UNDERGROUND ELECTRIC RAILWAY, LONDON—METHODS OF CONSTRUCTION.

In our issue of July 28, 1900, we described the scope and equipment of the new electric underground railway, London; we now present a set of views showing the methods adopted in sinking the shafts and boring the tunnels. The railway consists of two circular tunnels, side by side, one carrying the up and the other the down trains. Taken on the whole, the task of driving the tunnels did not present any abnormal engineering difficulties, inasmuch as for almost the entire distance they were bored through the London clay, which extends to a very great depth. This is one reason why it is so much easier and cheaper to conduct subterranean operations in London than in New York; for, whereas the foundations of the former city are almost entirely clay, the latter city is built for the most part upon hard rock.

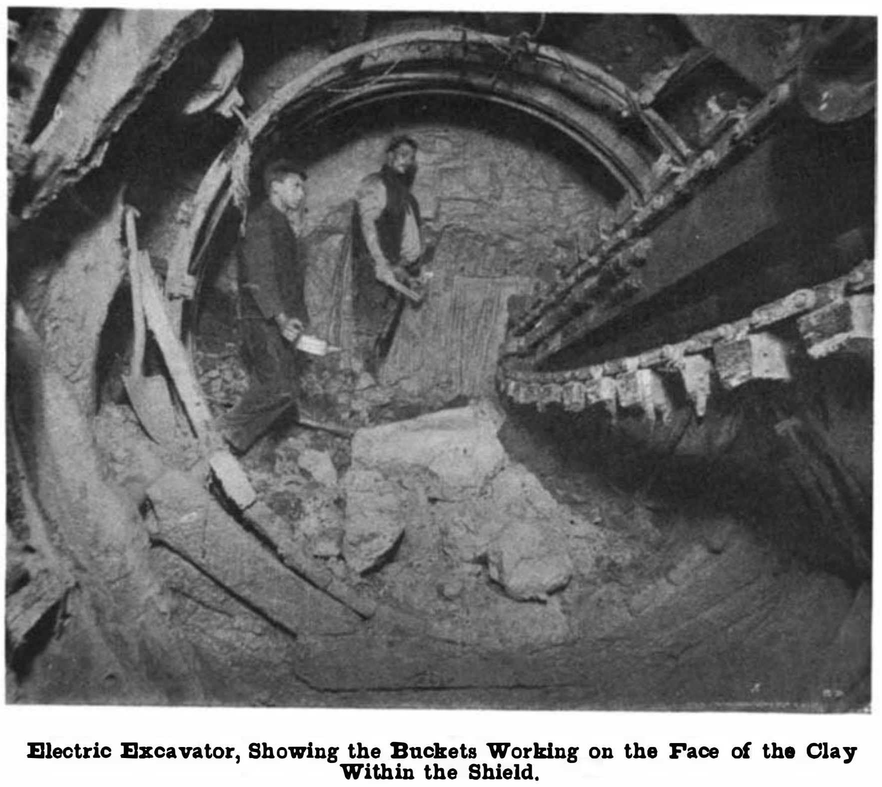
The contract for the construction and equipment of the whole system was given to the Electric Traction Company, of London, who sublet the work to various firms. The boring of the tunnels was undertaken by three firms, who each constructed a section. The first section, from the Bank terminus to the General Post Office, was built by Mr. George Talbot; the second section, from the General Post Office to the Marble Arch, by Messrs. Walter Scott & Co.; and the third section, from the Marble Arch to the terminus at Shepherd's Bush, by Messrs. John Price & Co. Perhaps the most expensive and difficult section to construct was the first. The city terminus is situated right in the center of the junction of the six busiest streets in London. It is flanked on one side by the Mansion House; on another by the Royal Exchange; and on the third by the Bank of England. The booking office is situated below the level of the street. This spot is the most impassable and dangerous for pedestrian traffic in the whole metropolis, and the city authorities exacted as a *quid pro quo*, for their permission to excavate, that the company should provide a circle of subways touching the ends of each street, so that foot passengers might effect a crossing from one thoroughfare to another without incurring any risk from the street vehicular traffic. This in itself was no light task. The majority of the London streets below the surface are thickly intersected with gas mains, sewers, pneumatic tubes, telephone wires, etc., and at this precise spot these barriers were extraordinarily intricate. With the exception of one large brick sewer, however, all the obstructions were successfully removed and diverted into a huge circular subway immediately below that provided for pedestrians. This innovation is peculiarly advantageous, since in the event of repairs, or the laying of new pipes, there is no necessity to disturb the surface of the roadway, as everything can be efficiently conducted in this tunnel. Then, in addition to these subways, five huge shafts and one wide stairway had to be sunk to give access to the platforms of the railway 68 feet below; while twenty feet lower still the City and South London Railway extends in a transverse direction. The whole of the street at this converging point is excavated below the roadway to a depth of 16 feet. The actual roadway itself, which is only 18 inches in thickness, entirely rests upon the troughed steel roofing of the booking office, though, of course, the necessary supports are more than adequate to resist the pressure that is at all likely to be brought to bear upon them. The whole of this excavation was performed without having to break the roadway in one single instance, and the traffic was only partially interrupted during the time the actual steel roof was being put in.

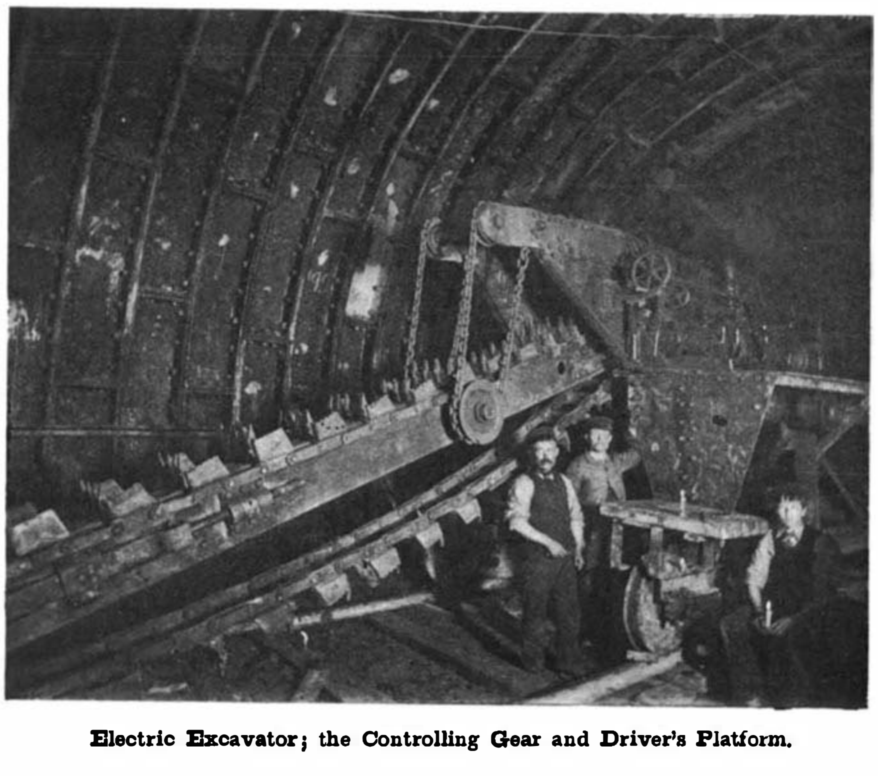
The five shafts for the electric elevators at the Bank terminus contain some of the widest elevators on the whole system, being each 20 feet in width. The process of constructing


Sinking a Caisson, Preparatory to Excavating the Tunnel.


Shepherd's Bush Station Tunnel, 21 Feet Diameter, Showing the Two 11-Foot Tunnels for the Tracks.


Interior of the Compressed Air Chamber.


Electric Excavator, Showing the Buckets Working on the Face of the Clay Within the Shield.


Electric Excavator; the Controlling Gear and Driver's Platform.

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these shafts was as follows: The friable soil was primarily removed, and the first ring of plates sunk and bolted in position. The clay inside the shaft was then excavated and the ring of plates underpinned until a sufficient depth had been attained to permit of a second ring of plates being bolted to those of the first. The digging was then continued, and the same processes of underpinning and bolting together of plates repeated until the shaft had been sunk to the desired depth. In reality, therefore, the iron shell of the shaft was constructed in a downward direction, ring by ring, from the top. By this means elaborated shoring up of the earth was rendered unnecessary, since the shaft was completed as work progressed.

When the bottom of the shaft was gained preparations were made to construct the tunnel itself. A sufficient quantity of earth was removed to admit the Greathead shield being placed in position. Two shields were employed in the work. The smaller one, which measured 11 feet 6 inches in diameter, was employed for the boring of the permanent way tunnels, and the other, which was 21 feet 2 inches in diameter, served to excavate the earth for the stations.

The process of boring was, briefly, as follows: The shield was forced slowly forward under the powerful application of hydraulic rams. The clay in the interior of the shield was then removed by laborers, and conveyed to the foot of the upward shaft in trucks hauled by horses or electric motors. When the clay had been removed, a ring of tunnel-plates was erected in the rear end of the shield and securely bolted up. The rams were once more brought into action and the same process repeated. The hydraulic rams, twenty-two of which were employed to drive the big shields into the earth, consisted of cylinder and case and crosshead. One end of the ram rested against the front flange of the last inserted ring of plates, while the head rested upon a similar flange on the rear end of the shield. When the power was applied, the shield was gradually pushed forward to the full extent of the stroke of the ram, which was equal to the width of the tunnel plates. The rams were so adjusted that they could be either employed in unison or individually, so that pressure could be directed upon any desired portion of the shield. In the case of the small shields compressed air engines were utilized for pumping the pressure water for the rams. With an exerted pressure of 50 pounds per square inch of compressed air a pressure of 2,240 tons was imparted by the water to the rams. In the case of the larger shields electric motors supplanted the compressed air engines. The tunnel plates being fixed inside the shield, when the latter was forced forward, a small annular space was left between the outside of the tunnel plates and the earth. This was filled up with grouting forced through holes purposely bored through the tunnel plates by means of compressed air. The rate of progress in the actual tunneling varied from 40 inches to 80 inches per working day of 10 hours; but on the average 1,000 tons of clay were excavated in that time. The removed clay was hauled to the surface, dumped into barges and carried down the river to Barking, where it was deposited in connection with some reclamation scheme.

At one or two points throughout the route the engineers were confronted with slight difficulties. Some of the streets under which they passed were so narrow that they would not admit of the tunnels stretching side by side without encroaching upon private property. This had to be avoided, so the tunnels and stations were constructed one above the other. Then again, at Holborn, where the line crosses the old Fleet River, and where the configuration of the ground brings the railway nearer the surface, and there was the additional weight of the viaduct and surrounding lofty buildings to carefully consider, compressed air was employed as a safeguard against any possibility of the earth collapsing; in this case work was continued in a chamber wherein the atmospheric pressure was increased to resist the pressure upon the shield. The increased atmospheric pressure was not very excessive, being only 35 pounds to the square inch against 15 pounds per square inch normal, but the total pressure in the interior of the lock upon the entire working face was about 150 tons.

Messrs. Walter Scott & Co. in their section experimented with an electric excavator, constructed after their own designs for the removal of the clay. This was the first occasion upon which such a contrivance, driven by electricity, had been employed for this purpose. So far no mechanical device has been placed upon the market that will successfully excavate the earth in limited confines, such as these small tunnels, and deliver it directly into the ballast wagons. This machine in design was not unlike a dredger—indeed, its principle was exactly the same. It consists of a carriage slung on wheels, traveling on rails set to a gage of 6 feet 3 inches. The superstructure of the excavator was raised to a sufficient height to permit the ballast wagons to run underneath it. The excavating was accomplished by means of dredging buckets passing over a long horizontal ladder, and scraping the face of the earth in their passage. There were 37 buckets in all traveling over a ladder 37 feet in length. The buckets were not buckets correctly speaking, since they consisted of only a bottom and a back. Into the back were securely fixed a number of wrought iron chisel-pointed teeth, for biting the earth, which after its removal was carried along in the bucket and emptied into the trucks underneath. The buckets, in the first instance, were made of cast-iron; but as one or two of them were broken through coming into contact with hard substances in the face of the earth, they were replaced by others made of gun metal.

The electric motor for generating the necessary power for working the digger was placed upon the platform of the carriage. To operate, the machine was driven up to the face of the earth and set in motion. The chain of buckets revolved rapidly, and as they passed over the nose of the ladder, pointed toward the earth, they removed a small quota of ballast with their sharp teeth. By means of levers it could be slewed round in any direction so as to excavate to the whole of the desired surface of the earth within the shield, with the exception of the extreme top and sides which it could not reach. When a sufficient quantity of earth had been removed, the machine was run back for about 12 feet, and the shield driven forward by the hydraulic rams. The cutting edge of the latter, as it was forced forward, brought down that clay which was not removed by the buckets of the excavator. To guard against any damage being inflicted upon the machine by contact with any impediments in the earth upon which it was in operation a fuse was placed in the lead of the motor. A reversing switch was provided in order that the motion of the bucket ladder might be reversed if necessary or withdrawn. The driver controlled the machine from a small platform placed upon the carriage. The utilization of this excavator was purely an experiment, and although it worked satisfactorily its services were not continued. It was economical so far as regards manual labor, since with six men in attendance it could do the work of fourteen laborers.

Particulars of the Six 22-knot Armored Cruiser for Our Navy.

The Secretary of the Navy has asked for bids for the construction of six armored cruisers authorized by the acts of March 3, 1899, and June 7, 1900, the cost of which will aggregate $24,750,000. The three vessels authorized by the first act are to be sheathed, and the other three unsheathed. The unsheathed vessels are to be of not less than 13,400 tons and the sheathed vessels of 13,800 tons displacement. No bids will be considered that do not conform to the above figures, and they must guarantee a speed of not less than 22 knots and a bunker capacity of not less than 2,000 tons. The maximum time allowed for completion is thirty-six months for each vessel, and there will be penalty of $300 per day for the first month, and $600 per day for each subsequent day, after the time for delivery has passed. No vessel will be accepted that falls below 20 knots in speed and there will be a reduced compensation of $50,000 for each quarter knot down to 21½ knots, and of $100,000 for each quarter knot below 21½ knots. The main battery will consist of four 8-inch breech-loading rifles, and fourteen 5 inch rapid-fire rifles. The secondary battery will consist of eighteen 3-inch rapid-fire guns, four 1-pounders, four 1-pound or single-shot guns, and ten smaller rapid-fire and machine guns. The limit of cost for the first three ships is $4,000,000 and for the three ships authorized in this year's Naval bill is $4,250,000.

Selenides of Iron.

M. Fonzes-Diacon has recently presented to the Académie des Sciences an account of his experiments in the formation of the selenides of iron. As regards the previous experiments in this direction, Little has obtained a selenide of iron corresponding to the formulas $Fe_2 Se_3$ by the action of selenium vapor upon iron heated to redness; the product thus obtained, melted under a layer of borax with an excess of selenium, gives the selenide of iron. M. Fabre has obtained a ferrous selenide of crystalline structure by heating, with iron filings, the product obtained by the action of selenium vapor upon pure iron wire. The experimenter has succeeded in forming the different selenides of iron, corresponding to the sulphides; these have the formulæ $Fe Se_2$, $Fe_2 Se_3$, $Fe_3 Se_4$, $Fe_7 Se_8$, and $Fe Se$.

The ferrous selenide is produced by the reaction of selenium vapor or hydrogen selenide upon iron at a red heat; the product has no appearance of crystallization. The ferric selenide is obtained by the action of hydrogen selenide upon ferric oxide, $Fe_2 O_3$, at a low red heat, the oxide being transformed into ferric selenide, $Fe_2 Se_3$. The sesquiselenide thus formed has the appearance of a gray crystalline powder with bluish reflexions; a microscopic examination fails to show any clearly defined forms. In another experiment, anhydrous perchloride of iron, or peroxide of iron, heated in a porcelain tube at white heat, are transformed, in a current of hydrogen selenide, to gray selenides, agglomerated in masses presenting violet or bluish tints. According as the temperature is more or less elevated, compounds are obtained corresponding to the formulæ $Fe_3 Se_4$ or $Fe_7 Se_8$. Some of the samples have a crystalline structure and appear to belong to the cubic system, but the forms are indistinct. The biselenide of iron, containing the greatest proportion of selenium, is prepared by reacting upon anhydrous perchloride of iron, heated below redness, with hydrogen selenide drawn through by a current of nitrogen. The perchloride, volatilized in part, collects in scales upon the cooler parts of the tube in which the operation is made; they are slowly transformed to selenide of iron, while still preserving the same pearly appearance. A corresponding phenomenon has been previously observed by M. Moissan in the preparation of sulphide of chromium. Analysis shows that this selenide corresponds to the formula $Fe Se_2$, making it a biselenide of iron. When heated in a current of oxygen it is transformed to red oxide of iron with disengagement of $Se O_2$. As to the general properties of the selenides of iron, they are attacked by concentrated or gaseous hydrochloric acid in greater or less degree, according to the proportion of iron; the $Fe Se_2$ containing the largest proportion of selenium is not attacked. Nitric acid transforms the selenides to selenites. Chlorine displaces the selenium without difficulty. When heated in a current of oxygen, they leave a residue of red oxide of iron, with sublimation of selenious anhydride. Hydrogen, at high temperatures, reduces them to ferrous selenide.

The New York Zoological Park.

It is less than two years since the Zoological Society assumed control of this park and began their first building. Simultaneously with the erection of dens, aviaries and other animal buildings, and the installation of the animals by the society, the city has been constructing miles of walks, roads, and sewers, has been trimming trees, deepening ponds, etc. Although only one-third of the proposed work is completed, the present condition reflects great credit upon the officers of the society and the generous founders and patrons whose gifts have made possible what has been accomplished.

Besides the 227 acres of partly-wooded, somewhat rocky upland and lowland, there are Bronx Lake of 25 acres, Lake Agassiz of 5½ acres, and the Aquatic Mammals Pond, Cope Lake and Beaver Pond; the last three include together, 3½ acres.

The Park is strewn with glacial bowlders of granite or trap rock; of these the largest is what is known as the Rocking Stone. This the visitor should not miss. It is a mass of quartzite granite, 7½ feet high, weighs about 30 tons and is so nicely poised on an angle that a pressure of 50 pounds will cause the apex to swing north and south about 2 inches. The stone is easily found, as it lies on a high point overlooking the Buffalo Range, not far from the West Farms entrance.

The animals are provided with ranges or houses of ample proportions. The buffalo and deer of various kinds have quite extensive grazing ground.

The Reptile House and the Bears' Dens about equally divide the children's attention at present, though the sea lions are a close second to either of these attractions. A great deal of interesting information about snakes of many kinds can be gained in the Reptile House, where each species has its own home with appropriate surroundings. Close by them he will see an anaconda climbing in a tree, and the graceful axolotl from Mexico swimming in its tank. If he stays long enough he will be able to watch the metamorphosis of the tadpole to the frog. If he is there at the right time he will see the alligators fed with whole fish, each one of the seven taking his turn like so many children, and some of them getting an affectionate pat from the keeper as they snap their huge jaws together.

The Prairie-dogs' Village is a comfortable looking place, where fifty marmots burrow and howl as they please, happy as they could have been in their native Montana home.

The Beaver Pond will, in time, be one of the chief points of interest, for all the materials for dam building are here, and they are to be so left that the cunning craftsmen can work under the only conditions they will accept—slight observation.

All these creatures and hundreds of others already installed, or soon to be, are on view every day in the week.

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A CAP NUT lock for propellers has been invented by Capt. Lewis Davis, of Liverpool, and is intended to prevent the loss of blades at sea, says The Engineer. The center of the cap nut and the center of the fixed stud or bolt are bored, and a left-handed flat-head bolt is inserted. Through the head of this bolt and on the cap-nut are a number of holes, so arranged that locking pins can be inserted. A flat cap piece is also screwed into a recess made on the head of the bolt, and again through the center of this is screwed a small-headed screw. The worming of each bolt or nut is contrary to that preceding, so as to check any loosening tendency. A rubber washer is placed under the flat cap to prevent the entry of water.