipelines, compressor stations and terminals in order to store and distribute the gas. This effectively rendered the former gas manufacturing plant redundant, with the exception of the gasholders and governors.

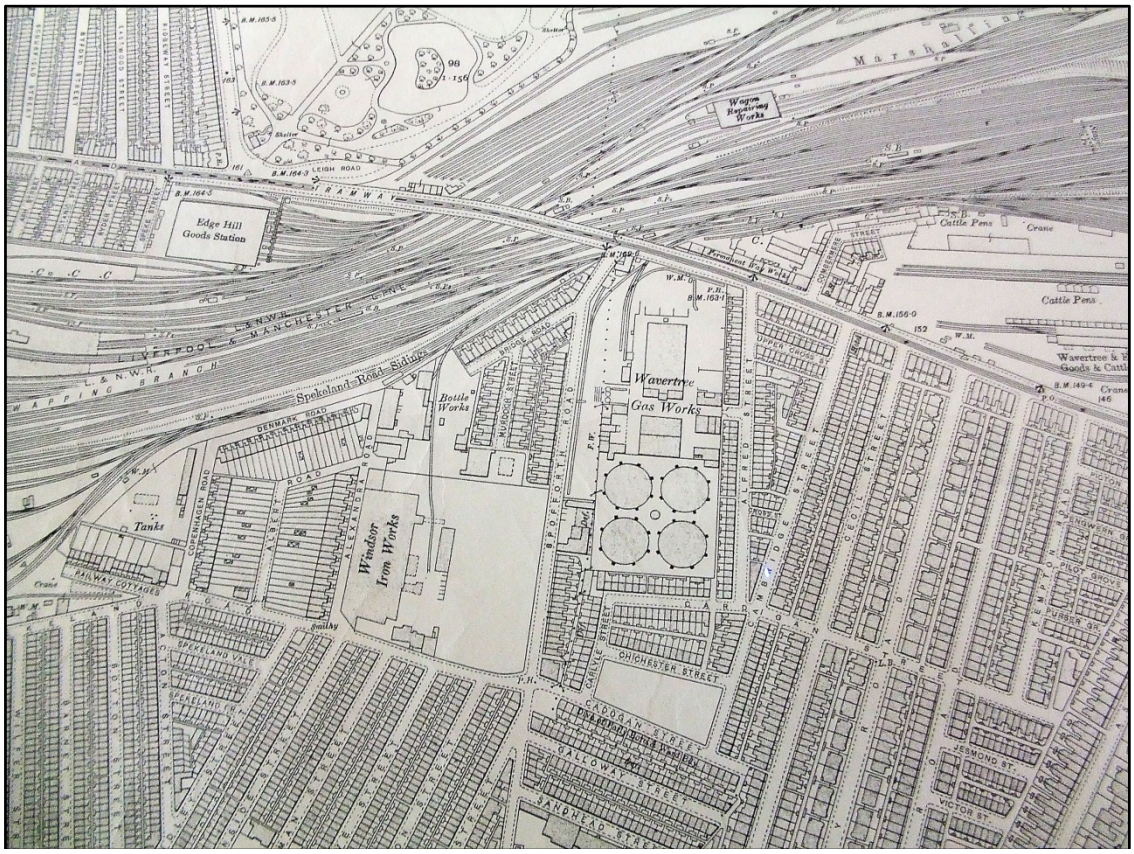
By 1967 the gas production plant at Wavertree had been made redundant and the site cleared of all plant and buildings except for the gasholders and the infrastructure required to operate them and maintain pressure and means of gas distribution (Fig 8).



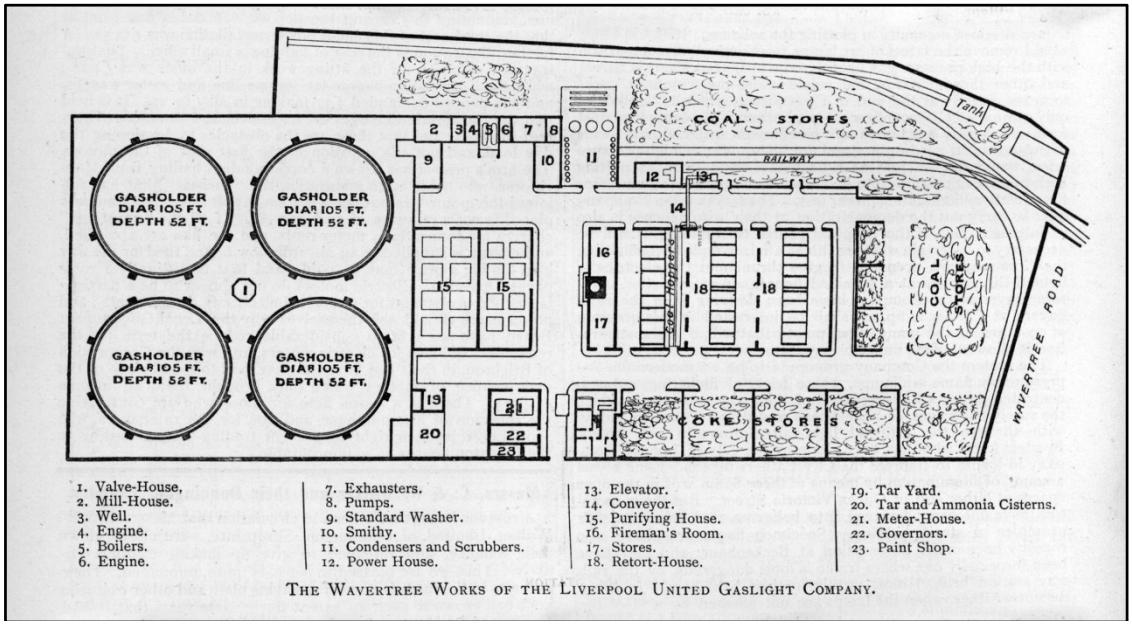
First Edition Ordnance Survey map of 1849 (with 1850s updates) Fig 3



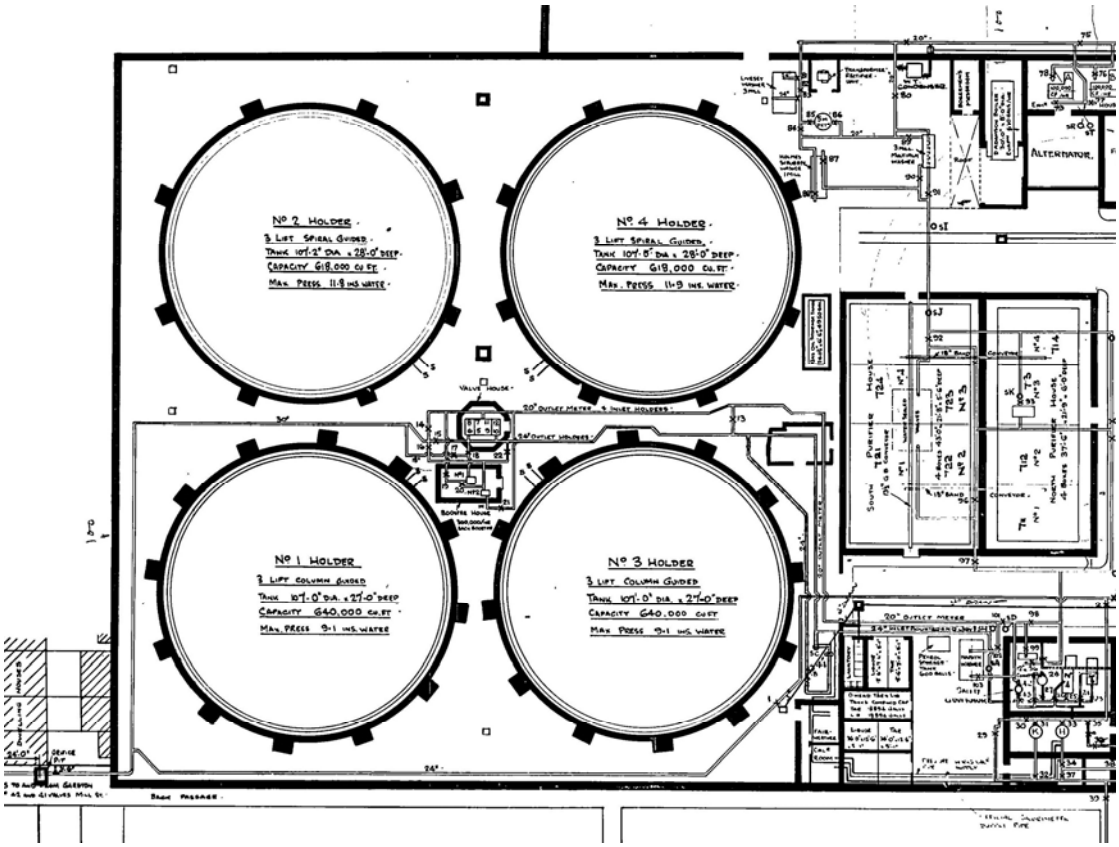
Ordnance Survey map of 1889-90 Fig 4



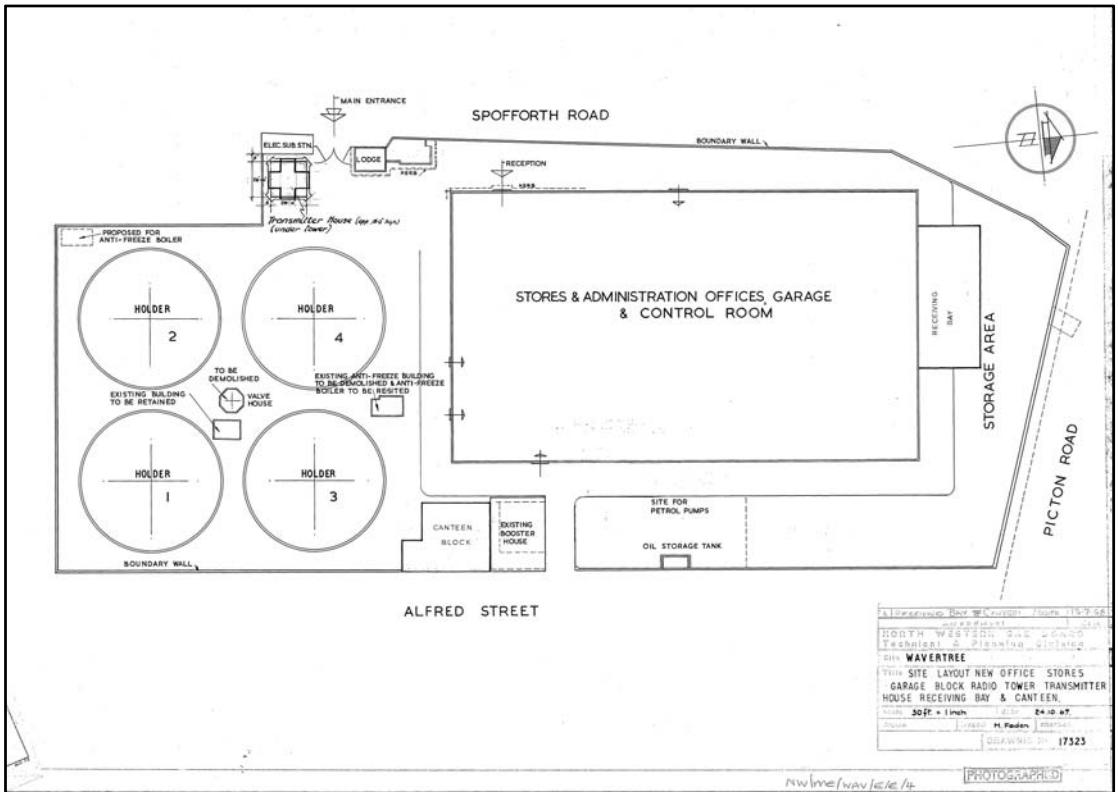
Ordnance Survey of 1927 Fig 5



Plan of the Wavertree Works in the early 20th century. Note that although gasholders 1 and 3 had been replaced or upgraded by this time, they are shown with only eight footings each (Journal of Gas Lighting and Water Supply 1906) Fig 6



Plan of the gasholders in 1953 (NGA ref NW/ME/WAV/E/E/3) Fig 7



Plan of the site in 1967 (NGA ref NW/ME/WAV/E/E/4) Fig 8

4 DESCRIPTION OF THE GASHOLDERS AND ANCILLARY BUILDINGS

The recording area comprised a roughly square gasholder compound enclosed by mid 19th-century walls to the east, south and west, with a modern fence separating the site from a former administration and office building which replaced the former gasworks to the north. The site was accessed from Spofforth Street to the west where there was a modern secure gate. Adjacent to the gate was a tall telecoms mast which is enclosed from the site. An electrical substation was positioned between the mast and the road. The gasholders formed a compact group occupying most of the available space with room for access and pipework to the former boosters, governors and valve house etc.

4.1 **Gasholders 1 and 3** (Figs 9, 11-27)

Both gasholders were built to an essentially identical design having been erected concurrently in 1904, replacing earlier gasholders on the same footprint and utilising the pre-existing tanks of the earlier holders. They were three-lift standard-guided gasholders with below-ground tanks, and each comprised twelve standards with three tiers of encircling girders. Although being of the same design and dimensions, slightly varying capacity values are provided by the gasholder data sheets. Gasholder 1 had a total storage capacity of 19,026 cubic meters (671,690 cubic feet) and Gasholder 3 19,020 (671890 cubic feet). Both gasholders stood to a height *c*26.4m (86' 62") in height. Both had a basal radius of *c*31.9m (104' 6") and an outer circumference of approximately 200m.

The gasholder information sheet for Gasholder 1 does not provide manufacturer details but that of Gasholder 3 states that it was constructed by Thomas Piggot & Co. Ltd. of Spring Hill, Birmingham. This company was established 1822, producing a range of steam engines, boilers, gas plant, and other iron workings (Grace's Guide 2017a).

The gasholder frames, roller carriages and lifts were primarily built of steel and wrought iron. Steel began to replace the use of wrought iron from the late 19th century onwards due to its higher tensile and compressive strength, corrosion resistance and economy. The vertical members of the static frame were comprised of twenty standards, each to an I-section design with lattice webbing. Each standard was set at a distance of *c*7m from its neighbours. From ground level to the first tiers was *c*8m, and a height of *c*15m was measured to second tier and *c*25m to the underside of the third tiers. The standards were secured to the tank edge by rectangular steel footings measuring 1060 x 1490mm. The footings overlay concrete pads and were secured by bolts through the pads. The outer and inner chords were formed of flat outer sheets (230mm in width and 10mm thick), with riveted angles securing the lattice webbing. At the base of each standard the outer chords were splayed outwards and forwards to match the footings and the basal plates and standards were joined by small overlapping and riveted sheets, The inner chords were likewise splayed outwards but continued the vertical line of the frame. Above the footings the outer and inner chords were stiffened by means of solid sheets with curved upper edges. The standard lattice comprised of rectangular steel straps 19mm thick and 95mm in width, overlapping one another with rivets at the overlaps. The ends of the straps were held between and riveted to the angles of the inner and outer chords.

The gasholder standards each had a numeric designation from 1 to 12, running clockwise, beginning and ending at the south-west corner of each gasholder. The numbers were simply hand written with paint or marker pen on the outer chord of each standard at a height of *c*1m. No other more permanent form of numbering was

visible on any of the standards. Those standards situated at the cardinal compass points had hand-painted lettering on the footings (i.e. W -west etc). Though now faded and generally illegible, the manufacturer's stamp LILLESHALL can be seen on the steelwork of several standards of both gasholders. The Lilleshall company of Shropshire were 'mechanical engineers, coal and iron merchants, iron founders and manufacturers, and steel manufacturers (Grace's Guide 2017b).

The gasholders were encircled by three tiers of girders which provided lateral stiffness to the frame, allowing wind load to dissipate throughout the structure and prevent the standards from swaying. The girders were of an I-section design with 'Type U' hexagonal castellation, formed of mirrored steel plates welded centrally. The girders terminated at bolted and riveted box members and were secured to the standards with tapered steel plates. It is possible that the girders have been replaced, though no historic photographs of the gasholders were found which might show a previous scheme. It was observed that no rivets were present on either of the gasholder's standards from the first tier up and that some of the standard outer chords showed empty rivet holes towards the top of the standards. It is possible therefore that the standards have also been subjected to rebuilding or remediation.

Diagonal bracing of the gasholder frames was achieved by a web of adjustable tensioning or bracing rods that spanned between each standard, forming three levels of bracing between the tiers and the standard footings. The rods had a circular profile of *c*80mm diameter and could be adjusted by means of hexagonal tensioning rods or couplers located at the outer end of each rod. The lowest tensioning rods attached to the standard footings by means of steel anchors riveted to the central footing plate and angled away from the footing plates. The rods at the upper levels were anchored to the upper and lower sides of the lateral girders. At the centre of each web was a coupler formed of two square plates to which the four rods attached. This allowed individual rods to be repaired without compromising overall integrity.

Following the classification of column and standard guided frames and their components as set out in the London Gasholder Survey (Tucker 2000), the gasholder frames broadly correlated with the type 24 and type 32 of the typology.

Roller guide channels formed of C or box profile rolled steel beams were held from the backs of the standards by steel or wrought iron brackets. The guidance system was comprised of triple sets of tapered 'goose neck' radial cantilever roller carriages, each comprised of steel or wrought iron side plates with riveted edge bracing and bolted framing members. The upper roller carriages, being the larger (*c*1.4m in length), also had additional splayed bracing in the form of angle struts which connected to the crown top curb at a distance of 1m from the roller carriages. The roller wheels were comprised of wrought iron spoked wheels, the largest being 530mm in diameter with with an outer edge 80mm. The rollers were of a fairly standard design and very similar to those recorded on gasholder 2 of the former Garston Gasworks (Bassir 2015).

The gasholder crowns were formed of concentric rings of slightly tapered steel sheets, those near to the top curb measuring 940mm x 1100mm. The sheets overlapped and riveted at the edges and staggered to avoid continuous joins in the crown. The thickness of the outer row crown sheets of Gasholder 1 are given by the data sheets as ¼" and those of gasholder 3 as ⅜". The gasholder data sheets describe both of the gasholders' crown rests as comprising *24 main bars 5" x 3" x ½" tee with tie bars and bracing*. Gasholder 1 has a single 2" gas vent in the crown centre and Gasholder 3 has 6" and 1½" vents in the centre. Both gasholders had two manholes located near the top curbs.

Both gasholder had rounded or 'bent-plate' cup and grips, these being 9" wide and 18" deep. In order to allow safe access over the curved grips, flat walkways were installed above them, spanning the circumference of each tank, with safety rails attached to the walkways.

Access to the lifts and top of the gasholders was via vertical ladders with landings at each tier. Both ladders were located at the southern sides of the gasholders, between standards 1 and 12. The base of the ladders were enclosed by safety cages which prevented unauthorised access. The full height of the ladders was enclosed by back cages. The lifts and crown were encircled by safety rails of a simple standard design. At ground level, adjacent to the each of the ladders were gaps in the safety rails, with stepped platforms allowing access to the crown walkways.

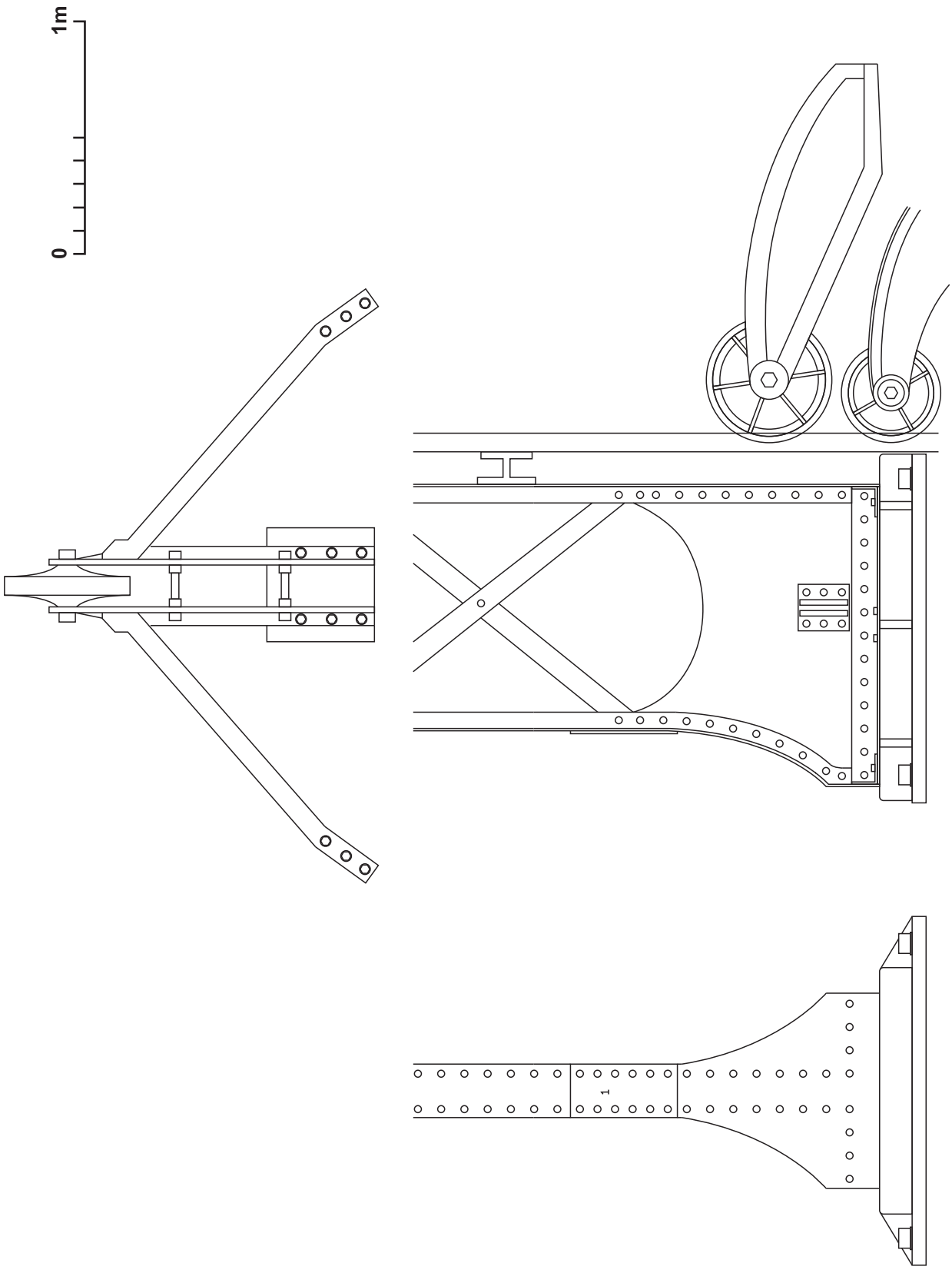
An unusual feature of Gasholder 1 were a series of tall rectangular concrete-filled metal boxes, which were located at irregular intervals around the south-eastern corner of the crown and connected to the safety rails. These did appear to be part of the original design and none were present on Gasholder 3. Their purpose was not clear and the author has not seen such features on other gasholders. A possible explanation is that they might be deliberately weighing down the lifts in this area in order to provide balance or stability to the gasholder, perhaps rectifying a defect in the structure.

The gasholders utilised a steam anti-freeze system and the boiler was originally housed in a rectangular building to the north of the gasholders, between holders 4 and 3. In the late 1960s, following the demolition of the gas production plant and construction of the larger offices and administration block, the previous anti-freeze building was demolished and the boiler re-sited to a new boiler house at the south-west corner of the compound. On both gasholders the anti-freeze valves and flexible pipes were located at the south-west and north-east sides of the holders, adjacent to standards no.2 and no.8. At each side of the standards were two vertical lengths of lagged pipe which rose to just below the first tier and midway to the first tier. From here flexible pipes connected to the tanks and rose and fell with the lifts.

Hammer switches and alarms relating to the movements of the lifts were, on both gasholders, located at their western and north-western sides, between standards nos.3 and 4. The hammer switches were elevated from the ground and in the usual fashion set at differing heights and labelled according to function i.e. Jet Booster Trip, Low Alarm, HCV Bot Trip etc.

The 20" and 24" inlet and outlet pipes for each gasholders were located side by side, at the north-west corner of Gasholder 1 and south-west corner of Gasholder 3 where they would be in closest proximity to the former valve house which was located in the central space between the four gasholders.

The tanks were not visible during this survey, however the gasholder data sheets note that both gasholders have masonry tanks, both 32.6m (107') in diameter and 8.2m (27') deep. No details about the dumplings are provided.



Scale 1:25 Details of the gasholder standard and roller carriage arrangement Fig 9

4.2 Gasholder 2 (Figs 10, 29-36)

This is a spiral-guided gasholder with below-ground base tank and three lift-tanks. It has a diameter of 32.66m (107' 2"), with a footprint of 837sq m, and rises to a total height of 25.9m (79' 7" plus 5' 6" crown rise). It has a total storage capacity of 18,590 cu. m. (656,450 cu. ft). The gasholder was built in 1929 by C & W Walker Ltd of Donnington, Shropshire. It utilises the pre-existing 8.5m (28') deep masonry tank of an earlier gasholder which was constructed in the mid-18th century. The top edge of the tank is lined with stone blocks, each 1.5m x 0.5m, and the remainder of the tank edge is covered by gravel. A large number 2 is carved into the stone curb at the north-east of the gasholder with white concrete poured into the number to allow it to stand out.

The gasholder has 24 outer roller carriages, 18 on the middle and 12 around the inner tank. The rollers are of a side-by-side dual-roller design; fairly compact, measuring 665mm x 290mm, with elongated grease tubes to each axel. The roller wheels are 220mm in diameter. The rollers of the inner tanks are of the same design but shortened to fit onto the grips. Eight of the outer roller carriages appear to utilise the footings of the earlier column guided gasholder. These are rectangular iron footings (1.6m x 1m), bolted to the tank at the corners, with the marks of truncated bolts on the flat surfaces. The central area of each footing surface is roughened, indicating the position of the former columns and a common indicator of this type of reuse. The remainder of the outer rollers are installed on trapezoidal footings, each measuring *c*1.1m in length x 1m at the widest edge and 0.6m at the shorter edge. All of the outer roller carriages footings are installed onto rectangular concrete pads. Those positioned at the cardinal points have the corresponding letters stencilled with white paint onto the footings.

The gasholder crown is formed of concentric rings of elongated rectangular sheets, staggered to prevent joins and riveted at the edges. The surface was found during the survey to be fairly sound but with numerous undulations relating to some weaknesses in the underlying crown support. The main crown sheets are 3/16" thick and those of the thicker outer row or curb are 1/4" thick. There are three manholes positioned around the perimeter of the crown, two located side-by-side at the north-east corner and one at the south-west corner. A gas or air vent is located at the centre of the crown and another close to the manholes at the north-east. As with most spiral-guided gasholders the tanks have square cup and grips 10" x 24½". The side sheets of the tanks are 1/4" at the top row and 3/8" at the bottom.

There are three inclined ladders, each attached to one of the lift grips and these are of an unusual steepness, owing to the comparatively small diameter of the gasholder. The ladder frames are formed of angle irons, riveted at the joins, with safety rails along the outer side of the ladders. When the gasholder is deflated the ladders come to rest at the south-western side of the tank.

Hammer switches and trip alarms are located at the north-eastern side of the gasholder. Cables trays are located adjacent to the switches and various telemetry and electrical equipment are located around the perimeter of the tank. The gasholder is located adjacent to the late 1960s replacement boiler house and utilises a steam anti-freeze system. At the south side of the gasholder is a single anti-freeze pipe support, *c*3m, and in the form of an open-fronted box with bars at one side. Projecting from the side of the support at the top is an iron ring from which a cable is draped. The cable runs to a geared pulley mechanism attached to the side of the support. Pipe trays which supported the anti-freeze pipes when the lifts were at rest are located close to the vertical pipe support.

The 20" and 24" inlet and outlet pipes are located together in a pipe pit at the eastern side of the gasholder. The pipes have been truncated and sealed and the pipe pit covered over in concrete.

4.3 **Gasholder 4** (Figs 10, 37-44)

This was spiral-guided with below-ground tank and three lift tanks. It was built in 1933, four years after Gasholder 2, and utilised the pre-existing masonry tank of an earlier column-guided gasholder. It had a diameter of 32m (105' 2¾") and rose to a total height of 26.4m (81' plus 5' 6" crown rise). The gasholder had a total storage capacity of 19,016 cu.m (671,570 cu. ft.). The masonry tank was 32.7m (107' 5") in diameter and 8.5m (28') deep with stone blocks forming the edge of the tank. The numerical designation, 4, was carved into the stone surface at the south-east corner of the gasholder and was of the same style as that seen at gasholder 2.

The manufacturer of the gasholder was Newton Chambers Ltd of Sheffield and commemorative plaques reading ERECTED BY / NEWTON CHAMBERS / & Co LIMITED / THORNCLIFFE IRONWORKS / SHEFFIELD / 1933 were set in raised lettering on several of the outer roller carriage footings around the tank. Newton Chambers Ltd was a fairly prolific manufacturer of gasholders across Britain and commonly set such plaques into their gasholders, such as gasholder 2 (1924) at Garston, Liverpool, or gasholder 1 (1937) at Meadowhall, Sheffield (Bassir 2016).

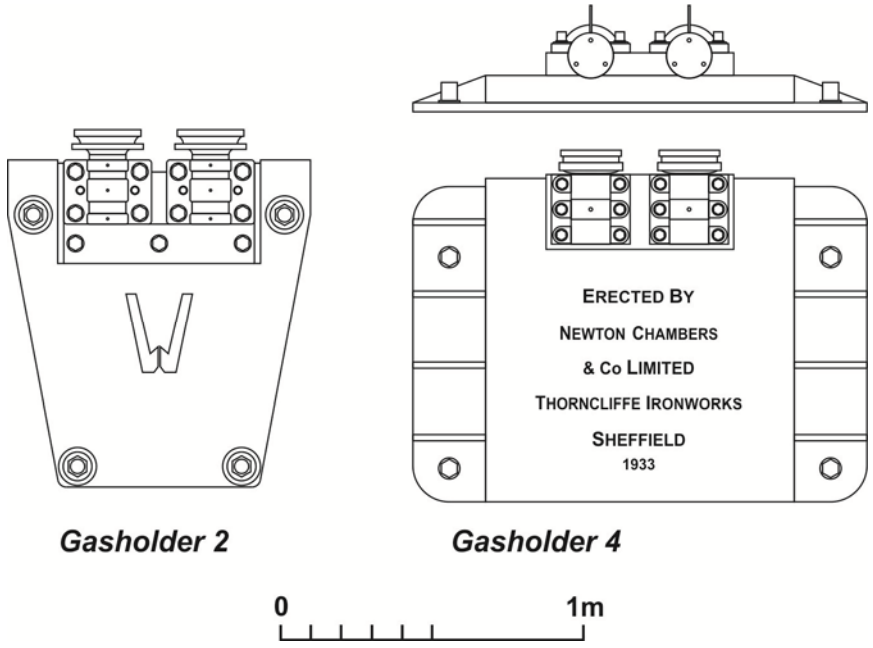
Gasholder 4 had the same configuration of roller carriages as Gasholder 2, i.e. 24 outer, 18 middle, and 12 inner rollers, this being the number of rollers best suited to the diameter of the structure. These were dual roller carriages of a fairly similar design to those on Gasholder 2, with more compact versions on the tank grips. As noted on Gasholder 2, eight of the outer roller carriages appeared to utilise the pre-existing footings of the former column-guided gasholder. These footings, measuring 1.6 x 1m, were of the same design as those on Gasholder 2. The other sixteen outer roller carriage footings had a different design to those of Gasholder 2, here being rectangular in shape with angled ribs between the upper surface of the footings and the base plate.

The crown was formed of elongated rectangular sheets, each tapered towards the top and riveted at the edges. The crown surface showed minor undulations on the surface but otherwise appeared be in fairly sound condition. It was pierced by three manholes, two at the north-west and one at the south-east side. At the centre of the crown were two valved vents and two air vents. The crown sheets of the outer row were 1/4" in thickness and those forming the main surface were 3/16". The gasholder data sheet gives the side sheet thickness of the top row as 3/8", intermediate rows 3/16" and bottom row as 3/8". The tanks have square cup and grips measuring 10" by 26".

Access to the lifts when inflated was via steeply inclined ladders set on triangular frames of the same design as those on Gasholder 2. When deflated these come to rest as a group at the south-west side of the gasholder.

Hammer switches, alarms and trips were located at the eastern side of the gasholder. These were elevated from the ground on steel posts and set at an angle so that they interacted with the rising tanks. A cable tray was positioned alongside the switches, formerly carrying cables to various electrical fittings and telemetry. The gasholder used steam anti-freeze system and had the same anti-freeze supports as Gasholder 2, these being located at the south side of the gasholder. A steam pipe, slightly elevated from the ground, spanned the most of the perimeter of the tank from the east to the south sides.

The 24" and 20" inlet and outlet pipes are located together in a pipe pit at the south-east side of the gasholder and formerly connected to the central valve house.



Detail of the roller carriages of Gasholders 2 and 4 Fig 10

4.4 Miscellaneous structures and infrastructure (Figs 45-50)

In the late 1960s the former Boiler House was demolished and the boiler re-sited in the south-west corner of the site. The boiler, decommissioned at the time of survey, was housed in a simple corrugated steel shed. The structure was not accessed due to the presence of asbestos. The shed had a two-level sloped roof and the boiler flue projected above the roof line. A single door was located in the north elevation.

A Pressure Reducing Station was located at the south of the compound, adjacent to the boundary wall. This was a simple steel box with double doors to the north. The interior was not accessed.

At the north-eastern corner of the site were a Booster House and Instrument Room, both decommissioned and inaccessible at the time of survey. Both were simple rectangular structure constructed of modern brick in stretcher bond and set upon concrete pads. Both had flat roofs of roofing felt and were accessed through double doors in the west walls.

A pair of elevated 24" pipes entered the gasholder compound in the south-east corner of the site and dropped vertically to the ground adjacent to Gasholder 3. The Wavertree and Garston works were formerly connected by 30" mains which entered the site at this position though the arrangement of pipes seen during the survey differed from that illustrated on archive plans of the works. One of the pipes had a Donkin flow valve and was labelled SV 123. The other pipe had a parallel return above ground level which appeared to align with a short length of sealed pipe projecting from the ground close to the Instrument House. A water pump atop a covered sump pit and labelled SV 102 was also located in this area.

The location of the former boiler house could be identified by the remnant concrete pad on which the building stood. Central to the pad was a large covered pit and a manhole was located at the south-east corner.

Although the former valve house was demolished in the late 1960s, its position could be identified by a group of defunct and sealed pipes located at the centre of the gasholder compound. The former adjacent booster house could also be identified from remnant concrete in the ground.

The gasholder compound was bound to the east, south and north by brick walls. The *c*3m high walls appear to retain their original mid 19th-century construction and comprised hand-made red brick in English Garden Wall bond with a *c*1.5m high plinth level with regular recessed panels and short pilasters above. The tops of the walls were finished with shaped decorative bricks.

5 DISCUSSION

The Wavertree Works was one of the last surviving gasworks to be conceived, designed, constructed and operated by Alfred King, who was one of the most outstanding personalities of the gas industry's first half century (Harris 1958).

The site was approved and operational within two years and was held as a model of gasworks design and layout by contemporary critics. The gasholders were placed in a compact grouping with pipes converging on a central valve house with adequate space around the periphery for infrastructure and operational plant.

The site was subjected to a phased upgrading of the original two-lift column-guided gasholders, first with two wrought-steel lattice I-section standard-guided holders in 1906 and subsequently by two spiral-guided gasholders in 1929 and 1933. The choice of the two types of gasholder is fairly typical of gasholder design at each period, with standard-guided holders being favoured in the late 19th and early 20th centuries and spiral-guided holders dominating from the early to mid 20th-century. The earliest spiral-guided gasholder was built in 1890 by Clayton Son & Co. Ltd of Leeds but the design did not gain prominence until the next century although both types of holder design were being built at the same time, each design presenting advantages and disadvantages over the other.

The manufacturers of the gasholders, Thomas Piggot & Co Ltd, Newton Chambers Ltd, and C & W Walker were major manufacturers of gasholders and gasworks plant and numerous examples of their designs exist around the country.

The site was not included in the *Step 3 Report for Monuments Protection Programme* (Truman 2002) which assessed 151 gas sites across the UK. The gasholders are all fairly typical of their type and the utilisation of existing tanks of former gasholders was very common on gasworks, though as seen at this site, the width of the existing tanks limited the height attainable by the gasholders, and therefore their capacity. As a general rule when upgrading gasholders the capacity was doubled, however the optimum height of a gasholder was generally a little less than or equal to the tank width.

Gasholder 1, looking south-east Fig 11

Gasholder 3, looking north-east Fig 12

General view of the tanks, grips and roller carriage arrangements, Gasholder 1
Fig 13

Example of the standard footings (GH3, No.1) Fig 14

Front view of standard footing (GH3 No.1) Fig 15

Example of the outer roller carriages Fig 16

The arrangement of roller carriages Fig 17

Example of the first tier standard / girder connections Fig 18

Example of the second tier connections Fig 19

Example standard apex Fig 20

Detail of the tensioning rod couplers Fig 21

Crown walkway and ladder access, Gasholder 1. Note adjacent concrete filled boxes
Fig 22

The concrete filled ‘balancing boxes’ of Gasholder 1 Fig 23

General view of the crown of gasholder 3, looking west Fig 24

Detail of telemetry and electrical fittings, Gasholder 3 Fig 25

Detail of hammer switches, electrical cable trays and anti-freeze pipe, Gasholder 3
Fig 26

Tank or dry well at the north-west side of Gasholder 1 Fig 27

Defunct elevated mains and other pipes at the north-east side of Gasholder 3 Fig 28

General view of Gasholder 2, looking east Fig 29

General view of Gasholder 2, looking south-west Fig 30

View of the arrangement of tank grips, railings and top curb Fig 31

Example of the outer roller carriages. Note stencilled W (west) Fig 32

Example of the larger roller carriage footings Fig 33

Detail of the tank grips and inner roller carriage Fig 34

The hammer switches, trips and alarms Fig 35

Gasholder designation ‘2’ in the masonry top curb Fig 36

General view of Gasholder 4, looking north-east Fig 37

General view of Gasholder 4, looking south-west Fig 38

Example of the outer roller carriages with commemorative plaque Fig 39

Detail of commemorative plaque Fig 40

Example of the larger roller carriage footings Fig 41

Anti-freeze support and attached cables Fig 42

Gasholder designation ‘4’ in the masonry top curb Fig 43

The gasholder crown with manholes Fig 44

Defunct pipework marking the position of the former Valve House, looking north
Fig 45

The Booster House and Electrical Switch Room Fig 46

The Instrument Room Fig 47

The modern Boiler House Fig 48

The concrete pad of the former Boiler House Fig 49

The Pressure Reducing Station Fig 50

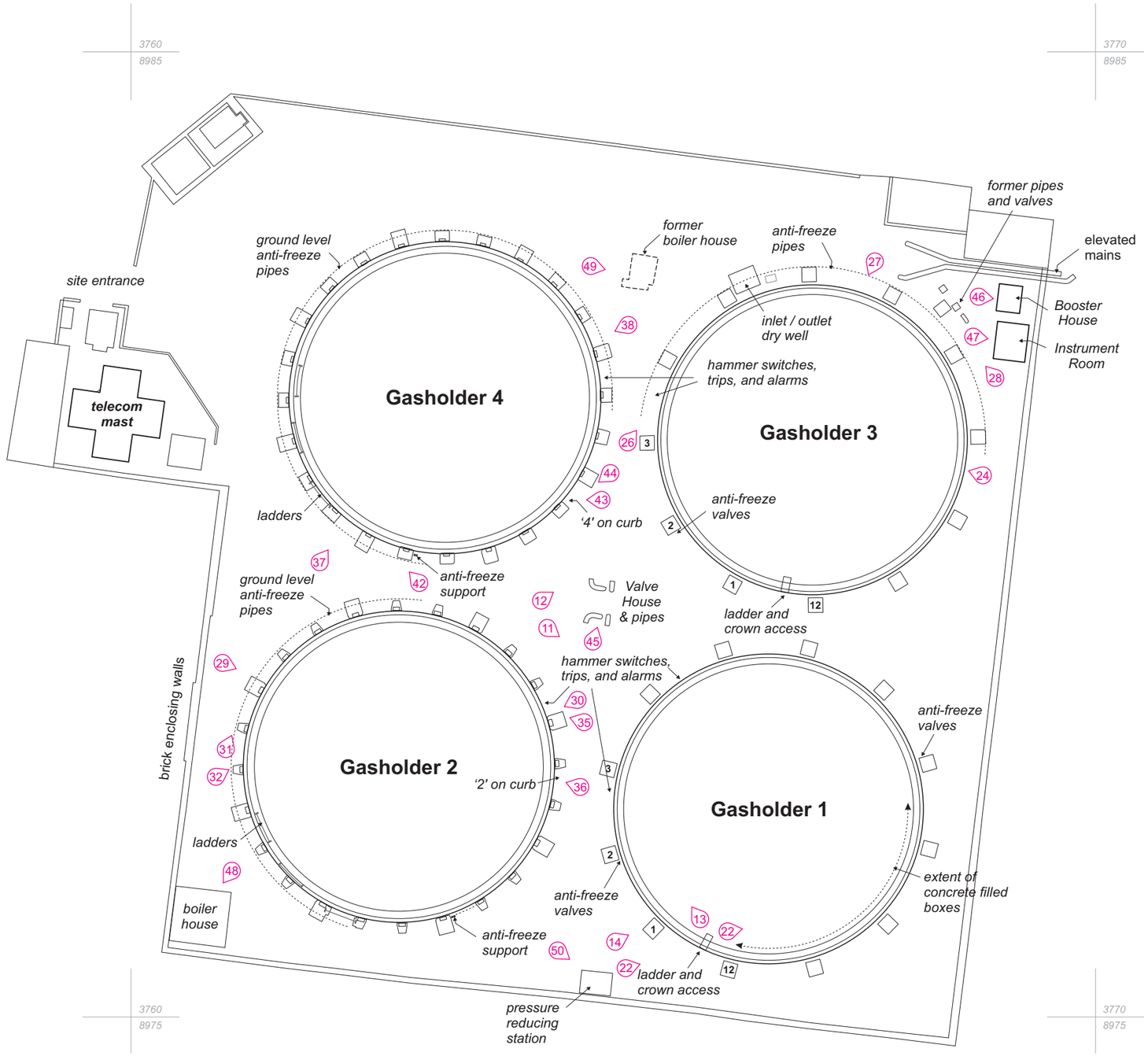


Illustration based on survey by Atkins Ltd

Scale 1:500 (A3)

Plan of the recording area, showing main features and photograph locations Fig 51

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