THE NEW AQUEDUCT.

The great aqueduct for carrying the water of the Croton River basin to the metropolis, in quantity adequate to supply its wants for years to come, is now fast approaching completion. When the last brick is in place, and the last masonry filling completed, New York may safely boast of possessing one of the wonders of the engineering world. Fifty years ago the old Croton aqueduct was considered a wonderful achievement. It has since been eclipsed by others. The present work, of three times its capacity, driven by preference through the solid rock, and carried thirty and three-quarter miles in a line almost straight, again leaves the other water conduits of the world behind.

The general features of the aqueduct have been often described by us, and much information concerning it will be found in previous issues of this paper and of the SUPPLEMENT. The general plan of the work has, however, been modified in the direction of greater solidity and finish. Originally it was proposed to utilize the peculiar conditions, as regards the great solidity of the country rock, by dispensing, as far as possible, with brickwork, and to have the aqueduct little more than a gigantic tunnel. Where the rock was not sufficiently firm, brick was to be used to re-enforce it. This plan was wisely departed from. The aqueduct is now lined throughout with brick, laid in cement mortar. The walls vary in thickness from twelve inches upward. As the rock excavation is quite irregular, the space behind the brick lining is to be filled with the best rubble masonry. Thus a smooth conduit is secured, one in which friction will have but a slight retarding influence, and the area or outline of the cross section can never be reduced or altered by debris falling from the roofs. These are the principal advantages due to the brick lining.

The old aqueduct, upon which the city is still entirely dependent, was built as near the surface as possible. It followed a devious course, for this reason much exceeding the new one in length. Considerable difficulty was encountered in places, owing to the poor soil, and portions of the line have sunk twelve or fifteen inches, with the lapse of years, and have become badly cracked. By careful repairs these portions have been made as good as ever. The new structure, embedded in solid granitoid and gneiss rock and marble, can only be disturbed by an earthquake, while its reduced length and freedom from sudden curves may increase its relative capacity beyond the calculations of the engineers charged with its construction.

The route was determined and laid out by the most careful surveys. Alignment monuments were set with their foundations below the reach of frost. In the center of each was a copper bolt. Where the line ran over surface rock, the monument was dispensed with and the bolt was set directly in the rock. Then a second sight was taken, and the exact alignment was marked with a center punch and hair line upon the top of the bolt. Bench marks were also placed as the basis of leveling operations. To insure the utmost accuracy, much of this work was done at night, the sighting being done against a plummet lamp. This avoided the error due to refraction. The line thus fixed was transferred through the shafts to the tunnel, giving both alignment and level. The shafts are about eight by seventeen feet, and are distant about one and a quarter miles from each other. Hence a base line of less than sixteen feet had to be used to drive the half mile of tuneling in both directions.

The ends of two wires were dropped down the shaft, their upper ends being secured above the surface. They carried in suspension a long iron beam representing a plumb bob. The wires were spaced as far apart as the shaft would permit, and were adjusted so as to be truly vertical. The elongated plumb bob hung in a trough of water to prevent oscillation. The wires at the surface were brought into the true line of the tunnel, and from this base the line was started at the foot of the shaft. Plugs were driven into the roof to act as monuments. The result was that in some instances the survey lines from separate shafts came within an inch of exactly meeting.

The same exactness and carefulness as regards detail was applied to all the measurements and inspections of material. A continual record of cement tests is kept on file, the reports being thoroughly systematized. Briquettes are made, soaked in water, weighed, and tested. The time when steel rods definitely weighted can penetrate into the cement briquettes is noted. The dry cements are passed through sieves, and the portions retained by the different sizes of mesh are determined. The dimension stone is also inspected and measured with similar thoroughness.

The section of the greater part of the aqueduct in general terms resembles a horseshoe 13·53 feet high and 13·60 feet wide. Over the top an arch of 6·80 feet radius is carried. This rests on two side walls, themselves forming segments of circles of 20·92 ft. radius, fixed by an accurately placed template. The side walls at their bases have courses of special bricks, whence springs an invert arch for the floor, which is of 18·50 feet radius. These proportions give a tunnel equivalent in cross area to a circle of 14 feet radius. The friction is slightly greater than if the conduit were circular. For most of the distance its rate of descent is 7-10 foot per mile.

There was no possibility of blasting out the rock so as to permit the brick to lie in close contact with it. Accordingly, it was determined to fill the space back of the walls, as fast as they were run up, with rubble masonry. The general requirements were that the brickwork should be carried up in sections or benches, and as each was finished that the rubble should be laid in the space behind by hand. By the terms of the contract, a specified rate per cubic yard was to be paid for such filling. To determine its amount, it became necessary to know the exact volume of the tunnel. Then by subtracting from it the known external volume of the brick lining, the amount of rubble presumably laid and to be paid for by the city would be known.

An instrument called colloquially a "sunflower" has been devised for this purpose. It is essentially a full circle protractor, arranged for vertical mounting on a tripod, with two levels at right angles to each other, and the usual adjustments. It is carried by a tube of about one-half inch bore passing through the usual ball and socket joint. A given portion of tunnel is laid off into lengths varying from three to ten feet. At each division a candle is placed exactly in the vertical plane containing the axis. The "sunflower" is set over the candle and adjusted so as to be truly vertical. Instead of a plumb bob the tube is used to fix its position. The attendant sights down the tube and shifts the instrument until directly over the candle. The level of the tunnel bottom has previously been taken. The face of the protractor is about 18 inches across, and an arm pivoted at the center of the protractor face is arranged to turn around freely. A pole, divided into feet and tenths of feet, shod with an iron strap, is placed upon the rotary arm, is brought to the vertical or zero reading of the instrument, and is pushed upward until it strikes the rock above. The reading in feet and tenths is taken, the pole is swung through ten degrees, and a second reading taken, and so on all around the circle. If necessary, even more readings are taken. The 180° reading gives the elevation of the center of the instrument, so as to fix the relation of the excavation to the brick lining.

Cross section sheets containing the outline of the tunnel are provided, printed on rather thin paper. When the readings are taken to the office, they are plotted on these sheets. A protractor printed on thin paper is mounted on a glass plate, beneath which the light can enter. The section sheet is laid upon this protractor, whose lines and figures can be distinctly seen through it. The point on the section sheet corresponding to the elevation of the center of the sunflower is brought exactly over the center of the protractor. Then the readings for the different degrees are marked off, and connected afterward by pencil lines. By planimeter or trigonometrical methods the area of the cross section is determined.

After the tunnel had been completed in parts, and these measurements had been taken, it was found that the filling back of the brickwork had been most perfunctorily performed, and in some places had been entirely omitted. As the contractors were paid in the neighborhood of seven dollars a cubic yard for tunnel excavation, and received five dollars per cubic yard for refilling the same with rubble masonry, the object of such neglect was obvious. They had every incitement to make the opening as large as possible, and then to leave it unfilled. In many cases the excavation was carried six feet higher than necessary, and great cavities of this height were left open. Sometimes portions of the cavities were partitioned off by a bridge wall so as to be masked, and thus escape notice. The space back of the side walls was often filled with loose stones, through and between which a long rod could be inserted clear back to the original rock. Two sample cavities above the rock, which were entered by the writer, were sufficiently lofty to enable a person to stand erect therein, and each contained some eighty cubic yards of space, for filling which, had it been undetected, the contractors would have collected four hundred dollars.

A very large corps of inspectors are kept in the tunnel, and should be an absolute preventive of these practices. Unfortunately, they have not for some reason succeeded in such prevention.

Much of this defective work has been done, but it is being detected by the thorough examination that is now being prosecuted, and the defects will doubtless be remedied in due time. A heavy rod tipped with iron, or a solid iron bar, is used as a sounder. With this the brickwork is struck, and the more or less hollow sound discloses the cavities and loose filling. By practice considerable expertness with this crude system is attained. Where a cavity is found, the wall is opened and the contractor is forced to refill it. In some cases liquid mortar, or grouting, is used, in other cases a gang of men are made to regularly build up the cavity. It will be noted that this method is applied to the completed structure. Had the inspectors done their duty, it would be quite unnecessary.

It cannot be said that the defective filling, as far as it has gone, will have any disastrous effect. Most of the aqueduct is to deliver water by gravitation only. But in the future it may be called upon to do high pressure work. Its capability for such service may be of the utmost importance. The city of New York is paying for the best work, and is entitled to have it. No excuse can be accepted for inferior filling or other neglect. By the special efforts made at this late day, there is reason to hope that good masonry will be secured for practically the whole length of the aqueduct.

To render the aqueduct fully effectual, more water than the present Croton Lake can hold must be impounded. This is to be supplied by the Quaker Bridge dam, which is planned to be the largest structure of that character in the world. We have no space here to discuss the mooted questions of the practicability of this gigantic work. The mathematical bases for its erection will be found presented by one of the aqueduct engineers, Dr. Edward Wegmann, Jr., in his work on "The Design and Construction of Masonry Dams." The very able reports of the Chief Engineer, Mr. Benjamin S. Church, should also be referred to. If the Croton River watershed is made the immediate source of the water supply for the metropolis, that by no means excludes the utilization of more distant sources. Should the New Jersey highland regions or the Catskill Mountains eventually be utilized, the new aqueduct, with its capacity of 250,000,000 gallons per day, will be a most important factor and link in the system.

The main contracts awarded prior to January 1, 1887, aggregate $13,801,117, nearly $3,000,000 under the engineers' original estimate. It would seem that this sum, with the very large staff of city employes engaged on the work, should have secured immunity from the evils we have so briefly described.

Determination of Phosphoric Acid.

The author proposes an abridgment of the molybdic method. If the ordinary yellow precipitate is heated to 400° to 500°, water and ammonia are expelled, and there remains a molybdenum phospho-molybdate almost of a black color. This compound, within certain limits of temperature, is very permanent, and as it is not hygroscopic, it can be weighed. The author proceeds as follows: The solution of the phosphate prepared as usual, and containing nitric acid and from 20 to 25 per cent ammonium nitrate, is precipitated at 50° to 60° with solution of molybdic acid, stirring constantly, and is allowed to stand for some hours without further heating, but with diligent stirring. After two to three hours the precipitate is collected on a filter, washed with a 20 per cent solution of ammonium nitrate slightly acidulated with nitric acid, until ten drops react neither with hydrogen sulphide nor (if iron is present) with potassium ferricyanide, and then a few times with cold water, or once each with a small quantity of cold water, alcohol, and ether. The dried precipitate is removed as completely as possible from the filter into a flat platinum capsule. The filter is incinerated separately at the lowest possible temperature in a platinum crucible, the ash is added to the bulk of the precipitate in the flat capsule, which is then covered with sheet platinum and ignited over a "Maste" burner with a triple air current at a temperature which suffices for a slow decomposition of the precipitate, indicated by blackening. If there is a considerable quantity of precipitate it is removed, after a time, from the flame, crushed with a glass rod having its end melted broad and flat, and heated again, bringing the yellow portions, which still remain unchanged, nearest the sides of the capsule which are hottest. In about fifteen minutes the mass is generally of a uniform blackness. It is let cool in the exsiccator and weighed. It contains 4·018 per cent P_2O_5. The residue can easily be removed from the capsule by means of dilute ammonia. If the temperature has been too high, and the residue has a light gray reflection, indicating partial formation of molybdic acid, the operation is not to be rejected. The mass should be carefully moistened with dilute ammonia, dried up, and heated afresh, but with caution in order to avoid loss by spurting.—*C. Meinecke.*

American Streets.

A writer in *La Nature* remarks that the streets of American cities have been laid out with the tape-line and at right angles. This, he observes, is very fine from a geometrical standpoint, but carries with it very serious consequences from an economical point of view. In fact, if we walk along the two sides of a square instead of following a diagonal, the distance is increased in the proportion of 40 per cent; that is to say, instead of walking 100 feet, we walk 140. Hence a loss of time, strength, and money. Prof. Haupt has calculated that the opening of two diagonal streets in Philadelphia (850,000 inhabitants) would reduce the extreme distances by one mile and a quarter. The annual number of passengers carried by the cars being 125,000,000, the total saving would reach about $180,000 per mile traveled. The passengers would gain 3,565 years in time and would save more than 8,000,000 horse power in motive power.