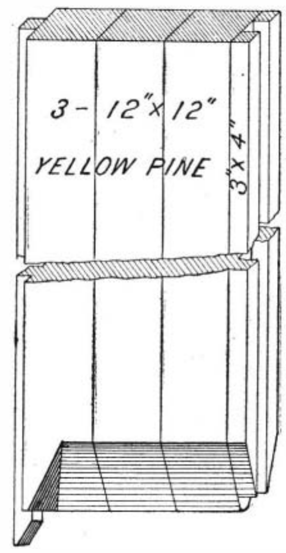
THE RAPID TRANSIT SUBWAY TUNNEL UNDER THE HARLEM RIVER.

In our issue of October 31, 1903, we described the novel method of construction used in building the Rapid Transit Subway tunnel under the Harlem River. This tunnel construction, it will be recalled, was invented by Mr. D. D. McBean, one of the contractors for that section of the Subway, to meet the difficult requirements of building the tunnel through the soft mud just below the surface of the river bottom. In order to prevent obstruction to the navigation of the river, it was required that the tunnel be built in two sections. Experience gained in the construction of the first half of the tunnel led to the development of important improvements which are now being successfully employed in the building of the second half. The original plan was to dredge out a channel in the mud along the line of the tunnel, drive two walls of sheet piling along this line and across the ends of the tunnel section and then to sink and bolt onto the sheet piling a heavy timber roof, thus forming a caisson within which, under a suitable pneumatic pressure, the workmen could construct the tunnel proper. In the improved method the same process is followed, except that the sheet piling is cut off on the spring line of the tunnel and the upper half of the tunnel, which is assembled in a pontoon at the surface of the river, is lowered and permanently secured to this sheet piling in place of the timber roof. Fully one-half of the work is thus done above water, and the remainder of the work, namely, that of forming the lower half of the tunnel, is done under a comparatively low pneumatic pressure. Considerable saving is effected in the amount of timber used, since the sheet piling is cut off twelve feet lower down than in the first half of the tunnel, and the timber roof is entirely dispensed with.

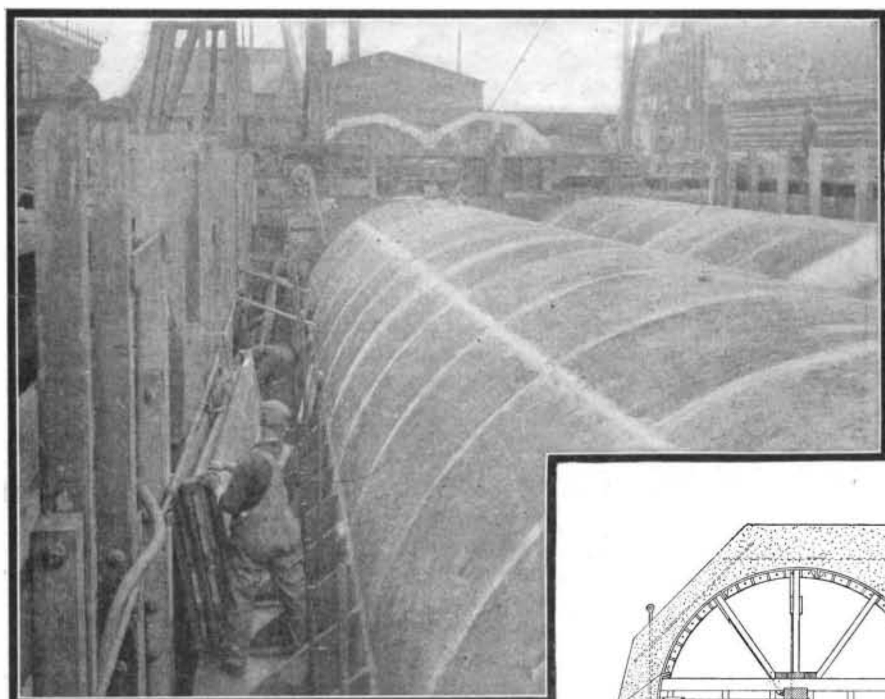
The improved method of construction may be described in detail as follows: As just stated, a channel was first dredged along the line of the tunnel, to a depth of about 12 feet below the top of the finished tunnel. Piling was then driven along each side of the channel to support two working platforms. In the channel, rows of foundation piles were driven at intervals of 8 feet. These were cut off about 20 inches below the spring line of the tunnel by a sawing machine traveling on the working platforms. The sheet piling was then driven in place to form the sides of the tunnel caisson. This sheet piling was made up of compound piles consisting each of three 12 x 12-inch yellow pine timbers, carefully planed to size and bolted together. A tongue was formed at one edge of the pile, and a groove at the opposite edge by fastening wooden strips thereon, as shown in one of our detail views. The tongue strip was made to extend somewhat below the rest of the pile, and the latter was tapered at its lower end in such manner that when it was driven it would be crowded against the pile previously driven, producing a tight joint therewith. In order to insure perfect alinement of the sheet piles, a guide frame was sunk to position on the foundation piles and brought to accurate lateral adjustment thereon, by means of wedge blocks. This frame was built with a pair of guide rails at each side, each pair being spaced apart the exact width of the sheet piles by blocks located at intervals of 8 feet. Between these rails the sheet piles were driven and were further guided by rails on the working platform.



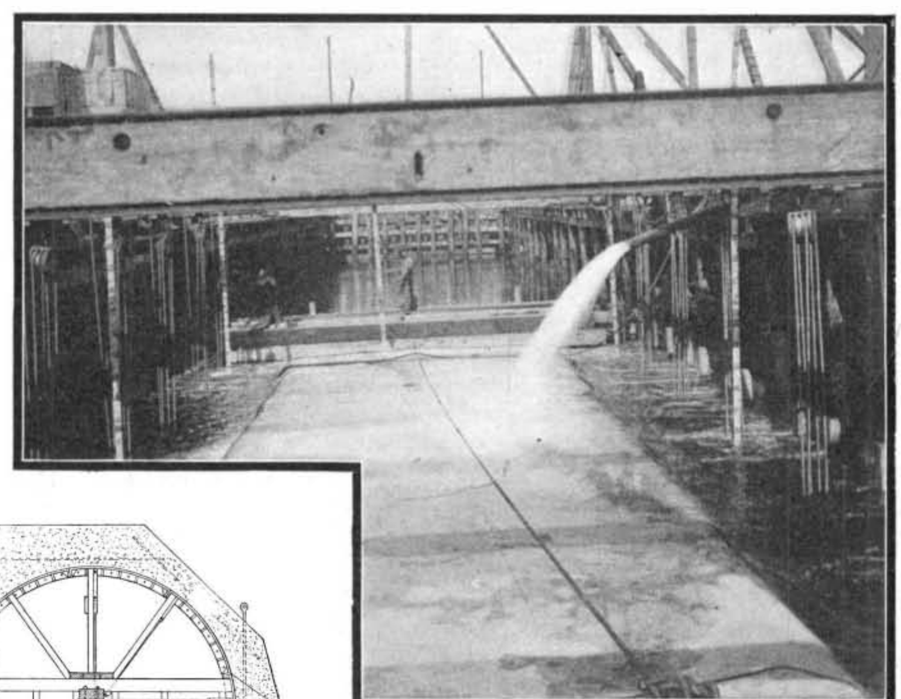
SHEET PILING USED FOR THE HARLEM RIVER TUNNEL.

A diver was stationed below to insure proper setting of the pile. Whenever a spacing block was reached he removed it, drilled a hole through the pile sheeting, and bolted the rails together against this sheeting. The diver also saw to it that a perfect joint was maintained during the driving of a pile. If any deflection occurred, it indicated the presence of a bowlder, or other obstruction. The pile was then withdrawn and three or four steel pilot piles were driven in its place. These either cleared the way for the wooden pile, or by the relative depth to which they would penetrate, indicated the form of the obstruction encountered, and the latter was then drilled into and dynamited. These pilot piles were but little used in the second half of the tunnel, as few obstructions were met with; but in building the first half of the tunnel they were constantly brought into use to locate the many bowlders encountered. In this manner the sheet piling was very closely fitted—so closely, in fact, that in the second half of the tunnel, for a length of 264 feet, the actual length of the sheet piling exceeded its theoretical length by a small fraction of an inch. After the two walls of sheet piling had been driven, they were cut off on the spring line by the sawing machine on the working platforms. The tracks on which this machine traveled were given the exact pitch or grade of the tunnel, and then by preserving the same reach of the saw shaft, the circular saw was made to cut the piling exactly on the spring line of the tunnel. This done, the work of assembling the upper half of the tunnel was begun. It was decided to build the tunnel roof in three sections of about 90 feet each, because, owing to requirements of grade, the entire length would make an awkward piece to handle. A pontoon was constructed between the working platforms, and in this the cast-iron sections of the tunnel shell were set up and bolted together. The ends of the half-tunnel were closed by vertical diaphragm plates, and the bottom was closed by a heavy wooden flooring. After the metal shell had been covered with concrete, which was molded to the form shown in our

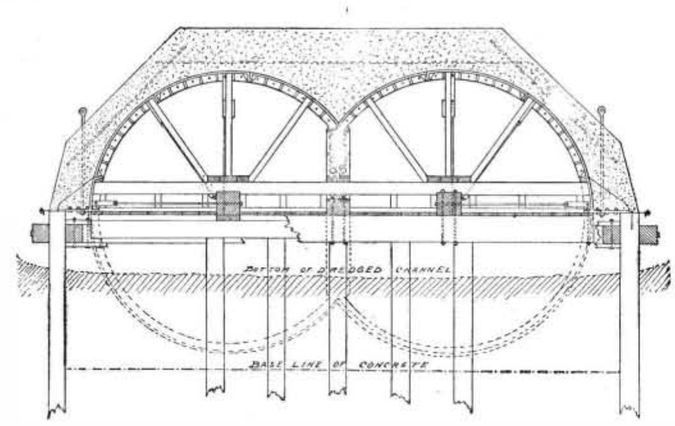
(Continued on page 8.)



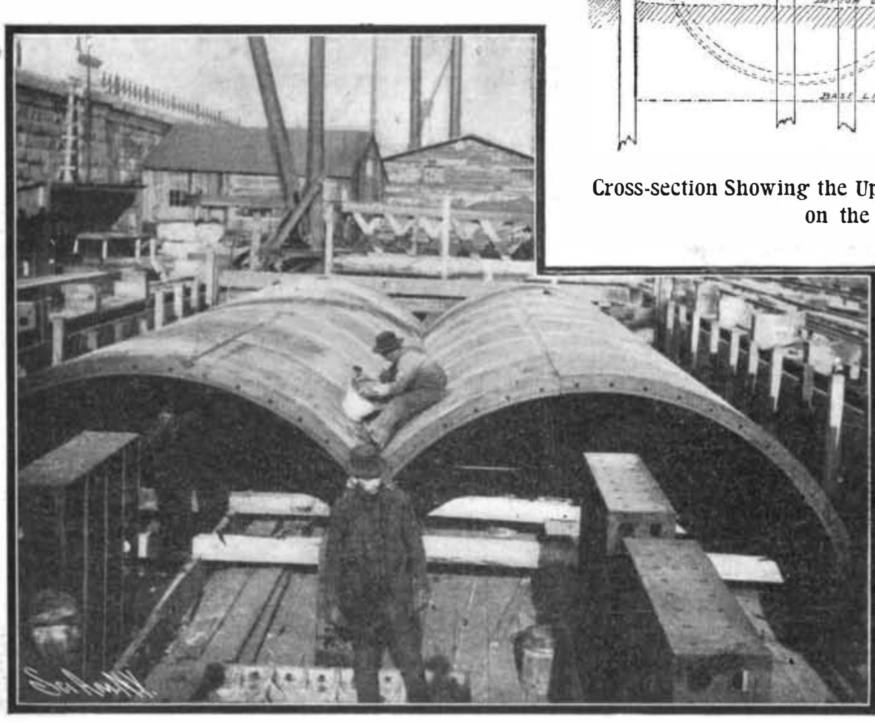
The Upper Half of the Tunnel Shell Assembled.



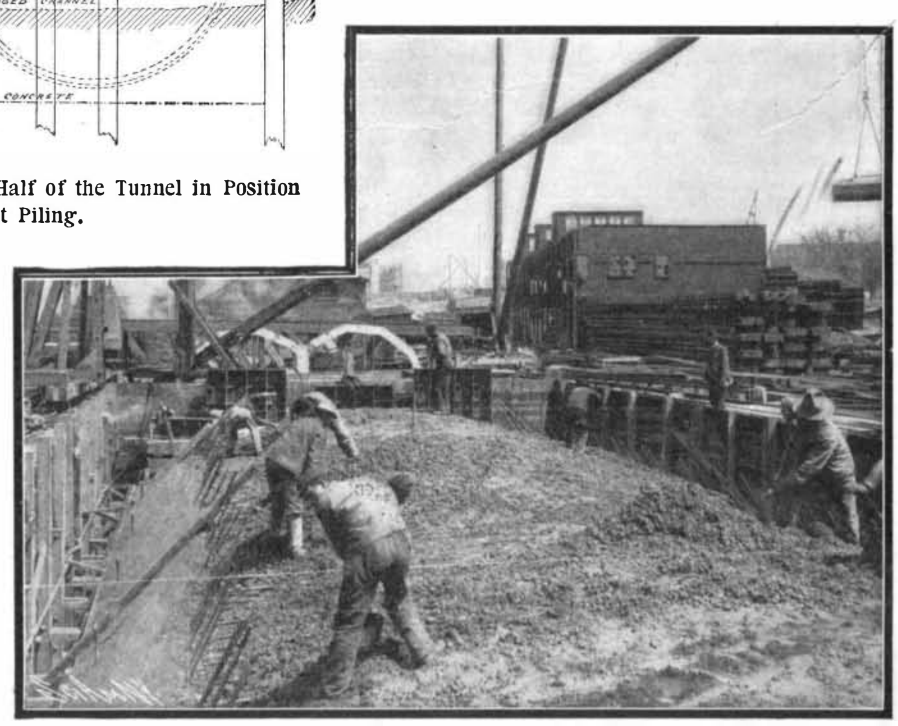
Sinking the Pontoon.



Cross-section Showing the Upper Half of the Tunnel in Position on the Sheet Piling.



Bolting Together the Cast Iron Rings of the Tunnel Shell.



Molding the Concrete Over the Tunnel Shell.

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Cotton wool, used on the stage for fruit, snow effects, etc., as well as all the varieties of paper employed, were successfully subjected to the same tests. Dress fabrics, plushes, draperies, and baize, all alike refused to break into flame, though held in the flaring gas jets long enough to be consumed by dozens of yards, if untreated.

What is technically known as a "profile," or tree form wing, was propped against the row of gas jets and left there for twenty minutes, with no other consequence than that the wood had been charred through, and broke on being handled; artificial flowers in garlands resisted ignition in varying degrees, the dyes used for pink, and perhaps one other color, having presented an admitted obstacle.

During the progress of the interesting experiments, a director of the theatre wrapped himself in a white sheet and passed himself along the row of jets, to be burnt. They would not, however, burn him, although in the case of the scenery "cloth" lowered down upon the men on the stage, they left blank patches and holes. The flimsiest kinds of clothing were lowered from the "flies" until they reached the flaming jets, but they were merely discolored.

The greatest interest was taken in the experiments with wood. The solution to fight fire is not merely applied to the surface, but is forced into every pore and fiber of the wood, and does not interfere with the polishing, where polishing is required. When this has been done, it is possible successfully to apply the test of abnormal heat to a splinter taken from the center of a block of wood.

A severe test was made during the experiments at the theatre, showing thoroughly the effect of the fire-resisting solution on the impregnated timber and the various species of material used in stage production.

Not satisfied with holding fabrics and scenery in the flames, or having great sheets of them lowered into the gas jets from the roof of the theatre, one of the directors had two powerful electric arcs lighted, and ordered successively timber, drapery, and other materials to be placed in the glowing arc. The pieces flamed as before, but certain pieces of every material that he tried to ignite, even including the cotton wool and paper, would do nothing but consume away in smoke.

Articles subjected to the fire-resisting treatment emit a smoke, but this is considered far less suffocating than the fumes from material which is not so treated.

The secret revealing the ingredients of the fireproofing solution so successfully employed by the manager of the Alhambra has not yet been divulged, but it is promised ere long that the theatrical world at large will be made fully acquainted with this preparation.

Progress of the Beet Sugar Industry, 1903.

A report on the Progress of the Beet-Sugar Industry in 1903, prepared by Charles F. Saylor, special agent of the United States Department of Agriculture, and printed by authority of Congress, is about to be issued. It shows that there has been an increase in the number of beet-sugar factories in the United States from 43 at the close of 1902 to 56 at the beginning of 1904. Fifty of these were in operation during the "campaign" of 1903.

According to the report the sugar-beet crop of 1903 amounted to a little more than 2,000,000 tons harvested from 242,576 acres, the average yield being about 8½ tons to the acre. The prices which the farmers received for beets from the different factory companies ranged from $4.50 to $5.60 per ton, the average being nearly $5. The average gross returns to the farmers were, therefore, $42.50 per acre. The estimated cost of growing beets by irrigation is $40 per acre, and in sections where irrigation is not necessary, $30. If $35 be taken as the average for the whole crop of 1903, the average net profit to the farmers was $7.50 per acre. In some of the sugar-beet areas, the returns were very much higher than this general average. As in the production of other crops, much depends on the season, the character of the land, and the kind of farmer who grows the beets. Many farmers have cleared from $25 to $50 per acre. The best result on record for 1903 was secured by a farmer of Otero County, Colorado. He grew one acre of sugar beets at a cost of about $37.50; the yield of beets was 33 tons, for which he received $158, his net returns being about $130.

The amount of sugar made from the beet crop of 1903 was 240,604 tons, as compared with 218,405 tons from the crop of 1902, and 184,605 tons from that of 1901.

Within the past few years there has been a remarkable increase in the percentage of sugar in the beets. A few years ago 12 per cent of sugar was the standard. Last year in many cases the entire crop sold to a factory averaged 15 to 18 per cent.

There is a prospect that many new factories will be built in the next year or two. Many improvements are being made in methods and machinery used in the growing and handling of beets. The beet pulp produced by the factories is used by the farmers as feed for their stock more generally than heretofore.

The report will be for distribution by Senators, Representatives, and Delegates in Congress, and by the Department of Agriculture.

Engineering Notes.

After prolonged delay the Italian government has at last introduced the measure sanctioning construction of the Apulian aqueduct. This project consists of an irrigation system for the arid tableland of Apulia. The aqueduct is to cross the Apennines by means of a tunnel 7½ miles long, and will have several subsidiary canals, so that twenty-one communes of the province of Foggia, and all those of the provinces of Bari and Leece, will receive an adequate supply of water. These communes contain a population of nearly two millions. It is estimated that the scheme will cost $25,000,000, and will not be completed before the year 1920.

Owing to the complete success that has attended the irrigation of the land by the erection of the barrage at Assuan on the Nile, a scheme is being formulated for increasing the height of the dam by 19 feet 6 inches. The realization of such a project will enable the Irrigation Department to retain behind the barrage an additional thousand million cubic meters of water, which will suffice for an increase to the perennially irrigated area of half a million acres and add $75,000,000 to the wealth of Egypt. According to the recently-published report of the Assuan reservoir compiled by Sir William Willcocks, late Director-General of Reservoirs, the whole of the water kept back by the dam has been devoted to special tracts, and the Egyptian government cannot entertain any applications for water. The cost of raising the barrage will involve an expenditure approximating $2,500,000, which sum will be defrayed out of the public debt surplus.

A more hygienic and expeditious system of emptying cesspools is to be experimented with by the Rumford Rural District Council in Essex (England). The apparatus comprises a double-cylinder steam-propelled motor carrying a large galvanized-steel tank with a capacity for 700 gallons of sewage. The tank is filled from the cesspool by suction, a steam air pump being attached to create a vacuum for this purpose. The foul sewer gas liberated by the disturbance of the fæcal matter is exhausted from the tank and passed through the boiler furnace where it is consumed, so that the whole work can be done without creating a nuisance. The motor will travel at speeds varying from six to eight miles per hour, will be fitted with reversing gear, and, in addition, a special device for rope haulage, should the machine get on soft ground from which it cannot propel itself.

It is a singular fact that the two great coal-bearing formations of the United States, viz., Carboniferous and Cretaceous, should be so widely separated. The first is found east of the Missouri River with its greatest development in the Appalachian region, and the second west of the 105th meridian. Yet, it is extremely fortunate for the operator that this separation exists since the great treeless plains intervene and furnish a growing market for his product, particularly for that of the mines situated on the eastern flanks of the Rocky Mountains and facing the so-called arid plains. Coking, gas, steam, and domestic coals occur along these hills, in Colorado with some breaks, from New Mexico to Wyoming. The arid plains are fast being dotted with towns containing manufacturing, lighting and power plants, and the market constantly grows, its eastern limit being practically the Missouri River. The coking-coal deposits are the most valuable and are situated largely in the southern part of the Raton field in Southern Colorado and Northern New Mexico.—Mines and Minerals.

An electric railroad is to be constructed up Mont Blanc on plans prepared by M. Ballot. The cog-wheel system as used on the Jungfrau road is to be adopted. The railroad will start from the village of Les Honches, 3,260 feet above sea level, and will climb 11,710 feet to the upper terminus, at a point near the Petits Rochers Rouges. The track will be nearly eleven miles in length, of which more than sixty miles will be in tunnels. The first station will be at the top of the Gros Bechand, 8,410 feet high, from which point of vantage a splended view of the Chamonix Valley is obtained. The second station will be just below the summit of the famous Aiguille du Gouter, at an altitude of 12,600 feet. Thence a hard snow path will lead to the Grand Plateau. The third station will be located in close proximity to the observatory and the refuge hut, at an altitude of 14,300 feet. From here a tunnel will be cut through the northern slope of Mont Blanc proper to the terminus, situated 14,970 feet above the sea. The highest summit, 810 feet above the terminus, will be reached from there on foot or by sledge. The entire train journey will only take two hours.

THE RAPID TRANSIT SUBWAY TUNNEL UNDER THE HARLEM RIVER.

(*Continued from page 6.*)

cross section of the tunnel, the pontoon was sunk, lowering the tunnel section into the water until it floated. One end of the pontoon was now removed, permitting the pontoon to be drawn out from under the tunnel section. Loose stone was loaded onto the tunnel structure, until its buoyancy was overcome, when it was lowered to position on the sheet piling by slacking off on the sixteen supporting tackles. Careful measurements were taken to bring the section to perfect alinement before it was lowered. A diver now removed a plate of the tunnel shell, entered therein, and bolted the end flanges of the tunnel to the flanges of the shore section. After the plate had been again bolted in place, the water was pumped out of the tunnel and air pumped in. It will be observed from our section view, that along the horizontal flanges of the tunnel, angle iron strips are secured, just outside the line of sheet piling. Between these strips and the piling, wooden blocks were driven to wedge the tunnel shell in place. So accurate was the alinement of the piling that the greatest variation discovered between the piling and the angle strips was less than half an inch. While the upper half of the tunnel was being constructed, metal tubes were set in the concrete, and by means of long rods passed through these tubes, drift bolts were now driven into the upper ends of the sheet piles, securing the horizontal flanges of the tunnel to them.

The same process was followed in sinking the other two tunnel sections, the last section having been successfully lowered in place two weeks ago. Mud is now being dumped on the tunnel to completely bury it, and to entirely overcome its buoyancy. The diaphragms which separate one section from the other are cut through, and the process of excavating the bottom of the tunnel to the required grade is under way. As soon as this is done the lower half of the tunnel shell will be assembled, and the concrete backing filled in.

It will be observed that this method of tunneling is much simpler and less dangerous than the shield method now commonly in use. In fact, the shield method could not have been used in constructing the Harlem River tunnel on the grade required, because the mud which forms the bottom of the river is too thin to support the necessary air pressure, and even if the shield were driven through at a much greater depth than that of the present tunnel, blowouts would be sure to occur. In the shield system of tunneling, a great deal of trouble arises from the fact that the air pressure at the top of the shield is just as great as that at the bottom, whereas a greater pressure is required at the bottom than at the top; and it is due to the impossibility of regulating this pressure as required for different parts, that blowouts occur. In the new system conditions are entirely changed and these difficulties are avoided.

The feasibility of building a tunnel under the Hudson or East River by this system has not yet been put to a practical test; but we see no reason why it could not be successfully done, and much more quickly and economically than with a shield. The work could be done in short sections, and could be attacked from a number of different points at once. While the dredging is being done in one section, the piling could be driven in another; at the same time workmen could be assembling the tunnel roof, while in a third section the lower half of the tunnel would be under construction within the tunnel caisson. Speaking of the application of this system to the Hudson and East River tunnels, Mr. William H. Burr, of Columbia University, who was recently appointed a member of the Panama Canal Commission, says: "No methods or procedures other than those employed in the Harlem River work would be needed in the construction of these tunnels, nor would the adaptation of these methods to the greater depth of work in the North and East Rivers involve any special difficulty. The requisite dredging would be carried on at no greater depths than those already reached in successfully conducted dredging work already completed at a number of points. In this system of tunnel construction, any shape desired may be given to the cross section, also any combination of metal tubes and concrete, either plain or armored, may be employed, or again a structure of all concrete steel may readily be built. Furthermore, a twin double-track tunnel may be as readily built as a single tube. Such a double-track tunnel with its great mass would possess materially increased rigidity and resistance to vibration under passing trains over two single-track tubes. This system of tunneling permits a much more rapid rate of working than other methods with which I am acquainted. It is reasonable to estimate that a double-track tunnel under the North River could be completed within two years from the time of beginning the work."

John G. Meiggs recently died in London. He was best known to engineers for having built the famous Oroyo Railroad.