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“The City Lines and Extensions (Inner Circle Completion)
of the Metropolitan and District Railways.”

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THE work of completing the “Inner Circle” of London Railways, although the length of railway is not great, is a work which probably merits separate description, and which fitly comes in continuation of Mr. Baker’s Paper on “The Metropolitan and Metropolitan District Railways.”

There is, the Author believes, no other example of a circular railway in a large town. The works of construction possess, owing to its situation, features of special interest, and the problems involved in its working are to some extent unique.

HISTORICAL.

Mr. Baker’s Paper leaves the work with which he was connected on the north at Moorgate Street, and on the south at Mansion House, both of which were, at the time to which he refers, terminal stations. As explained by Mr. Baker, the completion of the circle was authorized as long ago as 1864, but financial and other difficulties prevented its realization, and the powers of the Act of 1864 lapsed by efflux of time.

The completion of the circle was, however, always kept in view by both the Metropolitan and the District Companies, and Parliament was at all times in favour of the undertaking. The Metropolitan Company gradually extended their line in 1875 from Moorgate to Bishopsgate, of which portion Mr. E. Wilson, M. Inst. C.E., was engineer, and subsequently, in 1876, from Bishopsgate to Aldgate, of which portion Mr. Francis Brady, M. Inst. C.E., was engineer. The Metropolitan Company also, under an Act of Parliament of 1877, bought land southward of Aldgate, and were authorized to further extend the line under High Street, Aldgate, to the land in question. All these were steps towards the carrying out of the original intention of extending the Metropolitan Company’s line to Tower Hill, for which the original Act of Parliament

was obtained in 1864. In fact though the powers of that Act expired, Parliament refused to relieve the Metropolitan Company of its obligation to make the line to Tower Hill, and, as occasion served, that Company gradually took steps towards the fulfilment of that work.

The original Act of the District Company of 1864, authorized the construction of a line from Mansion House to meet the Metropolitan Company's line at Tower Hill, but financial pressure compelled it, in 1870, to apply to Parliament to be relieved from this obligation, and the relief was given. The District Company, however, had never failed to desire the completion of the Inner Circle, and, as soon as it began to contemplate the prosecution of the undertaking, supported a scheme promoted by an independent company (the Inner Circle Completion Company) for such completion. The independent line (which was authorized in 1874) joined the District line west of Mansion House Station, and passed by way of Cannon Street and Fenchurch Street so as to join the Metropolitan Company's authorized line slightly to the northward of Aldgate Station, which had not then been completed. By this scheme both Mansion House Station and Aldgate Station would have been on what are termed "dead ends." A new street between King William Street and Fenchurch Street was a feature of this undertaking.

The Inner Circle Completion Company, however, failed to raise the necessary capital, and in the meantime the Metropolitan Company had opened its terminal station at Aldgate, and were contemplating further extension southward to Tower Hill.

In 1878 the two Companies agreed to refer the mode of completing the Inner Circle to Sir John Hawkshaw, with the request that he would advise in the interests of all parties.

Sir John Hawkshaw recommended that the circle should be completed by extending the railway southward from Aldgate to Tower Hill and thence westward along Great Tower Street, Eastcheap and Cannon Street to join the District Company's railway at Mansion House, and that advantage should be taken of the prosecution of this work to invite the Corporation of London and the Metropolitan Board of Works to join with the two companies in the construction of a much wanted public improvement, viz., the widening of Eastcheap and Great Tower Street, and the construction of a new street between Mark Lane and Trinity Square.

The Author was appointed, in 1878, joint engineer with Sir John Hawkshaw, and was associated with him in the preparation of the

Parliamentary plans and in carrying the work through to completion.

It was seen that a very important addition could be made to the project by an extension eastward to join the East London Railway, so as to serve the large population of East and South London. Accordingly the Parliamentary plans included not only the completion of the Inner Circle, but also two short junction lines at Aldgate and a railway under the Whitechapel Road, giving both the Metropolitan and District Companies access to the East London Railway and the districts served by it south of the Thames. This extension also placed the systems of the South Eastern, Brighton, and Chatham and Dover Companies in direct communication with the north bank of the Thames, and with the northern Companies which join the Metropolitan Company's system, viz., the Great Northern, Midland, and Great Western Companies.

The eastern extension will not be referred to in detail in this Paper, which is more specially devoted to the Completion of the Inner Circle of the Metropolitan railway system. It need only be remarked, that it has been constructed under the Whitechapel Road and terminates by a junction with the East London Railway, and also by a terminal station (which has been constructed, for the exclusive use of the District Company) on the north side of the Whitechapel Road and adjoining the East London Company's Whitechapel station.

DESCRIPTION OF ROUTE.

To return now to the completion of the Inner Circle. The principal line (Railway No. 1 as laid down on the Parliamentary plans), leaves the Mansion House station at its eastern end, and then passes slightly to the southward of and parallel to Great St. Thomas Apostle and Cloak Lane, till it reaches Dowgate Hill, where it bends to the northward under the forecourt of Cannon Street Station, and is continued under the centre of Cannon Street to King William Street. At this point it is bent to the southward to give space for the construction of a station. It is then continued under the widened Eastcheap and Great Tower Street and the new street to Trinity Square, thence passing under the garden of Trinity Square and through some house property it crosses beneath the viaduct of the Blackwall Railway, and turning to the northward is carried under the roadway of the Minories, and joins the southern end of the Aldgate station. The total length is $1\frac{1}{2}$ mile.

Railways Nos. 2 and 3 are respectively the north and south curves connecting Railway No. 1 with the Whitechapel extension line, which is Railway No. 4.

The sharpest curve on the line is 8 chains radius, and the steepest gradient 1 in 100.

It is obvious that the term "Inner Circle" is somewhat of a misnomer. The Metropolitan and District Railways systems form an irregular ellipse rather than a circle, and the eastern portion of the ellipse is so flat that the two lines are approximately parallel and near to each other for some distance. The completion of the ring of railway has been rather the joining together of two parallel lines than the completion of a circle, and this circumstance has no doubt an important bearing on questions of traffic. Although the value of a continuous communication by railway is great, it is considerably depreciated by the long detour which is necessary between Blackfriars on the south and Farringdon Street on the north. The consequence, however, of the extension of the District line to the Tower, and of both lines to Whitechapel and the East London system, is of great value to Londoners, and will be more and more recognised.

ESTIMATE.

The Parliamentary estimate was—

	£.
Railway No. 1, Works	446,941
" " 2, " 	46,244
" " 3, " 	60,346
" " 4, " 	276,789
	<hr/>
	830,320
Land	1,534,941
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Total	2,365,261
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	£.
Street widenings and new street, in addition to the amount included in the estimate of Railway No. 1	929,412
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STREET IMPROVEMENTS.

The widening of Eastcheap and Great Tower Street, and the construction of the new street formed a very important feature in the enterprise, for it was seen by all parties that the congestion of the traffic in the old streets could not much longer be tolerated. Now that the new street, which is 60 feet wide at its narrowest point, is opened for traffic, it is difficult to believe that so much of the vast

traffic east and west, between London Bridge and the Tower was conducted along the old narrow and tortuous streets. Eastcheap and Tower Street were at their narrowest parts only 25 feet wide, *i.e.*, roadway 15 feet and two pavements of about 5 feet each. It was eminently desirable, in the interests of all parties, that the railway companies and the public authorities should join their forces for the construction of the railway and the streets simultaneously, inasmuch as the burden upon either of the two parties would have been too great for them to face individually.

Lengthy negotiations took place as to the amount which the public bodies should contribute in respect of the improvement, and eventually it was agreed that the Metropolitan Board of Works should contribute £500,000, and the Commissioners of City Sewers £300,000 towards the undertaking. The railway companies undertook the whole responsibility and risk of acquiring the property and constructing the new street and widenings. It may easily be understood that the mode and conditions under which the money was to be provided by the public bodies, gave rise to considerable discussion, and the result was that the year 1882 arrived before the negotiations were complete, and the sanction of Parliament was given to the agreement.

COMMENCEMENT OF WORKS.

In the meantime the Metropolitan Company, which had already bought land south of Aldgate, was anxious to proceed with the portion of the line from Aldgate to Trinity Square, and it was eventually arranged that it should construct this part of the line without waiting for the completion of the negotiations with the public bodies. Accordingly this portion of the works was commenced in 1881 under Mr. Joseph Tomlinson, Junr., as Engineer to the Metropolitan Company (Mr. T. A. Walker being the Contractor), and was completed as far as the east side of Trinity Square in 1882.

Matters having at length been arranged as to the contributions by the public bodies, the works of the remainder of the undertaking were commenced by Mr. T. A. Walker as Contractor in August 1882, and were completed and opened for traffic (together with the Whitechapel extension) in October 1884. Mr. E. P. Seaton was Resident Engineer, and Mr. J. Wardhaugh, contractor's agent on the Inner Circle railway works. Mr. R. C. H. Davison was Resident Engineer, Mr. L. P. Nott, contractor's agent on the Whitechapel extension.

SETTING OUT.

The location and setting out of a railway amid such a collection of streets, churches, railway stations, warehouses, shops, and offices, as exists between Mansion House station and the Tower of London, was a matter involving anxious consideration by all, and great care on the part of the executive staff. It was often a question of a few inches whether an important and expensive building could or could not be avoided, the decision involving an expenditure or saving of many thousands of pounds.

The gradients adopted had also to be very carefully considered so as to avoid raising the roadways and streets above the railway, and more interference than was absolutely necessary with the many important sewers which had to pass under the railway.

SEWER WORKS.

The course of the railway being approximately parallel to the Thames, many sewers draining large areas of London, were of necessity intersected. In all cases the arrangements have been so made that these sewers have been carried under the railway without resorting to inverted siphons; but great alterations of the sewers themselves were necessary in order to enable this to be done.

The first sewer of importance is that in Dowgate Hill, which is 6 feet in internal diameter and often runs full. This sewer had to be lowered almost from its storm outlet into the Thames at Dowgate Dock, and was passed under the railway in two cast-iron pipes 4 feet 6 inches in diameter. From the top of these pipes to the roadway of Dowgate Hill there is only an available space of 19 feet 6 inches for the construction of the railway station.

The next two large sewers which are crossed are the King William Street sewer, 8 feet by 7 feet, and the Gracechurch Street sewer, 8 feet 3 inches by 6 feet 8 inches. These were provided for by partial reconstruction, and by the use of cast-iron horizontal plates for the top of the sewer.

Another sewer running north and south, at Mark Lane, had to be lowered and passed under the railway. This involved the reconstruction of the sewer southward of the line for a considerable distance.

It was also necessary to construct a new sewer on both

sides of the railway throughout its course in Cannon Street, and Great Tower Street, and a portion of Eastcheap. The old sewer, which ran down the middle of the road, was wholly removed to leave room for the railway, but it had to be kept in use, or temporary troughs had to be employed, until the new sewers were finished. Upwards of 300 new connections were made between the drains of the houses and the sewers.

These sewer works, constructed as they were along narrow lanes in the City, with buildings in close juxtaposition, involved much anxious labour, and added greatly to the difficulties of carrying out the railway.

It will also be easily understood that the necessity for temporary accommodation of the sewers and house drains during the construction of the works involved great loss of time, and expense, and much discomfort to all concerned.

The construction of the sewer on each side of the line down Cannon Street, Eastcheap, and Tower Street, involved the works being some 10 feet wider than would have been necessary for the railway alone, and caused them to approach very nearly to the foundations of the important and weighty buildings in those streets. Thus the sewers made necessary what otherwise might have been a matter of doubt, namely, that the houses should be underpinned along almost the whole course of these streets.

COVERED WAY.

The cross-sections of the covered way for the railway, apart from special construction at particular portions of the line, are shown in Plate 3, Figs. 1, 3, 4 and 9. The high brick arch would have been adopted throughout if the levels of the ground had permitted; but a lower brick arch was necessary between Idol Lane and Seething Lane, and girder construction was required between Queen Street and Dowgate Hill. The arches are made of hard London stocks in Portland cement mortar; the side walls and invert of the covered way of Portland cement concrete. The gravel and sand of the concrete was to a great extent found upon the site of the works, but a considerable portion had to be supplemented by Thames ballast. The ordinary proportions of the cement concrete are as follow:—1 part of Portland cement, $2\frac{1}{2}$ parts of sand, $3\frac{1}{2}$ parts of gravel. The cement was in all cases kept on the Company's property for six weeks, and emptied out of the sacks on dry floors before being used.

Refuges or recesses for the platelayers 4 feet wide and 6 feet high are made in the side walls of the covered way, about every 30 feet on each side of the line.

Some small portions of the line near Minorities Junction and near Mansion House Station, are constructed between retaining walls. Plate 4, Fig. 14, shows their construction.

UNDERPINNING WORKS.

The underpinning of the buildings by the side of the railway is shown in Plate 3, Fig. 8.

The holes excavated beneath the foundations of buildings for the purpose of underpinning were usually about 4 feet long. After the holes had been carried to a good foundation, at least as low as the bottom of the side walls of the covered way, they were filled with Portland cement concrete, and then allowed to stand for thirty-six hours. The top portion was executed in brickwork in Portland cement, very carefully put in so as to ensure complete tightness below the footings of the old buildings. The works were completely successful, and with one exception there were no cases of any settlement or damage to any of the under-pinned buildings.

The case of settlement occurred in a very old house in Cannon Street, and was due to the fact that one end of the front of the house in question was supported on a timber post 9 inches by 3 inches, which was completely rotten at its bottom. This post rested on brickwork which had been successfully underpinned, but owing to some very slight extra pressure put upon the post it gave way suddenly, and there was for a time a risk of the house falling. Such an accident, however, was averted by promptly shoring and supporting the front of the house; but some alarm was created, and the tenants had to leave temporarily. This was the only occurrence of the kind, and it pointed out the necessity in such works, of carefully examining not only the foundations but also the supports of a building above the foundations.

Another interesting work of underpinning was that of the statue of King William IV., which is of massive granite supported upon a granite pillar finely jointed, and resting upon a foundation of lime concrete of rather inferior character. The statue, with its pedestal and foundations, weighs about 160 tons. The construction is shown in Plate 3, Fig. 11.

Previous to underpinning the statue the City authorities took very accurate levels and plumbed the statue, and these levels and plumbings were continued during the progress of the work. Some light timber strutting was erected as a matter of precaution against any damage to the statue itself. The next operation was to sink two holes at the east and west sides of the circular foundation of the statue. These were filled with concrete up to the level of the soffit of the future arch of the railway. Above the level of the soffit the underpinning was continued with brickwork, built in radial courses to suit the rings of the arch of the railway with which this portion of brickwork was intended hereafter to be amalgamated. When the underpinning in the two holes was completed, a short length of 7 feet of the side-wall of the tunnel was constructed, and subsequently further short lengths were put in, making in all a total length on each side of the railway of 30 feet. A heading 4 feet wide was then driven at right angles to the line of the railway through the concrete supporting the foundation of the statue, and in this heading a length of 4 feet of arch was built under the centre of the statue. Subsequently a second heading was driven parallel to the first, and another length of arch turned, a portion of which was the underpinning brickwork which was specially put in for the purpose. When this was finished a third heading was driven and the second underpinning pillar was amalgamated with another length of arching. The fourth heading completed the work under the centre of the statue, and this being finished, the remainder of the arching on both sides was accomplished. When everything had been finished the concrete legs beneath the statue were cut away. Not the smallest subsidence was experienced, and the work is in every way satisfactory.

The side-walls of the tunnel under and adjoining the statue are of brickwork in Portland cement, and the arch consists of four rings of Staffordshire brindle-bricks in cement and seven rings of stocks in cement, the whole backed up with stocks in cement.

WORKS BENEATH BUILDINGS.

A work of some interest was the carrying the railway beneath the warehouses on the south side of Great St. Thomas Apostle and Cloak Lane without pulling them down. It was executed as follows (Plate 3, Fig. 2):—The party-walls on each side of the future railway tunnel, and the western part of the front

wall, were underpinned with permanent work, and the eastern portion of the front wall was supported with temporary brickwork, which was carried up high enough to support the stone lintels of the front of the warehouse above its ground-floor level.

The portions of the side walls of the tunnel which passed through the party walls themselves were constructed as underpinning-work in short lengths of brickwork in cement. When these were completed the intermediate portions of the side walls were undertaken in short lengths and finished up to the level of the springing of the tunnel arch. The portions of the arch of the tunnel between the party-walls were next built and finished with their backing. Each party-wall in turn was then needled on timbers resting on the portions of the completed arches intermediate between the party-walls, and the walls beneath the needles were removed in small pieces to such an extent as would permit of the arch-rings being gradually built in the wall. The arch of the tunnel was thus united beneath the party-walls, and the party-walls were firmly pinned upon the extrados of the arch and backing. When this had been done, the lower parts of the party-walls beneath the soffit of the arch were cut away, the dumpling was removed, and the tunnel completed.

At the eastern portion of the warehouses the roadway of Great St. Thomas Apostle was so low that there was no room for the construction of an arch. In this case girders were inserted instead, the weight of the buildings being borne, during the operation of underpinning, by the temporary piers of brickwork before described, which supported the superstructure while the piers of the building were cut away and the girders were being put in place.

Another work of some little difficulty was the carrying of the railway beneath the old viaduct of the Blackwall railway. In view of a desire of the Great Eastern Railway Company to proceed with the widening of this viaduct in 1880, this work was carried out under a separate contract with Messrs. Lucas and Aird before the remainder of the railway was undertaken. The foundations of the old viaduct were removed and underpinning substituted without in any way disturbing the structure or interfering with the large traffic of the Great Eastern and the Tilbury and South-end railways using the viaduct.

TEMPORARY WORKS.

A very important part of the work of constructing a railway through the heart of the City of London is that of the temporary works for keeping the street traffic open.

The Act of Parliament contained the following clause :—

“8. In the event of the two companies requiring for the purposes of the Railway or any part of the Railway (subject to the restrictions in this Act contained) to open or in any manner to interfere with the surface of any street or road or of any public footpath then and in that case they shall not proceed so to do unless and until the two Companies shall to the reasonable satisfaction of the chief surveyor or surveyors as the case may be for the district in which such street road or footpath may be situate have provided a temporary bridge or roadway or footpath of a reasonable width, except that for the purpose of providing such temporary bridge roadway or footpath they may open the surface of the street road or footpath between the hours of six p.m. to six a.m. or except only one-half of the surface of such road and one footpath shall be first opened or interfered with leaving the other half of the said street or road and one footpath for the passage of the public until such time as that the half of the said street or road and the footpath first opened or interfered with has been restored to a good and proper state for the safety and convenience of the public and then and not before it shall be lawful for the two Companies temporarily to shut up the other half of the said street or road and to open and interfere with the other footpath but wherever they interfere with or open up any footpath or any portion thereof they shall leave a footpath or provide a temporary footpath of reasonable width and shall also provide or preserve reasonable means of ingress and egress for carriages to and from all courtyards abutting on the footpaths.”

The engineers, however, considered that, both from the point of view of the interests of the railway companies as well as from that of the convenience of the public, it was necessary that further accommodation beyond that stipulated in the clause above mentioned should be given while the works were being carried on, and accordingly a clause was inserted in the contract as follows :—

“In constructing the works, the contractor's attention is drawn to the circumstance that the roadway and footpath traffic is not to be interrupted. The contractor will be required, in constructing the Railway along or across streets, and at such other places as the engineers will direct, to provide over the whole site of the covered way a temporary platform, or coverings which will consist of balks of whole timber not less than 12 inches square, laid at distances of not less than 4 feet centre and centre, and covered by two layers of planking, the lower layer not less than 4 inches thick, and the upper layer not less than 3 inches thick. This platform will have to be effectually supported by timber, and effectually maintained, and beneath which the works will have to be carried on.”

This arrangement was adhered to throughout the works, and was ingeniously and effectively carried out by the Contractor and the

resident staff. Plate 4, Figs. 18 to 26, will explain the mode in which the timbering was executed in Cannon Street so as to allow space for the works to be constructed, and at the same time accommodate the street traffic.

The first operation was to lay down at night, over such a length of street as could be safely undertaken with a certainty of the operations being finished before 6 o'clock in the morning, the cross-timbers running from one side of the street. These were 12 inches by 12 inches, and placed 4 feet apart from centre to centre, as provided by the contract. Upon them were laid 4-inch planks longitudinally with the roadway, and on the top of these 3-inch planks at right angles to the roadway.

When a sufficient length of this plank roadway had been completed a hoarding was erected upon it about 10 feet wide and about 50 feet long, in which a portable steam-crane was used so as to be able to fill carts at either end of the enclosure.

The next operation was to drive the main heading, and from it cross-headings by which to approach the backs of the cellar walls of the houses. These walls were then broken through, and access was thus obtained to the foundations of the front walls of the buildings without any disturbance of the roadway or foot-pavement. Where there were no cellars the headings were continued up to the front walls, and a side heading was driven parallel to the side of the houses. From the side heading, or else through the cellars, holes (usually about 4 feet long) were then sunk beneath the foundations, and the underpinning concrete and brickwork were placed in position. When this operation was completed the main trenches for the side walls and the sewer were undertaken.

These large trenches, about 9 feet wide, involved very considerable rearrangements of the timbering, in order to support the cellar walls, the roadway, and the gas and water pipes, while leaving a free space for the execution of the trenches. The main trenches were then filled with concrete, the sewers were built, and everything was prepared for the setting of the centres.

This, again, involved new alterations of the timbering to leave a space free for the turning of the arch of the covered way in lengths of 12 feet. When this was done, and the backing put in, the cellar walls were supported.

Brick piers were carried up from the backing to support the large gas and water mains, which during the progress of the excavations had up to this time been propped by temporary expedients on the timbering. The dumpling, or earth included

between the walls and the arch, was then removed, and the invert was inserted in lengths of 12 feet, the walls being well strutted until the invert was hard.

The earth was finally filled in over the arch between the timbers, and was allowed to settle below the timbers and planking for a considerable time, additional earth being added as subsidence took place. At last, when the earth seemed well consolidated, the timbers and planks were removed in lengths and the streets repaved, one-half of the roadway being always available during repaving for the street traffic.

STATIONS.

The stations between Mansion House and Aldgate are three in number, namely, Cannon Street, Monument, and Mark Lane. A temporary station, called "Tower of London," was built by the Metropolitan Company at the eastern side of Trinity Square, and was used by that Company as a terminal station prior to the opening of the Inner Circle, but, owing to its nearness to Mark Lane Station, it has since been closed. Each station presents distinct features of its own.

Cannon Street Station had to be constructed partly under Dowgate Hill, where there was only 1 foot of available height between the top of the railway and the road, partly under the forecourt of Cannon Street Station and partly under Cannon Street itself. The booking-office had to be accommodated between the top of the railway construction and the surface of the forecourt, and provision had to be made for interchange of traffic with the South-Eastern Company's Cannon Street Terminus. Thus, under the forecourt there are three tiers of traffic, viz., (1) the trains, (2) the passengers using the booking-offices, and (3) the cabs and carriages in the forecourt. Plate 3, Figs. 5, 6, and 7, show the construction at this portion of the station. The total height from the level of the rails to the surface of the forecourt is 25 feet 6 inches, and this small height necessitated the employment of cantilever girders which have only a depth of 2 feet at the centre of their span. The girders are held down on the side walls, and are supported at intermediate situations on the platforms by wrought-iron columns. Longitudinal girders are placed between the cantilever girders, and jack-arches of brickwork are turned between the longitudinal girders.

Ventilating-spaces for Cannon Street Station are provided west

of Dowgate Hill, on the site of the old churchyard of St. John Baptist upon Walbrook, and also on a strip of land adjoining the east side of Dowgate Hill, and by a ventilator on the east side of the forecourt. A transverse underground passage lined with glazed bricks gives access from the booking-office floor to the platforms of the South-Eastern Company's station.

Monument Station is constructed on the site of the old Weigh-House Chapel, and has more area open to the sky than the other stations. It commences at King William Statue and terminates at Pudding Lane. The northern side-wall of the station is so far north of the southern face of Eastcheap that much intricate girder work was required, more especially as it was necessary to provide for carrying a row of buildings on the south side of Eastcheap. The general arrangement is shown in the cross section, Plate 3, Fig. 12. Fish Street Hill and Pudding Lane are carried across the station, the former on girders, and the latter by a brick arch of 52 feet span.

Mark Lane Station is constructed wholly beneath the new street, and is covered by girders in one span of 52 feet, the jack-arches in this case being at right angles to the line of the railway. Where gangways for giving access to the platforms and booking-offices were required, the girders were made deeper, the space between the flanges of the girders being lined with white glazed bricks. Ventilating-spaces are provided on the sides of the line by recessing the walls so as to leave considerable openings; the girders at these points are supported by blue-brick piers or by wrought-iron stanchions (Plate 4, Fig. 17).

The minimum length of the platforms at all the stations is 300 feet, and the minimum width of each platform is 16 feet. The width of the stairs is generally about 8 feet, and the stairs and lobbies are in all cases recessed so as not to encroach on the minimum width of the platforms.

There is nothing peculiar in the arrangement of the station buildings except that they are somewhat more commodious than the older stations. It has been provided that the incoming and outgoing streams of passengers should not be intermingled.

VENTILATION.

The ventilation of this portion of the underground railway caused some considerable difficulty. The Act of Parliament gave the companies the right to construct ventilators in the roads and

open spaces, such as those known as "blow-holes"; but when the works were being undertaken, the outcry and agitation against the blow-holes was at its height, and Parliament had gone so far as to take away from the District Company the right to retain some of the blow-holes which it had in a previous session authorized them to construct. The Author does not conceal his preference for blow-holes as an efficient and reasonable mode of ventilating a railway tunnel, and he believes that if they were carried out with a little more consideration for artistic effect, and not carried up quite so high as those which were at first constructed, they are the least objectionable means, as they certainly are the most efficient, of ventilating an underground railway. The agitation against their use was, however, so great in 1883, that the Joint-Committee of the two Companies shrank from encountering another storm, and the City authorities and the Metropolitan Board of Works strongly urged that no blow-holes should be made; indeed, the latter body went so far as to say that if any opening were made in the new street, they would not grant their contribution of £500,000 towards the improvement. The result was that it were decided to adopt the alternative which had been pressed upon the District Company by the public authorities, namely, putting up fans to exhaust the foul air from the tunnel by machinery.

Accordingly, fans have been erected, one in Cannon Street, midway between Cannon Street and Monument Stations, another midway between Monument and Mark Lane, and one in the Whitechapel Road. The Cannon Street and Whitechapel fans have a diameter of 18 feet, with a width of 4 feet, and the Tower Street fan a diameter of 15 feet, and a width of 5 feet 6 inches. Gas-engines of 12-HP. were employed to drive the fans, and the fans when driven at sixty revolutions a minute, expelled about 70,000 cubic feet per minute from a shaft, the top of which was at least as high as the adjoining buildings. The general arrangement is shown in Plate 3, Fig. 10, and Plate 4, Fig. 15. The fans had no sooner been set to work than complaints began to arrive of the vibration which was set up. The subject being inquired into, it was found that the vibration complained of was due, not to any defect in the engines or fans, but to the undulatory motion imparted to the air by the fan itself. Some of the inhabitants of Cannon Street and Tower Street applied to the Court of Chancery for an injunction to restrain the Companies from using the fans, and the injunction was granted.

It may be interesting to compare the work of one of the fans

with the work performed by the blow-holes. The following Table gives the amount of air expelled and indrawn at the various blow-holes which were erected upon the District Railway in 1883:—

Ventilator.	In-draught per hour, Cubic Feet.	Out-draught per hour, Cubic Feet.
No. 1 . . .	1,813,500	1,156,080
” 2* . . .	797,040	616,800
” 3* . . .	1,672,080	1,065,000
” 4* . . .	2,448,300	1,285,560
” 5* . . .	1,381,680	1,096,020
” 6* . . .	1,976,520	2,592,720
” 7 . . .	1,219,200	967,200
” 8 . . .	1,359,000	1,782,480
” 9 . . .	718,200	569,880
” 10* . . .	284,280	3,459,240
	13,669,800	14,590,980

Those marked * are the result of actual quantitative measurements, the remainder are deduced from these.

In the case of ventilating by blow-holes, the air drawn in and expelled at the tunnel-fronts has either to be taken into account in arriving at the total ventilation of a length of railway, or else in the ordinary case on the District Line of there being two blow-holes between each station, the indraught and outdraught of air at the two blow-holes have to be added together in order to arrive approximately at their effect.

It will be seen that the work performed by the fan, at a very considerable expenditure of engine-power, amounts to much the same as what is effected by one blow-hole, such as that in Queen Victoria Street or near Victoria Station. In the case of the blow-holes the power is provided by the induced current due to the passage of the trains, and thus each hole acts as a lung or gill, working rateably with the number of trains travelling on and fouling the railway. Thus the same agency which fouls the air of a tunnel by the passage of an engine, supplies the power for purifying the air. The Companies are now undertaking experiments to endeavour to obviate, or at any rate to reduce, the vibratory motion of the air near the fans.

TRAFFIC.

The Author does not propose to enter on the subject of the value of the traffic of the Inner Circle line, further than to say that up to this time it has been financially disappointing. No

doubt it has not at present been fully developed, and though perhaps the value of the circular working has been over-estimated, it is probable that the east and west traffic may become yearly of more importance. It may be interesting to state what the present train-service is.

There are on each line of way, during the working hours of the day, the following number of trains per hour between Mansion House Station and the Minories Junction, which is the point south of Aldgate Station at which the Whitechapel extension joins the Inner Circle line:—

Eight Inner Circle trains, running every seven and a half minutes completely round the circle, by way of Aldgate, King's Cross, Paddington, High Street, South Kensington, Westminster, and Mansion House. Six District Company's trains from Ealing, Richmond, and Fulham, by way of Earl's Court, South Kensington, and Mansion House to Whitechapel or (*viâ* the Thames Tunnel) to New Cross—Total, fourteen per hour.

Between South Kensington and Mansion House there are, in addition to the above, two trains per hour on the Middle Circle, running from Aldgate by King's Cross, Bishop's Road, Addison Road, and Earl's Court; and two trains per hour on the Outer Circle, running from Broad Street (L. and N. W.) by Dalston, Camden Town, Hampstead, Willesden, Addison Road, and Earl's Court. Thus between Mansion House and South Kensington there are eighteen trains per hour on each line.

The Metropolitan Company works a service of two trains per hour in each direction between Aldgate and Whitechapel, and under the river to New Cross.

On the Metropolitan line, between Moorgate and Edgware Road, there are in the busiest hours of the day eleven trains per hour, in addition to the eight Inner Circle trains, and thus there are at those times nineteen trains per hour on this part of the Metropolitan Company's system. These trains are exclusive of those which use the two lines on the Metropolitan Railway between Moorgate and King's Cross, which are devoted to the traffic of foreign companies working over this part of the Metropolitan system.

CONCLUSION.

The execution of the works was greatly facilitated by the support and assistance given by the Metropolitan Board of Works, the City Commissioners of Sewers, and by their engineers, Sir

J. W. Bazalgette, C.B., Past-President, and Mr. W. Haywood, M. Inst. C.E., and by the way in which the latter body met the requirements of the Companies as to the conduct of the traffic of the streets. The Author ventures to hope that the confidence which was thus given to those in charge of the undertaking has not been considered, by the City Commissioners of Sewers, to have been misplaced. It was the anxious desire of all concerned to cause as little inconvenience as possible to the important interests of the public using the streets traversed by the new railway.

The whole cost has amounted to about £20,000 less than the Parliamentary estimate of the works, and the cost of the land was also less than was estimated.

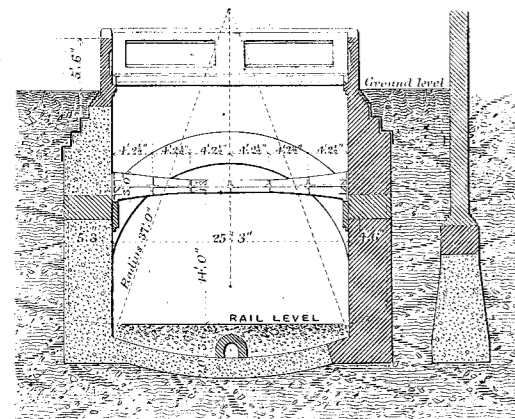
It is gratifying to be able to remark that no serious accident occurred in the carrying through of the enterprise.

The work was prosecuted with great energy and fertility of resource by the contractor; the average number of men employed when the works were in active operation was about 850 by day and 500 by night.

Considering the intricate nature of the work, and the many interests involved, the time occupied in their execution, namely, two years, was not great. Much of the work had of necessity to be undertaken in successive stages, one portion having to wait for the completion of the other.

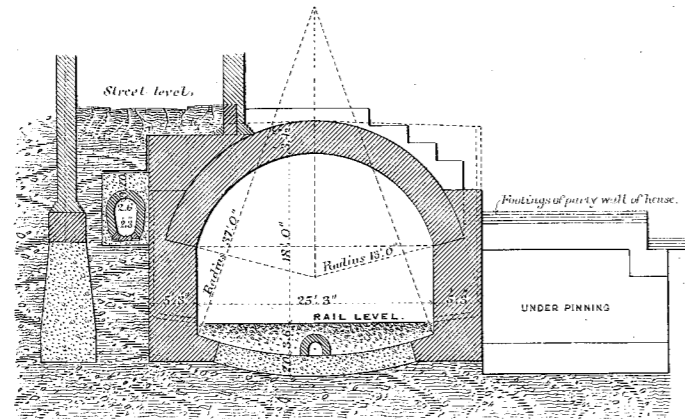
The Paper is accompanied by numerous drawings from which Plates 3 and 4 have been engraved.

Fig: 1.



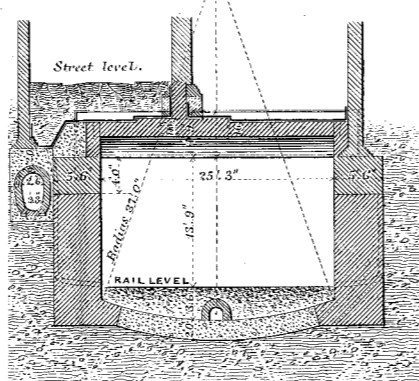
CUTTING AT GARLICK HILL.

Fig: 2.



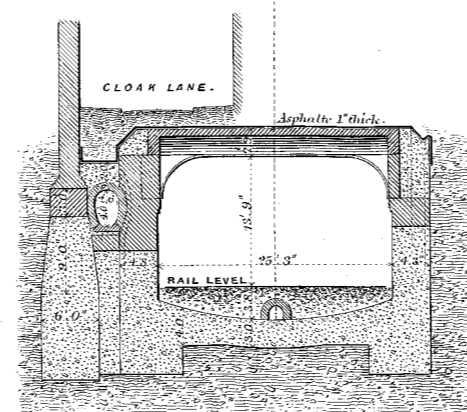
UNDER WAREHOUSES AT GREAT ST. THOMAS APPIS

Fig: 3.



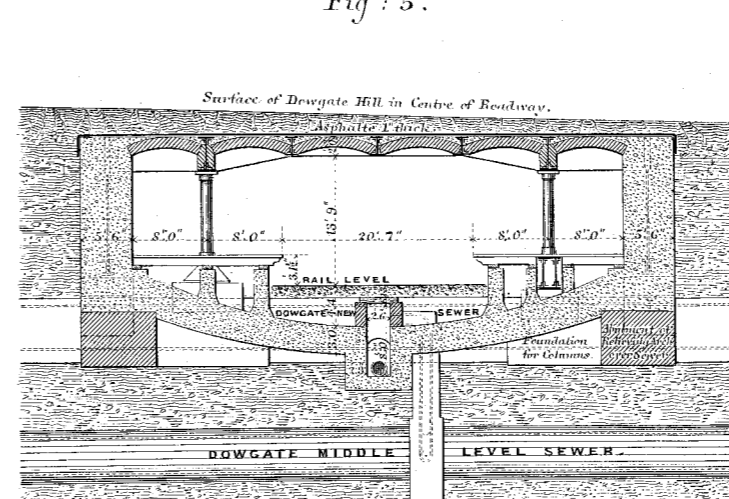
UNDER CLOAK LANE.

Fig: 4.



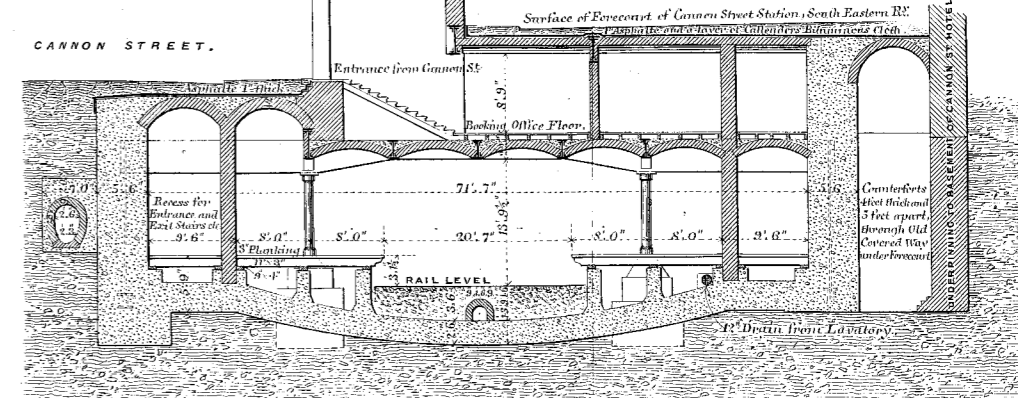
UNDER CLOAK LANE.

Fig: 5.



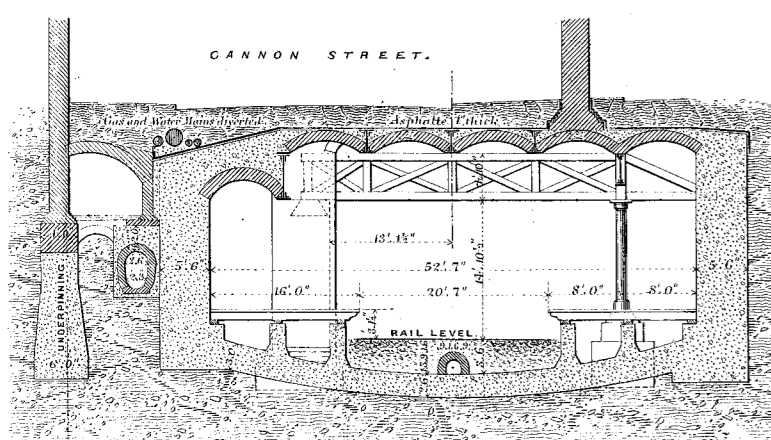
CANNON STREET STATION.

Fig: 6.



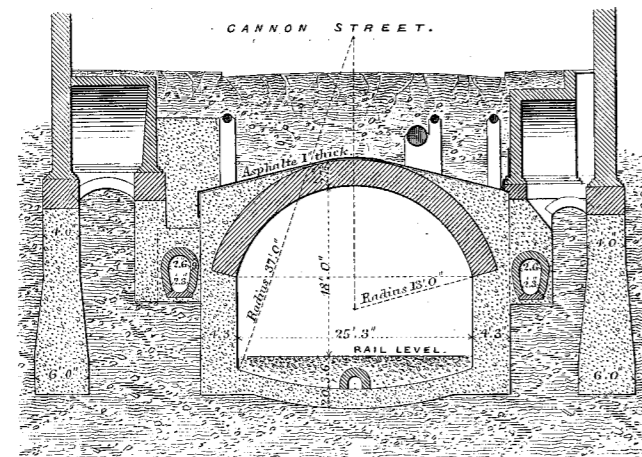
CANNON STREET STATION.

Fig: 7.



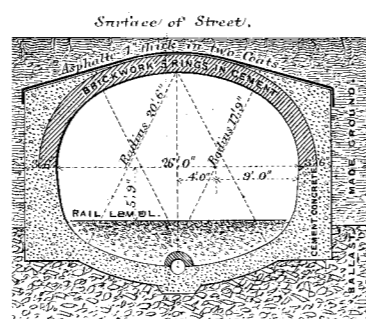
CANNON STREET STATION.

Fig: 8.



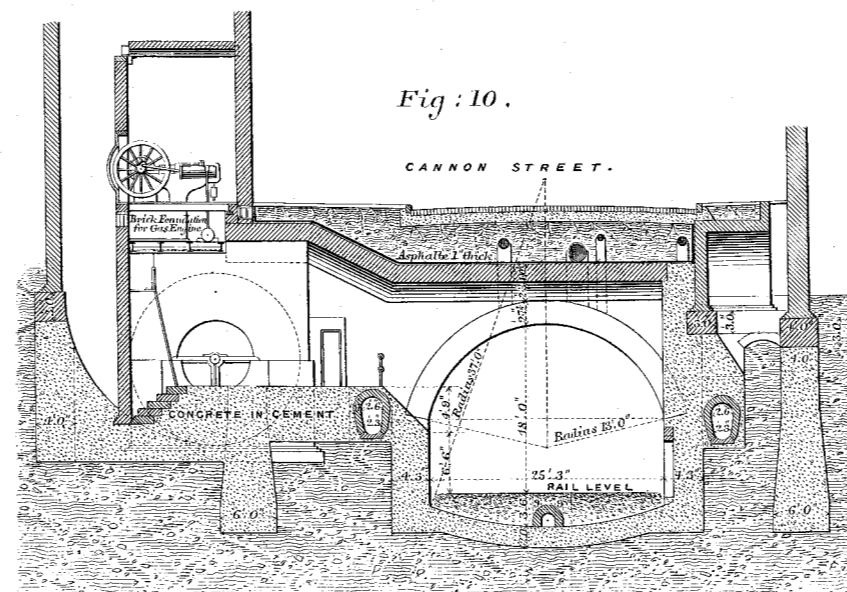
CANNON STREET.

Fig: 9.



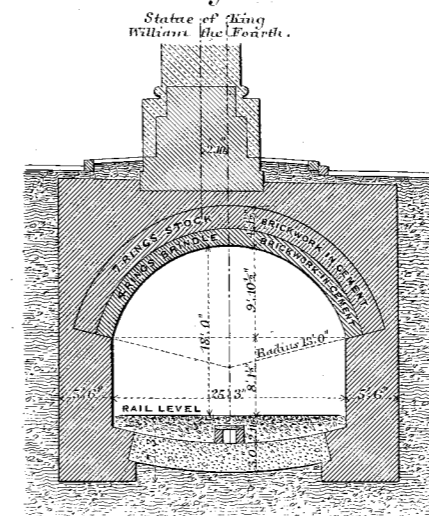
SECTION UNDER CRESCENT.

Fig: 10.



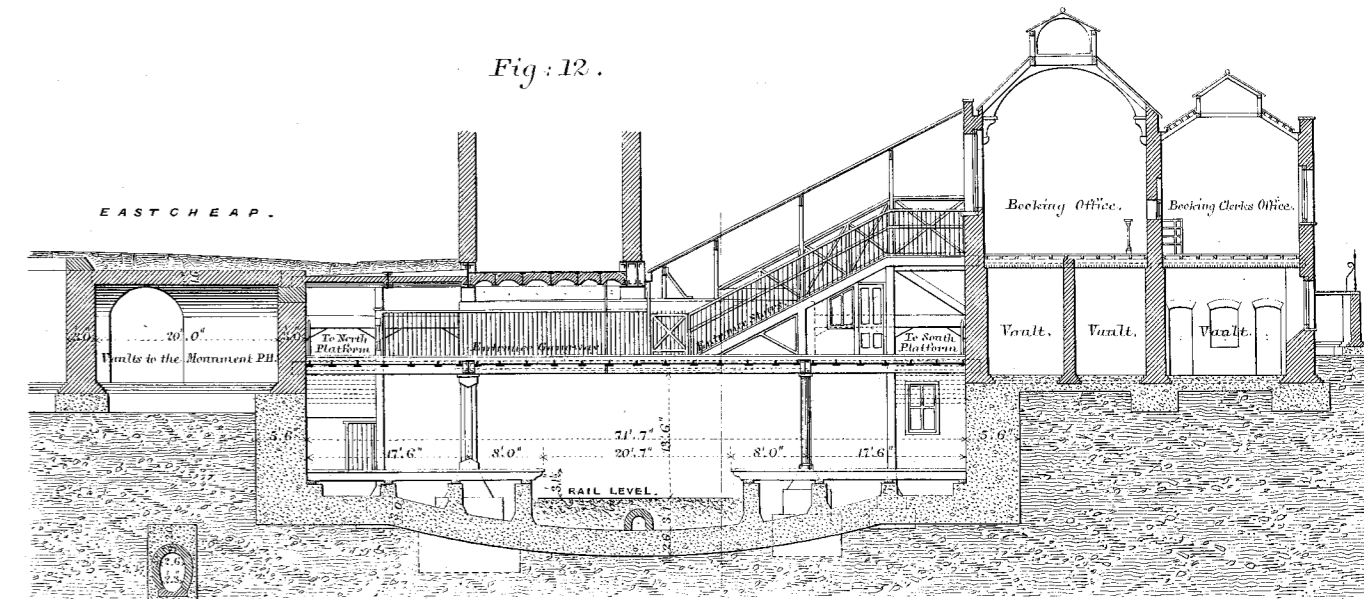
VENTILATING FAN, CANNON STREET.

Fig: 11.



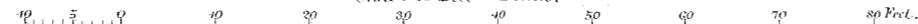
UNDER STATUE OF WILLIAM THE FOURTH.

Fig: 12.



MONUMENT STATION.

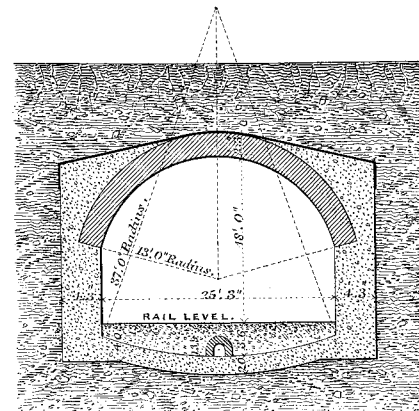
Scale: 20 Feet = 1 Inch.



INNER CIRCLE COMPLETION.

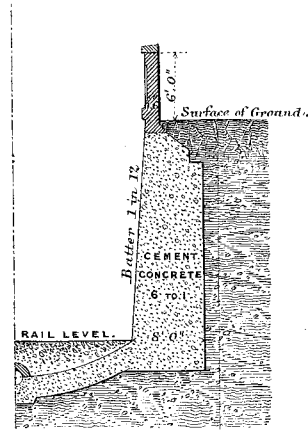
TIMBERING IN CANNON STREET.

Fig: 13.



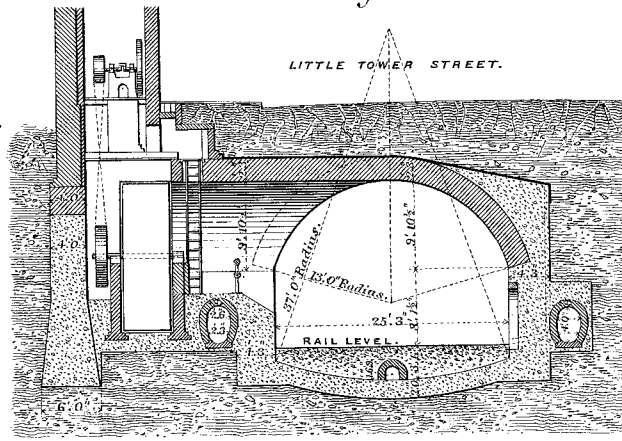
HIGH COVERED WAY.

Fig: 14.



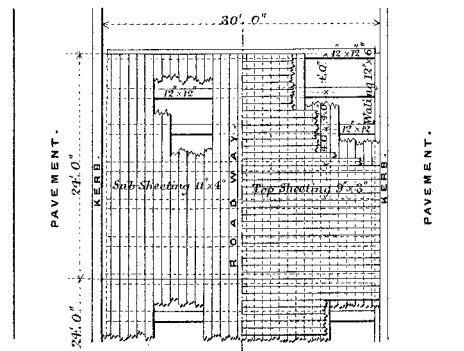
RETAINING WALLS AT CHEQUER YARD.

Fig: 15.



VENTILATING FAN, EASTCHEAP.

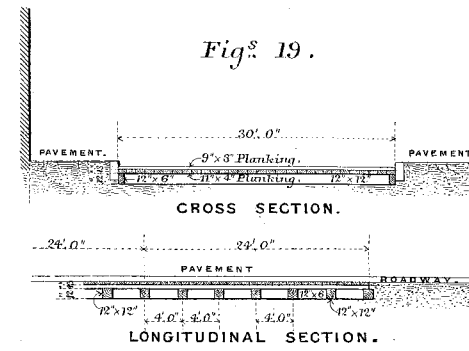
Fig: 18.



PLAN.

TEMPORARY BRIDGE.

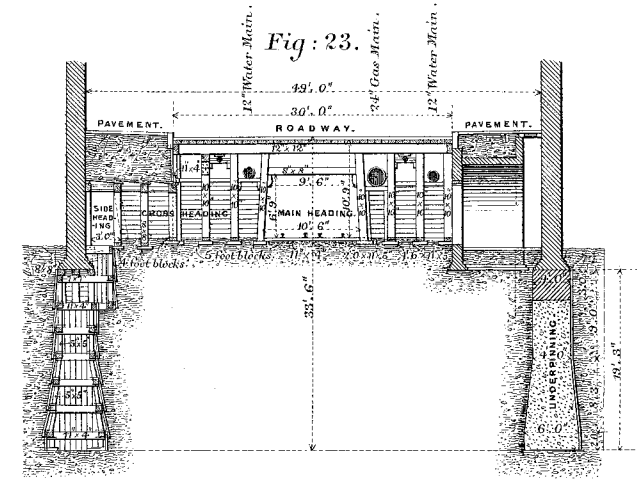
Fig: 19.



CROSS SECTION.

LONGITUDINAL SECTION.

Fig: 23.



MAIN HEADING, CROSS HEADING, SIDE HEADING AND UNDERPINNING.

Fig: 24.

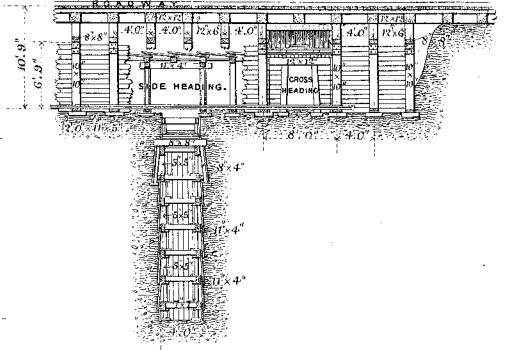
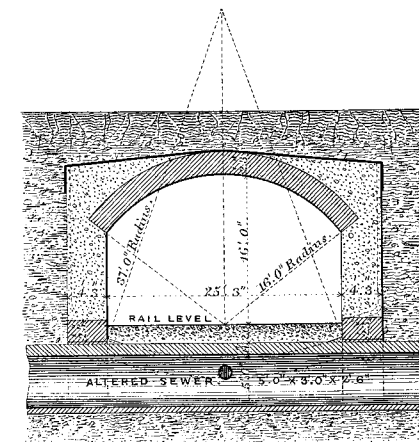
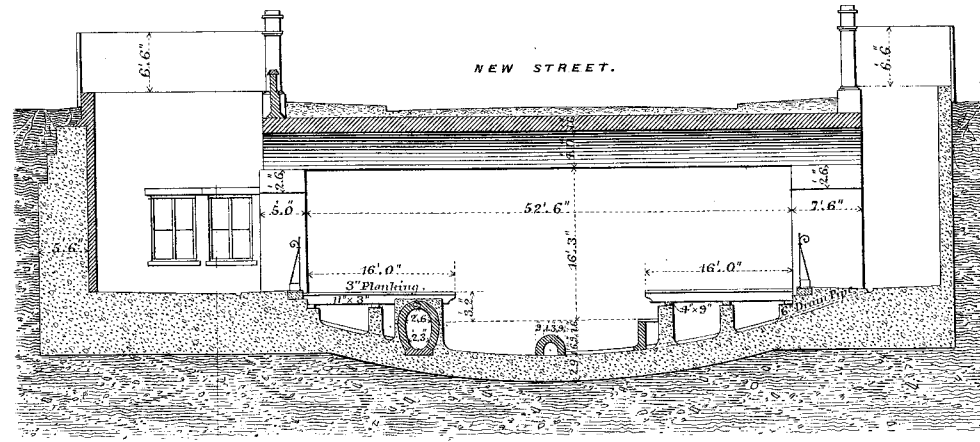


Fig: 16.



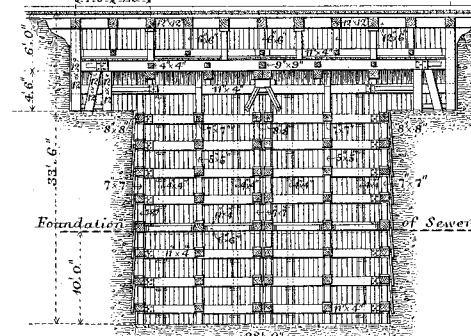
LOW COVERED WAY.

Fig: 17.



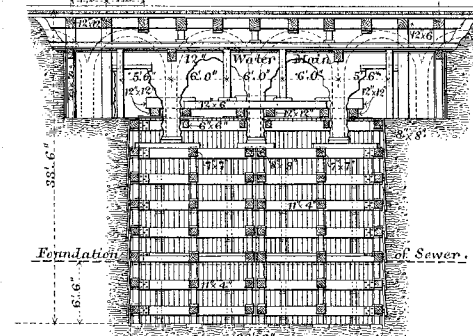
MARK LANE STATION.

Fig: 20.



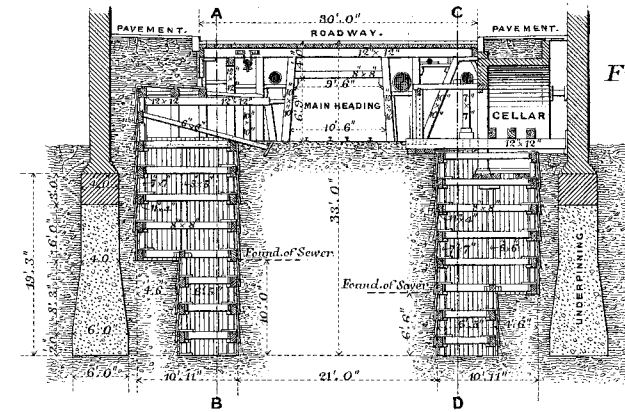
28 FEET TRENCH, SECTION A.B.

Fig: 21.



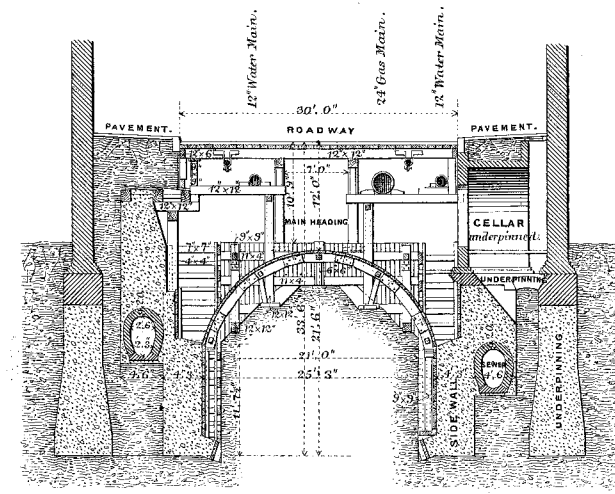
28 FEET TRENCH, SECTION C.D.

Fig: 22.



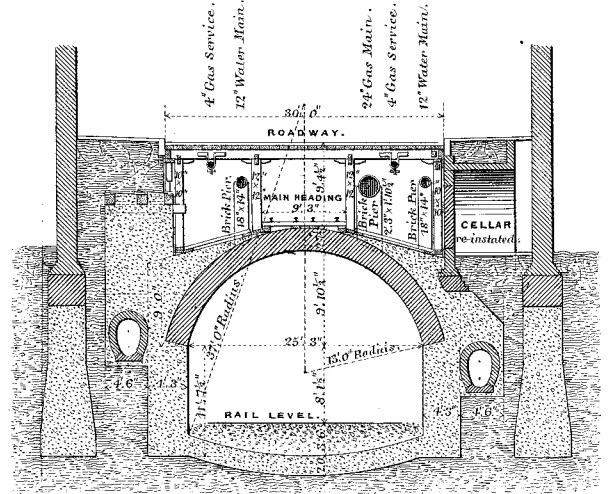
CROSS SECTION OF SIDEWALL TRENCH, READY FOR CONCRETE.

Fig: 25.



SIDEWALLS UP, CENTRES SET AND READY FOR ARCH.

Fig: 26.



TUNNEL COMPLETE.

Scale: 20 Feet = 1 Inch. 0 10 20 30 40 50 60 Feet.