PROGRESS OF CONSTRUCTION OF THE RAPID TRANSIT TUNNEL.

In spite of the long and exceedingly trying summer weather, the work of constructing the Rapid Transit Tunnel has been pushed forward with greater activity than at any other period since the work was opened in March of the year 1900. At the present time there are 8,000 men employed on the work, and up to date $9,700,000 has been expended. This represents over a quarter of the contract price for the work of $35,000,000.

The force of men is at work in day and night shifts, and at the present time the total monthly cost of the construction averages nearly $1,000,000. If there should be no unforeseen obstructions and delays, the railroad will probably be completed and in operation by Christmas of 1903 or early in the year 1904. The line of the tunnel has been opened over two hundred blocks, while on about thirty blocks the tunnel is practically completed.

The accompanying progress plan of the work shows the location of the road. Commencing at City Hall Park there is a single-track loop, which swings over to the west in front of the City Hall, and curves around to a junction with the main four-track line, near the Hall of Records. Southward from the station a two-track tunnel will be built below Park Row and Broadway to Whitehall Street, where it will descend and pass beneath the East River to Joralemon Street, Brooklyn. From Joralemon Street it will pass to the City Hall of the Borough, and be extended to the Flatbush Avenue station of the Long Island Railroad. From the City Hall, Manhattan, northward there will be a four-track tunnel, which will extend beneath Center and Elm Streets to Lafayette Place; from which it will diverge diagonally northeast to Fourth Avenue, and up Fourth Avenue to Forty-second Street. Here it will swing to the left, following Forty-second Street to Broadway, when it will turn to the north again and follow Broadway to 104th Street. At 104th Street it will split into two branches, the easterly branch diverging as a two-track structure, and passing diagonally beneath the northwest corner of Central Park to Lenox Avenue, which it will follow to 141st Street. Here it will swing to the right and pass beneath the Harlem River. From the river it will be carried, chiefly as an elevated structure, to Bronx Park. The westerly branch will extend up Broadway as a three-track structure from 104th Street to 145th Street, and from 145th Street to the terminus at Bailey Avenue it will be a two-track structure.

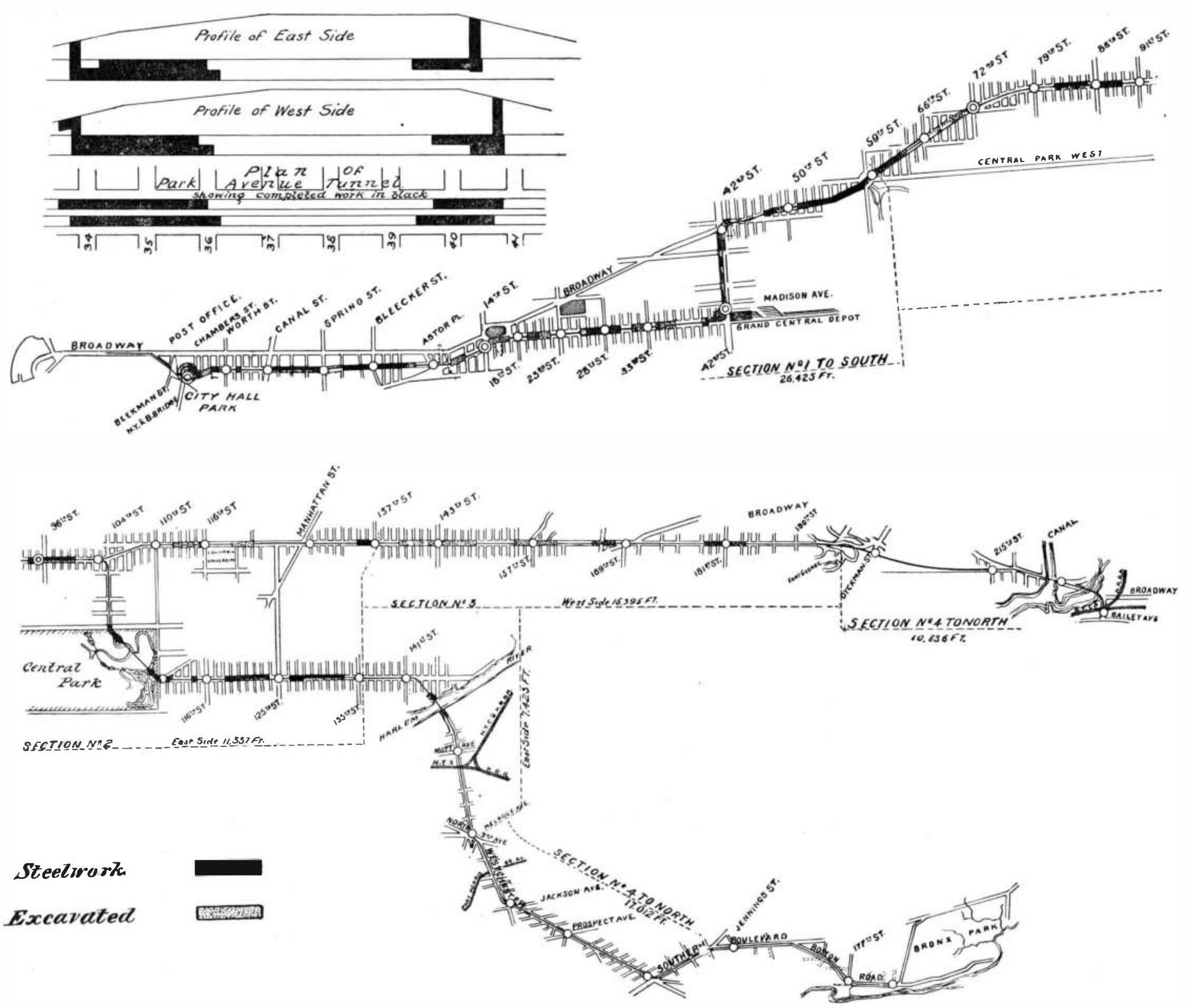
The work of excavation is advancing so rapidly that already orders have been given for the necessary steam and electrical plant for the power station, and John B. McDonald, the contractor, and Chief Engineer William Barclay Parsons, with others, have left for London and Paris to inspect the underground systems in those cities and determine upon the best system of traction to employ on the tunnel. We presume that this trip will include a visit to Budapest, and a thorough investigation of the Ganz system, for which the contractors of the underground railroads in London have lately claimed an economy of 30 per cent as compared with the ordinary direct-current system as used on the Metropolitan railways in this city. Work on the loop at City Hall Park is well advanced. A considerable part of the concrete arched tunnel has been built and about 70 feet of this completed tunnel has been filled in, and the original surface restored. From Chambers to Duane Street two tracks out of the four have been entirely excavated, and from Duane Street to Pearl Street the full four-track width is excavated and roofed in and the steel in place. From Leonard to Franklin Street ground has been broken and excavation is well under way. From Howard Street to Grand Street excavation has been commenced, and from Grand to Spring Street the width of two tracks has been excavated and the steel framework of the tunnel is in place. From Spring Street to Prince Street the width of two tracks has been excavated along the western side of the tunnel, and from Prince Street to Bleecker Street excavation is completed, the steel, walls and roof are in place, and the concrete arches have been turned. From Bleecker Street to Fourth Street all of the excavation and steel work has been executed for about a total of half the distance. The tunnel through Lafayette Place is about half excavated and a third of the steel is in place. From 10th Street to 12th Street all the excavation has been done, and the steel and concrete work is about half completed. Through Union Square from 14th to 17th Street the tunnel is entirely through rock, which here is met near the surface. The surface tracks of the Metropolitan Street Railway Company have been moved over to the eastward until they are clear of the easterly line of the tunnel. Excavation has been carried out to grade along the westerly side, and the rock is gradually being blasted back to the easterly line. From 19th Street to 22d Street three-quarters of the excavation is completed and half of the steel work has been erected. From 25th to 26th Street excavation has been carried on for about half the block, and is practically completed; on the west side of the tunnel from 26th to 30th Street, the tunnel is excavated and about three-quarters of the steel work completed. From 31st to 33d Street excavation has been completed for the full width of the four tracks.

An exceedingly interesting portion of the work is that which extends below the level of the Fourth Avenue tunnel. At this point the four-track tunnel divides into two two-track tunnels, each running below and somewhat to the side of the Fourth Avenue tunnel. Two shafts have been sunk at 34th Street and excavation has been completed in each tunnel for a distance of two blocks and a half. Between 40th and 41st Streets two shafts have been sunk and a top-heading has been driven for a distance of a block and a half, the full section of the tunnel being excavated for three-quarters of a block in the easterly tunnel.

On 42d Street, between Fourth Avenue and Broadway, the work has been carried forward with considerable activity. At the turn from Fourth Avenue and 42d Street, at the location of the 42d Street station, a large excavation has been made. There is another excavation at 42d Street and Madison Avenue for two blocks, which includes the width of two tracks. Between Fifth and Sixth Avenues the excavation is about complete for the width of two tracks on the south side, and a considerable amount of steel has been built in. From Sixth Avenue to Broadway all the excavation has been done and nearly all of the steel is in place. The excavation at this point has been carried out by a process known as "slicing," in which the roof is carried by temporary struts until the steel posts are in place, the balance of the material being subsequently removed without disturbing the roadway.

From Long Acre Square to 45th Street there are intermittent stretches of excavation, but, as yet, no steel has been put in place. From 47th Street to 50th Street the material has been excavated along the western side for a width of two tracks, the steel has been erected, and "slicing" has been commenced across to the eastern side of the tunnel. Excavation for two tracks has also been carried along on the eastern side from 51st Street to 52d Street, and also from 53d Street to 57th Street, where the steel has been put in place. From 57th Street to 59th Street the western half of the tunnel is excavated and the steel is being built in. Across the "Circle" all the excavation and steel work is completed, and experimental work is being carried on at the station, which is located here, with a view to determine the best kind of tiling to use in finishing off the many stations throughout the tunnel. From 60th to 64th Street the excavation is all done and about half of the steel is in place. From 64th to 72d Street about half of the excavation is completed, while from 72d Street to 81st Street nothing has, as yet, been done. Part of the excavation and steel work has been completed between 81st Street and 84th Street. From 86th Street to 89th Street the tunnel has been excavated for the full width and the steel work and concreting finished.

From 94th Street to 100th Street excavation has been done off and on, and part of the steel has been placed. On the western branch of the road excavation has been more or less completed between 112th and 116th Streets, but no steel has been put in. Another stretch of excavation exists between 120th and 123d Streets. About half of the foundations for the columns of the Viaduct across the Manhattan Valley have been completed. From 135th to 137th Street the tunnel is completed, with steel and concrete in place. There are stretches of excavation from 140th to 150th Street, while from 155th to 160th Street the excavation is all done, and from 155th Street to 159th Street the arched masonry has been constructed, except at the opening which is left for the station. At 167th Street and 181st Street two shafts have been sunk and the excavation has been run for about an eighth of a mile in each direction, north and south, while about a quarter of this excavation has been



MAP OF THE NEW YORK RAPID TRANSIT TUNNEL SHOWING PROGRESS OF CONSTRUCTION.

taken out to the full section of the tunnel. On the eastern branch of the road a shaft has been sunk at 104th Street and Central Park West, and excavation for the top-heading has been pushed forward for 600 feet in a northeasterly direction. The road is to be carried in tunnel diagonally across the northwestern corner of the Park, and at the northwestern exit about 200 feet of the heading has been driven. North of this about 350 feet of the two-track subway has been entirely completed, and the surface restored, and the traffic of the driveway has been running over it for several months.

The work from 114th to 115th Street is practically completed, both excavation and steel work, and another completed stretch is found from 118th to 120th Street. From 120th Street to 124th Street the excavation is partly done and much of the steel work has been erected. From 126th to 128th Street there is a stretch in practically the same condition. From 130th to 133d Street excavation is well under way, and in places the steel framing of the sides and walls has been erected. At the crossing beneath the Harlem River the excavation of the approaches on each side is well under way.

The progress of construction, as outlined above, is eminently satisfactory and reflects the greatest credit upon both engineers and contractors. If the present rate is maintained, the tunnel will probably be completed and trains running from nine months to a year before the contract date for completion.

In the following issue of the SCIENTIFIC AMERICAN we shall give a series of views showing the various methods of construction adopted in carrying out this great work.

WASTE-HEAT AUXILIARY ENGINE.

In the SCIENTIFIC AMERICAN for March 24, 1900, we published an account of the waste-heat auxiliary engine which has been installed in the laboratory of the Royal Technical High School at Charlottenburg by Prof. Josse. Even at that time this engine was considered to be an original and highly interesting experiment involving the efficiency of steam engines by utilizing the heat of the exhaust steam for evaporating another liquid having a lower boiling point than water, the process being the joint discovery of a Hamburg engineer, Herr G. Behrend, and Dr. Zimmerman, of Ludwigshafen. Through the courtesy of our Consul-general at Berlin, the Hon. Frank H. Mason, we are able to present our readers with a most interesting series of pictures showing the latest developments in the waste heat auxiliary engine.

It is well known that a large proportion of thermal energy delivered to a steam engine from its boiler is lost in the unused steam which exhausts into the air by a non-condensing engine, or is absorbed by the cold water of the condenser in a low-pressure machine. Multiple expansion engines of high efficiency economize this waste power by using the steam successively in a second, third and even fourth cylinder, but even then the loss is considerable, being about eighty per cent of heat, namely, the difference between the temperature of the condenser, 140 deg. F., and that of the circulating water, which will average about 60 deg. F. The idea of the waste-heat auxiliary engine is to utilize this wasted heat for evaporating a liquid which boils, and therefore volatilizes, at a much lower temperature than water. Two such liquids, ammonia and sulphur dioxide, have been successfully used in the refrigerating industry, for the reasons that sulphur dioxide has a viscous consistency and does not attack iron, but, on the contrary, lubricates it, and because the pressure of its vapors at the temperature of waste steam is readily controlled. It has therefore been used from the first as the best material for this purpose. At 140 deg. F. sulphur dioxide vapor has a pressure of 156 pounds to the square inch, while at 60 deg. F., the mean temperature of the cooling water in the condenser, the pressure is about 41 pounds per square inch, thus offering a range of 80 deg. F. through which the exhaust steam from a steam engine will evaporate sulphur dioxide with such energy that its vapor will exert an expansive force. The conservation of this expansive force of this mechanical motive power is the function of the "waste-heat," or as it is otherwise called, the "cold-steam engine." For this purpose an additional auxiliary single-cylinder engine is placed adjacent to the steam engine, and geared either to the same driving shaft or run independently with its own driving shaft and flywheel. The sulphur dioxide is evaporated by the exhaust steam heat in a special type of boiler called the "atomizer." The vapor thus generated passes through the cylinder, and its effective work being done, it escapes into the sulphur dioxide condenser, where it is condensed to liquid form and pumped back into the vaporizer, thus forming a cycle, and being used over and over again indefinitely.

Although the process is technically direct and simple, it was found to possess many mechanical difficulties. All the joints and packing had to be made so perfect that, however great the pressure, none of the poisonous dioxide gas or liquid should escape. In the presence of air or water, the dioxide rapidly oxidizes into sulphuric acid, which attacks iron and other metals. It is, therefore, necessary that the whole apparatus should be air and water tight, and this to resist an internal pressure of 150 pounds per square inch requires the best materials and workmanship as well as intelligent supervision. The surface condenser also offered great difficulties. A cold-vapor cylinder of 10½-inch bore and 19½-inch stroke was attached to a 150 horse power, triple-expansion, Görlitz engine of high efficiency, which is regularly employed by the Technical High School for electric lighting and experimental purposes. The engine, which is shown in one of our engravings, is of an improved modern type, the high and intermediate pressure cylinders being placed tandem and horizontal, while the low-pressure cylinder is vertical, and all three act upon the same crank and driving shaft. The cold-vapor cylinder is made of cast iron covered, not with a heating jacket, but with a simple sheet iron casing packed with felt. It is proportioned for a maximum working pressure of 215 pounds.

The vaporizer and condenser, which are also shown in our engravings, are of cylindrical form and about 10 feet in length. They are set in a steel frame, one above the other, and below will be noticed the pump which ejects the liquid dioxide coming from the condenser up into the vaporizer, as shown underneath the condenser. Both contain a system of tubes very carefully fitted so as to prevent the leakage of water or dioxide. The vaporizer is 34⅝ inches internal diameter and has about 753 square feet of heating surface, by which the exhaust steam of the engine acts upon the liquid dioxide and converts it into vapor. It then passes through the cold-vapor cylinder and returns to the condenser, which has an internal diameter of 41 inches and about 720 square feet of cooling surface. The valves are set in both pipe systems so that sections can be cut out for examination and repair without withdrawal of the dioxide. The feed pump is worked by an eccentric on the main shaft, and to operate it only three-quarters of one per cent of the power developed by the engine is required. The super-imposition of the vaporizing condenser was rendered necessary on account of the lack of space, but they may be placed at any desired position convenient to the engine. The waste heat engine at the Technical High School has been run almost continuously for over a year without accident or any serious difficulty. When the storage batteries are being charged, it is run up to a speed of 168 revolutions per minute.

In the report recently issued by Consul-General Mason appears the following statement:

The load has been a direct-connected continuous-current dynamo, with a rated output, at 150 revolutions, of 400 amperes and 240 volts, which, as the official report states, was sometimes overloaded as high as 40 per cent as a means of testing the increased capacity obtained by the addition of the waste-heat cylinder. The result, in respect to both steam consumption and electrical output, has been measured by the highly perfected standardized instruments and methods with which the Technical High School is fully equipped. The complete official record is too elaborate and technical for comprehension by other than an expert reader; but it will be sufficient for the present purpose to say that as a net result, the waste-heat engine delivered an additional energy equal to 34.2 per cent of that of the triple-expansion steam engine. Its economy is measured by the fact that, when working, it enabled the steam consumption to be reduced from 11.2 pounds to 8.36 pounds per indicated horse power hour, a very successful result when the smallness of the unit is considered. The same proportionate saving in large engines of 2,000 or 3,000 horse power would constitute a highly important economy in these days of costly fuel and insatiable demand for vast steam power in electrical power and lighting stations.

While these careful and continuous experiments have been in progress at the Technical High School, a cold-vapor-engine plant has been constructed, put in operation, and tested in actual daily service at the central station of the Berlin Electrical Works in Markgrafen Strasse. This is the oldest of the power stations of the company, and is equipped with what is now considered relatively small units, viz., vertical compound engines of 360 horse power, of Belgian construction, which have an average steam consumption of 18.35 pounds per indicated horse power hour. With a steam consumption as high as this, there is abundant chance for economy by utilizing the waste heat. Moreover, this was a case in which more power was urgently needed at the station. Either the cold-vapor auxiliary plant or new steam boiler and engine had to be supplied.

Accordingly, a cold-vapor engine of 175 horse power was built by Freund, of Berlin, and put in operation in May of this year. It is a single, horizontal cylinder machine, the piston being 17¾ inches in diameter, with 20-inch stroke, and, unlike the smaller engine at Charlottenburg, is geared independently to a directly coupled dynamo, which feeds into the service cables of the company. Working thus as a separate unit, the efficiency of the cold-vapor engine can be measured and recorded with great precision, and the net result may be condensed into the statement that at an average speed of 130 revolutions per minute, it delivers 150 brake horse power—an addition of 41.7 per cent to the working energy of the compound steam engine, from which it receives and utilizes the waste heat in form of exhaust steam. What this means will be made more plain when it is considered that the combined power stations of the Berlin Electrical Supply Company contain steam engines which, with an average steam consumption of 12.3 pounds per indicated horse power hour, have a total output of 142,300 horse power, to which, by the use of cold-vapor engines, there may be added 55,000 horse power without increasing by so much as a pound the consumption of coal. The system adapts itself with especial readiness to large plants which, like power and lighting stations in growing cities and towns, have to meet a steadily increasing demand for current. This the cold-vapor engine enables them to do without increase of boiler or steam-engine capacity, by simply saving heat energy which has previously gone to waste.

Although it has been from the first in careful and scientific hands, it need hardly be said that the dioxide-vapor engine is as yet in the infancy of its development and application. It has been regarded with skepticism and incredulity by most practical engineers in this country, but these have yielded to the hard logic of its demonstrated efficiency. It has not yet been tested on shipboard, but it is believed that in view of the tremendous losses of heat energy in the condensers of an ocean greyhound, the abundance of cooling water, and with all the incentive to fuel economy at sea, its most important future application may be in connection with marine engines. It has not yet been tested with the waste heat of furnaces, although it is well known that even in the best installations, from 20 to 25 per cent of the thermal energy generated by the burning coal escapes up the chimney. The burnt gases and heated cooling water of gas engines are also a leak of wasted energy which the cold-vapor engine may in future serve to close. Experience shows that in an average gas engine, not more than 26 per cent of the thermal energy of the gas is transformed into work, while 71 per cent is carried off in the waste gases and water of circulation. The gas engine is only less wasteful than the steam engine: both leave a wide margin of loss to be garnered and saved by the resources of modern science.

The report of Prof. Josse, from which the foregoing results are derived, goes extensively into the question of comparative costs of installation. Condensed to their most concise compass, his conclusions are that a combined steam-waste-heat plant of 1,600 horse power, including compound steam engines of 1,200 indicated horse power, and a cold-vapor plant of 400 indicated horse power, complete in every detail, would cost in Germany 212,000 marks ($50,456), while a triple-expansion steam engine of 1,600 horse power, without vapor engine, would cost 206,000 marks ($49,028), a difference of only $1,424, which, with steam coal at $4.15 per ton, as at Berlin, would be saved in a short time by the cold-vapor auxiliary.

Coming down to actual facts, the net cost of the 175 horse power waste-heat-engine plant at the Markgrafen Strasse power station was 49,700 marks ($11,828.60), and of a gas-engine plant, also of 175 horse power, 47,625 marks ($11,334.75), a difference so slight as to be negligible in presence of other and more important considerations.

New Electric Cars in London.

It is intended to provide sufficient rolling stock for the operation of a three-minute service between Finsbury Park and Moorgate Street, London, says The Trade Journals' Review. Each train is to consist of seven cars, the two end cars and the center one being provided with motors. The scheduled time for the run is 13½ minutes, inclusive of three intermediate stops of 20 seconds each. This stopping time seems unnecessarily long, as 10 seconds should be quite enough with a smart train crew. The plant at the generating station will comprise four vertical cross-compound condensing engines, developing 1,250 indicated horse power as a normal load and 1,875 indicated horse power as a maximum, when running at 100 revolutions per minute. Each engine is to be coupled direct to an 800-kilowatt generator mounted between the cranks. These generators will have 14 poles, and are designed to give 525 volts at no load and 575 at full load. Current will be collected from a third rail weighing 80 pounds per yard, and supported on porcelain insulators. There are to be 36 motor cars, each mounted on two 4-wheeled trucks. The three motor cars on each train will be operated as a single unit by means of a suitable connection and controlling gear.