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 diameter 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 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.

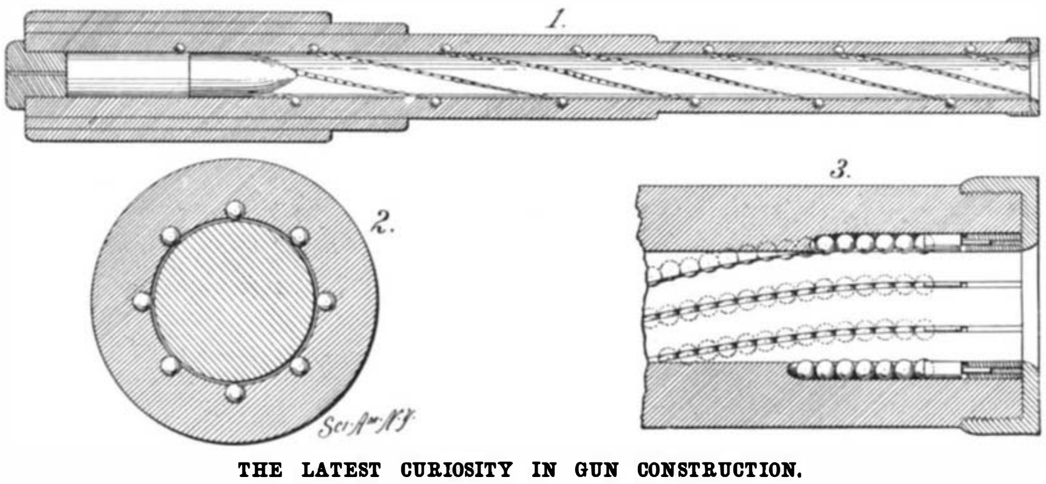
"This is to be accounted for in two ways. First: The elasticity of the balls and the smooth-walled projectile; second, from the fact that the projectile gets away from the gun (calculus will prove this in addition to actual trials that have been made) in one-fortieth [sic] (approximately) of the time 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



THE LATEST CURIOSITY IN GUN CONSTRUCTION.

as alleged had ever taken place at Sandy Hook or any other government proving ground.

We present illustrations of the gun as being a distinct curiosity showing, as it does, how absolutely Mr. Cullen and the papers that have lauded this invention have failed to understand the elementary principles of the modern rifled gun. Curiously enough they have overlooked the fact that the balls, being locked in by a cap at the muzzle, *could not roll*.

As a matter of fact the velocity would be reduced, and as the shell has no copper rifling band, it would be shot out of the gun without receiving any rotary motion about its longitudinal axis, the mere surface friction between the balls and the projectile being entirely insufficient to overcome its inertia.

So far as the velocity of the projectile is concerned it would be reduced below that of an old black powder weapon. The absence of the rifling-band which, in the ordinary type of gun expands under the pressure of the powder gases, filling the rifling and making a tight gas-check to prevent the white-hot powder gases from rushing past the projectile, would render the gun worse than worthless. The gases would rush through the grooves in in which the balls are placed, and through the clearance space between projectile and gun, burning out the balls and the inner tube only less rapidly than streams of boiling water would cut channels in a block of ice.

That such a delusion as the Cullen ball-bearing gun should have been given publicity to such an extent in the public press, leads us to think that either the journals in question were very hard up for matter, or that the "military expert" must have been enjoying a temporary leave of absence.

A FRENCH TROLLEY AUTOMOBILE.

Of late years various attempts have been made to run an electric carriage by current drawn from an overhead trolley wire. The chief obstacle encountered in using an aerial conductor was the difficulty of holding the trolley wheels in contact with the wires, particularly when the vehicle was rounding curves. The results obtained were not very encouraging. The underrunning trolley wheel carried on a pole, could not be used; for the carriage could not turn out of the way of other vehicles on the road. The substitution of a cable for the pole and the employment of a trolley running over instead of under the wires prove no more successful; for the trolley was merely dragged along by the vehicle. These difficulties seem to have been very ingeniously overcome in a system devised by a French engineer, M. Lombard-Gerin, in which a self-propelling trolley is employed, running along at a speed corresponding with that of the vehicle to which it supplies current.

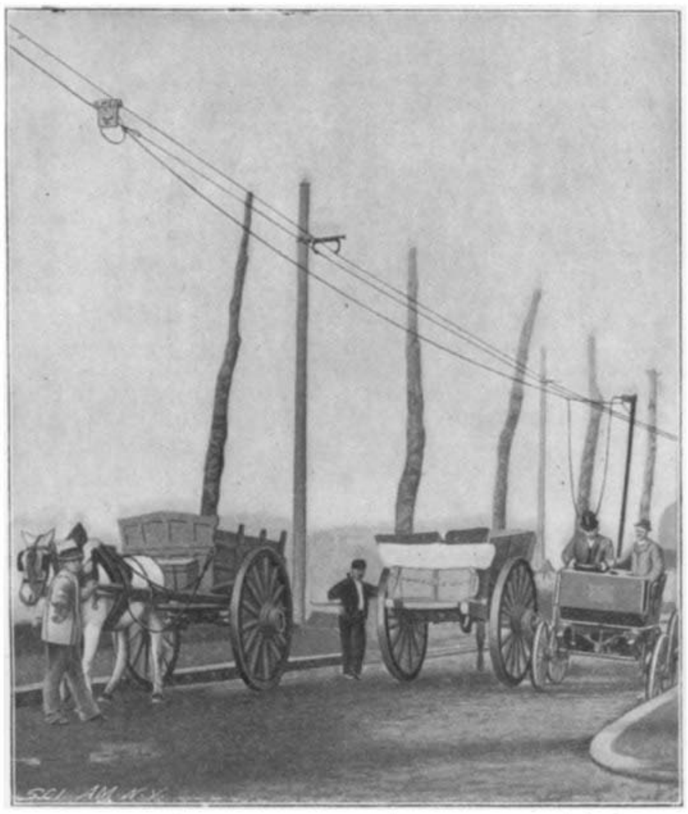
The trolley is driven by a small, three-phase, induction-motor, supplied with current generated by the motor of the vehicle. The trolley-carriage comprises two metal wheels running on the feed and return wires and serving to make the contact. Between these wheels are two insulating, fiber friction-wheels, which engage the motor and thus drive the trolley-carriage. The trolley is driven at a speed slightly greater than that of the vehicle. This small excess of speed is absorbed by the slip of the motor, the slip between the friction wheels and motor, and the slip of the trolley-wheels. Tension on the cable increases the resistance and consequently the slips. The trolley-motor is provided with an electromagnetic friction-brake, actuated by current taken from the trolley-line. The trolley-carriage is elastically suspended by means of springs, the tension of which can be regulated as desired. The cable leading to the vehicle is connected with a double frame on the carriage by a universal joint, which enables it to swing in all directions. The entire trolley-carriage weighs only forty pounds (18 kilos.), for the reason that aluminium is largely used in its construction.

The vehicle-motor is of the continuous current, series wound type. At the side opposite the commutator, the armature carries three rings connected with the winding at three points separated from one another by a distance equal to one-third the angle between two like field poles. The three-phase current generated by the motor flows through three conductors in the flexible cable, directly to the three-phase motor of the trolley-carriage. The speed of the trolley motor depends on the frequency of the three-phase current by which it is actuated; and this frequency in turn depends upon the number of revolutions of the carriage motor. Hence the speeds of the trolley and vehicle motors are practically synchronous; and the trolley carriage automatically regulates the rate of its motion to that of the vehicle.

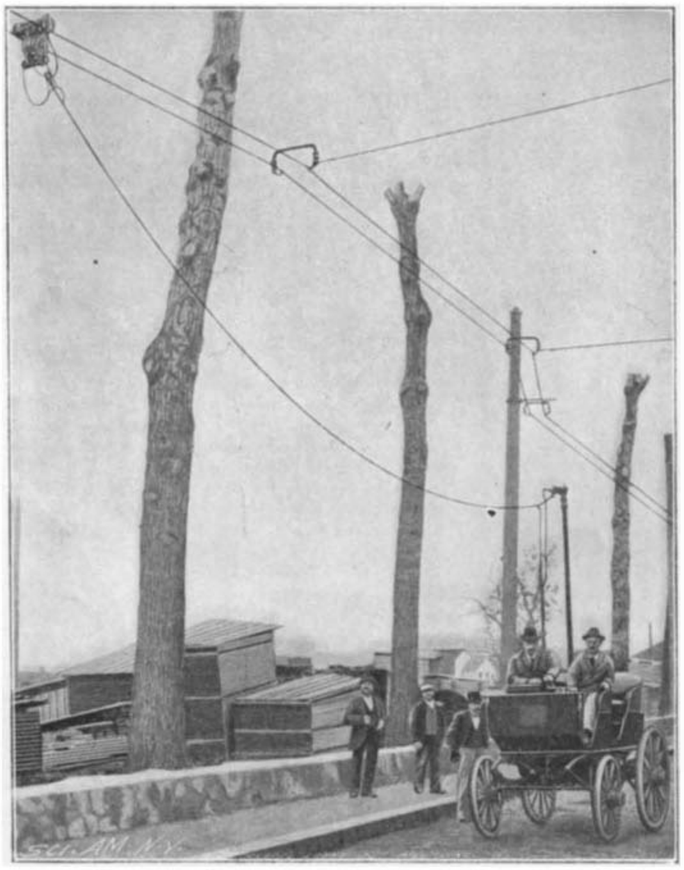
The flexible cable is composed of six conductors.

THE AUTOMOTOR TROLLEY.

Two wires of large cross section serve the purpose of conducting the overhead current to the motor of the vehicle. Three smaller wires supply the trolley-motor with the triple-phase current generated by the automobile-motor, and one small wire connected with a pedal in the carriage serves to throw the magnets of the trolley-motor brake into the circuit of the main line. The brake is used when the trolley is running on a steep incline of the wire. The carriage is not essentially different from the ordinary electromobile.



TROLLEY-AUTOMOBILE PASSING VEHICLES ON THE ROAD.



AUTOMOBILE FED BY AUTOMOTOR TROLLEY.

It is provided with a pole which carries at its extremity a junction-box for the reception of the cable. The boxes of the carriages on the line being similar and interchangeable, it is possible for vehicles running in opposite directions to exchange their cables and continue their journey. To permit the trolley to move in either direction a pole-changing switch forms part of the three-phase circuit, so that the connections of two of the conductors can be reversed, to change the direction of the motor's rotation.

M. Lombard-Gerin's system has been tried on an experimental line 900 meters in length, on the Quai d'Issy-les-Molineaux along the Seine, just outside of the city of Paris. According to Le Génie Civil, the results of severe tests made on this line were very encouraging.

A Congress on the History of Science.

Among the different congresses to be held in Paris at the time of the Exposition, that devoted to the history of science promises to be one of the most interesting. This is a branch of the general section of comparative history and has been organized with a view of bringing together the persons interested in this subject, to establish a resumé of the history of the leading sciences from antiquity to the present day, and to study the proper methods of increasing the researches founded upon original documents. The organization committee have proposed a certain number of questions to be considered, the intention being not to make an exhaustive study of each, but rather as showing where the support of new documents and researches will be the most desirable. Among these may be mentioned the following: Origin of modern numerals; history of astrology, relating especially to the influence which its doctrines have exercised upon the development of astronomy; history of the establishment of units of measure; ancient mathematical instruments, applied to surveying, astronomy, measure of time, etc.; divers meridians of longitude; establishment of the principles of dynamics; alchemy and chemistry; ancient and modern philosophical and scientific theories; geology and physical geography in antiquity; evolution of anthropology and paleontology; history of medicine and hygiene. Communications may be submitted in the principal languages, and in this case notification should be given before the first of June.

The April Building Edition.

The April issue of the BUILDING EDITION OF THE SCIENTIFIC AMERICAN is one of the finest numbers ever published of this artistic periodical. The colored plate represents a modern residence at Plainfield, N. J. A residence at St. Louis, Mo., is illustrated by a number of views showing the exterior and the beautiful interior. The Architectural League exhibition forms the subject of two engravings. Prof. C. F. Holder has an article entitled "The Old Missions of California on the Old King's Highway." It is accompanied by an exquisite full-page group showing four of these interesting old buildings. There is also an unusual collection of moderate priced houses. The literary contents afford good reading.

The Current Supplement.

The current SUPPLEMENT, Number 1266, has many articles of unusual interest. "The Sewerage Problem of the City of Worcester" describes a most important plant which has been in successful operation for some time; it is fully illustrated. "English Artillery in the Transvaal" is a timely article. "Destroyers for the Japanese Navy" is accompanied by illustrations of one of these little vessels making a speed of 31·15 knots. "The Classification of Warships" is a most important article by Frederick P. Jane. "The Bird-Stone Ceremonial" is an abstract of a monograph by Prof. Warren K. Moorehead and is fully illustrated. "Is the Steering of the Modern Screw-propelled Vessel Defective?" is the conclusion of a valuable article by the late Capt. Cornelius W. McKay. "Tooth Powders" gives the method of making them in great detail.

Contents.

(Illustrated articles are marked with an asterisk.)