SCIENTIFIC AMERICAN

A WEEKLY JOURNAL OF PRACTICAL INFORMATION, ART, SCIENCE, MECHANICS, CHEMISTRY, AND MANUFACTURES.

Vol. XXXVI.—No. 21. [NEW SERIES.] NEW YORK, MAY 26, 1877. [$3.20 per Annum. [POSTAGE PREPAID.]

THE DELAWARE AND LACKAWANNA TUNNEL THROUGH BERGEN HILL, N. J.

About a mile from the west shore of the Hudson river, and forming a spine along the peninsula bounded by that stream and New York Bay on the east and Newark Bay on the west, there extends a range of irregular eminences known as Bergen Hills. These are a continuation of the Palisades; and as the extremity of the peninsula is reached, their height grows rapidly less. The ridge thus formed constitutes the great barrier between New York and the inland traffic of New Jersey and Pennsylvania; and an immense amount of engineering skill and capital have been directed toward surmounting it. Where the hills are low, open cuttings have been resorted to; and the tracks of the Pennsylvania and Newark and New York railroads are thus conducted through; but further to the north the elevation no longer admits of such an expedient, and tunnelling has been necessitated.

In 1860, the Bergen or Long Dock tunnel, 4,311 feet long, 23 feet high, and 30 feet wide, crossing the hill diagonally, was completed at a cost of some one million dollars. Since then, this bore has formed the only available pathway for the enormous traffic of both the Erie and the Delaware and Lackawanna railroads, which for a long period has greatly exceeded the capacity of the tunnel. As it is not permitted for one train to enter until another preceding it in the same direction has emerged, and the passage occupies some five minutes, and as the tunnel belongs to the Erie road, the other line has been under a disadvantage, not only in being compelled to purchase right of passage and to yield precedence to Erie trains, but also, as the annexed map plainly shows, to make an S-shaped *détour*, turning to the left to gain the mouth of the tunnel and then making another bend on emerging. The line through the new tunnel will be straight from the Hoboken terminus to the Hackensack river, gaining in point of actual distance 0·65 mile, and saving two stops now necessitated by the crossings of the Erie road, which together involved a loss of some ten minutes' time.

Work upon the tunnel began in September, 1873, and has since been simultaneously prosecuted in each direction at the bottom of the six shafts and at the two approaches, making fourteen headings in all. The character of the excavation presented no extraordinary features, as it was entirely through trap rock. Hand drilling, for reasons of economy, was chiefly employed. The first year's labor consisted in sinking the shafts to depths varying from 77 to 93 feet, and in opening 690 feet of tunnel. During the succeeding year, 2,922 feet of bore were finished, and finally on January 18, 1876, the last heading was connected and the rock was penetrated over the distance of 4,210 feet. In May, 1876, the last bottom was finished; and for the past year, the work has been in arching and enlarging the roof of the tunnel for the same. The total completed length, from face of ma-

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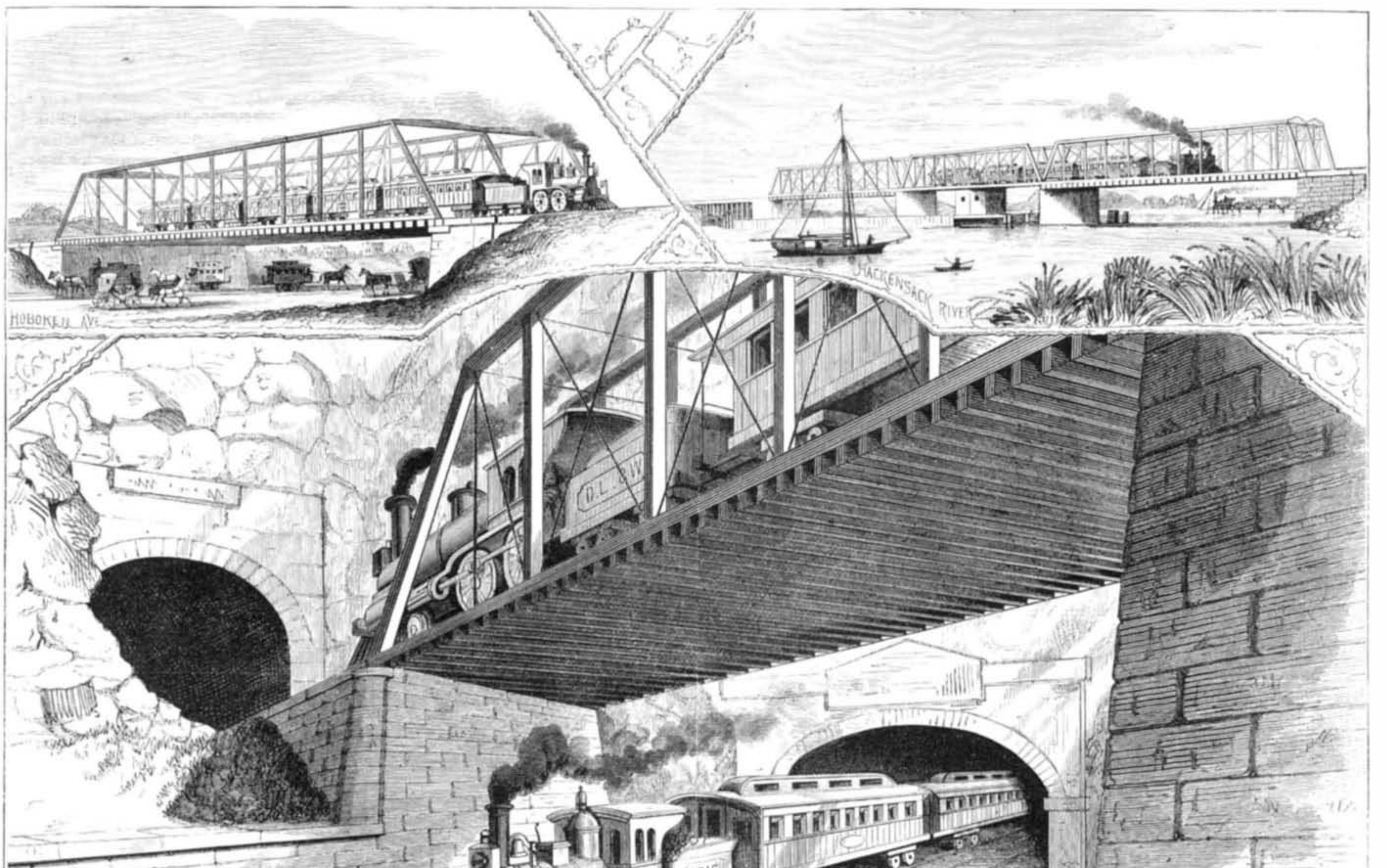
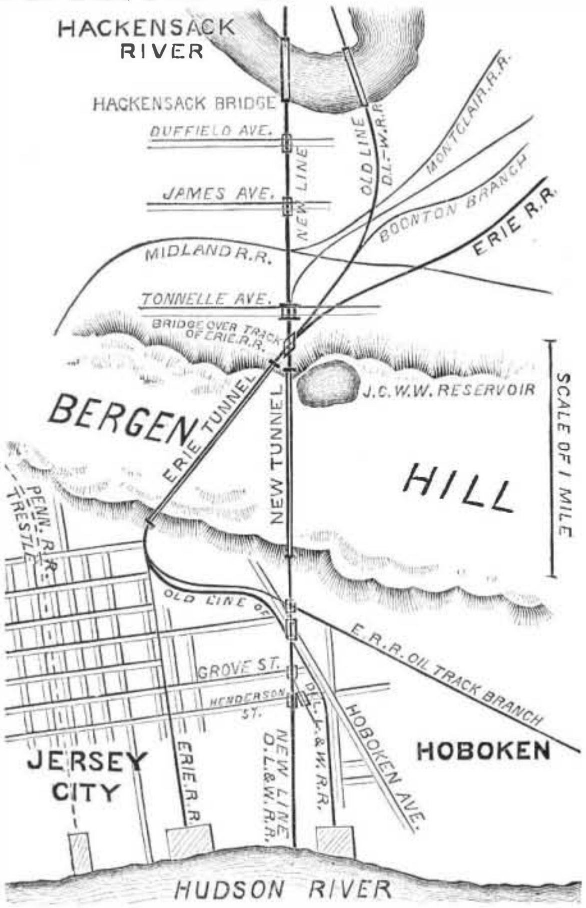


THE ENGINEERING WORKS OF THE DELAWARE, LACKAWANNA, AND WESTERN RAILROAD, HOBOKEN, N. J.

[*Continued from first page.*]

sonry at the east end to face of masonry at the west end, is 4,280 feet, there being 35 feet of arching constructed outside of the rock faces, in order to prevent loose earth, stone, etc., from falling on the track. The back arching within varies from 22 to 34 inches in thickness, and extends over some 3,100 feet, or about three quarters of the entire length. The roof was thus reinforced wherever it was considered not absolutely safe.

The east end of the tunnel enters the rock about 2,700 feet north of the entrance of the Bergen tunnel, with which its line forms an angle of 40°, the west end appearing on a higher plane and within some 50 feet of the older bore. It is 27 feet wide in the clear, and the total height is 20 feet 7 inches. Ventilation is secured by seven shafts, all (with one exception) brick lined. Three are elliptical in section, opening the full width of the tunnel in the long, and measuring 8 feet in the short diameter; one is 16½ feet by 7 feet, two are 6 feet in diameter, and another, opening the full width of the tunnel, is 12 feet wide.



MAP OF THE DELAWARE AND LACKAWANNA RAILROAD'S NEW WORKS.

Besides the actual excavation, considerable labor has been necessitated in the construction of approaches. The natural bog on the east side of the ridge has been filled in to support about three quarters of a mile of track. On the west side, a mile and a half of new road has been built to connect with the old line, passing through the Bergen tunnel. In both of these short sections, several fine bridges, which are illustrated in the accompanying engraving, have been erected. On the east side there are three bridges at Henderson street, carrying over seven tracks; at Grove street there is one four-track bridge. This last, together with the iron skew bridge of 193 feet span over Hoboken avenue, and the bridge over the Erie oil track, are represented in the illustration. On the west side, there is a fine iron skew bridge near the mouth of the tunnel, so that the line of the road passes directly over the Erie track. This will be found represented in the engraving, together with the bridges over Tonnelle and James avenues, and the celebrated skew structure across the Hackensack river. The last mentioned bridge is a triumph of engineering skill, owing to the difficulties offered by the marshy soil and destructive power of the river. It has two spans of 200 feet and one draw of the same length. The material is iron built upon masonry, which found a stable foundation only after 1,700 piles had been driven. The eastern abutment was washed away soon after completion, and wholly wrecked, despite the fact that it was built on over 300 piles, each a foot in diameter and each driven down forty feet.

The cost of the tunnel and approaches, as nearly as can be ascertained at present, was as follows: Excavation and shafts, $800,000; brick arching, $105,000; filling bog, grading, track laying, etc., on east side of ridge, $450,000; land, right of way, road, etc., on west side, $875,000; bridges, $557,000. The total cost was therefore about $2,787,000. If to this be added the outlay for the ship canal (now in progress), 3,000 feet long and 100 feet wide and 20 feet deep, designed to increase the dock facilities of the Delaware and Lackawanna Company, the entire expense of all the engineering work undertaken by that corporation reaches an aggregate of $2,850,000.

The engineers of the tunnel were Mr. James Archbald, Chief Engineer of the railroad, and Mr. Samuel Rockwell, Resident Engineer. The contractor was Mr. John McAndrew, and the bridges were mostly constructed by the Delaware Bridge Company. It is expected that the trains will pass through the bore for the first time during the present month.

Communications.

The French Exhibition.

To the Editor of the Scientific American:

If Congress should fail to make any appropriation for the proper representation of this country at the French Exhibition next year, there are men patriotic enough to give their services for such an end; and the sooner a commission is formed, and intending exhibitors invited to apply for space, the better. One chief commissioner, with two or three assistants willing to work, would be ample; and exhibitors would gladly pay their own expenses rather than depend on the favors they may get from such strugglers for place and power as have characterized our two last exhibition commissions abroad. A small appropriation of course would be desirable (to fairly pay the expenses of the commission), when judiciously applied, and for fitting the space allotted and keeping it clean; and the resolution making the same should specify that not more than $5,000 should be paid the chief commissioner, and not more than $3,000 each to three assistants, to include all their private expenses; about $20,000 for fittings and decorations, and $5,000 for labor and the like. Then about $10,000 should be strictly applied to assisting exhibitors, making $50,000 in all. This, in honest and judicious hands, would be ample.

The government has plenty of transports and seamen, and should send to Havre or Ostend all the United States' contributions. With this, exhibitors would be satisfied; and I think, if taken hold of in time, a very good show on the part of the United States would be made.

The SCIENTIFIC AMERICAN can bring this about, and so assist in the matter that the thing can be accomplished without a "fuss," as has been generally the case. When Congress failed (in 1861) to make an appropriation and the Cabinet continued to me the position of Commissioner, in place of the 24 who resigned, I took hold and carried it through; and because there was no money to quarrel about, we had a good and peaceful time; out of 109 exhibitors, we had 97 prizes awarded, and 59 of them first-class. Contributions from several wealthy Americans enabled me to fairly fit up and decorate the space allotted; and with a private expenditure of $1,700 we kept our credit good with foreign commissions, and came out of it, I believe, with the perfect goodwill of every exhibitor. My whole expenditure did not exceed $7,000, of which over $5,000 was voluntarily contributed, McCormick, Osborn, and Walter A. Wood each giving $150; Steinway and the Glen Cove Starch Company also did the fair thing. I would try it again rather than that we be behind time or shut out altogether.

I presume Mr. Corliss would accept the chief commissionership, if tendered him; and no doubt Charles Francis Adams, or perhaps Mr. Washburn, late Minister to France, if wanted. Let us have a good American exhibit. We surely shall not have if we wait till the end of October.

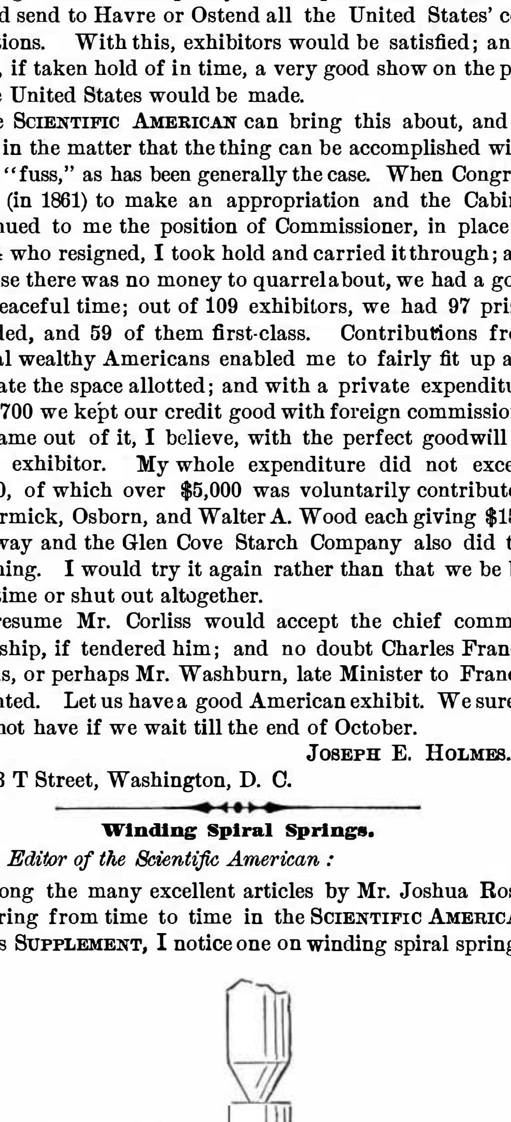
JOSEPH E. HOLMES.

1013 T Street, Washington, D. C.

Winding Spiral Springs.

To the Editor of the Scientific American:

Among the many excellent articles by Mr. Joshua Rose, appearing from time to time in the SCIENTIFIC AMERICAN and its SUPPLEMENT, I notice one on winding spiral springs.



Now as many of your readers who have lathes may not have the means of cutting a spiral, and others may want a spring for an odd job where it would cost too much to make a mandrel, I send you a sketch of the method we practice here. We simply take a common straight mandrel, or a centered rod of round iron or steel, a little smaller than the inside diameter of the spring is to be, place an ordinary dog on one end, and put it into the lathe; then we take the wire to be wound, and bend about ⅜ of an inch at one end at right angles. This can generally be done by placing the end in the vise and bending cold. Insert this bent end into the dog, letting it rest against the screw, give the lathe about half a turn by hand, then put on the guide, which is an iron rod, preferably square and as thick as you want the spirals to be apart. Bend one end to form a hook that will pass over the mandrel freely, the other end being left long enough to pass down between the lathe shears to keep from revolving. Start the lathe, holding the wire against the guide with a slight pressure, and the spring will wind, feeding the guide along ahead of it. After the spring has been wound, turn the lathe backwards one or two turns, or enough to take the pressure off the spring, before it is relieved from the lathe. I have found no difficulty in holding No. 6 steel wire in my hand while being wound over a ⅝ mandrel; but for larger sizes, especially if hard, a rest may be inserted in the tool post, and the wire allowed to pass over that. This rest, to prevent abrading the wire, may be a piece of hard wood of a size that will go into the post, and extending 10 or 12 inches, being supported on the outer end by a block. If a number of short springs are wanted, one can be wound as long as the strength of the mandrel or length of the lathe will admit, and afterwards cut into lengths. The short end of the guide hook is bent to conform to the spiral.

Hamilton, Ohio. J. T. G.

Steam Economy Computations.

To the Editor of the Scientific American:

A correspondent, W. A. Mussen, in your issue of May 5, alludes to a method of computing theoretical steam economy, which he finds in the circular of a manufacturing company. Having had something to do with the preparation of the rules he quotes, I deem it but just to the rules, and to the critics whose opinions he invites, to offer a trifle of explanation. The "constant number 859,375" is found by the following process, for which credit is due, so far as I am aware, to Mr. Jesse Warrington, now of Jackson, Mich.

The standard horse power is 33,000 foot-lbs. per minute. Hence $33{,}000 \times 60 \times 12 = 23{,}760{,}000$ is its equivalent in inch-lbs. per hour. This, it is evident, will be the displacement in cubic inches per hour of an engine which will give one horse power with 1 lb. mean pressure. Then taking the number 27·648 as the number of cubic inches per lb. of water, we have $23{,}760{,}000 \div 27{\cdot}648 = 859{,}375$ (and singularly enough, without a remainder), as such displacement in lbs. of water. From this point your correspondent gives the *rationale* of the process clearly enough; but when he makes an application of it, he takes for the volume of 16 lbs. (the terminal pressure of his diagram), the number 954, which is not the volume of that pressure by any table I know of. According to the authorities referred to, it is 1,515, and by the older tables, 1,576. Taking the former, his diagram would figure 22·304 instead of 35·46. So far as he has quoted the circular, no tables of volumes need have been referred to. It contained a table, in the preparation of which they were used, hence the reference; but this he has not quoted. This constant number may be used with any table of volumes which may be considered most accurate.

The method of determining the proper allowance for clearance and compression also needs a word of additional explanation. When the exhaust takes place above the return or counter pressure, a certain amount of loss takes place from the expansion of the steam in the clearance space. But when the compression pressure reaches that of the release, this loss is restored; and whatever percentage of the stroke remains to be made after that may be deducted from the theoretical rate. When the compression pressure does not reach that of the release, we may find, by extending the compression curve theoretically till it does so, how much further the piston must have traveled to have restored the release pressure, and add an equivalent amount to the result of the calculation.

Finally, it is not expected nor claimed that calculations of this kind can give very closely the actual consumption of any engine. Their chief value is for the comparison of different engines, and different conditions existing with the same engine. They also give the theoretical maximum economy, with which to compare the actual, in order to judge of the degree of perfection existing in the engine and its surroundings. No engine can ever reach it; but a large one, furnished with dry steam somewhat superheated, with well protected pipes and cylinder, may possibly come within 10 or 12 per cent of it, but the average loss is probably much nearer 30 per cent.

Like Mr. M., I cordially invite criticism and exchange of ideas on this and kindred subjects.

Salem, Ohio. J. W. THOMPSON.

The Water Consumption of Steam Engines.

To the Editor of the Scientific American:

In a recent issue, I notice an article entitled "Water Evaporated through Engines," in which was published a method of computing the water consumption per horse power per hour. As the method was furnished by myself, I will say that all that is claimed for the process is that it will give identical results with other more complex processes, in which the size of cylinder, number of revolutions per minute, total piston displacement per hour, and clearance are used as factors in the calculation. It does not depend for its accuracy on the fact that steam follows the Mariotte law of expansion. While it does not account for leakage of piston, or condensed steam that passes out of the cylinder as water, it does account for leakage of steam into the cylinder between the point of cut-off and release; and the supplement-