THE GREAT RAILWAY TUNNEL UNDER THE ST. CLAIR RIVER, BETWEEN THE UNITED STATES AND CANADA.

Owing to the steady increase of traffic over the Grand Trunk Railroad, of Canada, and the Chicago and Grand Trunk, Detroit, Grand Haven and Milwaukee, and the Toledo, Saginaw, and Muskegon railroads of the United States (practically one company) during the last few years, it became obvious that some other means of transit than the steam car ferry now in operation would be necessary, as that method is a great annual expense, and is also very unreliable, especially so in the winter, when the ice in Lake Huron becomes loose and is carried down the St. Clair River, often catching the ferry boat and carrying it down the river with it, with its cargo of passengers or freight. This necessitates the maintenance of a powerful tug, always in steam, and ready to go at a moment's notice to aid the ferry and break the ice if necessary.

In view of the extreme flatness of the country, and the low-lying ground in that part of the country, it was found impracticable to build a bridge, in consequence of the great height to which it would have to be carried, to allow of free navigation, as the traffic at this point is very great, and the current very swift, viz., eight miles an hour. So the construction of a tunnel was decided upon, to extend between Port Huron, Mich., on the American side, and Sarnia, on the Canadian side. The St. Clair Tunnel Co. was formed in the year 1886.

In the following year test shafts and tunnels on both sides of the river were completed, and attempts were then made to begin the work of the large tunnels by sinking large shafts; but the efforts failed, and after much loss of time and money, it was decided to open horizontal cuttings to the required depth on each side of the river, and in the headings thus formed carry the tunnel through on the proper grades by means of the Beach hydraulic shields. Work upon the great cuttings was begun in January, 1889.

The walls of the tunnel are constructed of cast iron segments, thirteen of which and a key form the circle. The dimensions of the cast iron segments are: Length, 4 feet 10 inches; width, 18 inches; thickness, 2 inches, with flanges inside 6 inches deep and 1¾ inches in thickness. These segments are cast with 32 holes in them, viz., 12 in each side flange, and 4 in each end; they are secured in their places with bolts ⅞ inch in diameter. The outside diameter of the tunnel is 21 feet, and 20 feet inside. The circle, taken by the bolts in the flanges, is 20 feet 5 inches.

The tunneling is being carried on by means of a pair of Beach hydraulic shields, one of which is employed in each heading. At this point a brief history of this device may not be uninteresting.

It is the invention of Mr. Alfred E. Beach, of the SCIENTIFIC AMERICAN, and was designed by him and tried in 1868 (patented 1869) for the purpose of excavating under the streets of New York, with a view to an underground railway. At that early period the need of rapid city transit for passengers was strongly felt, but there was great opposition on the part of property owners along the line of the proposed railway, through fear that the buildings would be injured if a tunnel were carried on a lower level than the foundations; added to which would be serious loss of business by the closing and tearing up of the streets during the construction of the work. Mr. Beach determined to show the fallacy of both of these objections by excavating a short piece of tunnel under the most crowded part of Broadway, at a lower depth than the adjacent buildings, and without interrupting business or traffic. He accordingly constructed the hydraulic shield or underground boring machine, which he set to work, and with it constructed a tunnel extending under Broadway from Warren Street to Park Place, large enough to receive a small street railway car, the length of the tunnel being between three hundred and four hundred feet. This tunnel was 9 ft. 4 in. in exterior diameter. It was started at the head of Warren Street, from which it turned underground on a radius of about 50 ft. into Broadway. The curved portion of the tunnel was walled with cast iron plates, put up in segments and united by means of screw bolts; the straight portion was walled with brick masonry. The object of the shield was to protect the workmen while excavating the earth and building the tunnel.

The shield consists of a strong cylinder somewhat resembling a huge barrel with both heads removed. The front end of the cylinder is sharpened, so as to have a cutting edge to enter the earth. The rear end of the cylinder, for a length of two feet or so, is made quite thin, and is called the hood. Arranged around the main walls of the cylinder and longitudinal therewith are a series of hydraulic jacks, all operated from a common pump, each jack having cocks, whereby it may be cut off from the pump whenever desired.

Within the shield are vertical and horizontal braces and shelves. When at work, the iron plates or the masonry, of which the tunnel is composed, are first built up within the thin hood of the shield, the hydraulic jacks are then made to press against the end of the tunnel plates or masonry, which has the effect to push the shield ahead into the earth for a distance equal to the length of the pistons of the jacks, say two feet, or not quite the length of the hood, and as the shield advances, men employed in the front of the shield dig out and carry back the earth through the shield. By the advance of the shield, the hood, within which the iron or masonry tunnel is built, is drawn partly off from and ahead of the constructed tunnel, thus leaving the hood empty. The pistons of the hydraulic jacks are then shoved back into their cylinders, and a new section of tunnel is built up within the hood as before described. The shield is then pushed ahead, and so on. The extreme end of the tunnel is always within and covered and protected by the hood. In this manner the earth is rapidly excavated or bored out, and the tunnel built, without disturbing the surface of the ground.

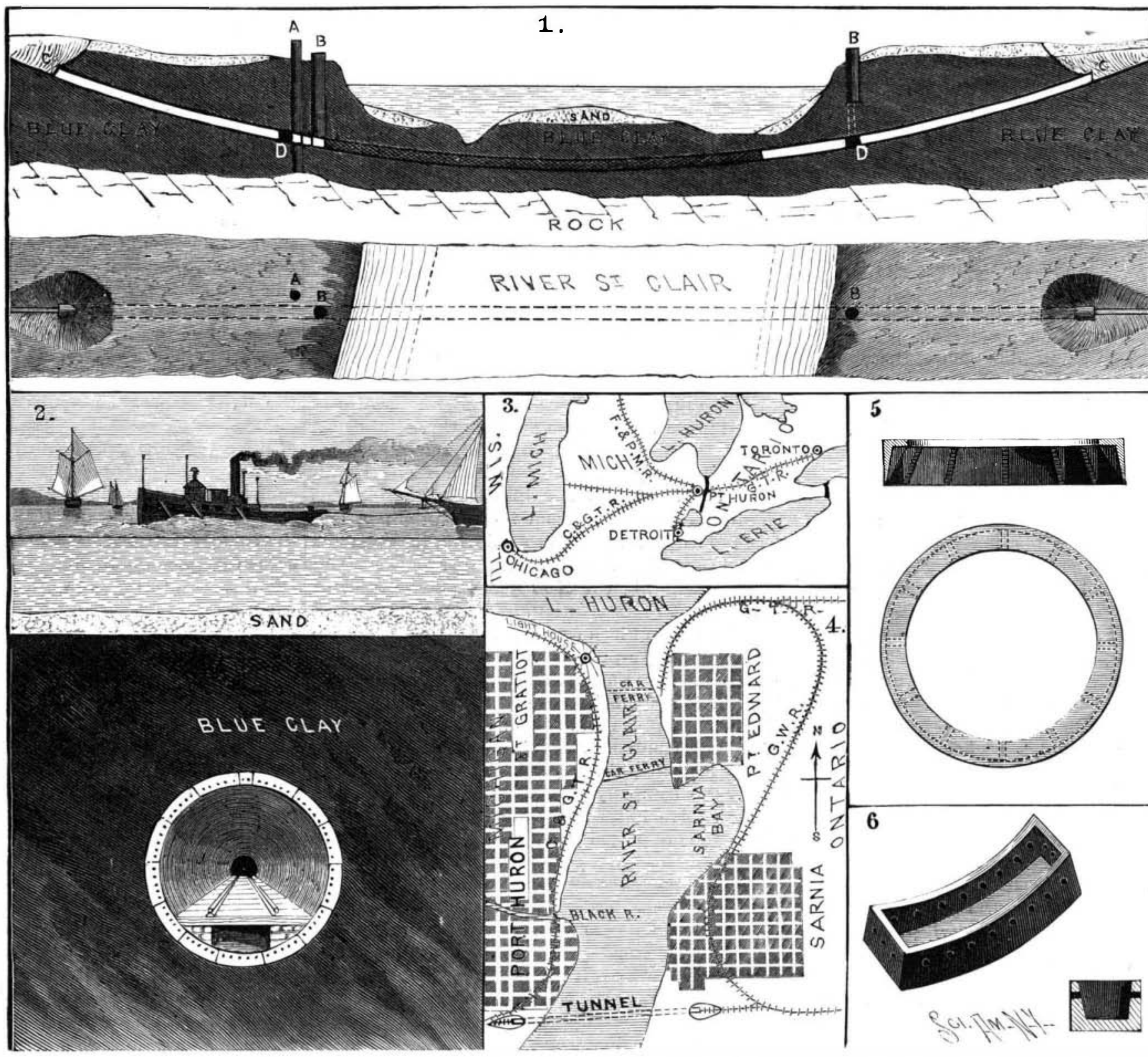

Fig. 1.—Sectional elevation and plan of tunnel; A, pump shaft, B, brick air shafts, C, cuttings, DD, bulkheads. Fig. 2.—Cross section of tunnel and river. Fig. 3.—Map showing location. Fig. 4.—Plan of Pt. Huron and Sarnia, showing position of tunnel. Fig. 5.—Section and plan of iron shoe of shaft. Fig. 6.—Segment of cast iron of which the tunnel is composed.

THE GREAT RAILWAY TUNNEL UNDER THE ST. CLAIR RIVER, BETWEEN THE UNITED STATES AND CANADA.

The floor of the Broadway tunnel above mentioned was 21½ feet below the pavement. It was carried under sewers and beneath the Croton water mains. The work was executed while the street was thronged with omnibuses and heavy teams, and few persons, except those directly interested, had any knowledge that a tunnel was in progress until after it was completed. It was then opened to the public, and many thousands of people enjoyed the privilege of riding in the car, which was worked back and forth in the tunnel by the pneumatic or air pressure system.

By means of the system of hydraulic jacks capable of either combined or separate action, Mr. Beach was enabled to govern the direction of his tunneling shield with the utmost precision, making it to ascend or descend in the earth, according to grade required, or travel on a curve of any desired radius. The first machine attracted much attention on the part of engineers. It was illustrated and described in the SCIENTIFIC AMERICAN of March 5, 1870, also in the *Manufacturer and Builder* of the following year, and in various other publications.

Since the construction of the Broadway tunnel the Beach hydraulic shield has been employed on a number of important engineering works, with much success, and it is now generally recognized as an important adjunct in the execution of various classes of underground tunnels. At Buffalo it was used to carry a large sewer under a main street and under a canal. At Chicago it was used in the construction of one of the lake tunnels. In London, 1886–89, it was employed in the construction of the City and Southwark Subways, recently completed, and soon to be opened for public traffic as the underground electric railways. These two tunnels extend from the Monument, London, and pass under the Thames River, Great Dover Street, Kennington Park road, and other thoroughfares to Clapham, a distance of about three miles. The exterior diameter of each of these tunnels is 11 ft. 6 in.

The Beach hydraulic shield has also been brought into use recently in the railway tunnels now in process of construction under the Hudson River, between New York and Jersey City, N. J. The shields here used have an external diameter of 19 ft. 11 in.

As before stated, the tunneling of the St. Clair River is being carried on by means of the Beach hydraulic shields, which precede the diggers. This remarkable machine is illustrated on our first page. Each shield is circular, 21 feet 7 inches in diameter, 16 feet long, and is built of plate steel one inch thick. It is divided into twelve compartments by means of two horizontal and three vertical stays, which are built up to a thickness of two inches. These stays have a knife edge in front and extend back ten feet, leaving six feet of clear cylinder, into which the end of the tunnel extends. Ten of the compartments are permanently closed and bracings of angle iron placed across them. The other two are provided with heavy iron doors, which can be closed at once in case of accident or danger. These doors are situated at the bottom in the center, and through them is passed all the excavated matter. Flush with this heading (with their cylinders extending forward into the compartments) are twenty-four hydraulic rams at equal distances around the shield. These rams are eight inches in diameter and have a stroke of 24 inches. By their means the shield is forced forward enough to admit of another section of castings, viz., 18 inches. Each of these rams can be worked separately, as may be seen by the sketch of the back view of the shield.

The power is supplied by a Worthington pump, which is capable of producing a pressure of 5,000 pounds per square inch, which will amount to 125 tons per ram, or 3,000 tons on the 24 rams. The greatest pressure as yet used is 1,700 pounds per square inch, which is 40 tons per ram, and 1,060 tons on the shield. These shields weigh eighty tons each, and were built by the Tool Manufacturing Company, of Hamilton, Canada. They were brought to their destination in pieces, and erected on the tops of the great cuttings, on the north side in both cases, at which side are also the machine and work shops which have been erected. This immense machine, when completed, was rolled down the side of the cutting on a wooden track composed of four rails of wood, each one foot square and placed about four feet apart. It was restrained in its downward course by means of six large ropes, which were passed around it, fixed at one end to the upper end of the wooden track and coiled around piles, with a number of men to lower out when the order was given. From the time at which the machine first moved to the time it was resting on the cradle of wood (which was prepared for it) at the bottom was only one hour and twenty minutes. A better idea can be obtained by referring to the engraving (Fig. 5), which is taken from a photograph, and which shows them in the act of lowering the shield on the Canadian side. When in position a backing of timbers one foot square was erected against the dead clay, and to this backing the first section of the tunnel was bolted, and others were added by means of the derrick, which is shown in the engraving of the cutting on the American side. (See Fig. 2.) A similar backing was used on the Canadian side, with the exception that instead of having a solid back of clay as a support, it had a number of shores.

The erection of the castings composing the tunnel is accomplished by means of a circular crane, which revolves on a spindle in the center of the shield (see Figs. 1 and 3), and is provided with a vise at one end, with which to grip the casting, and a counterbalance weight at the other. When a casting has been made secure, the arm of the crane rises about nine inches, thereby shortening the vise arm and lengthening the counterbalance arm. This gives the cast iron segment a clearance to travel around to the desired point, where it can be placed in position by reversing the sliding motion.

The machinery plant necessary for this great undertaking is as follows: One boiler house, containing three boilers, two of which are kept in steam at a time; one machine shop, containing one planing machine, one drilling machine, and one bolt screwing machine. The planing machine is provided with an extra bed at each end, distant from the working bed about 2 feet. It is also supplied with an extra table. By this means the plane is kept almost incessantly at work, as while one table load is being planed the other table is being unloaded and loaded again. When one lot is finished the table is run on to one of the extra beds and the newly laden table on the other bed is placed on the plane. There is one carpenter's shop, one smith shop, one electric light room, containing two dynamos and engines, a room containing blower engine and blower, a hoisting engine in another apartment, and a pump in the pit to pump out loose water. This plant is precisely similar on both sides of the river.

The tunnel when completed will be 6,050 feet in length from cutting to cutting, and is divided as follows: From the American cutting to the river edge, 1,800 feet; from the Canadian cutting to the river edge, 1,950 feet; and distance across the St. Clair River, 2,300. Of this 6,050 feet, 4,150 feet has already been constructed, viz., 2,215 feet on the American side and 1,935 on the Canadian.

The tunnel proper was commenced in August of 1889, and the expedition with which it has been completed so far (for its manner of construction renders it complete as the shield proceeds) has beaten all previous records of tunnel construction, and has so far proved a success beyond expectations, inasmuch as it shows a fewer number of accidents than other types of tunnel, the most serious accident up to date being a broken leg. The idea of building this tunnel of cast iron segment originated with Mr. Joseph Hobson, of Hamilton, Ontario, who is chief engineer of the St. Clair Tunnel Company, and also chief engineer of the Great Western division of the G. T. R. of Canada. The fact that no less than 4,550 feet out of the 6,050 has been constructed speaks volumes for Mr. Hobson's skill in tunnel construction. At a meeting of directors a short time since, Sir Joseph Hickson is reported to have expressed his belief that the tunnel would be completed for traffic within 18 months. Mr. Thomas Murphy, of New York, who is superintendent of excavation, is thoroughly sanguine about its healthy state. Mr. Murphy is a man well versed in these matters, and is thoroughly competent, having been connected with the construction of several tunnels of note throughout the United States.

The tunnel will drain itself into the pump shaft, A, Fig. 1, on the Canadian side. This shaft is 18 feet in diameter and 112 feet in depth, being carried to the rock which lies at that depth.

The cost of this tunnel was estimated at $3,000,000, but it is now thought that (notwithstanding the immense amount of money expended on the test and brick shafts) it will not reach that figure. Should another tunnel be put through, which we shall not be at all surprised to see in the near future, we shall have a much fairer chance to compare the certain and marked advantages that the cast iron tunnel possesses over the old style brick and cement tunnels.

The tunnel proper is 6,050 feet in length and 21 feet outside diameter, the Beach hydraulic shield being 21 feet 6 inches in diameter. The amount of soil excavated for this portion of the work amounts to 2,196,400 cubic feet, and will require 55,962,500 pounds of cast iron lining, secured together with 859,242 bolts seven-eighths inch in diameter. The success attained by Mr. Hobson, in the face of so many obstacles and the difficult nature of the soil to be gone through, indicates his complete mastery of the subject, and reflects high credit upon his skill as an engineer. The tunnel construction furnishes employment for 700 hands.

REFERENCES TO THE ENGRAVING ON FIRST PAGE.

Fig. 1.—Rear view of the Beach hydraulic shield, showing the hood within which the tunnel is built and the heads of 24 hydraulic rams by which the shield is pushed ahead. Also showing the swinging crane for placing the cast iron segments.

Fig. 2.—The shield in place, on grade, and ready to enter the heading. The cutting edges of the shield are seen in front. At the rear of shield is seen a portion of the constructed iron tunnel pushed up against the temporary timber backing.

Fig. 3.—Interior view showing the Beach hydraulic shield as worked in the heading. The cast iron segments composing the tunnel are built up within the thin rear part or hood of the tunnel. The hydraulic rams are then made to press against the end of the tunnel, as shown, which forces the shield ahead and leaves the constructed tunnel behind in the earth. The swinging crane assists in placing the cast iron segments. As the shield advances, the men in the front part dig and throw back the earth.

Fig. 4.—The front of the shield, showing its cutting edges, its cross shelves and vertical supports.

Fig. 5.—The great shield as it appeared when being lowered by cables to its place at the heading.

American Industry in Cuba.

The rich iron ore deposits near the coast in the southeastern portion of Cuba are now in a fair way to be developed on a very extensive scale, by American enterprise, to help supply the demand for Bessemer ores in the United States. The Juragua Iron Co., established in 1883, was the first in this field. This company, whose office is in Philadelphia, has been extending its operations each year. In 1889 it shipped 256,278 gross tons of iron ore to this country from its Cuban mines, and it expects to ship over 300,000 tons during 1890. It was announced some time ago that a number of Cleveland capitalists, including the Hon Geo. H. Ely, president of the Western Ore Association, had secured control of an extensive tract of iron ore land in the vicinity of the Juragua Company's property. We are advised that these gentlemen are now making preparations to open up their portion of this iron ore region.

A third company is now in this field, called the Sigua Iron Co. This company was organized last spring, and represents Philadelphia capital. The property controlled by the company comprises about 34,000 acres, extending twelve miles along the coast and inland to the mines, the ore property, which includes about 2,000 acres, being about seven miles from Sigua Bay. This extent of territory gives the company ample room for mining towns, shops, harbor facilities, etc. The Sigua mines are about eight miles east of the Juragua mines. The Sigua River runs by the mines into Sigua Bay. The company is already preparing to build a railroad from the mines along the river to the bay and to provide suitable docks for shipping the ore.

The quality of the Sigua ore, which is red specular in character, is fairly shown by two analyses. The first analysis represents an average of all ore exposed on the surface of the ground, and is as follows: Iron, 58·10 per cent; silica, 15·50 per cent; phosphorus, 0·034 per cent; sulphur, 0·046 per cent. The second analysis was more carefully sorted, and was taken by knocking off three hundred small pieces. It resulted as follows: Iron, 64·20 per cent; silica, 5·10 per cent; phosphorus, 0·023 per cent; sulphur, 0·042 per cent. No traces were found of titanium or other substances which would render iron made from this ore poor in quality.

The estimated cost of delivering the ore from the Sigua mines to the docks at Philadelphia, including a royalty of 25 cents and the duty of 75 cents per ton, is $4.40.

The committee which examined the property included men thoroughly familiar with all the details of determining the quality of ore and of mining, transporting, selling, and smelting it. This committee was composed of Messrs. S. H. Chauvenet, David Thompson, Clarence M. Clark, E. V. D'Invillers, and Edmund D. Smith. Mr. Chauvenet was for nine years chief engineer of the Pennsylvania Steel Co., and later was manager of the Robesonia furnace, at Robesonia, Pa. Mr. Thomas is manager of the Thomas Iron Co., at Hokendauqua, Pa. Mr. Clark is first vice-president of the Virginia Development Co., which is opening up the mineral regions of Virginia. Mr. D'Invillers is an iron ore expert, and has been a member of the State Geological Survey of Pennsylvania. Mr. Smith has been actively engaged for twelve years in the handling and transportation of foreign and domestic iron ores. The committee also obtained the services of Mr. W. J. Rattle, the well known iron ore expert of the firm of Rattle & Nye, of Cleveland, to make a careful and conservative report upon the Sigua property. The reports made by Mr. Rattle and the committee were most favorable in all respects.

As at present constituted, the officers of the Sigua Iron Co. are as follows: President, S. H. Chauvenet; Vice-President, Thomas H. Graham; Secretary and Treasurer, George F. Baker; Chief Engineer, Captain D. B. Greene, the well known harbor expert. Included in the directory of the company are Edmund D. Smith and David Thomas. With such eminently practical men controlling its affairs, the success of the company is assured.—*Bulletin of the American Iron and Steel Association.*

Captain Ericsson.

John Ericsson, by virtue of his appointment as Knight Commander of the Royal Order of Isabella the Catholic, was a Spanish nobleman, and his position as Knight Commander, First Class, Danish Order of Dannebrog, gave him the title of "Excellency," with rank next to that of field marshal and admiral, and entitled him to the military honors due to a lieutenant-general. The army regulations provide, paragraphs 427, 449, that officers of foreign services shall be received and saluted according to their rank. It says nothing concerning funeral honors to be paid them, but the regulations provide that on the occasion of the burial of a lieutenant-general a salute of fifteen guns shall be fired and a funeral escort be provided, under the command of a lieutenant-general or an officer nearest to that grade in rank, to consist of a regiment of infantry, a battalion of cavalry and a battery of artillery (paragraphs 445, 467, 474, 475). As Ericsson ranked next after an admiral, or with a vice-admiral, under the Danish law, this fixes his status under the navy regulations governing the matter of funeral ceremonies. Aside altogether from the question of merit, the honors bestowed upon Ericsson while living may serve as a guide in the arrangement of the function attending the transfer of his remains to Sweden. Besides the decorations referred to, he received those of a knight of the Swedish Order of Vasa, a knight commander of the Norwegian Order of Saint Olof, and a knight commander with the Grand Cross of the Swedish Order of the Polar Star. He received by formal vote the thanks of the American Congress, of the Legislature of the State of New York and of the Swedish Diet. He never made any display of these honors, and when he was once asked what titles should accompany his name in the dedication of "Haswell's Engineering Handbook," he answered "Captain and LL.D." He was proud of the title of captain, received in his youth from the Swedish government, and of the degree bestowed as a recognition of his contributions to science. We have by no means given a catalogue of Ericsson's honors. They include the bestowal in 1862 of the Rumford Medal, which had up to that date been awarded but once before in this country, during a period of nearly three-quarters of a century since the establishment of this fund by Count Rumford.—*Army and Navy Journal.*

Lead in Lace.

Ph. De Clarmont gives an account, in *Le Moniteur de la Teinture*, of a white satin dress totally ruined by its trimming with English lace. The dress had been worn but once, had then been packed into a trunk which was deposited in a damp place and exposed to emanations of hydrosulphuric acid from gas. When taken out, it was found that the pattern of the lace, particularly of its tulle ground, had been printed in indelible black upon the white satin. The accident was not difficult to explain. English lace is habitually charged with sulphate of lead, which in this case had absorbed hydrogen and hydrosulphuric acid from the atmosphere, forming sulphide of lead, which had been imprinted and fixed upon the white satin, which naturally had also absorbed hydrogen and hydrosulphuric acid. The seller of the lace showed that charging English lace with white lead (sulphate of lead) was commercial usage, and thereby escaped paying the damage. An objectionable usage it is at any rate, as the absorption of lead through the skin from such lace may become dangerous to health.

The Cost of Firing a 110 Ton Gun.

According to a calculation made by the *Economiste Belge*, the cost of firing a 110 ton gun is, in round numbers, $832, divided as follows:

990 lb. of powder	$380
1,980 lb. projectile	435
Silk for cartridge	17
	$832

But this is not all. The 110 ton gun, it appears, can be fired but 95 times, and after that becomes incapable of being used, and requires repairs. Now, the cost of the piece being $82,400, it is necessary to estimate the cost of wear at about $868 for each shot, thus raising the cost of each charge to $1,700.