THE BLACKWALL TUNNEL, LONDON.

During the ceremonies inaugurating the work of the construction of the New York Rapid Transit Tunnel, the Mayor expressed himself as being in favor of the extension of the system to Brooklyn by means of a tunnel beneath the East River, and it is the opinion of the Chief Engineer of the Rapid Transit Commission, and of the Commission themselves that such an extension would be entirely feasible. The preliminary soundings, borings and other survey work are now being done, and it is probable that the Brooklyn extension will be put in hand and built simultaneously with the main tunnel on Manhattan Island.

In prosecuting this important work the engineers will not be entering upon any new or untried field. A large tunnel already exists beneath the East River, at Blackwell's Island, which is 10 feet in diameter and serves to convey the mains of East River Gas Company from Ravenswood to Manhattan Island. The city of London can also boast of several tunnels be-

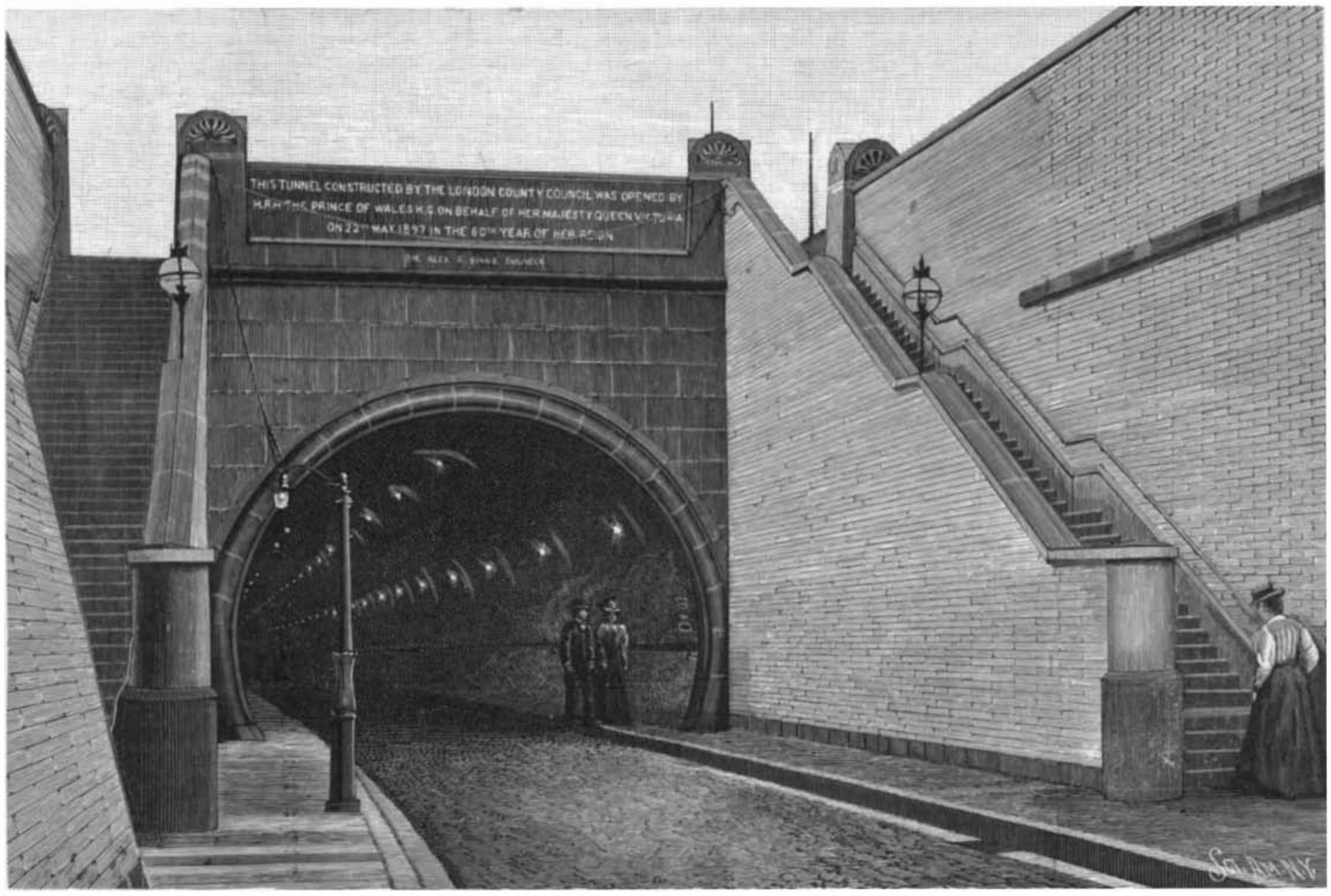

Fig. 4.—ENTRANCE TO TUNNEL ON THE SOUTHERN OR KENT SIDE.

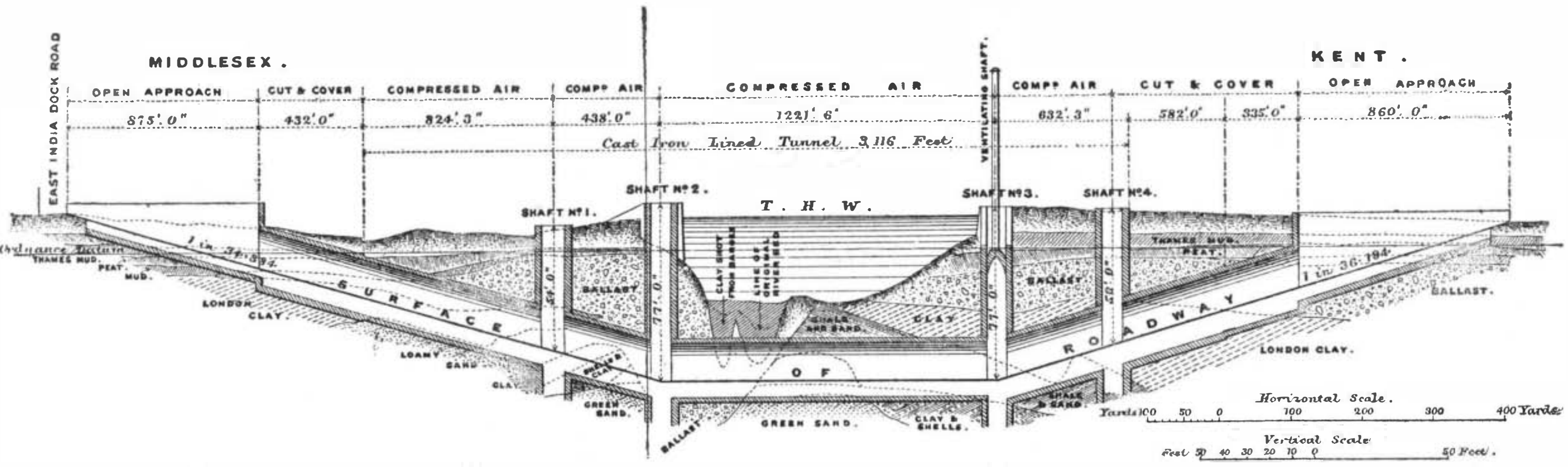

Fig. 5.—LONGITUDINAL SECTION ON CENTER LINE OF TUNNEL.

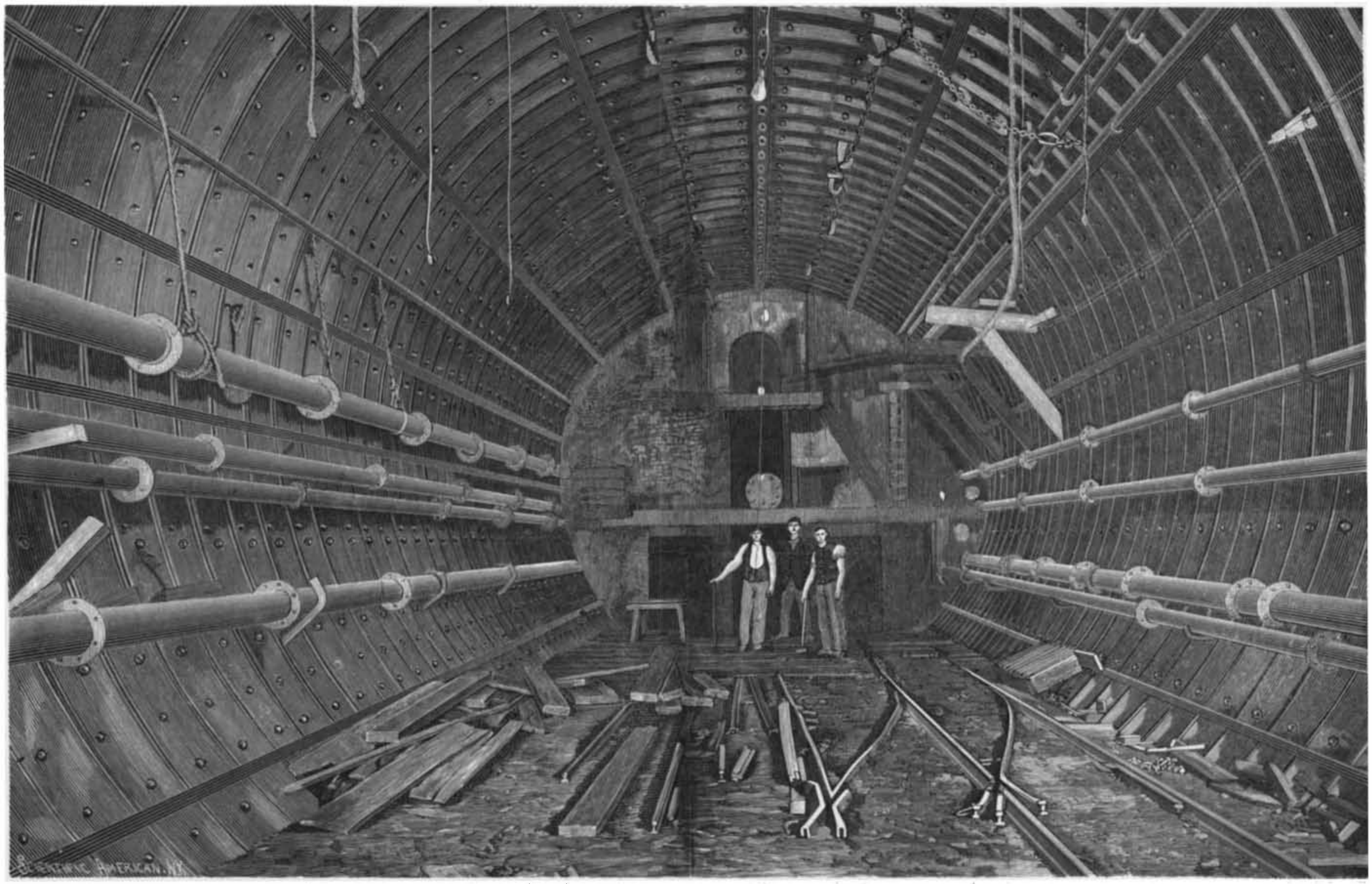

Fig. 6.—INTERIOR VIEW OF BLACKWALL TUNNEL, BENEATH THE THAMES, SHOWING CAST IRON LINING COMPLETED.

SCIENTIFIC AMERICAN

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Fig. 1.—Northern or Middlesex Entrance.

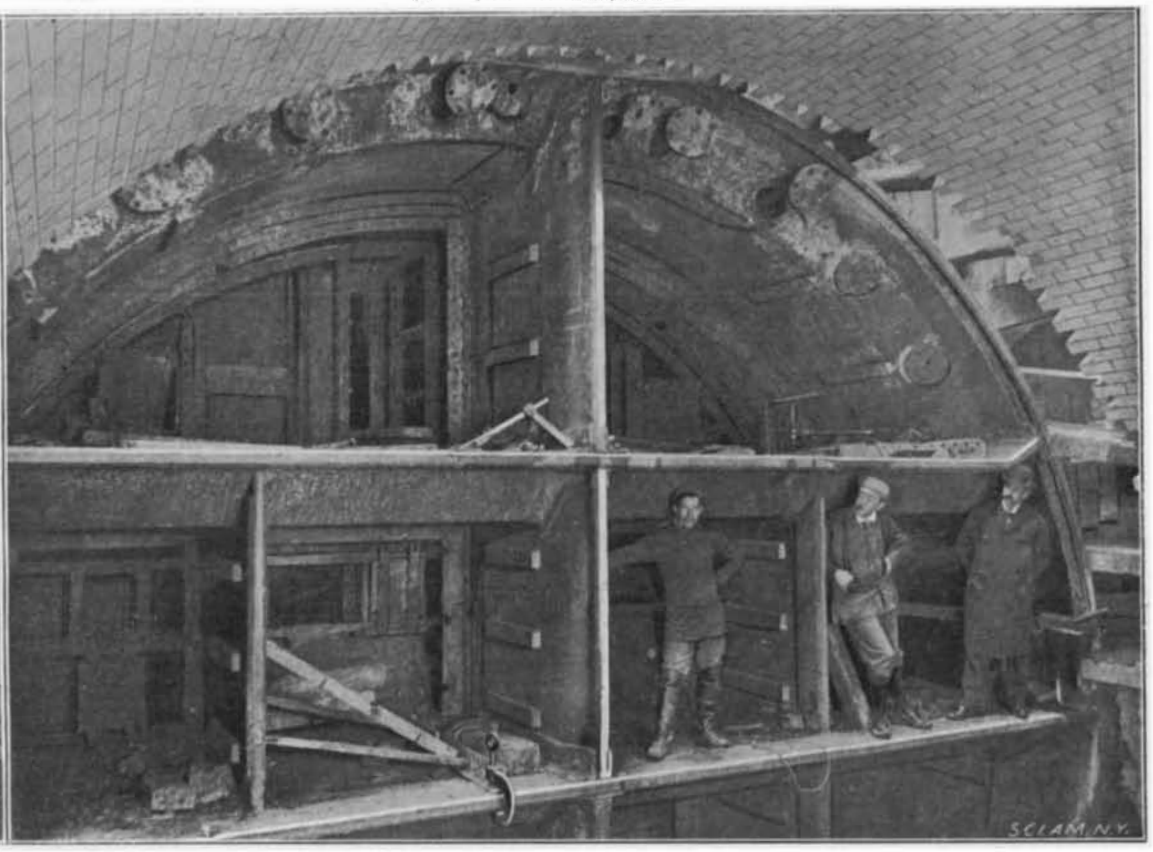


Fig. 2.—The Two Upper Floors of the Shield.

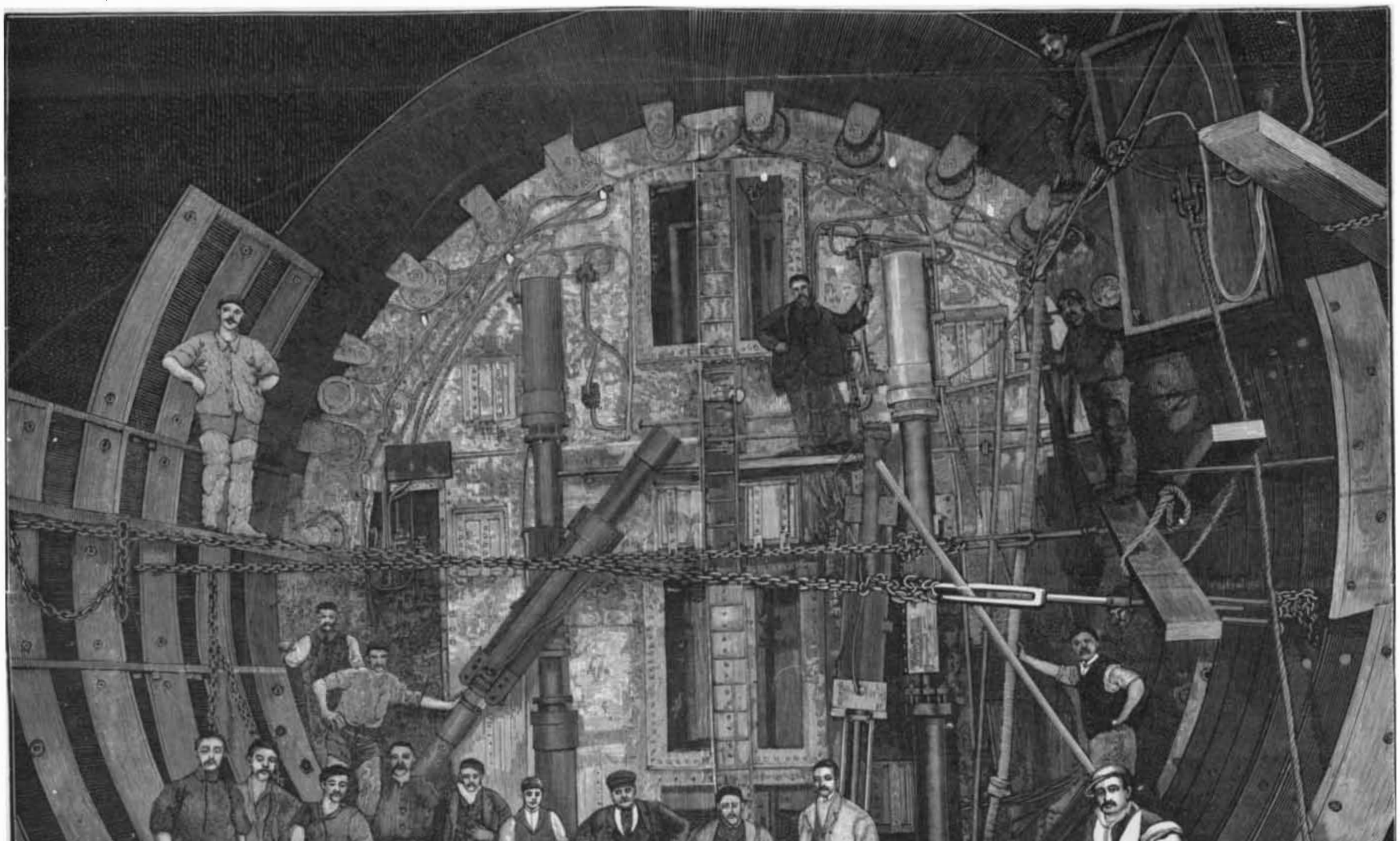


Fig. 3.—View at the Rear of Shield During the Driving of the Tunnel, Showing Cast Iron Lining and the Hydraulic Erectors.

THE BLACKWALL TUNNEL, LONDON.—[See page 217.]

neath the Thames River, some for street traffic, and others for the use of various railroads. The most important of these is the great Blackwall Tunnel, which was opened in 1897 and is now in daily use by pedestrians and vehicles. As the methods of constructing this tunnel were similar to those which will be adopted for our own Rapid Transit Tunnel, the accompanying illustrations and some description of the work will just now be of special interest.

It was about the year 1875 that the Metropolitan Board of Works realized the necessity for the construction of more river crossings below London Bridge, and after various schemes, both for bridges and tunnels, had been considered, the Blackwall Tunnel act was passed in the year 1887. The original design called for three tunnels, two for vehicles and one for foot-passengers. It was decided to construct the latter before commencing the others. After considerable delay construction was started on the present tunnel at the close of the year 1891, the contract being let for a round sum of $4,215,640. We present a longitudinal section on the center line of the tunnel, from which it will be seen that its total length is 6,200 feet of which 1,220 feet is below the river itself. The total length of that portion of the tunnel which is lined with cast iron is 3,112 feet. At each end of the tunnel there is an open approach for about 875 feet followed by 432 feet of what is known as "cut and cover" work on the north side, and by 915 feet of the same work on the south side of the river. Our illustration, Fig. 4, is taken in the open approach and shows one of the entrances. "Cut and cover" is so-called because of the method of construction, which is to excavate an open cutting, build in the brick tunnel, and then fill in above the the tunnel, restoring the original surface of the ground. This will be the method adopted for the greater part of the New York Rapid Transit Tunnel. This portion of the Blackwall Tunnel consists of four layers of brickwork, built in concentric rings, and surrounded by a waterproof band of asphalt, one and a half inches thick, with a thick coating of 6 to 1 of cement concrete outside of the asphalt.

To facilitate the work four large shafts were sunk in the line of the tunnel, two on the north side and two on the south side of the river. The sinking was done by means of huge caissons, which were 58 feet in external diameter and were formed of two shells with a space of 5 feet between them which was filled with concrete.

After the shafts were sunk they were finished off with an internal lining of glazed brickwork, and circular stairways were put in to give admission at these points to the tunnel. Two circular openings were formed on opposite sides of each shaft on the center line of the tunnel, and these openings were closed during the sinking by temporary iron shutters or plugs, which were capable of being removed after the shaft was sunk to make way for the advance of the excavating shield.

The difficulty of driving the tunnel was greatly increased in places by the nature of the material to be passed through. By reference to the longitudinal section, Fig. 5, it will be seen that the material consists largely of what is known as "ballast." This is a gravelly, water-laden, and very loose material, which gave considerable trouble during the sinking of the shafts, and in one or two instances, during the driving of the tunnel, resulted in a serious inrush of water.

The diameter decided on for the tunnel was 27 feet. Two patterns of cast iron lining were used, one 2 inches and the other 1½ inches in thickness both being of the same external diameter. The rings of both sections are 2 feet 6 inches in length and are built up of 14 segments, each of which is about 6 feet long circumferentially. The center section at the top of the tunnel consists of a solid key. All the joints were machined and the segments were joined without any packing between them; but recesses were formed on the inside of the flanges and these were carefully caulked, the joints being thus made perfectly watertight. After the tube was bolted up, it was grouted with cement, the grouting being poured in through tapped holes which were afterwards carefully closed with screw plugs.

The shield, shown in Figs. 2 and 3, was constructed of steel and was designed to meet the exceptional difficulties due to the nature of the ground to be passed through, one of which was the probability of meeting with large boulders trunks of trees, etc., and the necessity for cutting through the hard beds which form the base of the London clay. The total length of the shell was 19 feet 6 inches and the diameter was 27 feet 8 inches. The outer skin was built up of four thicknesses of ⅝ inch steel plates making a total thickness of 2½ inches and the twenty-eight plates of which it was made up extended the full length of the shield, all the joints, therefore, being longitudinal. The forward half of the shield was stiffened by three horizontal and three vertical plate diaphragms, which also served to divide the working space into four floors and twelve compartments. The shield was formed with a double shell, one 24 feet and the other 25 feet, inches in diameter, the shells being strongly braced together by circular girders, in the webs of the last two of these holes were cut for the passage of the ram cylinders. For forcing the shield forward 28 hydraulic rams were originally provided. They were each 8 inches in diammeter with a stroke of 4 feet. In driving through the wet sand, or ballast, beneath the river, however, this number had to be increased by six other rams, which were 10 inches in diameter, but had a shorter stroke. The maximum water pressure used was 2¾ tons to the square inch, making a total pressure to move the shield when all the rams were employed of 5,165 tons. Upon the rear face of the shield were carried two hydraulic erectors, see Fig. 3, which were used for lifting the tunnel segments into place. The circular motion was obtained by a rack or piston, which worked vertically between two hydraulic cylinders, the rack serving to revolve a pinion on which the rotating arm was carried. This arm was extensible by means of another hydraulic jack fixed in its base. The segments of the tunnel were brought up to the shield upon the two tracks, one on either side of the floor of the tunnel, where they were picked up by the extensible arm, swung around to the desired position, and then thrust out radially into place and bolted up.

The method of starting the tunnel from one of the vertical shafts was as follows: A portion of the cast iron lining, extending to the opposite side of the shaft, was first temporarily built up behind the shield to form an abutment for the hydraulic rams in driving the shield forward. The plug facing the direction in which the tunnel was to be driven was then removed from the tunnel opening, and the shield was driven forward through the wall of the shaft into the surrounding material.

It will be noticed in referring to Fig. 5, that there is a layer of London clay between the tunnel and the river bed for about three-fifths of the distance beneath the river. After the clay was passed, what was probably an older and deeper bed of the river, now filled with "ballast," was met with. As was anticipated, there was no difficulty in maintaining a sufficient pressure of air to keep out the water as long as the clay covering continued. In starting from No. 3 shaft the upper part of the shield was in clay and the lower part in sand, and the rate of progress at this point was greater than that in any similar tunnel hitherto constructed, for in two months' time more than 500 feet of the tunnel was completed, and occasionally five rings, or a length of 12 feet 6 inches, was constructed in twenty-four hours. During one day, therefore, 300 cubic yards of material was excavated and about 75 tons of cast iron lining put in place. When we bear in mind that these materials, in addition to lime and other necessaries, and empty wagons, had to pass through the air locks, the nature of the performance will be understood.

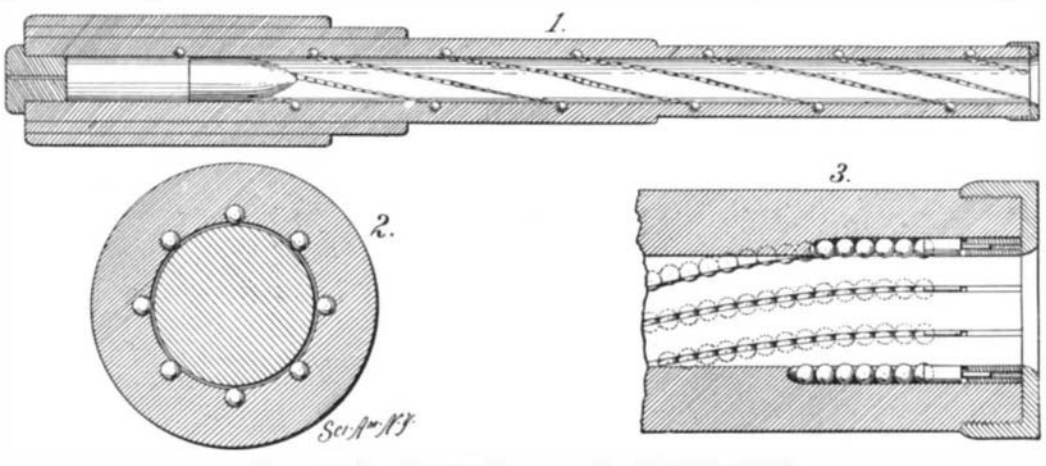
By reference to the longitudinal section it will be seen that at one point the shield passed within about 5 feet of the bed of the river, the overlying material being open ballast, pervious to water. To meet the difficulty, clay was deposited on the river bed for a length of 450 feet on the line of the tunnel, the maximum depth of the clay being 10 feet. The clay offered resistance to the air escaping from the tunnel through the open ballast, and its weight prevented the bed of the river from being blown up by the air pressure. After the tunnel had been driven through this portion of the river bed, the clay was dredged out.

Shutters for closing the face of the shield proved invaluable when passing through the "ballast" or any open material. In each compartment of the three upper floors were three shutters each consisting of ⅝-inch iron plate, stiffened at the edges by heavy angles, and sliding on guides fixed at the sides of the compartments. The shutters were controlled by long screws fixed to their ends and extending through bearings on the side of the compartment. When working in ballast, previously to shifting the shield forward, the face of a compartment was completely closed by its three shutters which had been screwed forward as close to the cutting edge as possible, the shutters being directly over each other and the small space between them being filled with clay. When the shield was to be shifted forward, the nuts of the screw were loosened on the forward side of the bearings along the shutters to move back as the shields were shifted forward. Mr. E. W. Moir, M. Inst. C. E., the designer of the shield, to whom we are indebted for our illustrations and particulars, says that the difficulties encountered while driving through ballast suggests modifications in shields for tunneling similar material. The shutters should be placed as close as possible to the cutting edge, and their area in relation to that of the face should be as large as possible. Much of the difficulty in driving the shield was due to this difference of areas and it would probably be little felt in passing through soft material which flows easily, but in gravel the resistance from this cause is very great. In Fig. 2 the shield is shown in position at the end of the "cut and cover" work, ready to commence driving.

All the cast iron lined portion of the tunnel is lined with 4 to 1 Portland cement concrete and faced with white glazed tile, so as to secure uniformity of appearance with the cut and cover portion of the work. The roadway is carried on a 9-inch brick arch, leveled up with concrete. The subway thus formed provides room for water and gas mains, or if it be desired, for a ventilating trunk. The roadway provides for two lines of vehicles and there is a sidewalk for passengers on either side. The tunnel is brilliantly lighted and the effect is greatly assisted by the white tiling with which the whole thoroughfare is lined.

THE CULLEN BALL-BEARING RIFLED GUN.

There has recently appeared in the daily press a description of a so-called ball-bearing rifled gun, which possesses considerable interest both for its undoubted novelty of construction and for the display of ignorance of the very first principles which govern the construction and action of modern guns. The inventor of this curious weapon called at the office of the SCIENTIFIC AMERICAN and informed the editor that the gun had been subjected to exhaustive tests by the government, and had achieved results which were embodied in an official report that was about to be made public. As statements to the same effect have appeared in the articles in the public press above alluded to, the editor was led to make inquiries as to the results reputed to have been obtained at the government testing ground at Sandy Hook, and to examine into the claims of the inventor. The latter believes that if the passage of the projectile through the bore can be made more easy, its velocity as it leaves the muzzle will be proportionately increased. Hence he deepens the ordinary rifling, giving it a circular cross-section, and fills it with rows of steel balls.



THE LATEST CURIOSITY IN GUN CONSTRUCTION.

The claims of the inventor can best be put foward in his own words:

"The strains on the walls of a gun are reduced seventy-five per cent (except over the breech where initial explosion of propellant occurs), thus obviating the necessity for two at least of the jackets that are shrunk over the tube of an ordinary stiff-rifled gun.

"This is to be accounted for in two ways. First: The elasticity of the balls and the smooth-walled projectile; second, from the fact that the projectile gets away from the gun (calculus will prove this in addition to actual trials that have been made) in one-fortieth [sic] (approximately) of the time it takes to get away from an ordinary gun, same charges of propellant and same weight projectiles being used. The life of the gun is prolonged indefinitely.

"The piece has been fired 2,311 rounds, in some cases with excessive charges (and with sand in the ball bearing grooves for ten rounds), and the report shows that the gun is only three per cent less effective than when first fired.

"The average velocity was 3,200 feet per second at the muzzle against 1,800 feet per second for the Driggs and Hotchkiss, and 2,000 feet per second for the Maxim (all of which were tested at the same trial).

"The three guns mentioned were tried in a competitive test with ball-bearing gun by Gen. Flagler and with other ordnance experts, with results which were verified by Gen. Miles' tests."

The statements in the above quotation were so startling, touching the results of the tests, that our Washington correspondent made inquiry at the Army Bureau of Ordnance as well as at the Bureau of Ordnance and Fortification, of which Gen. Miles is the head, and at neither bureau, could it be learned that any such tests as alleged had ever been made. In fact, it was positively stated by a leading official that no such test