THE HUDSON RIVER TUNNEL.

In some respects a most remarkable piece of submarine engineering was that begun some twelve years ago, when the first work connected with the tunnel to unite Jersey City and New York by a passage under the bed of the Hudson River was done. Important to the engineer because of its vast magnitude, the difficulty and danger attending its prosecution, and particularly because of the new methods of working introduced; important to commerce, as it would afford a quick and sure means of crossing the river, and would reduce the time between New York and the South and West on each of the great railroads terminating at Jersey City. The work has not been carried forward continuously. During 1882 the headings were advancing rapidly, and the underground affairs looked very bright, when a financial stumbling block was met, and all work ceased in the fall of that year. Since then the tunnel has been flooded. A short time ago the water was pumped from the New Jersey end, the compressors started, and now the heading of the north tunnel is moving toward the opposite shore. We understand from Mr. D. C. Haskin, the manager of the company, that there will be no further difficulty concerning funds, and that all of the four headings will be opened as soon as possible.

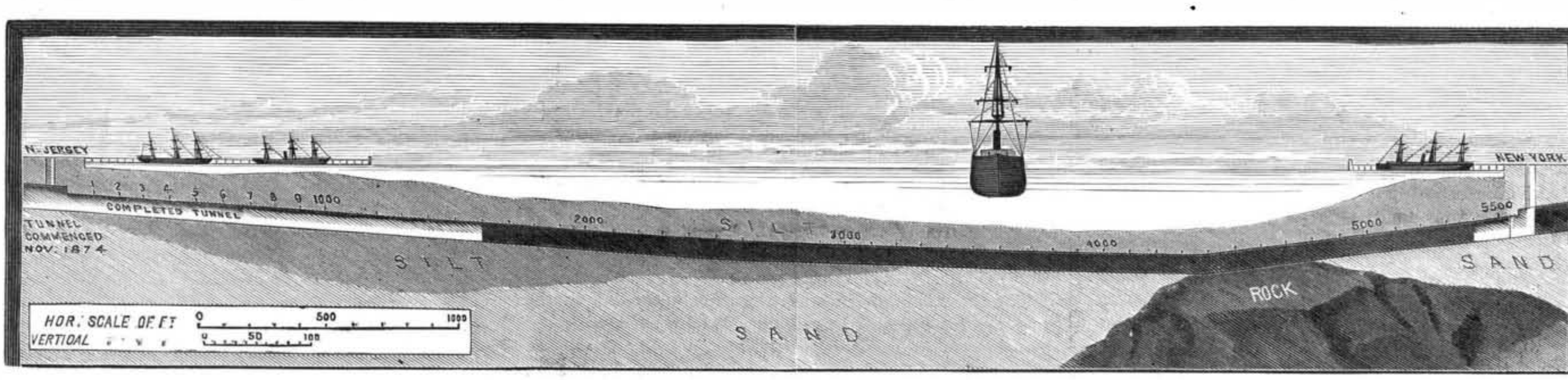
The plans, as projected, contemplated the erection of one large double track tunnel, but this was soon changed, and two parallel single track tunnels, 18 feet high by 16 feet wide, inside, were substituted. That section of the tunnel passing beneath the river ends at the foot of Morton Street, New York, and Fifteenth Street, Jersey City, where the approaches begin that will extend the tunnel at an easy grade to the surface. Work was commenced at the western end by sinking a brick shaft 30 feet inside diameter down to the line of the tunnel, 60 feet. At 29 feet from the top an opening was cut through the river side of this shaft, and an air lock 6 feet in diameter and 15 feet long was forced in by lock was begun. The intention was to build a masonry connection between the shaft and ends of the tunnel. When this section had been nearly all excavated, the roof near the inner end of the lock caved in during a change of shifts, and the door was so wedged and held by the plates as to prevent twenty men from entering the lock. After vain endeavors to remove the obstructions, the outer door of the lock was opened, and those who had passed the barred door escaped. The air being thus removed, the work was soon flooded. To recover the bodies and again start the work, a caisson 41½ feet by 24 feet 10 inches was sunk between the shafts and tunnels. When the caisson rested in line with the bottom of the shaft, holes were cut through its eastern side and connection made with the tunnels; the opposite side was then pierced, and the shaft entered. The entire interior of the caisson was then lined with brick, forming a large working chamber, from which, before the shaft opening was made, all the supplies were handled. In each tunnel at 430 feet from the shaft, bulkheads were built, and in each were placed two independent air locks, similar to the one in the shaft; the tunnels between the locks and shaft were then relieved of air under pressure. The south tunnel has been finished for 600 feet. A second bulkhead, having one lock, was built in the north tunnel 800 feet from the shaft, and a third at 1,200, when the first one was removed. The north heading has been carried 1,600 feet.

At the New York end, the conditions being different, the plans were slightly modified. The caisson there sunk was 48 feet long, 29½ feet wide, and 25 feet high. The interior was rectangular instead of being circular, as in the case of the other. It was provided with the usual locks for men and material. The caisson was sunk until its shoe was 60 feet below high water and 3 feet above the line of the exterior of the invert of the tunnels. The caisson was then completely embedded in sand and gravel which had little holding power upon Its four years' bath has completely covered it with a thick rust. The tunnel appeared to be in the same condition as when we last saw it; no cracks could be seen, and even the cement washing covering the masonry had flaked off only in small pieces.

Entering the lock and assuming as comfortable positions as its circular form would permit, and being careful to keep out of the line of the air entering through the forward valve, we were soon under a pressure of 22 pounds to the square inch. Passing into the next or middle section and walking 400 feet, the second lock was met. Through this, and we were under the full pressure of 27 pounds, and after stumbling and splashing—the illuminating power of a single flickering candle is not great, and the sections are only fully lighted at each end—400 feet further, we were at the heading.

When the work was stopped, a rough timber bulkhead was built across the heading and through the cracks; in this the silt had entered, completely filled the heading and gone up the tunnel, gradually decreasing in thickness, over one hundred feet. After this had been removed, it was found that the entire pilot had moved about 18 inches toward the north or up stream, and as the plates projecting beyond the end of the tunnel masonry had been braced from the pilot, they were forced outward to a like extent. The plates at the roof and south side were bent inward, but only a few inches. Why the pilot should shift as it did has not been explained. One would naturally suppose that no movement would occur other than in a vertical direction.

One section of 10 feet has been finished, another section has been lined with plates, and the heading has been extended correspondingly. In no particular have the plans been changed. The face of the cutting is divided into steps, in order that the men can easily reach and remove the silt from all points. When an excavation has been made, a plate is put in and bolted to those adjoining. This work is of course begun at the bottom and carried up, so that the outer edge of



PROGRESS OF THE RAILWAY TUNNELS UNDER THE HUDSON RIVER BETWEEN NEW YORK AND NEW JERSEY.

hydraulic jacks until its inner end projected a short distance beyond the face of the wall. The lock was then entered, its outer door closed, and an air pressure of 12 pounds admitted, when the inner temporary wooden door was removed and the iron one replaced. The earth was then gradually dug away, and plates were inserted to form a tube 8 feet long extending horizontally from the end of the air lock. This work was intently watched, as it was the first practical test of the system adopted, and it established the fact that the material passed through was sufficiently tenacious to separate the air upon one side from the water upon the other, and that it would serve as a self-sustaining wall as long as the air and water pressures were kept nearly equal upon each side. Eleven rings of plates, each 2 feet wide and each 18 inches larger than the one preceding, were built from the tube, thus forming a cone, the lower side of which was stepped. From the last ring, which was 20 feet in diameter, the two tunnels were started, the material being excavated a little at a time to admit iron plates, constituting a tube, within which the masonry was placed. No serious difficulty was met except when passing the piles of the dock, some of which were in the line of the tunnel, and had to be cut off. The silt was more ready to flow, and had to be exposed very carefully. It was found that the crown plates, owing to the pressure of the silt upon them, would settle somewhat before the masonry could be laid. Digging out more than was necessary, so as to allow for settling, did not obviate this, as the rate of settlement, owing to slight differences in the character of the material, which could not be gauged, was unequal. This led to the introduction of the "pilot," which was a tube six feet in diameter, built of interchangeable flanged plates and having a length sufficient to permit its forward end to enter some distance into the heading and its rear end to be abreast the completed masonry. Each end being thus supported, the intermediate points served as a center from which to brace the plates. After this there was no trouble in keeping all parts of the tunnel in line. When the headings of both tunnels had been advanced several hundred feet, work in them was stopped and the removal of the cone-shaped entrance from the the air as compared with silt. The sand at the bottom of the caisson was dug out, and in each small excavation as made, a flanged plate was inserted, bolted to those adjoining and held by braces. Brickwork was then laid upon this iron shell. This plan provided a working chamber similar in many respects to the one at the other shore. The caisson wall was then cut through and the tunnels started. To keep the exposed portion of an excavation from flaking, planks were instantly placed against it to hold it until the plates could be bolted and braced. The material at the heading was held by a movable bulkhead of plates. In building this portion, it was absolutely necessary to covere very part of the interior with plates, which were supported by braces, the air pressure being depended upon to counterbalance the water pressure. When a section, ten or twelve feet, had been plated, it was cleaned, and the masonry put in as upon the other side. When work was stopped in 1882, the north tunnel had been completed nearly 200 feet, and its heading was about half in sand and half in silt. The south tunnel was 30 feet from the caisson. The accompanying engraving shows the line of the tunnel, the distance completed, and that remaining to be done.

A representative of this paper visited the tunnel recently, and after donning the prescribed regimentals—rubber boots, coat, and an old hat—passed through the locks to the heading of the north tunnel under the guidance of Mr. C. A. Haskin, the superintendent. Near the mouth of the shaft are the boilers, air compressors, and dynamo supplying the arc lamps that light the tunnel. Running in the shaft is an elevator, carrying the men and material up and down. A track leads from the elevator to the place where excavated material is dumped and to a near dock where all the supplies are received. The cement is mixed dry at the top, in the proportion one cement to two sand, and is taken to the heading in bags. At the bottom of the shaft is a pump which drains the shaft and furnishes water to the heading. Being here provided with a very thick candle having a very little wick, we enter the left of two large gloomy openings and walk down the north tunnel 800 feet to the first air lock, the only bright, untarnished part of which is its glass bull's eye. the plates is parallel with the heading. The plates are supported from the pilot by braces, which are removed as the brickwork advances. The labor is so divided that the heading, plates, and masonry move forward at the same rate. The exposed silt is not protected, except by a braced plank here and there, to prevent large masses from falling, and yet it answers perfectly as a dividing wall, preventing the passage of either air or water, and having strength enough to resist any slight excess of pressure there may be upon either side of it. The silt cuts easily, and may be taken out in regular blocks, and yet when mixed with a little water it is more difficult to confine than quicksand. The pressure of the air is regulated by the condition of the silt itself; when the pressure is too great, the water is driven back and the silt drops off in little flakes, and when it is not enough, the water weeps through and runs down in little streams.

The required pressure does not depend directly upon the height of the water or the depth of the tunnel below the surface of the river, but seems to be more nearly controlled by the density or compactness of the silt. A small leak can only be detected by passing a candle flame over the face of the silt, when the flame will be drawn in by the outrushing air. A larger leak makes a noise precisely resembling the blowing off of steam. A little silt applied to a leak will effectually stop it, and as the opening rapidly grows, the remedy must be quickly applied. Mr. Anderson once tried a novel way of stopping a leak that was rapidly growing dangerous, by forcing his shoulders into the opening. He was instantly caught by the air and held until the silt had settled down behind him, when there was ample time to force silt into the weak spot. It is safe to predict that this method will not be generally adopted. During the work through the sand on the New York side, the best material for covering the joints between the plates to make them air-tight was silt which was brought from the other side, and so freely used that in some places the plates were entirely covered with it.

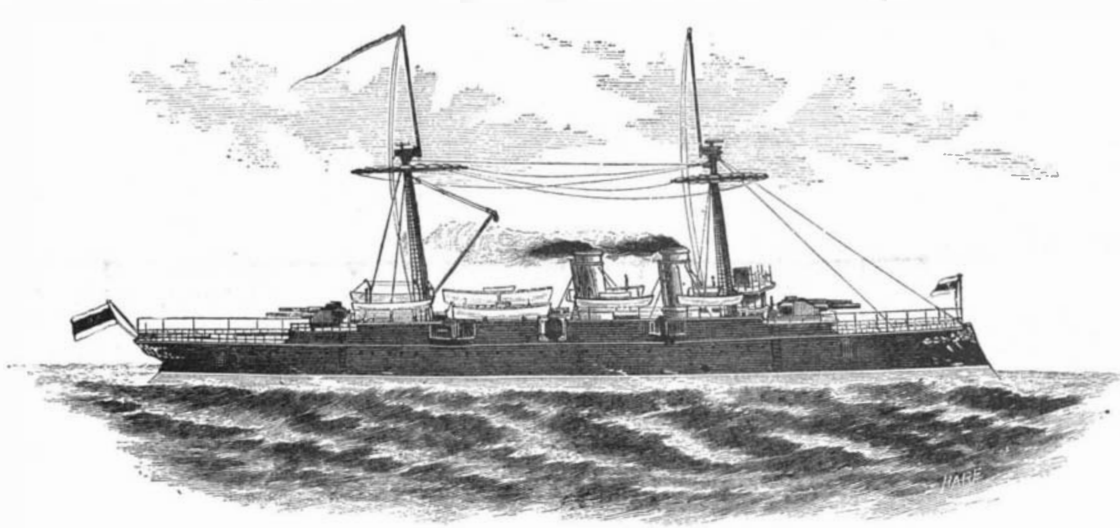
The masonry where the plates had been forced outward by the movement of the pilot was increased to 4 feet in thickness, in order to prevent there being any break in the plates; and to reduce the thickness to the usual 30 inches, each ring of plates is separated from the two on each side by blocks of wood, so that the opening between the plates is wedge shape, the rings touching on the south side, and being a few inches apart on the north side.

The way in which the supplies are brought in and the excavated material taken out will be understood if we follow a load of silt from the heading to the surface. It is loaded upon a small car, which is pushed along a track up to the lock, into which it is rolled over a short section of movable track placed across the sill of the door. Having passed this lock, it is drawn to the second one—first from the shaft—by a mule, which seems to be contented to work continuously under compressed air. This animal has been in the tunnel for three or four weeks, and his physical condition appears to have been most decidedly improved. Passing this lock, the car is drawn by a second mule to the bottom of the shaft, where a small turntable guides it to the elevator, up which it is lifted and then hauled to the dumping ground. Supplies for the heading go over the same route, and are handled in the same way, except that, the grade being down, the cars run by gravity. It is expected to soon replace the arc lights now used at long distances apart by an incandescent system, as the light can be more evenly and generally distributed.

The journey out of the tunnel is quickly made, and it is certainly with a marked sense of relief that the investigator of dark places finds himself in the wash room at the top of the shaft, removing all traces of his travels.

NEW ARMORED CRUISER FOR THE SPANISH NAVY.

On February 24 there was launched from the shipyard of Messrs. J. & G. Thomson, Clydebank, a new Spanish cruiser, named the Reina Regente, of which our illustration is a general external view as she is intended to float when finished.



THE REINA REGENTE, NEW ARMORED CRUISER FOR THE SPANISH NAVY.

This vessel was contracted for after the leading shipbuilders in Britain and other countries had submitted competitive designs to the Spanish government, the designs submitted and since carried out by Messrs. Thomson being adopted. Among the conditions laid down by the Spanish authorities to be fulfilled in this vessel were that she was to be of the protective deck type, the deck having a thickness of 3¼ in.; to have four 20 centimeter 12 ton guns, six 12 centimeter guns, and a numerous small armament; to be able to maintain a speed of 19 knots, and to have a radius of action of 5,500 knots. These stipulations have been much more than met in the vessel as constructed, her builders having arranged for a protective deck of 4¾ in., four 24 centimeter 21 ton guns, six 12 centimeter guns, a speed of 20½ knots, and a radius of action of as much as 12,000 knots.

The Reina Regente is 330 ft. long, and in fully equipped condition she will displace 5,600 tons, although her usual sea-going displacement will not exceed 5,000 tons. She is of steel throughout, and depends for her protection in an engagement partly upon the armored protective deck and partly upon the unusually minute subdivision of the hull between this deck and the one above it; or, in other words, of that part of the ship between wind and water. This part is divided into no fewer than 83 separate watertight compartments, most of which will be used as coal bunkers. The space below the armored deck is divided into 60 watertight compartments, and for the whole length of the vessel a cellular bottom is fitted. The total number of watertight compartments in the ship is 156.

The vessel will be propelled by twin screws, the engines, contained in separate watertight compartments, being of the horizontal type, triple expansion. The boilers, four in number, are also in separate watertight compartments. Well above the water line there are two auxiliary boilers, supplied by Messrs. Merryweather, for raising steam rapidly in cases of emergency. These boilers are connected to all the auxiliary engines on board, which altogether number no fewer than 43. In addition to the two sets of main engines, there are two starting engines, four centrifugal pumps, bilge and fire pumps, feed pumps, ten fan draught engines, steering engine, capstan engine, two electric light engines, two boat hoisting engines, also ash hoisting engines. The four centrifugal pumps are connected to a main pipe which runs right fore and aft, receiving branches from every compartment. The branches are so arranged that the compartments are always in connection with the pumps, and if they become flooded are immediately pumped out; but if water seeks to enter the compartment from the pipe, it is at once prevented by an automatic valve. Should it be desirable, however, to flood any compartment, the action of this valve can be suspended. The automatic nature of this pumping arrangement should be of the greatest value in an engagement, when men have little time and little power in which to think and act.

The highly important quality of turning power has received special attention in this new cruiser. The patent sternway maneuvering rudder of Messrs. Biles & Thomson, introduced with very marked success in the recently built Spanish torpedo cruiser El Destructor and the Russian torpedo boat Wiborg, is again a noteworthy feature in the new vessel. This contrivance, it may be mentioned, is a combination of a partially balanced rudder with a rudder formed as a continuation of the after lines of a ship. The partial balance tends to reduce the strains on the steering gear, and thereby enables the rudder area to be increased without unduly straining the gear.

The armament of the Reina Regente is, for her size, very formidable. It comprises four 24 centimeter and six 12 centimeter Hontorio guns, six 6 pound Nordenfelt guns, fourteen small guns, and five torpedo tubes. On the main deck, right forward, there are two torpedo tubes, there is one aft, and one in each broadside amidship. There are four gun towers on the level of the main deck, but projecting beyond the side of the ship. Each of the two forward ones fires five degrees across the bow, and to within 30 degrees of right aft. The after guns have a similar range round the stern. The remainder of the armament is placed on the upper deck.

At the fore end there is a platform, about 4 ft. above the deck, upon which two of the 21 ton Hontorio guns are placed. These fire right ahead, and to within 40 degrees of right aft. A similar platform right aft receives the other two 21 ton guns. Between these two platforms, and ranging along both sides, are placed the six 12 centimeter guns, two of which fire forward, two aft, and the remaining two have a range of 140 degrees.

Besides the six Nordenfelt guns, there are two 37 millimeter Hotchkiss revolving guns, and of the smaller guns there are five for boat and field service and four for working from the mast heads.

The vessel will be fitted with accommodation on the main deck for 50 officers and about 350 men. The launch took place from Messrs. Thomson's yard, in the presence of a large assembly, the naming ceremony being performed by the Duchess of Wellington.—*Marine Engineer.*

Slag as a Fertilizer.

The slag from the Thomas-Gilchrist process for making steel has long been supposed to have valuable properties as a manure. In the Bessemer converter, there is a lining of lime which, in the process of manufacturing the steel, takes up a large percentage of phosphorus, in the form of phosphoric acid. Phosphate of lime has been used as an artificial manure, in a variety of forms, with very beneficial results on most lands. It was thought that the basic cinder obtained in the Thomas-Gilchrist process might, from its large percentage of lime and phosphoric acid, have a manurial value.

Some two or three years ago, experiments in this direction were undertaken in Germany by M. Fleisher and others, and from the data which they obtained, it appeared that under certain conditions basic slag had a very marked influence upon crops grown on soils which had been top-dressed with it. It was ground into a very fine powder, and then the acids of the soil were able to dissolve the phosphoric acid which it contained; and it was then in a condition to be readily assimilated by plants. Attention is again being called to this point in consequence of a series of similar experiments which have been carried out by Dr. Munro, at Downton, for the North Eastern Steel Company, and which fully confirm the earlier experiments of the German investigators. It was thought that probably the slag would be more efficacious if it were first converted into a "superphosphate," in a similar manner to bones; but Dr. Munro and Mr. Wrightson seem to think that this is unnecessary, if care be taken to have the basic cinder in as pure a state of division as possible.

As basic slag is a waste product, and hitherto has had no industrial application, it ought to be obtainable at a much cheaper rate than the Canadian apatite, coprolites, and bone manures, which have until recently been the chief artificial fertilizers used in agriculture. Dr. Griffiths has recently, in papers read before the Chemical Society of London, advocated the use of iron sulphate as a manure, and as basic slag contains a considerable quantity of iron in the same condition of oxidation as in ferrous sulphate, it may also have some effect upon the manurial value of the Thomas-Gilchrist slag.

The Latest Large Guns.

It may be assumed, says *Iron*, that we are proud of our 110 ton gun; but the satisfaction of being at the head of all other nations in gun making is destined to be but short lived, for already we hear that the formidable Krupp, of Essen, is going to lick all creation, this little island included, in the art. His latest monster, now being manufactured, is to weigh close upon 139 tons, or 143,000 kilogrammes, against our 111,760 kilogramme arm, and to have a caliber of 40 centimeters (15·7 inches). Its length is 16 meters, or 52½ feet. The projectiles to be used with this gun are of two kinds, one a steel shell 1·12 meters (3 feet 9 inches) long, and weighing 740 kilogrammes (1,630 pounds), and the other 1·60 meters (5 feet 2 inches) long, and weighing 1,050 kilogrammes (2,314 pounds), equal to the weight of the barrel of a 12 centimeter gun. The service charge consists of 485 kilogrammes (1,069 pounds) of brown prismatic Dunwalde powder. With this charge, the lighter shell will have an initial velocity of 735 meters (2,411 feet), the heavier shell one of 640 meters (2,099 feet) per second. Attention might be drawn to the fact that when rifled guns were first introduced, the highest initial velocity attained was only 300 meters (984 feet). The lighter shell will penetrate a wrought iron plate 1·142 meters (45 inches) thick, or two plates of the respective thicknesses of 0·55 meter (21·65 inches) and 0·838 meter (33 inches), placed a short distance from the muzzle of the gun. In the case of the heavier projectile, the figures are 1·207 meters (47·52 inches), 0·60 meter (23·62 inches), and 0·88 meter (34·64 inches) respectively. As far back as 1868, the artillery of the day was unable to penetrate as many millimeters of armor as now centimeters; its penetrative power has consequently increased tenfold, and Krupp is now able to pierce with his new gun an armor plate three times as thick as the bore of the gun. But he is reported to be even now endeavoring to surpass his latest achievement, for a 45 centimeter (17½ inch) gun is in contemplation, weighing 3,000 cwt. The shell to be fired from this piece of ordnance is to weigh 30 cwt., and to be 1·80 meters (nearly 6 feet) long.

A SELF-CLEANING METAL VALVE.

The illustration herewith shows a valve which turns or rotates on its seat before and after the water or steam, or both, are turned on or off, this rotating and grinding action being designed to at once repair any damage caused by the cutting and destructive force of anything in the water, as well as clean off lime scale or rust. The stem of the valve, as will be seen by the engraving, has an enlarged inner end portion, screw-threaded on its exterior, which engages a screw-thread in the barrel. The valve, which is shown closed upon its seat, is connected in a free manner with the inner end portion of the stem by a stud entering loosely within an axial recess, the parts being further united by a screw or pin fitted to pass freely through a longitudinal or oblong slot in the enlarged portion of the stem. In closing the valve, both valve and stem move longitudinally until the valve rests upon its seat, after which, by continuing to work the stem in the same direction, the valve is simply rotated, while the stem is both rotated and moved inward longitudinally. The greater the pressure on the valve, the better it will polish both itself and its seat, and no leather or rubber is used in connection with it.

This invention has been patented by Mr. Samuel W. Smith, of Pinley House, near Coventry, Warwick County, England.