NIAGARA FALLS
SUSPENSION BRIDGE,
&c.
PAPERS AND PRACTICAL ILLUSTRATIONS
OF
PUBLIC WORKS
OF RECENT CONSTRUCTION,
BOTH
BRITISH AND AMERICAN.

Supplementary to previous Publications.

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FIFTY ENGRAVINGS.

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MEMOIR

OF THE

NIAGARA FALLS SUSPENSION

AND

NIAGARA FALLS INTERNATIONAL BRIDGE.

The success of this extraordinary bridge is now to be considered an established fact. The trains of the New York Central, and of the Great Western Railroad in Canada, have been crossing regularly since the 18th of March, averaging over thirty trips per day.

One single observation of the passage of a train over the Niagara Bridge, will convince the most sceptical, that the practicability of suspended railway bridges, so much doubted heretofore, has been successfully demonstrated.

The practicability of suspended railway bridges of large spans, was a practical question of great importance to this peculiar country, intersected as it is by numerous large rivers and deep gorges, at a depression far below the general surface of the surrounding country.

The free and unobstructed navigation of the great rivers in the United States, which are to be crossed by railways, also demanded a new class of viaducts, such as will safely pass the Locomotive with its train at one bound, and at an elevation, that will leave no obstruction to the sailing and steaming craft below. The great rivers of this continent will no longer offer an insurmountable obstruction to the formation of uninterrupted lines of railways. At the com-
pletion of the first road to the Pacific we shall possess continuous lines of rail of over 3000 miles extent, over which, if desirable, cars loaded with treasure at San Francisco, may be passed to New York without breaking bulk.

The subject of suspension railway bridges was indeed a question of great importance. A railroad is now being constructed through the central part of the state of Kentucky, known as the Lexington and Danville line, which, with its extension to the state line of Tennessee, will form the connecting link between two great networks of railways, north and south, of such an immense extent as can only be found on the North American continent. This important connection will have to be abandoned, if a suspension railway bridge of a single span of 1224 feet, now in course of construction, across the Kentucky river, which there forms an abrupt chasm of 300 feet deep, cannot be accomplished.

The Kentucky river, the Niagara, and many others which have been ploughing their courses through limestone formations, will not admit of any other mode of crossing but by a suspension bridge. Tubular as well as arch and truss bridges are in those localities impracticable.

While the European engineers are engaged in the construction of short lines of railways, at such enormous cost that in most cases the capital invested yields no remunerative dividends, the task of the American engineer is to lay down thousands of miles with extensive bridging, at a cost which would barely suffice in Great Britain to cover the expenses of preliminary proceedings.

The work which I had the honour to have entrusted to my charge has cost less than 400,000 dollars,—less than £80,000. The same object accomplished in Europe would have cost one million of pounds, without serving a better purpose or insuring greater safety. The mixed application of timber and iron in connection with wire, renders it possible to put up so large a work at so small a cost. When hereafter, by reason of greater wealth and increased traffic, we can afford to expend more on such public works, we shall construct them entirely of iron, omitting all perishable materials. We may then see railway bridges suspended of 2000 feet span, which will admit of the passage of trains at the highest speed.

As regards the success of this great work, more has been accomplished than
SUSPENSION BRIDGE.

was promised. The idea of a perfectly rigid structure, such as a tubular bridge, was never held out. The Niagara Bridge possesses all the stiffness that is wanted, and much more than is actually needed for the safe passage of trains. It is gratifying to notice the entire absence of all such vibrations as would easily be noticed, or would eventually prove a source of destruction. There is no bridge in the world, neither of stone, cast or wrought iron, which is free from all vibrations. The effect of the concussions of a fast moving train may be sensibly felt miles off through the solid earth, while buildings of brick in the immediate vicinity of a railroad are very perceptibly shaken. Sitting upon a saddle on top of one of the towers of the Niagara Bridge during the passage of a train, moving at the rate of five miles an hour, I feel less vibration than I do in my brick dwelling at Trenton, N. J., during the rapid transit of an express train over the New Jersey railroad, which passes my door within a distance of 200 feet. I will further remark that the land cables are not at all affected by the passage of trains; the very slight vibrations and concussions noticeable in the superstructure are not transmitted over the towers. This fact is gratifying, as it will insure the durability of the masonry. The stiffness of the lower floor has been a matter of general observation ever since its opening. Strange as it may appear, a number of loaded teams produce more motion than results from the transit of a train. But for the rumbling noise over head, such transit would not be noticed by persons on the lower floor.

Suspension bridges have generally been looked upon as loose fabrics swung up in the air, as if for the very purpose of swinging. Repeated failures of such works have strengthened this belief. My success in the construction of suspended aqueducts, however, should have been deemed a strong argument against it, at least by professional men. This fact should have cautioned them against forming hasty conclusions upon a subject which they had but partially investigated. I have built five such works, and two of them of large capacity and great extent, which have all proved successful, and are to all intents and purposes as rigid as stone or cast iron aqueducts. The principle of suspension is certainly much easier applied to aqueducts than to railway bridges; but still these works require a degree of solidity and stiffness, which, as was at the time
reasoned by the profession generally, could not be obtained. But some non-
professional men saw much clearer than professional men, and so the thing was
done. A good deal of the same sort of reasoning which was made use of
against aqueducts, was equally directed against railway bridges, but with no
better success, as the result shows.

Professional and public opinion having been adverse to suspended railway
bridges, the question now turns up, what means have been used in the Niagara
Bridge to make it answer for railway traffic? The means employed are:
Weight, girders, trusses, and stays. With these any degree of stiffness can be
insured, to resist either the action of trains or the violence of storms, or even
hurricanes; and in any locality, no matter whether there is a chance of applying
stays from below or not. And I will here observe, that no suspension bridge is
safe without some of these appliances. The catalogue of disastrous failures is
now large enough to warn against light fabrics, suspended to be blown down, as
it were, in defiance of the elements. A number of such fairy creations are still
hovering about the country, only waiting for a rough blow to be demolished.

Weight is a most essential condition where stiffness is a great object,
provided it is properly used in connection with other means. If relied upon
alone, as was the case in the plan of the Wheeling Bridge (U. S.), it may become
the very means of its destruction. That bridge was destroyed by the momentum
acquired by its own dead weight, when swayed up and down by the force of
the wind. The weight of a suspension bridge should not bear too small a
proportion to the transient loads it is calculated to support. The smaller the
transient weight is in proportion to the weight of the structure, the less
disturbance such passing loads will cause in its equilibrium. When a train
enters the Niagara Bridge it produces a slight depression upon that part of it.
But this depression cannot take place without a corresponding rise at the
opposite end. The greater therefore the weight of the structure, the less its
equilibrium will be affected by transient weights. This is certainly plain, and
will appear so to the most careless observer. Consequently, a high wind, acting
upon a suspended floor, devoid of inherit stiffness, will produce a series of
undulations, which will be corresponding from the centre each way. And from
SUSPENSION BRIDGE.

5

this follows the necessity of introducing the principle of the triangle, so as to form stationary points and thus check vibrations and restore balance. The effect of trains has to be met in the same way by the application of the triangle, either in the form of stays or trusses, or both. Undulations caused by wind will increase to a certain extent by their own effect, until by a steady blow a momentum of force may be produced, that may prove stronger than the cables. And although the weight of a floor is a very essential element of resistance to high winds, it should not be left to itself to work its own destruction. Weight should be, simply, an attending element to a still more important condition, viz.: stiffness. Before enlarging upon the subject I will here remark, that an engine and tender of 34 tons weight, together with one passenger car, crowded with persons, making a total load of about 47 tons, caused a depression in the centre of 5½ inches. This flattening of the camber is partly owing to an actual elongation of the cables, and in part to the disturbance of the equilibrium, the weight in the centre causing the ends next the towers to rise. But suppose the superstructure to possess no inherit stiffness at all, and together with the cables to be perfectly flexible, then the depression caused by the above weight would be much greater.

Let \( x \) represent the deflection of cables in feet.

\[ w \quad \text{the weight in the centre in tons,} \]

\[ W \quad \text{the weight of the whole structure, then the formula } \frac{x}{2} \frac{w}{W} \]

will give the depression produced in the centre in feet. Substituting now 59 feet for \( x \), 47 for \( w \), and 1000 for \( W \), we shall have \( \frac{59 \times 47}{2 \times 1000} = 1.386 \) feet.

But the actual depression, as observed by an instrument, was only 5½ inches or 0·45 feet. The difference of 0·936 feet, therefore, is owing to the inherent stiffness of the structure. A single engine of 23 tons weight, including tender, caused a flattening of the camber in the centre of 0·3 feet. The formula applied to this case would give a depression of 0·678 feet, or 0·378 feet more. The above formula, however, does only consider the equilibrium of the catenary. Neither the elongation of the cables, nor the movement of saddles on the towers, nor the reduction of deflection of the land cables are taken into account. To
provide for all these movements, would exceedingly complicate the construction of a formula. The importance of weight however is rendered manifest, because it is shown that depressions are indirectly as the weight of the structure, and directly as the weight of the transient load; also, directly as the deflection of the cables. The flatter the cables are the stiffer they will be, but also less able to support a load.

In depending upon weight as guarding against a disturbance of equilibrium, such element should also serve to increase the stiffness of the structure mechanically and not only statically. I object to weight put on simply as loose weight.

In those discussions which took place in Great Britain on the subject of suspension bridges previous to the adoption of the tubular plan for crossing the Menai Straits, a more thorough investigation of the subject would have led to the conclusion that there is no inherent defect in the suspension principle, and that by simply adding to its weight, without providing any other means of stiffness, its adaptness to railway traffic would have become clear.

The idea of absolute rigidity must be abandoned, when considering the practicability of suspension railway bridges. We can only obtain a comparative degree of rigidity in any kind of structure, no matter whether it is a stone or cast-iron arch, iron or wooden truss, or a hollow wrought-iron beam. Such being the case, the next question is: What degree of rigidity is necessary for the safe passage of trains at certain speeds? Flexibility in a bridge is no objection, provided it offers no obstruction to its use, and is compatible with safety and durability. The Conway tube of 400 feet span deflects 3 inches, under a weight of 300 tons placed in the centre. How much would a tube of 800 feet span deflect under the same load, provided such tube had the requisite depth and strength? Probably no less than 9 inches. When the Niagara Bridge is loaded with a freight train, covering its whole length, and weighing about 326 tons, the camber is reduced 0.82 feet, or nearly 10 inches. On removal of the load the structure rises again to its former level. In the case of the Conway tube, the deflection is owing to the elasticity of the iron plates composing it. In the Niagara Bridge the same cause produces the same effect, but in different
directions, and under different circumstances. In the tube one portion of the iron is exposed to tension, while a greater portion is exposed to compression. But the tensil power of wrought-iron is much greater than its resistance to compression. In a suspension bridge, on the other hand, nothing but the tensil force of wrought-iron, of a form and size which insures the best quality, is employed. The tubular principle involves a great waste of material when compared to the suspension principle, and consequently, whenever great weights are to be supported over large spans, the first cannot successfully compete with the latter. In a country where the engineer’s task is to make the most out of the least, the suspension principle will henceforth take the lead of the tubular in all ordinary localities. For extraordinary long spans the tube cannot compete on any terms.

Every train that passes over the Niagara Bridge causes a certain depression, but this being far within the safe limits of the elasticity of wire no injury results from it. Every train that passes through the Conway, or through the Britannia tubes, causes a depression. Now, can it be said that this deflection is an objection to the tubular principle? Certainly not, because these deflections are far within the safe limits of the elasticity of the iron plates composing them. But tubular bridges are designed to be rigid, while suspension railway bridges are designed to be flexible.

Next to weight as a means of preserving equilibrium, the most important feature in the Niagara Bridge is the girders which support the track. They are made of timber, and in connection with four lines of rails serve to distribute the pressure of concentrated loads. The efficiency of these girders became evident at the first trial. On the 8th of March I made the first trial trip with an American built engine of 23 tons weight, with four drivers placed but a short distance apart. The general depression in the centre was 0·3 feet. But its passage was also accompanied by a local depression or slight flattening effect, which amounted to about 1 inch extending over a length of 100 feet. Another American engine of 22 tons weight produced nearly the same effect. I then made a trip with an English built freight engine of 34 tons weight, with six drivers, placed at a considerable distance apart, which, owing to its weight being
less concentrated, did not cause more of a local deflection than half an inch, but together with a loaded passenger car produced a general reduction of the camber in the centre of \(5\frac{1}{2}\) inches. Without girders the trusses would not long resist the action of trains.

The Niagara Bridge, of a span of 821 feet 4 inches from centre to centre of towers, forms a slightly curved hollow beam or box of a depth of 18 feet, width of bottom of 24 feet, and of top 25 feet. The lower floor is used for common travel, while the upper is appropriated to railway business and sidewalks. The two floors are connected by two trusses of a simple construction, so arranged that its resisting action operates both ways, up as well as down. The suspenders are 5 feet apart. The beams of the upper and lower floor are connected by posts arranged in pairs, leaving a space between for the admission of the truss rods. The ends of the posts are secured between the beams in a manner that no part is weakened, and that any amount of strain can be thrown upon them without injuring or loosening their connections. *There are no joints to work loose.* If the timber should undergo a further shrinkage, the truss rods will simply require tightening. The depressing action of any loads is by these posts transmitted from one floor to the other. From the end of each pair of posts, a truss rod extends each way to the fourth pair of posts at an angle of 45 degrees. The rods therefore cross each other and form a diamond work. They are 1 inch diameter, their screw ends \(1\frac{1}{8}\) inch. The pressure upon any pair of posts is by these rods spread 40 feet apart. The nut work on cast-iron plates is placed above or below the posts.

Without adding much to the weight of the structure, a surprising degree of stiffness has been obtained by the united action of the girders and trusses. They have fully realized every expectation. The pressure of an engine and of a whole train of cars is so much distributed, that the depression caused by a light freight or ordinary passenger train is not readily observed. A freight train of twelve loaded cars with a 25 ton engine, covers little more than half the length of the floor. Its effect is more marked and noticed than either a smaller or larger train. When in the centre the result is only a flattening of the camber, but when near the towers, where the grade forms nearly a straight line, the
depression is from 3 to 4 inches. A longer train of greater weight in proportion disturbs the equilibrium less, as it covers a greater extent. Passenger trains of fifteen long cars, which frequently cross the bridge, make little impression observable by the eye. While the severe action of trains upon common arch and truss bridges causes great wear and tear, I am persuaded that the woodwork of the Niagara Bridge will suffer much less. My observations during the last month have not caused me to change this view, which I have always expressed.

The *tubular* or *box* plan of the bridge has added much to its stiffness, vertically as well as horizontally. There is an entire freedom from all lateral motions during the passage of a train. It is a surprising fact, that half a dozen heavy teams on the lower floor produce a more perceptible horizontal motion, and a much greater jar and trembling than is caused by a train of cars moving at the stipulated speed of five miles an hour. The smoothness, evenness, and perfect level condition of the railroad tracks partly accounts for this. While teams on the lower floor generally move forward *outside* of the centre of the bridge, the trains are exactly poised in the centre. The great *horizontal* stability of the work is mainly owing to the powerful lateral bracing of the upper cables, which are suspended in a very considerable inclination. There is no reason to suppose that the durability of the woodwork of this bridge will be less than that of a common suspension bridge, serving for ordinary travel alone.

The next means of stiffness I have applied are stays, above as well as below the floors. These, as well as the suspenders, are all made of wire rope, manufactured at my works at Trenton, N.J. There are 64 diagonal stays, of 1 2/3 inch diameter rope, above the floors, equally distributed among the 4 cables. They are fastened to the suspenders by small wrappings, so as to form straight lines. Each of these stays represents the hypothenuse of a rectangular triangle, of which the two cadets are formed by the towers and the floors. These two being solid and rigid in the direction of the lines they represent, by preserving the straight line of the stay, and not allowing them to sag or deflect, we form as many triangles as we have stays. Now the triangle is the only geometrical figure whose corners cannot be shifted, consequently, by keeping those stays...
under a good tension, we form so many stationary points in the flooring as we have stays. But these stays do not only stiffen, they are also a great assistance to the cables. Their number being limited, and the cables possessing an abundance of strength, I did not continue them over the towers to the anchorage. They are secured to the saddles, and allowed to move with them. No fear need be entertained that they will pull the saddles forward. The friction of the cables in the saddles is, at the lowest estimate, equal to one-third of the pressure. The constant pressure upon each tower is 500 tons. This would give 166 tons. The ordinary tension of each stay being about 4 tons, the united horizontal force of 16 stays applied to 2 saddles is found to be about 56 tons, to which a resistance of 166 tons is opposed, without taking into account the curvature of the cables in the saddles, which will nearly double it.

To the underside of the lower floor 56 stays are attached, which are anchored in the rocks below, and occupy positions calculated to insure against horizontal as well as vertical motions. Their principal duty is to guard against the force of winds, but at the same time they contribute materially to preserve the equilibrium of the structure during the passage of trains. Their usual tension averages from about 2 to 3 tons. Considering their positions, their aggregate force, exerted upon the lower floor in a vertical direction, at a medium temperature, is less than 100 tons. In summer this force is less, in winter it is more. In the disposition of these stays, I have taken advantage of the ample opportunity this locality offers. There are bridge sites where this cannot be done, and where security against the force of winds has to be entirely obtained by over floor stays, and by the inherent stiffness of the structure. But the difficulty is no greater in the one case than in the other. In all localities perfect safety against the force of winds can be obtained.

To present a fuller analysis of the work, I will review its various parts in the same course in which they were put up, and commence with the

ANCHORAGE.

The anchorage was commenced in September, 1852, and was formed by sinking 8 shafts into the solid limestone rock that here composes the uppermost
stratum of the cliffs. This layer is solid for a depth of 14 feet, underlaid by a limestone shale, which again is followed by a solid stratum. Three of the pits on the New York side are sunk to a depth of 25 feet. The fourth one, south east, is only 18 feet, where the rock proved very solid and without any fissures. This shaft was not sunk deeper, on account of the great influx of water and difficulty of bailing. In consequence, the lowest link of that chain was omitted, and a greater hold given to the rest by reverse arches thrown against the knuckles, also by the introduction of crossbars. With the exception of this shaft, all their others, on both sides of the river, have been sunk to an equal depth, 54 feet below the railroad track. The surface of the rock on the Canada side being 10 feet higher than on the New York side, the depth of shafts was increased that much, and the height of the masonry above reduced in proportion. Each shaft has a cross section of $3 + 7$ feet, enlarged at the bottom to a chamber of 8 feet square. The anchor chains are composed of 9 links, all of which are 7 feet long, except the uppermost or last one, which is 10 feet. The first or lowest link is composed of 7 bars, $7 + 14$ inches, and is secured to a cast-iron anchor plate by a pin of $3\frac{1}{2}$ inches diameter, ground upon its seat. The next link is composed of 6 bars of the same size, and 2 half bars on the outside. The aggregate section of each is 69 superficial inches. From the fourth link on the chain curves, and the section is gradually increased to 93 superficial inches. Four of these chains were manufactured of the best quality of Pennsylvania charcoal blooms by Everson and Preston, of Pittsburgh, the other four were made at Napannock, Ulster Co., N.Y., by Mr. Frederick Bange. They were manufactured out of Salisbury pig, puddled in wood fire. Both these irons can be depended upon for a strength of 32 tons of 2,000 lbs. per square inch. I have tested them thoroughly by cutting up a number of extra bars and pins, and forging them over into various shapes. All the sockets attached to the ends of the wire rope suspenders and stays, which are very difficult to forge, and require the best quality of material, have been made of this Naponnock iron.

The tension of the different links composing each chain diminishes as they descend, the strain upon the vertical links being more than one-third reduced,
in consequence of position, friction, and hold in the masonry. The lowest link is secured to a cast-iron plate of 6 feet 6 inches square, 2½ inches thick at the edges, with 8 heavy ribs upon the lower side. The central portion through which the bars are admitted has a depth of metal of 12 inches. Where a seam in the rock offered a good chance to form a solid bed, one-half of the plate rests against it, and the other half against masonry. After securing the position of the plate and chain, the whole shaft was filled out with masonry laid in cement mortar and copiously grouted. Great care has been taken to grout the bars well. My experience has given me ample proof, that cement grout will take a firm hold of iron, and will effectually guard it against oxidation. The bars were well oiled with linseed oil, then painted twice with zinc paint and Spanish-brown. Where no solid face could be obtained, the roof of the chamber was cut out prismatically. The masonry resting upon the plate presses against this roof like a wedge. Large stones were laid upon the knuckles, so that every joint has a hold in the masonry, above as well as below the surface of the rock. Above the rock, where the chain curves, each knuckle rests upon a cast-iron plate, bedded upon a large cut stone. This again rests upon one still larger, or upon two flat stones, which distribute the pressure upon the masonry below. No labour has been expended upon the face work of the anchor-walls, but the inside has been faithfully executed to insure a strong job.

The aggregate section of the upper links of the four chains is 372 square inches, and their ultimate strength, at 32 tons, equal to 11,904 tons. The strain upon the lowest link is at least diminished one-third, which leaves 7,936 tons. This pressure on the New York side is resisted by a sheet of solid rock of no less extent than 100 feet long, 70 feet wide, and 20 feet deep. This rock weighs about 160 lbs. per cubic foot. Now, assuming only 200 lbs. of resistance in the solid rock, we have a mass of 140,000 cubic feet opposing a force of 14,000 tons, without taking into account the weight of the superincumbent masonry and embankment. Admitting that the rock was full of fissures and seams, which is not the case, the entire safety of the anchorage is evident.

The great and very sudden changes of temperature to which this locality is exposed, and also the intense cold sometimes experienced in winter, made it
necessary to enclose the whole length of the chains in masonry. The temperature of the iron is thus preserved more uniform. The chains end at the level of the coping, where they connect with the cables, which are also enclosed in grout and masonry for a length of 12 feet, the latter terminating in ornamental blocks above the coping. The strength of wire is not affected by sudden changes of temperature; no further protection of the cables therefore is required.

I will add here that the anchor plates were cast of a very strong cold blast charcoal metal, at the foundry of Oliver T. Macklem, Esq., at Chippewa, who supplied the castings for the whole work.

MASONRY.—See Appendix D.

This part of the work was given out in contract to Mr. John Brown, on the Canada side, and to Messrs. Latham and Gage, on the New York side. Its inspection was placed under the charge of the late Mr. George Watson, who fell a victim to the cholera last year. The base of the towers presents a rock face, the stones are large, and well bonded and bedded. The beds of the backing were all cut true, and all the stones were laid in a heavy bed of cement mortar, and the joints grouted. In the towers above a uniform bond has been observed, all the blocks being dimension stone. The backing was bedded with the same care as the face. To increase the solidity of this work still more, the upper courses were dowelled. The entire security of this masonry may be relied upon. Without expending much labour upon its appearance, nothing has been spared to secure its strength.

The base of the lower work at the level of the lower floor is 60 + 20 feet, pierced by an arch of 19 feet wide, which forms the entrance to the lower bridge. Each of the four towers is 15 feet square at the base, 60 feet high above the arch, and 8 feet square at the top, therefore has a top surface of 64 square feet. The limestone, of which this masonry is built, will support a pressure of 500 tons upon every superficial foot, without crushing. Whilst the greatest weight that can fall upon one tower will rarely exceed 600 tons, it would require a pressure of more than 32,000 tons to crush the top course.

The base and towers on the New York side contain 1350 cubic yards,
which weigh about 3000 tons. Add to this the weight of the superstructure of 1000 tons, and we have a total of 4000 tons, in a compact and solid mass. For lateral stability, I have relied entirely upon this weight and the central direction of the forces, which act upon the top course. The inclination of the tangents of the suspension cables very nearly coincides with the angle of the land cables, consequently their united tensions will produce a vertical pressure through the axis of each tower.

As regards the apparent lateral pressure of the cables upon the towers, the danger is only imaginary and not real. The strongly inclined position of the upper or railroad cables, which insures that remarkable degree of lateral firmness so observable in the upper floor, appears to produce a lateral pressure towards the inside, which these small masses of masonry could not long resist. When, however, the observer takes his stand, either on top of the towers or back of the anchorage, in line with the anchor cables, he will discover that all is right and as it should be. A medium line between the two anchor cables, when continued towards the river, will be found to correspond precisely with a mean line between the tangents of the two suspension cables, consequently, the force growing out of the united tension of the cables, is bound to keep within a vertical plane, which descends through the axis of the towers. The horizontal projection of the cables on the plan, shows the perfect safety of this arrangement. By connecting the towers by an arch, and forming a gateway, instead of isolated columns, the appearance of the want of lateral stability could have been avoided. But this would have changed the whole plan of masonry, and its cost would have been more than doubled, without adding to its safety.

The character of the anchor masonry is that of strong rubble, laid in cement mortar, no regard being had to outside appearance.

**SADDLES ON TOWERS.**

On the top course of each column a cast-iron plate was laid down, well bedded in cement, 8 feet square and 2\(\frac{1}{2}\) inches thick, and strengthened by three parallel flanges for the reception of two independent saddles. The top of the plate and the bottom of the saddles are planed off. Each saddle rests on ten
cast-iron rollers, 5 inches in diameter and 25½ inches long, turned off to the same size. They are placed close together. The ordinary pressure upon each tower being about 500 tons, makes each roller bear 25 tons. The object of these rollers is to admit of a slight movement of the saddles, whenever the equilibrium between the land and suspension cables is disturbed, either by changes of temperature or by passing trains. The rollers were cast of a very close-grained, dense, and uniform metal.

Although a movement of the saddles is caused by a small difference of tension, no motions are thereby communicated from the suspension cables to the land cables. A train moving at the rate of 10 miles an hour, scarcely produces enough of motion to be perceptible in the suspension cables, and none at all in the land cables. A single engine of 20 tons weight causes a movement of $\frac{1}{32}$ to $\frac{1}{16}$ inch. This conclusively proves, that in no case will a horizontal force of 10 tons be directed upon one tower, in consequence of difference of tension between the suspension and the land cables.

The experimental freight train, which passed over the bridge on the 18th of March, and covered its whole extent, weighed about 326 tons of 2000 lbs. each, and caused the saddles to move forward 0'041 feet, or nearly half an inch. The tension which results from this weight is 590 tons. Now, according to my own experiments, which I have made with wires of 1000 feet long, to ascertain their contractions and expansions, caused by changes of temperature, as well as by weights or tension, and which agree with those of Barlow and others, wire will stretch $\frac{1}{2000}$ part of its length for every gross ton of 2240 lbs. per square inch of section. The average length of the land cables and chains is 266 feet, their elongation, caused by one gross ton per square inch, therefore is $\frac{266}{2240} = 0'0266$ feet. The aggregate section of the 4 cables is 240 square inches, therefore the tension, caused by the above load, is

$$\frac{590 \times 2000}{240} = 4917 \text{ lbs.},$$

and we find the elongation $x$

$$\frac{2240}{4917} = \frac{0'0266}{x} \Rightarrow x = 0'0583 \text{ feet.}$$
Now the actual movement of saddles was 0.041, or 0.0173 less than calculation. Considering that the chains would only be partially affected, calculation approaches the fact very near. This examination also shows, that the whole strain of the suspension cables must have been very nearly communicated to the land cables, and that consequently the towers were not exposed to any horizontal thrust.

Cables.

There are 4 cables of 10 inches diameter, each composed of 3640 wires of small No. 9 gauge, 60 wires forming one square inch of solid section, making the solid section of each cable 60.40 square inches, wrapping not included.*

The construction of these massive cables required extensive and somewhat complicated arrangements. The patent machinery for the transmission of wires across rivers was employed. This process, now so well known, was carried on for two seasons. I will therefore confine my remarks to the principles of this operation only, for the purpose of showing how a uniform tension and perfect work was insured. The appearance of the cables is not only pleasing, but their massive proportions are also well calculated to inspire confidence in their strength. The reflecting man, however, will naturally inquire: is this mass of wire put together so that the different strands bear all alike? Does each individual wire perform its duty, so that, when exposed to a great strain, they will resist with united strength to the last? This question can be answered in the affirmative; and that the tension of these 3640 wires composing each cable is so nearly uniform, that I feel justified in using the term perfect. The following remarks will explain more fully.

Each of the four large cables is composed of seven smaller ones, which are called strands. Each strand contains 520 wires. One of these forms the centre, the six others are placed around it. The 520 wires composing one strand are in fact one endless wire, obtained by splicing a number of single wires. The ends of strands are passed around and confined in cast-iron shoes, which also receive the wrought-iron pin that forms a connection with the anchor chains.

* The wire was made of the finest quality of iron, and each piece was carefully tested before leaving the manufactory.
The strands were manufactured nearly in the same position which they now occupy in the cables, with about one-third of their present deflection; this was for the purpose of increasing the tension of the wires, and to facilitate their adjustment.*

All the preparatory operations, as oiling, straightening, splicing, and reeling, were carried on in an extensive shed, erected on the Canada side, back of the anchorage.—The mode of splicing has been frequently witnessed, and it has been noticed that the wire will break at any other point before it gives way at the splice. Fourteen large reels were constantly kept supplied with wire, ready prepared or spliced for going into the cables. The machinery for plying the wires across the river was worked by horse-power. The adjustment of the wires in the centre of the span was intrusted to two intelligent workmen, who were stationed on a platform, suspended by four wire ropes, about forty feet above the upper floor. Communicating all orders by means of signal flags, this whole operation went on very satisfactorily, occasional interruptions from high winds excepted. Owing to the influence of the sun, and the sudden changes of temperature of the wires on the opposite sides of a strand during the progress of its manufacture, great care was required on the part of the men stationed in the centre. These and other circumstances have all been properly attended to; and there is every confidence that any difference of tension that may exist, does not exceed a few pounds per wire. The tension of one complete strand was about 50

* It is an important fact that iron of a suitable quality for wire is increased in strength or tensile power nearly threefold by being drawn into wire. Thus a rod of iron capable of sustaining say 30 cwts. when drawn into wire of only one-third its sectional area, or, what is the same thing, into three times the length of the rod, will still sustain a load of 30 cwts. The expense of drawing the rod into wire bears only a small proportion to the increased length which is obtained. The expense of drawing wire to one-third its original size averages about 30 per cent. upon the cost of the rod iron, while its length is increased 300 per cent. This it is which has led to the extensive adoption of wire rope for collieries, railway inclines, and, still more recently, for the standing rigging of ships, in all of which there is great economy over the use of chains and hemp ropes. The advantage of using wire ropes instead of hemp ropes wherever they can be adopted, consists chiefly in their greater lightness and cheapness. A hemp rope capable of sustaining a given weight will weigh fully two and a half times more than a well made wire rope of the same strength. In the manufacture of wire ropes it is of the first importance that the wires be so laid together as that each individual wire shall bear its proportionate share of the load. Messrs. Newall & Co., of Gateshead, invented and patented machinery which perfectly accomplished this object. Their patent has, we understand, recently expired.—Ed.
tons, or 200 lbs. per single wire. Two strands were made at the same time, one for each of the two cables under process of construction. On the completion of one set, temporary wire bands were laid on, about nine inches apart, for the purpose of keeping the wires closely united, and securing their relative position. They were then lowered to occupy their permanent position in the cables. On completion of the seven pair of strands, two platform carriages were mounted upon the cables, for laying on a continuous wrapping by means of the patent wrapping machines. During this process, the whole mass of wire was again saturated with oil and paint, which, together with the wrapping, will protect them effectually against all oxidation.

Five hundred tons of the wire used in the cables were manufactured by Richard Johnson and Brother, of Manchester, in England, and contracted for by Mr. James Cocker and Co., of New York. It is but justice to these parties to state here, that they have faithfully observed all the stipulations the contract imposed upon them. The specification required (see Appendix E.) that the wire, when suspended between two posts 400 feet apart, should not break at a greater deflection than 9 inches; also, that it should stand bending square over the jaws of a large pair of pliars, and rebending without rupture.—The size of wire was to be 20 feet per pound, but subsequently modified to 18 feet. The above test of strength corresponds to a tension of 1300 pounds per single wire, measuring 20 feet per pound, or to 90,000 lbs. per square inch of section. The contractors submitted a number of skeins for testing, which were all accepted. They then secured sufficient stock of the same quality of iron to fill the whole order, and were thus enabled to insure a uniform quality throughout. On delivery, the tests were continued with the same favourable results. From a great number of tests, which varied but slightly, I found the average deflection at which rupture took place, to be 0·683 feet, or a little over 8 inches. The wire measures 18·31 feet per pound, and the above strength, therefore, is equivalent to 1640 lbs. per single wire, or nearly 100,000 lbs. per square inch. By this mode of testing the wire is sure to give way at the weakest point. The above result, therefore, shows a remarkable uniformity in the iron, and great care in the manufacture of the wire.
Assuming the above average strength, the aggregate strength of the 14,560 wires composing the four cables will be 23,878,400 pounds. But their actual strength is greater, because the above calculations are based upon a minimum strength of the individual wires. The weak points of the different skeins will not happen to meet all at the same point. Being closely, and very compactly bound together, they will greatly assist each other. It is, therefore, safe in estimating the strength of the cables beyond the result of the above calculation. We may assume their aggregate ultimate strength at 12,000 tons, of 2,000 pounds each.

Next to severe strains, repeated vibrations and concussions of great intensity prove the greatest source of destruction to all kinds of metal. The more uniform and dense the iron is in its grain or fibre, the greater will be its durability. Good wire is a very safe and reliable material where great strains and vibrations are to be supported. Wire rope on inclined planes, where it is exposed to severe usage, and to an almost incalculable amount of vibration, lasts but a limited time. Its durability, however, will be found in direct proportion to the speed of its working, and to the consequent degree of vibration. Wire ropes of 1½ inch diameter, on such inclined planes as those of the Alleghany Portage, in Pennsylvania, where there is a speed maintained of seven to twelve miles an hour, and where the machinery is very imperfect, and always out of repair, will not last longer than one and a half to two years, and will pass about 300,000 tons, gross weight, over planes of half a mile in length, and rising one in ten. Ropes of less size will perform five times the business on the planes of the Pennsylvania Coal Company, and on the inclines of the Carbondale road, because the treatment and machinery are so much better. Those in use on the inclined planes of the Morris Canal are 2 inches diameter; draw loads of 100 tons over inclinations of one in twelve, at a speed of five miles an hour, and last, in consequence of perfect machinery and good usage, seven to eight years. These facts are mentioned to show conclusively that the durability of wire rope and cables is in proportion to usage. The same rope will last much longer under a heavy strain moving slowly, than it will under a light strain moving faster.

Of this fact I have the most ample evidence. The experience is cited of wire
ropes on inclined planes as an extreme, and by way of contrast. Suspension bridges should be built, so as to be entirely, or very nearly exempt from vibrations. The cables and suspenders of the Niagara Bridge are sustaining but a moderate tension, far within their elastic limits, and may be considered as at rest. They are also well protected against oxidation, and will consequently last an indefinite length of time.

In connection with this subject I will cite another interesting fact. The small cables which supported the temporary bridge put up under the superintendence of Mr. Ellet, and afterwards strengthened by Mr. Buchanan, had been exposed occasionally to heavy strains and to great vibrations. The wire originally was very good; about the same quality as that in the new cables, and made by the same manufacturer. On removal of the old work it was tested, and its strength and toughness scarcely impaired; so little, indeed, that I did not hesitate to work it into the new cables. Another fact is worthy of notice. The old cable measured 1\(\frac{1}{4}\) to 2 inches in diameter, and had been rapped at intervals of about 9 inches. The wire had been originally well coated with linseed oil, and the cables afterwards repeatedly painted with Spanish-brown or linseed oil on the outside, which made them impervious to water. On taking them apart I found the oil inside still in a soft condition, forming a tenacious varnish, and no trace of oxidation. These cables were put up in 1848 and removed in 1854; consequently had served six years. It is difficult to state how long this wire would have proved safe if it had remained in the same situation, exposed to the same usage. The wire suspension bridge at Friburgh, in Switzerland, the largest span in Europe, is still considered a safe work. It was completed about 1830. The roadway of the bridge is 808 feet long; weighs about 300 tons, and is supported by eight cables of 5\(\frac{1}{2}\) inches in diameter, containing in all about 4700 wires, No. 10. Its comparative strength is, therefore, much less than that of the Niagara Bridge, whilst it is frequently exposed to severe gales, and not secured against oscillations.

Wire cables, if guarded against oscillations, and not exposed to an undue tension, may be looked upon as of indefinite durability. I have cited wire rope on inclined planes as an extreme fact regarding durability. Severe friction,
short bending, constant vibration, high tension, and frequent severe shocks, will soon wear out the best material. The more we can reduce these exposures, the greater will be its durability. The conditions of durability are certainly most favourable to the cables of the Niagara Bridge. An instance of comparative great durability is furnished by wire sofa springs, which, when made of good material, will not lose their elasticity under fair usage in a life-time. As another very remarkable case of great durability under the most severe exposure, we may refer to the wire strings of a piano, which are kept at a high tension, and in that state exposed to an almost incalculable amount of vibration. Common wire would not resist this action twenty-four hours. Piano wire is therefore made either of the best steel, or of bars which form a good steel outside, and a fibrous iron inside, purposely manufactured. Good piano wire furnishes a very remarkable instance, how much strength, and what a degree of elasticity can be obtained, by an improved quality of iron and steel. In this connection I may also point to the great durability of steel springs used for the support of carriages and railroad cars. Their great exposure to severe vibrations and constant concussions is well known; as also, their great durability. In all such cases of extreme service it has been well observed that the safe limit of elasticity is not exceeded, else the material will soon be destroyed. Bridges of half a mile span for common or railway travel may be built, using iron wire for the cables, with entire safety. But by substituting the best quality of steel wire we may nearly double the span, and afford the same degree of security.

STRENGTH OF BRIDGE.

Both ends of the bridge rest upon the cliffs, and are anchored to the rock. As far as supported by the cables, it is estimated that its weight is less than 1000 tons, which includes the weight of cables between towers and the pressure of the river stays below. For convenience sake I will assume this weight at 1000 tons of 2000 lbs. each. By multiplying with the factor 1·81—see Appendix B., we find the tension of the cables, which results from this weight, 1810 tons. Their ultimate strength was stated at 12,000 tons, therefore their permanent tension is to their ultimate capacity, as 1810 is to 12,000, or as 1 : 6·63.
The sixty-four over-floor stays have an ultimate strength of 30 tons each, or 1920 tons in all. Their average supporting capacity is to their strength as one to two and a half, or equal to 768 tons. With no loads on the bridge, their tension is about 5 tons each, consequently they relieve the cables $\frac{768}{5} = 153$ tons. But their principal service is to preserve the equilibrium of the structure under heavy loads, and to assist the trusses and girders. Being under that tension, and kept in a straight line, they yield but little under passing loads. Their action is within the tangent of the cables near the towers, where stiffness is most wanted. Being not carried back to the anchorage, they are of no assistance to the land cables.

Trains of more than 200 tons weight will only cross the bridge experimentally, or at any rate but very seldom. Add to this a number of teams and persons on both floors, weighing in all about 50 tons, and we have a total weight of 250 tons, to which the bridge will be occasionally subjected. Ordinary passing loads are within this figure. The tension produced by this weight is $250 \times 1.81 = 452$ tons. Add permanent tension of 1810 tons and we get 2262 tons, to which a strength is opposed of 12,000 tons, or over five times, without counting upon the stays at all. Now the facts show that the motion of trains and their speed has no perceptible effect upon the cables, and will be, at any rate, greatly overbalanced by the assistance of the stays, consequently we may rely upon the unimpaired capacity of the cables for support, and consider transient loads as at rest. There is a possibility of much heavier loads taxing the bridge occasionally, but this may not happen once in a year. A large crowd of persons and teams on the lower floor, while a heavy train is passing above, may add considerably to the above tension, but there is an abundance of strength to meet it. What is considered of most importance to the durability of the cables is the fact that the strength is nearly six times as great as their ordinary working tension, and equally important is the fact that their strength will never be impaired by vibration. In calculating the strength of suspension bridges it has been customary to allow from three to five times of ultimate strength for the support of a maximum tension. This is a good rule provided the maximum load bears a large proportion to the weight of the structure. But if
this proportion is small, as must be the case in railway suspension bridges, it is a bad rule, as it allows too little strength for the permanent and ordinary tension.

There are 624 suspenders, each capable of sustaining 30 tons, which makes their united strength equal to 18,720 tons. The ordinary weight they have to support is only 1,000 tons. A locomotive of 34 tons weight, including tender, spreads its weight, by means of the girders and trusses, over a length of no less than 200 feet. Of course the greatest pressure is under the engine, and is there supported by no less than 20 suspenders. If by any accident a sudden blow or jar should be produced, the strength of suspenders will be abundant to meet it. Although the tension of the different suspenders is not by any means as uniform as that of the wires in the cables, it being impracticable to secure a perfectly uniform bearing; their strength is so abundant that they will easily resist a hurricane, should they ever become exposed to such a trial.

EFFECTS OF HEAVY LOADS.

Every train that passes over the bridge causes an actual elongation of the cables, and consequently produces a depression. If the train is long, covers nearly the whole length of the bridge, and is uniformly loaded, the reduction of the camber or curvature of the track will be uniform. If the train is short, and covers only a part of the floor, the depression will be less general and more local, and will be the joint result of an elongation of the cables, and of a disturbance of the equilibrium. Depressions will be in direct proportion to the loads, and indirectly as the length of the trains. After the passage of a train the equilibrium of the work is restored, and it rises again to its former level. The elasticity of the cables is fully equal to this task, and will not be impaired by the constant repetition of this process. Nor will the wooden superstructure be affected by it. The worst that can result is a certain degree of looseness, either by further shrinkage or working, which can easily be corrected by tightening the bolts. My observations since the 18th of March have confirmed this opinion.
On this last mentioned day the railroad floor was opened for business by passing an experimental freight train, composed of twenty full-loaded cars, pushed by a 26 ton engine, from the Canada to the New York depot.

The gross weight was estimated at 326 tons.
Tension of cables resulting 520 "
Aggregate section of cables 240 sq. in.
Therefore tension per square inch 4917 lbs.
" of single wire 82 "
Average length of cables and chains 1359 feet.
Elongation of wire per square inch caused by
2,240 lbs. \( \frac{1}{10000} \)
Elongation of cables by 2,240 lbs. 0.1359 feet.

From these data we can now find the elongation of the cables caused by 326 tons,

\[ 2240 : 4917 = 0.1352 : x \text{ and } x = 0.2983 \text{ feet.} \]

The depression of the bridge, caused by this elongation, is found by the following formula (see Appendix C):

\[ x = \sqrt{\frac{3}{4} (z^2 - y^2)} \]

where \( Z \) expresses half length of curve, or 416 feet.
Y represents half length of chord, or 410.66 "
The deflection was 57.50 "
The elongation of the whole cable 0.2983 "
One half 0.1491 "
Add value of Z 416.0000 "

Gives value of \( z \) to be substituted in formula 416.1491 "

The above quantities substituted, make

\[ x = \sqrt{\frac{3}{4} (416.1491^2 - 410.66^2)} \]

or \( x = .58.34 \text{ feet.} \)

deduct former deflection .57.50 "

And we get the depression caused by the load 0.84 feet.
The actual depression ascertained by the instrument was 0.82 feet.
Calculation, therefore, and fact, agree almost exactly.

On the removal of this train the structure rose again to its former level. Ordinary freight, or large passenger trains, cause a depression of 3 to 5 inches, which is as much the result of elongation as of disturbance of equilibrium. A short heavy freight train will produce as much, or rather more, depression than a very long passenger, or empty freight train of greater weight, for the single reason, that the equilibrium is more disturbed by the short train than by the long one. To construct a suspension bridge which shall not sink under heavy loads, or by an increase of temperature, cannot be done. These motions are a legitimate result of the nature of a suspension bridge, and are rendered harmless by its elastic properties.

**EFFECTS OF TEMPERATURE.**

According to experiments which have been made with wires 1,000 feet long, their expansion, caused by an increase of temperature of one degree, is \( \frac{1}{146000} \) and for 100 degrees \( \frac{1}{1460} \). The average length of cables between the chains is 1,227 feet. Therefore, their expansion from 100° is \( \frac{1237}{1460} \), which is equal to 0.8404 feet. Now suppose the deflection of cables at a temperature of 0° to be 57 feet, we find half the length of catenary, by using the formula in Appendix C.

\[
Z = \sqrt{Y^2 + \frac{4}{3} X^2}
\]

Now substitute for \( X \) . . . . . . 57 feet.
for \( Y \), or half the chord . . . . . . 410.666 "

\[
Z = \sqrt{410.666^2 + \frac{4}{3} \times 57^2}
\]

or \( Z = \) . . . . . . . . . . . . 415.9009 feet.

Now add elongation of half the length of cables, due to 100 degrees . . . . . . . . . . . . 0.4202 feet.
and we get half the elongated cable = . . . . . 416,3211 feet.
To find deflection due to this elongation, apply the formula for X in Appendix C.

\[ X = \sqrt{\frac{3}{4} (Z^2 - Y^2)} \]

Substitute for Z \( . . . . . \) 416.3211
and for Y \( . . . . . \) 410.6666

Therefore \( X = \sqrt{\frac{3}{4} (416.3211^2 - 410.6666^2)} \)

or \( X = \) \( . . . . . \) 59.25 feet.

deduct deflection at 0° \( . . . . . \) 57.00

difference arising from 100° \( . . . . . \) 2.25 feet.

Therefore a change of temperature of 100° causes a difference in the level of the floor of 2 feet 3 inches, which calculation very nearly agrees with my observations.

The lower floor or river stays have enough of slack or deflection to adjust themselves under these changes. The only difference will be, that they are tighter in winter than in summer, consequently that the equilibrium of the bridge will be less affected by passing trains in cold weather than in warm.

**EFFECTS OF HIGH WINDS.**

The destruction of the Wheeling bridge by a high wind on the 17th of May last year, the greatest disaster of the kind on record, has naturally given rise to doubts as to the safety of suspension bridges generally. One of the scientific journals remarked at the time, that the failure of this bridge would appear to be conclusive evidence against the practicability of large spans. Although I would much prefer to leave this subject alone, I cannot conscientiously do so. It is my duty to establish the safety of the Niagara Bridge, which has already, and in the brief space of one month, become one of the greatest thoroughfares on this continent. I cannot do so without drawing a comparison with other works, and without pointing out the defects which caused the destruction of the Wheeling bridge, and on the other hand explaining the means of safety which have been employed in the Niagara Bridge.

The Wheeling bridge formed a span of 1010 feet from centre to centre of towers; the floor was 960 feet long, and 26 feet wide outside of railings, its
weight, including cables, was about 440 tons. The number of cables was 12, containing in all 6600 wires of No. 10. With the exception of two small stays under the floor at each tower, which appeared to be put up after the completion of the work, and were in a loose and ineffective condition at the time I examined it, there was no provision in the whole structure, aside from the inherent stiffness of the floor, which could have had an effect in checking vibrations. Owing to the provisions made for resting the cables on the towers by means of large rollers, and to the wire being arranged in a number of small cables in place of one large one, is to be attributed the fact of the ready communication of vibratory motion from the suspension cables to the land cables. The motion caused by the transit of a single team was readily communicated to the land cables. In consequence of this sensitiveness the great force to which the suspension cables were subjected on the 17th of May, was fully transferred to their connection with the anchor chains: the result was their failure on the Wheeling side. A competent eyewitness stated, that the waves of the floor, caused by the wind, rose to a height of over 20 feet. This may have been an exaggeration, but no ordinary strength of cables can resist the momentum produced by such a weight falling even 15 feet. The destruction of that bridge was clearly owing to a want of stability, and not to a want of strength. This want of stiffness could have been supplied by over-floor stays, truss railings, under-floor stays, or cable stays. If by these means no high degree of stiffness could have been obtained, they would at any rate have proved quite sufficient to check oscillations, and to keep them within safe limits. In the Niagara Bridge most ample provisions for stability have been made. The superstructure, forming a hollow box or beam, of 24 feet wide by 20 feet deep, with solid girders of five feet depth, and effective trusses, possesses enough of stiffness to resist the action of any gale. To be prepared, however, for the greatest emergency, there are 56 wire rope stays or guys attached to the lower floor, which are firmly anchored either to the solid rock of the cliffs, or to large masses of detached rock. Each of these ropes has an ultimate strength of 30 tons, they would therefore resist with an aggregate force of 1680 tons. But, owing to their inclinations, they would probably not oppose a greater resistance than
1000 tons, if that pressure was vertically applied against the lower floor. The ordinary tension of these stays does not exceed from two to three tons.

Now the weight of the bridge without the cables and stays is 600 tons. To this add the anchorage at each end of the lower floor, which is estimated at 300 "

Resistance of cables in centre 100 "
Resistance of stays is 1000 "

Total 2000 tons.

Let us suppose a hurricane expending its power upon the whole extent of both floors, and at the rate of 50 lbs. per superficial foot uplifting force.

The surface of the upper floor is 20,000 feet.
" " lower " 18,000 feet.

Total 38,000 feet.

Pressure at 50 lbs. 1,900,000 lbs.
or 950 tons.

to which a resistance is opposed of 2000 tons. No tornado, however, will act with equal force upon both floors at the same time, nor uniformly throughout their whole extent. Before the two floors were connected I noticed, that while the lower one was sensibly affected by a gale the upper one showed no motion at all, its force appeared to be expended below. Owing to the bend of the river the Canada shore is well protected, while the opposite side is exposed from all quarters. Not the slightest motion from high winds was ever noticed since the two floors were connected. The work has been frequently tested by the strongest gales that blow in this vicinity. I am also convinced that it will be proof against a hurricane.

The tornado which recently made such havoc at the town of Niagara, and was also severely felt at Lockport and Rochester, did not expend its full force upon the bridge. Its vortex was either too much elevated, or too far north east. Only a severe momentary shock, accompanied by great darkness was experienced, and lasted but a few seconds. This shock did not produce the slightest perceptible motion. Tornadoes are believed to be whirl-
winds on a large scale, produced by the struggle of two winds moving in opposite directions in the upper regions of the air. Impelled in the directions of the strongest wind, the two contending forces move on within the sphere of a double cone, the most violent action being at the union of the two bases. This view being correct, the Niagara Bridge can never experience the full force of a hurricane. The towers may come within the sphere of its action, but not the bridge itself; certainly not enough to experience a great uplifting force.

EFFECTS OF THE TROTTING OF HORSES OR CATTLE, OR THE MARCHING OF MEN.

This is a subject which, next to the effect of high winds, is most important to be considered. The Niagara Bridge is a great thoroughfare for all kinds of stock. Drovers of cattle are, according to the regulations, to be divided off in troops of twenty, no more than three such bodies, or sixty in all, to be allowed on the bridge at one time. Each troop is to be led by one person, who is to check their progress in case they should start off on a trot. If these rules and regulations are strictly observed the bridge will be spared much abuse. On several occasions I have noticed the injurious effect produced by twenty heavy cattle under a full trot. Standing on the lower floor at the time I could perceive no apparent motion in the bridge, but felt a most intense trembling and short vibration. If the cattle happen to move all on one side, outside of the centre, the effect produced is also lateral, and consequently severe upon the framing. The great inherent stability of the structure will so far resist this action as to prevent all such motions as would be readily discovered by the eye. But I will state here that in my opinion a heavy train, running at a speed of twenty miles an hour, does less injury to the structure than is caused by twenty heavy cattle under a full trot. Public processions, marching to the sound of music, or bodies of soldiers keeping regular step will produce a still more injurious effect. No bridge, constructed without regard to stability, will long resist such tests. The best built suspension bridge, as well as all kinds of wooden or iron structures, not excepting tubular bridges, will suffer from this cause. The Covington
Suspension Bridge opposite Cincinnati, with a single span of 550 feet, erected last year, and since rebuilt, fell down under twenty cattle trotting over.

The above remarks have been made with a view to correct popular notions upon this subject, and also to draw attention towards it, so that the superintendent of the bridge may be directed to see the rules and regulations already laid down strictly enforced.

In conclusion I will state that the woodwork was entrusted to the charge of Mr. D. McKenzie, as master carpenter, who last year sustained a serious injury while removing the old wooden towers on the Canada side, and has been since assisted by Mr. L. Anson. The wire work and other parts have been attended to by Mr. David Rhule. During the first two seasons I was assisted by W. O. Buchanan, Esq., and latterly by J. H. Fisher, Esq., who is also acting in the capacity of Secretary to the Joint Board. To all these gentlemen I wish to express my obligations for their cordial and efficient co-operation in the execution of the works.

In this memoir, and reporting on the final and successful completion of the bridge, I should be doing injustice to my own feelings as a man if I did not avail myself of this opportunity to thank the President and Directors of the Niagara Falls Suspension and Niagara Falls International Bridges Companies for the unwavering confidence which they have always placed in my professional ability. When engineers of acknowledged talent and reputation freely expressed their doubts as to the success of this work, a wavering of confidence on their part would have been but natural. But I am happy to state here that in all my operations I have always met with a cordial support. It is a great satisfaction that this work has turned out equal to the promise made, and also to acknowledge the mutual confidence that has existed.

JOHN A. ROEBLING.

NOTE.

The railroad tracks are leased to the Great Western Railway Company, and the contract requires that the bridge should be inspected and examined by
the Government engineer of the provinces of Canada, the Hon. H. H. Killaly.

The following is the certificate of that officer, addressed to the respective companies:

Department of Public Works.

Quebec, 31st April, 1855.

Sirs,—I had the honour a short time since to receive a letter from Mr. Roebling, requesting I would name a day on which I would meet him for the purpose of inspecting and testing the Niagara Suspension Bridge. I have also had a communication from the Managing Director of the Great Western Railway Company to the same purport.

Having had repeated opportunities during the course of its construction of judging of and observing the careful and scientific attention given to it in all its details—the selection of the best of materials, of their respective kinds, used in it, and the severe tests to which it has been already subjected—I do not require any further proof to satisfy me of its stability and sufficiency for the purposes for which it is designed; nor do I conceive it necessary to require the engineer again to go through the ceremony of testing it.

The respective examinations I have made of it, from time to time, the trials it has undergone, the ingenious and talented calculations made of its strength, &c., by Mr. Roebling, to which I have had access, convince me fully, that with due care in the maintenance of it, it will be found a safe and permanent work, the principles, plan, and details of construction of which reflect the highest professional honour on that gentleman.

I am, Sir, your obedient Servant,

HAMILTON H. KILLALY,
Assistant Commissioner of Public Works, Canada.

To the President and Directors of the Niagara Suspension Bridge Companies.
APPENDIX.

APPENDIX A.

TABLE OF QUANTITIES.

Length of Bridge from centre to centre of tower, 821 feet, 4 inches.
Length of Floor between towers, 800 feet.
Number of Wire Cables, 4.
Diameter of each cable, 10 inches.
Solid Wire Section of each Cable, 60·40 square inches.
Aggregate Section of each of the four Cables, 241·60 square inches.
Aggregate Section of Anchor chains, lowest links, 276·00 square inches.
Aggregate Section of Anchor chains, upper links, 372·00 square inches.
Ultimate strength of Chains, 11,904 tons.
Aggregate number of Wires in Cables, 14,560 tons.
Average strength of one Wire, 1,648 lbs.
Ultimate strength of four Cables, 12,000 tons.
Permanent weight supported by Cables, 1,000 tons.
Tension resulting, 1,810 tons.
Length of Anchor Chains, 66 feet.
Length of upper Cables, 1,261 feet.
Length of lower Cables, 1,193 feet.
Deflections of upper Cables at medium temperature, 54 feet.
Deflections of lower Cables at medium temperature, 64 feet.
Average deflection, 59 feet.
Number of Suspenders, 624.
Aggregate ultimate strength of Suspenders, 18,720 tons.
Number of Over-floor Stays, 64.
Aggregate strength, 1,920 tons.
Number of River Stays, 56.
Aggregate strength, 1,680 tons.
Elevation of Railway track above middle stage of river, 245 feet.

APPENDIX B.

To find tension of cables:
Let \( x \) represent deflection.
Let \( y \) represent half the span.
Let \( W \) represent weight of cables and load equally distributed.
Let \( T \) represent tension resulting,
SUSPENSION BRIDGE.

and the following formula will give the value of tension:—

$$T = \frac{W}{4x} \sqrt{4x^2 + y^2}$$

Substitute for $x$, 59 and $y$, 410·66, and

$$T = \frac{W}{4 \times 59} \sqrt{4 \times 59^2 + 410\cdot66^2}$$

or $T = W \times 1\cdot81$.

The tension of the cables, therefore, will be obtained by multiplying the weight $W$ by the factor 1·81.

APPENDIX C.

The length of span and deflection being known, to find the length of the cable, calculated as a parabola:

Let $y$ express half the length of span.
Let $x$ express deflection.
Let $\delta$ express half the length of cable.

Then $Z = \sqrt{y^2 + \frac{1}{3} \delta^2}$

The following formula will give deflection when length of span and of cable are known:

$$X = \sqrt{\frac{1}{4} (z^2 - y^2)}$$

APPENDIX D.

CONTENTS OF MASONRY.

<table>
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<tr>
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<tbody>
<tr>
<td>In base of Towers</td>
<td>786 cubic yards.</td>
<td>459 cubic yards.</td>
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<tr>
<td>Arch</td>
<td>45 &quot;</td>
<td>45 &quot;</td>
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<tr>
<td>Towers</td>
<td>511 &quot;</td>
<td>511 &quot;</td>
</tr>
<tr>
<td>Pier</td>
<td>151 &quot;</td>
<td>154 &quot;</td>
</tr>
<tr>
<td>Wings and Anchorage</td>
<td>2006 &quot;</td>
<td>1163 &quot;</td>
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3499 cubic yards. 2312 cubic yards.

Contractors were requested to annex their bids for one cubic yard of masonry of 27 cubic feet, for each class of masonry, on each side of the river, as follows:

On American Side.
For each cubic yard of masonry in base of Towers.
" Arch.
" Towers.
" Pier.
" Wings and Anchorage.
On Canadian Side.

For each cubic yard of masonry in base of Towers . . . .
" " Arch . . . .
" " Towers . . . .
" " Pier . . . .
" " Wings and Anchorage . . . .

THE ORIGINAL SPECIFICATION WAS AS FOLLOWS:

For the erection of the Masonry of the Niagara International Suspension Bridge for Railroad and common Travel.

1. There will be two towers for the support of the wire cables on each side of the river, connected by an arch below. Those on the American side will be about 88 feet; those on the Canadian side 78 feet high. The base of the Towers from the abutments of the bridge will be 28 feet high on the American and 18 feet on the Canadian side, leaving the towers 60 feet high.

2. Character and Masonry of Abutments.

This masonry is to be carried up in courses of 18 inches high, each course to be laid down with headers and stretchers alternately, as marked in the plan. The beds or stretchers to be no less than 2 feet wide, the length of headers to be no less than 5 feet. The size and courses and the plan of bond as laid down in the drawings cannot be departed from except with the express permission of the engineer. The face of the outside stone may be left rough as they come from the quarry, to form rockface, except under the archway, where they must be scabbled more carefully and uniformly. The beds and joints must be dressed with the tool so as to be perfectly even and true, without however being cut smooth and fine. They must be perfectly parallel and true to the square and straight edge. Joints to be close, not exceeding 8½ of an inch. Every course must be level on top, but no dressing or levelling will be permitted upon the wall. None but perfectly sound and solid stone will be permitted to go in this masonry, and every stone must be laid on its natural bed.

The backing is to be composed of scabbled blocks of the same thickness and size as the face stone. The blocks are to be quarried as if intended for cutting, they must be scabbled and axed all around so as to be true to the straight-edge and square, and perfectly out of wind, ready for the cutter's tool. No spalls or small stones, for filling up, will be allowed to go into this backing, except where a smaller one is wanted occasionally to fill up a gap, or to observe a good bond. No joint in the backing to be over 2½ inches wide.

The beds of all stone to be laid in cement mortar, the joint to be grouted at the completion of every course. The batter of this masonry will be one inch per foot rise on all sides, except where it connects with the arch.

The upper or coping course will be formed of 4 facestones on each side, with backing to correspond, the whole top to be perfectly level and true and prepared for the reception of the first course of the masonry of the towers.

Connecting Arches.

These will be 17 feet wide and 15 feet long. The archstones, except at the spring, will be 3 feet long, 1 foot thick, and no less than 2 feet wide, laid so as to break joints. The bed of all the voussoirs to be cut smooth and true to the level. The face of the ring stones will be rustic with a draft of one inch around the edge, the inside face to be dressed in the same manner. At the spring of the arch
the voussoirs must connect well with the abutment masonry. The face of the spandrils to be coursed as shown in the drawing.

_Towers._

Will be 60 feet 6 inches high including the cast iron saddles on top; 15 feet square at base, and 8 feet square on top. Each tower will be built in 30 courses, the plan for each course, the size of stone and bond, for face as well as backing, is exhibited in the sixth and seventh course, which will follow alternately, the size diminishing with its elevation, to conform to the batter of the column. A special working plan will be made out for every course. No deviation from the plans whatever will be permitted.

The base of each tower is 6 feet high, with plumb face, and will be built up in 3 equal courses. The face stone will have a draft of 1\frac{1}{2} inches wide around the edge, and the inside will be picked coarsely, so as to present a coarse but uniform rustic appearance. The beds and joints must be cut perfectly true and form close joints. The backing to be also cut stone, beds cut true and parallel, but the sides are to be only well seabbled or axed, so as to be square and out of wind, and to form joints not exceeding 2\frac{1}{2} inches in width. No small stones whatever will be allowed to go in. Every block for backing must correspond to the size laid down in the plan. The base is formed by courses No. 1, 2, and 3.—The 4th course is only 16 inches thick and forms the base moulding. A separate plan will be given for this course.

The shaft of the tower is built up in 20 courses, numbered from 5 to 24, a little less than 2 feet in thickness. The plan as laid down for the sixth and seventh course will be alternately pursued. The beds and joints of all the facestone must be cut perfectly true, and the backing will be the same as in the base. The quality of the facestone has to be selected with care; it must be solid and sound throughout, of a uniform texture and colour, free from all seams, spots, or blemish. The face of the outside blocks will have a draft cut smooth, 1.2 inches wide, around the edge, and the balance picked fine to present a fine rustic appearance, in contrast to the base, which is rougher.

Separate plans will be given for the upper six courses, composing the neck, capital, and top, and averaging 2 feet in height. The face of these courses will be cut smooth, as also the moulding course between the base and the shaft. The ornaments on the neck and capital will be cut after they are up. —Separate bids are required for the cutting of this ornamental work. The contractor will also be required to hoist the cast iron saddles on the top of the towers and to set them, as will be directed, on a bed of cement mortar.

_Piers between Towers and Wings._

They are 27 feet long and 5 feet wide on top, sides battering one inch to the foot. The masonry is to be cut stone and rock face, put up in courses of one foot or more, either equal courses throughout, or diminishing from the foundation upwards. The beds to be one half wider than the height of courses. A regular bond of headers and stretcher must be observed. Backing to be composed of good large flat rubble stone, well bedded and bounded. All the stone to be laid in cement mortar, the facestone to be grouted.

_Masonry of Wings and Anchorage._

The wings-walls commence at a distance of 136 feet 6 inches from the center of abutments. They are connected by a breastwall, which serves as abutment for the adjoining span. The breastwall is 45 feet long on the top, and 5 wide, battering one inch per foot outside, and forming 5 stops of 9 inches wide.

The wings extend 134 feet. For a length of 44 feet they are 3 feet wide on top, and serve as retaining walls to hold the embankment. For the remainder of the distance they serve as anchorwalls for the support of the anchor chains, and are 6 feet wide on top.
The breastwall as well as the wings and anchorwalls are to be built good and strong, coursed or ranged work. No course to be less than 1 foot in thickness, the courses to be of equal rise or diminishing from the foundation upwards.

The beds and joints of the facestone must be hammer dressed, so as to be out of wind and square, but no tooling is required. The face is to be scabbled to imitate rock face.—A good bond of headers and stretchers must be observed in all the courses on the face as well as the backing. The backing to be composed of good flat stone, corresponding in size to the facestone. No bonders or round stone will be allowed to go in the backing.

The inside of the anchor masonry must be built up of large flat wellshaped and solid backing stone, and a good bond observed throughout, particularly where the pressure of the anchor chains is to be supported. Every stone must be well settled down in its bed of mortar and not to be disturbed again. The pressure of each chain is to be supported by five large, sound, hard, and solid blocks, 5 feet long, 3 feet wide, and no less than 18 inches thick. These are to be bedded on large backing stones, no less than 6 inches by 3 inches by 1½ inch, and in the position indicated in the plan. The beds of the upper blocks are to be cut smooth, also the upper beds of the lower blocks; the sides are to be scabbled and axed, so as to be out of wind and square.

A cast iron plate will be laid upon the cutface for the support of the chain. An opening will be left around the chain, which is to be fitted with cement-grout, as the wall is carried up.

This grouting is not to be included in the bids for masonry, but will be done by the Company's hands or as extra work.

The face of the wing and anchorwalls will have to be neatly pointed when completed.

The whole of these walls are to be covered by a cut stone coping, 3 feet wide and 1 foot thick, cut with a slope to shed the water and secured by clamps on top.

The putting up of the iron railing is not to be included in the contract for masonry.

Where the anchor chains and cables connect on top of the wall they will be enclosed by large cut stone blocks, for which separate contracts will be made.

General Remarks.

In all cases the lowest course of masonry must be commenced upon the solid rock, and the rock-bed must be prepared and levelled off for its reception. This labour is to be included in the price of masonry.

No dirt or dust must ever be allowed to collect upon a wall, it must be kept clean at all times.

An abundance of water must also be used to keep the stone moist and thereby facilitating its connection with the cement mortar. This will be particularly enforced in dry weather.

No dressing or cutting of stone will be allowed upon the wall. If a stone is too large and requires retcutting, it must be removed from the wall.

More particular directions will be given during the progress of the work by the engineer or the inspector of masonry whom he may appoint.

Cement.

All the cement used for mortar or grout must be of the best quality of hydraulic cement, it must not have been manufactured more than three months previous to being used, and must be delivered in good tight barrels packed in paper.

The sand to be mixed with the cement must be good clean sharp quarry sand, and be washed if necessary. The usual proportion of mortar will be one part of cement and two parts of sand, unless directed otherwise. Cement mortar shall not be prepared sooner than one hour at most before it is
sed, and in very dry and warm weather it must be kept moist and worked all the time until it is used. No mortar which has stood over one hour, or has been left over night, shall be used, it must be removed. Grout is to be used immediately on being prepared.

Further Stipulations.

In case the contractor shall not, in the opinion of the engineer, well and truly from time to time comply with and perform all the conditions herein stated, the said engineer, at his discretion, may dismiss him from the work, and then the agreement between the contractor and the Bridge Companies shall become null and void, and all claims for any balance for work done or material provided which would have been due shall have been forfeited, and shall become the right and property of the Bridge Companies as damages for breach of contract. Or engineer may employ other parties to hasten the completion of the work, or any part of it, whenever in his opinion it shall be requisite to insure the completion of the work within time specified. The contractor shall have no right to let or transfer any part of the work to other parties without the knowledge and consent of the engineer. Upon notice by the engineer the contractor will be bound to discharge any incompetent mechanic or workman in his employment for improper work or conduct.

The stone for the masonry on the Canadian side must be obtained on that side, and for the masonry on the American side must be obtained on the American side. No stone is to be quarried within a distance of 200 feet above or below the site of the bridge on the banks of the river.

The stone for the American towers and masonry may be obtained from Lockport.

The whole masonry is to be completed within twelve months from the time the contract is signed.

Monthly estimates during the progress of the work will be made by the engineer of work done and materials delivered upon the ground. Eighty per cent. of the full value of this work will then be paid by the Bridge Companies to the contractor in current funds. And when on completion of the whole masonry the work shall have been finally accepted by the engineer, then the Bridge Companies will make a final payment to the contractor, or his accredited agents, for the balances due to him on the several estimates.

APPENDIX E.

PROPOSAL FOR FIVE HUNDRED TONS OF WIRE.

By the undersigned, on the part of the Niagara Fall International Bridge Company, for the construction of the wire cables of the Railroad Suspension Bridge, of above 800 feet span, to be erected over the Niagara river, below the Falls, for the delivery of one million pounds of iron wire, or any portion of it, not less than 100,000 lbs., at the site of the bridge, on the following conditions:—

1. The wire is to be of No. 10 size, so that 20 feet will weigh exactly one pound.
2. The skeins to weigh no less than 18 lbs. An offer for 30 to 40 lbs. will be greatly preferred.
3. The wire must be finished with a lime coat, smooth and even, both ends of the same thickness.
4. It must be finished in 3 holes, or nearly as hard as spring wire.
5. The iron must have been manufactured of the best quality of charcoal blooms, which will make hard wire of great elasticity, strength, fibre, and toughness.
6. The blooms must have been manufactured of cold-blast charcoal pig, and not of anthracite pig, nor of hot-blast pig.
7. Satisfactory evidence will be required beforehand of the quality of the iron, of which the wire is to be drawn.
8. The wire must be drawn on blocks of no less than 2 feet diameter.
9. It must be put up in bundle of 200 lbs., as near as can be done, without small skeins.
10. The wire is to be delivered in five equal portions, during the months of May, June, July, August, and September of the year following.
11. On delivery, the wire will be examined and tested in the following manner:—Of every 5 bundles or 1,000 lbs. one skein will be selected, and suspended between two posts 400 feet apart, the one end attached to a capstan, by which it will be gradually hauled on until it breaks. The condition now is, that this wire must not break with a greater deflection than 9 inches, which is equivalent to 1,300 lbs., or 90,000 per superficial inch of solid wire section. If it stands this test, then further examination of that one thousand pounds, in respect to other qualities, will be continued; but if not, it will be rejected and placed at the disposal of the contractor.
12. As regards toughness and fibre, each end of a skein will be tested by bending it square over the jaws of a large pair of new and sharp pliers, and bending it back again. The wire must stand this test without the least sign of failure. Its hardness and elasticity will at the same time be examined by bending and swinging, also by hammering, filing, and notching the ends, which forms part of the operation of splicing.
13. Such lots as have stood the various tests satisfactorily, will then be accepted conditionally, and 80 per cent. of its full value will then be paid to the contractor in bankable funds.
14. The 20 per cent. will be reserved for four months longer. Should in that time, during the construction of the cables, any more defective skeins be discovered, such skeins will be rejected and placed at the contractor’s disposal, either broken or whole, oiled or not oiled, in such condition as they happen to be during the progress of the work. The value of such wire, together with the labour expended upon it, will then be deducted of the 20 per cent. reserved.
15. The undersigned, as the engineer of the bridge, will be the sole judge of the above tests; he will stand as an impartial umpire between the contractor and the bridge company, and from his decision there shall be no appeal.
16. Proposals for imported wire will be accepted. One half, or 500,000 lbs., will be used on the Canada side, and may be bonded, if imported by way of New York.
17. Proposals will be received until the 1st October next; they are to be directed to the undersigned at Niagara Falls, N. Y., and should be marked on the envelope, “Proposals for Bridge Wire.”
18. Those contractors, whose proposals are accepted, will be informed of the fact by mail, before or on the 10th October next.

John A. Roebling.
Engineer of the Niagara Falls Railroad Suspension Bridge.

Niagara Falls, N. Y., August 5th, 1852.
DESCRIPTION OF ILLUSTRATIONS TO THE NIAGARA SUSPENSION BRIDGE FOR RAILROAD AND COMMON TRAVEL. BY JOHN A. ROEBLING, C.E.

Plate 1.—The whole elevation of the bridge, together with the plan and end elevation of the towers, showing the entrance to the rail and common road, from centre to centre of tower, 821 feet of suspension.

Plate 2.—Half plan of traversing wires across the Niagara River for making cables, with scaffolding working endless ropes, &c.

Plate 3.—Half plan of ditto completing the same.

Plate 4.—Elevation of the western towers with figured dimensions and plan.

Plate 5.—Section of ditto with dimensions.

Plate 6.—End view river side plan, land side showing the masonry, with dimensions.

Plate 7.—Plan of masonry on the New York side.

Plate 8.—Plan of masonry on the eastern side, longitudinal section through anchorage or abutments, elevation of wires in connection with the tower, with dimensions.

Plate 9.—Long section through anchor walls, showing two chains, with plan of chains, with dimensions.

Plate 10.—Plan and section of anchor plate (abutment) with dimensions.

Plate 11.—Plan and section of saddles and plates on top of towers, with dimensions.

Plate 12.—Sections of cast iron saddle for stirrups of lower suspenders (see Plate 20). B. shows footing for stirrup; a, a, bolt holes for fixing to oak block.

Plate 13.—Apparatus for lifting and moving strands on top of towers, with dimensions.

Plate 14.—Cross section of superstructure of bridge, with dimensions.

Plate 15.—Section and elevation of ditto.

Plate 16.—Plan of adjoining spans, longitudinal section through track, and side elevation, with dimensions.

Plate 17.—Plan showing the connection of truss posts and of the floor-beams of bridge, with dimensions.

Plate 18.—Plan showing connection of suspenders and stirrup of lower floor, also connection of truss posts and lower beams, with dimensions.

Plate 19.—Oak block for upper suspenders for saddles (see Plate 12).

Plate 20.—Oak blocks for stirrups for lower suspenders for saddles (see Plate 12).

Plate 21.—Section and top view of truss rods.

Plate 22.—Cable blocks, coping of anchor walls, section of anchor walls.
Plan of Masonry on the New York side.

N. R. R. S. B.

Scale: 20 ft - 1 in.

John A. Roebling.
Plan of Masonry on Eastern Shore.

N. R. R. S. B.

ELEVATION

LONGITUDINAL SECTION THROUGH ANCHORAGE.

PLAN.

John A. Roebling.

Long Section through Anchor Walls, Showing 2 Chains.
N.R.B.S.B.

Scale 8 Feet = 1 Inch.
Anchor Plate.

N.R.R.S.B.
Plan of Saddles and Plates on top of Towers.

N. R. R. S. B.

Scale 1 Foot = 3/8 of an Inch.

John A. Roebling.

Apparatus for lifting and moving strands on top of towers.

Plan of Superstructure.

SECTION

ELEVATION

Scale 1 ft. = 1 inch.
Plan showing the connection of the Trussposts and of the Floorbeams
N. R. R. S. B.

John W. Hale, London, 1856.
Plan showing connection of Suspenders and Stirrup of lower floor, also connection of tranposed lower beams.

N. R. R. S. B.
Oak Blocks for Upper Suspenders.

N. R. R. S. B.

12 inches wide - 15 inches long

Scale 2/3nds Full Size.

John W. Roebling

Oak Blocks for Stirrups of Lower Suspenders.

Scale Quarter Size.
Plate for Truss Rails.

Section.

Topview.

John A. Roebling.

Scale ½ Size.

John Wesley, London, 1866.
MEMOIR
OF THE LATE
BRIGADIER-GENERAL SIR SAMUEL BENTHAM.

Many instances have been recorded of uneducated men who have been the inventors of important machines; but in the following Memoir of Brigadier-General Sir Samuel Bentham will be seen the good effects of a scientific education combined with a practical one; and it may be gathered from the subsequent pages, that an intimate knowledge of the whole circle of sciences conduces to the perfection of things, which apparently have little or no relation to any other than mere mechanical skill. The pecuniary means of every father may not, it is true, enable him to afford the time and money which were bestowed on Samuel Bentham's education, but it is in the power of every student to avail himself of the numerous opportunities now so easy of access, for obtaining knowledge at a cheap rate. It must not be assumed, however, that every boy, though going through the best course of instruction, should turn out a Samuel Bentham, for he had a peculiar genius, to which was added a mind prone to logical discrimination, and a habit of turning all he saw to account.

It should be added that no invention is mentioned in this Memoir, but such as could be verified by existing documents, as by letters patent, and by records at the Admiralty which date from the year 1791.

The talents of the late Brigadier-General Sir Samuel Bentham having been devoted to the Naval department of Government; no record exists of his many inventions, or of the numerous improvements he introduced; it has, therefore, been supposed that a recital of them could hardly fail to be interesting. Hence the following Memoir has been drawn up. The documents from which the sketches are taken consist of correspondence, of his several patents, of his official
papers during the seventeen years he was in the British service, his subsequent proposals to the Admiralty, and his publications. There are also some few particulars mentioned that were collected from himself.

Sir Samuel Bentham was the youngest son of Jeremiah Bentham, who retired from the practice of the law soon after Samuel's birth. At an early age the boy was placed at a private school, from whence, at the age of six, he was sent to Westminster. His father had married the widow of Mr. Abbot, whose son Charles, being about the same age as Samuel, was also educated at Westminster; the boys being day scholars, came home to Mr. Bentham's in Queen Square Place. It has often been remarked that early trifles influence the future bent of the man—it might have been so in respect to Samuel Bentham, for in the stable yard of his father's house were spacious workshops let to a carpenter, and there Samuel spent his leisure time working with his tools; he must have acquired some skill, for at the age of thirteen he had completed, with his own hands, a carriage for his playmate, Miss Cornelia Knight. He afterwards spoke frequently of this vehicle as being a remarkable instance of juvenile precocity in workmanship. What it was that gave him a turn for naval concerns is unknown, but his predilection for them was so powerful that his father abandoned all idea of training his son for a liberal profession, and bound him at fourteen years of age to the Master Shipwright of Woolwich Dockyard. At that time such an apprenticeship was considered the best mode of educating a youth for the service of the Navy, as the superior officers of a Royal Dockyard were exempted from keeping their apprentices at hard labour, and thus time was allowed them for general instruction. Samuel, however, early perceived that practical manipulation was no less essential than theoretical knowledge, and determined to work with his hands at the dockside every day till breakfast time, but devoted the rest of the day to scientific acquirements. Many of his notebooks still remain; they show that the whole circle of the sciences engaged his attention, and his father procured the best masters for him. Samuel and his master were removed from Woolwich to Chatham Dockyard, thus enabling him to obtain a practical knowledge of the behaviour of vessels at sea; for he was often permitted to sail to the British Channel, sometimes extending the voyage
to the Isle of Wight. His brother, the celebrated Jurist, Jeremy Bentham, had by this time returned from college, and instilled him with many first ideas of political economy; Samuel having often on the Saturday walked up from Chatham to his brother's chambers in Lincoln's Inn.

The seven years' apprenticeship ended, Samuel spent another year in the other Royal Dockyards, and at the Naval College at Portsmouth; then went to sea as Captain Macbride's guest, whose ship was one of Lord Keppel's fleet. Thus knowledge was acquired of many circumstances influencing the health and comfort of the ship's crew. On this occasion he suggested sundry improvements in the apparatus of a ship, which were executed in Portsmouth Dockyard. In consequence of abilities manifested in the young man, advantageous appointments were offered him, but his father objected to his acceptance of them on various accounts; when Lord Howe, then first Lord of the Admiralty, proposed his visiting the several ports in the north of Europe, to learn their different practices in the art of Naval construction. His father assented, and furnished pecuniary means, Lord Howe contributing letters of introduction to our foreign ambassadors and consuls. Bentham embarked for the Continent in 1780, visited the great Naval establishments of Holland, where he was treated with especial favour by the most renowned Dutch shipbuilders, and by our ambassador at the Hague, Sir James Yorke. From Holland he proceeded to the north of Europe, acquainting himself with the resources and necessities of each country he passed through; for he had long perceived that the business of a naval engineer embraced a wide extent of scientific knowledge, and a familiarity with a vast variety of manufactures.

Arrived at St. Petersburgh, our ambassador, Sir James Harris, honoured him with his friendship, and introduced him to the best society, amongst others to Prince Potemkin, who on further acquaintance treated Bentham with peculiar distinction, and invited him to accompany his Highness in a journey to the Crimea. There Bentham was gratified by obtaining the friendship of the celebrated traveller Pallas, who advised a journey to the Ural Mountains, with a view to the obtaining information respecting mines and metals. On Bentham's return to the north, he profitted by Pallas' advice and letters of introduction,
and set out on a visit to the principal mines and manufactories he had indicated, amongst others to the great fabric of Count Demidoff. The Count had directed his superintendent at Nigno Taghilsky to treat Bentham as a favoured guest, and to comply with all his desires: this was done, even to the construction of a carriage of Bentham's invention. It was an amphibious vehicle, that is, it was a wheel-carriage on land, but, being of the form of a boat, it was capable of being navigated across or along a stream of water. Bentham's practice as a handicraft's man here served him in good stead, for the workmen, though amongst the best in Russia, were awkward manufacturers of wood, so that he had not only to trace out the dimensions of every piece intended for the carriage, but often also actually to work at it himself. Not brooking the acceptance of such expensive labour gratis, and conceiving that the improving the works at the fabric would best prove his gratitude, he invented a machine that would plane wood accurately and expeditiously, and which also, by merely changing the cutting tool, would form mouldings. The engine worked perfectly well, and he was about to profit by it, when Sir James Harris advised him to reserve this invention for "Old England." (Subsequently this invention formed the basis of Bentham's patent, No. 1838). Bentham extended the utility of the amphibious carriages, so as in another form to serve as army baggage waggons, and Prince Potemkin ordered some of them to be furnished to a regiment at Jassy. These also were introduced in England about the year 1793, when His Royal Highness the Duke of York requested that one should be built for the English service, and it was successfully tried on the river Thames; but, like many other of the General's inventions, it was abandoned on his appointment at the Admiralty. The English baggage-waggon was remarkable as being, it is supposed, the first navigable vessel of which the hull was entirely of metal.

During his sojourn in the Ural Mountains, Bentham saw reasons for visiting the mines to the eastward and southward of Siberia, and, as he had acquired the Russian language, the Empress, Catherine the Second, appointed an officer of her army to attend him, and furnished orders to even the highest authorities in Siberia to forward the views of the traveller, and to receive him honourably. Provided with such distinguished proofs of Imperial favour Bentham traversed
Asia, from Archangel to the frontier of China, and eastward as far as Nerchinks, informing himself of the several practices in mines and manufactories.

Here let us pause awhile, for Bentham now looked upon his education—so to call it—as finished, and determined to return to England shortly after his arrival at St. Petersburgh. His visit to that city was for the purpose of communicating to the authorities his political and manufacturing observations on Siberia, and to pay farewell visits to his many friends; but his temporary sojourn caused a material change of his future career in life. It so happened that he was introduced to the wealthy heiress of one of the noblest families, a mutual attachment sprung up between them, and he accepted Russian service for her sake. He was named a Conseiller de la Cour, and had the direction of the Fontanka Canal given to him. In this work, though a lover, his inventive genius did not forsake him, for he contrived an endless ladder for the driving of piles (knowing that the weight of a man much exceeds his muscular strength), so that every step of a man on the ladder lifted a weight equal to his own. The family of the young lady would have approved of the marriage had not Bentham been a foreigner, but on that account objected to it. Hence a period of indecision, the Empress herself having advised an elopement; but Bentham had too honourable feelings to take such a step, and it ended in his final relinquishment of the lady; his conduct was so noble that our ambassador, although a stranger to the father, wrote to him extolling the honourable conduct of his son. The affair thus terminated, Prince Potemkin induced him to accept military service with the rank of Lieutenant-Colonel, and appointed him to the command of a battalion stationed at Critcheff in White Russia, with injunctions to make shipwrights and sailors of the men. Bentham on his arrival there found the battalion much disorganised, but he soon rectified matters. Knowing that the Prince's manufactories in the neighbourhood had been grossly mismanaged, he offered to superintend them; the proposal was gladly accepted by the Prince, and thenceforward Bentham had the sole management of all the Prince's fabrics and manufactories at Critcheff. This superintendence familiarised him with an infinite variety of works, but he soon perceived the necessity of his own constant inspection of what was going on, and he contrived a Panoptican
building, or inspection-house, the centre of which commanded a view of all its parts. His brother Jeremy having been on a visit to him whilst he devised this Panoptican, its contrivance has frequently been attributed to Jeremy, though in his works he repeatedly says it was his brother's. Architectural routine has hitherto only adopted the Panoptican principle for gaols, but Jeremy Bentham has shown that it is equally desirable for a great variety of buildings.

Whilst the Lieutenant-Colonel was at Critcheff the Empress Catherine's visit to the Crimea was determined on, and Prince Potemkin wished him to construct an entirely novel kind of vessel for her conveyance down the Dnieper. Bentham, therefore, devised jointed vessels, the Dnieper and its affluents being shallow, tortuous, and their navigation often impeded by sand banks and sunken trees. The Imperial vernicular was so shallow that it drew but six inches of water when loaded, and with 124 men at the oars on board; it was in six links, all connected together by a peculiar mechanism, whereby the vessel was enabled to accommodate itself to a winding channel. Bentham constructed many vessels on the same principle for carrying the produce of the Prince's establishments and manufactories to the Black Sea, and even vessels for its navigation. Jointed vessels were proposed some years ago for navigation in the rivers of India, but have not been in use since those that were built at Critcheff.

Little is now known of the improvements Bentham introduced at Critcheff; it however appears, that he reduced the cost of glass materially, though of improved quality; that he effected the improvement of steel; made a variety of Reaumur's porcelain so insensible to variations of temperature, as to bear, when red-hot, to be plunged into cold water, and so impervious as to form crucibles for melting brass. Reaumur's porcelain, from its many good qualities, well merits further experiments for its improvement.

On the breaking out of war with Turkey, Bentham was sent to the south with his battalion, of whom he had made shipwrights and sailors; and shortly afterwards, by the joint order of Souvaroff and Admiral Mardvinoff, was commanded to fit out vessels at Cherson to oppose the enemy. It happened that he had the sole command of the arsenal at Cherson, in which he found an immense stock of ordnance of all description, but no better navigable
vessels than the pleasure galleys which had brought the Empress and her suite down the Dneiper. But, nothing daunted, he set to work. He reflected that it is not size of vessel that ensures victory, but that it is gained by the fleet that can throw the heaviest weight of missile in the shortest time, joined to the facility of manoeuvring vessels. He removed the hatchways of the galleys to the sides of them, thus making room for great guns. The shipwrights asserted that such vessels could not sustain the shock of large artillery, or even its weight, but he strengthened them with a few pillars under their decks, and invented a mode of passing the breachings of bow-chasers for long guns over a pulley, so that the recoil of one gun drew out the other,—a mode of fitting ordnance to recoil that has never been imitated, though Sir Samuel having in action pointed these guns himself, speaks of the extraordinary facility of working them, and their powerful effect on the enemy. In the middle of these vessels, armed with these bow-chasers, he also fixed 13-inch mortars. On board ships' long boats he fixed the largest land-mortars, but not on the usual beds, for he had devised a new mode.

The Lieutenant-Colonel, though in the land service, could not refuse to serve in a flotilla he had invented himself, so different in most respects from established practice; he was appointed commander of it, but an order having been received to give Prince Nassau Liegen some post where he could distinguish himself, the command of the flotilla was assigned to him, thus leaving Bentham as second to his Highness. The flotilla was stationed in the liman of Otchakoff, to oppose a doubly numerous flotilla, supported by twelve Turkish ships of the line, and commanded by the Captain Bashaw, then flushed with the victory he had just obtained. Paul Jones, it is true, had a fleet in the liman, but he took no part in the defence of it, which was left solely dependent on the flotilla. Engagements with the Turks were undertaken on three separate days; in all of them the flotilla was victorious, for it not only conquered the enemy's doubly numerous flotilla, but burnt or sunk no less than nine of their ships of the line, made about 3,000 prisoners, besides, it was supposed, blowing up or drowning four or five thousand Turks. These successes were further remarkable, as, with the exception of half a dozen British
sailors, few of the men on board the flotilla had ever before seen a gun fired. They are supposed to have been mostly those who had been trained as seamen by Bentham at Critcheff.

These victories naturally led him to value small vessels of light draught of water, to appreciate ordnance of the largest calibre, and to estimate fully the mischievous effects of shot charged with inflammable materials.

The Empress Catherine rewarded Bentham for the three victories by as many honourable rewards,—rank in the army, a gold-hilted sword, and the Cross of the Order of St. George, never bestowed at that time but for feats of valour in actual warfare. Prince Nassau retired, and command of the flotilla was given to Colonel Bentham; but, as naval officers could but ill brook a superior of the land service, he was appointed to the command of one of the best Russian regiments, and the choice of station left to him. He preferred Siberia to all other parts of the Russian empire, and was nominated to the protection of its eastern frontier, his command extending from the northern part of the Ural Mountains to the confines of Russia in the Chinese dominions. The inspection of his regiment required him frequently to travel from north to south; and, being desirous of acquainting himself with the little known interior of Siberia, he built amphibious carriages for himself and his attendants. They were improvements upon his first design, their thin planking being placed diagonally, and were made water-tight by covering them with hides smoked after being fixed. This manner of rendering hides impervious to water, might be found particularly desirable in North America. During his excursions he travelled far into the Kirghees' country. Their rulers would not have permitted any visible measurement of their country, he therefore invented a new description of way-metre; it was a kind of spring projection on the felloe of a wheel, which on pressure against the ground gave motion to a recording mechanism of the distance passed over. His troops being anything but learned, he established schools at Kiachta, where the pupils made considerable progress, even in scientific acquirements. After being a couple of years with his regiment, he obtained leave of absence to visit his father and friends in England, and in passing through Paris happened to be, with his friend the Duke de Richelieu, at the theatre the last night his Grace was allowed the possession of his box.
Here commences another epoch in Sir Samuel's life. He found his brother Jeremy absorbed in investigations relative to jurisprudence; his so-called brother, Charles Abbot, highly esteemed for his political knowledge. Jeremy, however, had not forgotten his brother's Panoptican, but had proposed it to their father for the County Gaol for Middlesex. This led to some explanations with ministers, and ultimately to their decision to entrust Jeremy Bentham with a thousand convicts, of whose labour he was to make the best use he could. After a few weeks spent with his relations in London, Samuel went to visit the principal manufactories in England; he found steam-engines used for giving motion to machinery for spinning cotton, but nowhere was this prime mobile applied to the working of wood, metal, &c., nor indeed, any mechanical apparatus for saving labour, excepting turning lathes, and some boring tools worked by horses, for making blocks for the navy. Bentham therefore patented in 1791 his machinery for planing and making mouldings, specifying its improvements on the machine he had constructed in 1781.

His brother's arrangement with Government for the industrial employment of convicts being concluded, the Colonel considered that the most profitable means of employing them would be the working of machines for saving manual labour, and at the same time ensuring the accuracy of their work; he therefore exerted his mechanical genius to the perfecting several engines he had contrived and used in Russia, and patented his inventions in the specification (No. 1951).

This patent may be considered as an important epoch in the manufacturing industry of Great Britain. Its specification did not particularise improvements in this or that handicraft, but classed machinery according to the operation to be performed; hence sawing generally, whether for coarse or fine work, was made a section of his patent; modes of boring another section, and so on through an ample series of the different operations necessary for the working of wood, metals, stone, &c. Nor did the Colonel confine himself to verbal descriptions of his machinery, for he actually constructed several of the machines specified. Existing bills prove that his mechanical genius was not limited to words, but that these machines were really constructed under his own eye, by common operatives, at his brother's residence in Queen Square Place. The rude articles
obtained from a master millwright were such as wheels for giving motion; and indeed, one machine for cutting corks was completed by the same mechanist, according to the General’s patent.

Amongst the machinery completed in Queen Square Place was an apparatus for making wheels, and another for all the parts of a window sash-frame; both of these preparing the materials with the invariable accuracy of machinery, so that nothing was left to the skilled workmen but the putting the several parts together. There were also planes of various different descriptions, one of them for cutting shavings the whole breadth of a deal, suitable for laminated work; saws for cutting veneers as thin as a sheet of paper, yet with scarcely any loss of the material in saw-dust; machines for rebating, boring, dovetailing, sawing at pleasure to different depths and thicknesses, cutting stone, &c., &c. Machines for metal work were not attempted, on account of the necessary force for working them, if of large dimensions, the Queen Square Place apparatus being all worked by men.

The slide-rest especially ought to be noticed in this Memoir, for to this invention is due the performance of an immense variety of machines, as well as the giving facility to the mechanist in the adoption of machinery to an almost infinite variety of operations. This invention alone would suffice to establish a mechanist’s reputation.

Such machinery being actually at work failed not to attract attention. It was visited by persons of various descriptions—mechanists, manufacturers, and the simply curious. Several of His Majesty’s Ministers went repeatedly to inspect it; amongst others Mr. Secretary Dundas (afterwards Lord Viscount Melville), who stated in the House of Commons that it opened a new era in the manufacturing prosperity of the country. But the circumstance which completely changed Bentham’s future destiny, was the frequent visits of the first and other Lords of the Admiralty, who soon perceived the advantages that would accrue to the civil service of the navy by the introduction of such machinery in the naval arsenals. Earl Spencer, too, during his visits to Queen Square Place, became acquainted with Bentham’s intimate knowledge of shipbuilding, and of naval concerns generally, and thus his Lordship felt desirous of re-
engaging the General in the British service. It happened that his long leave of absence from Russia still left him time to visit the Dock-yards on Government account in the beginning of the year 1805, and in thus fulfilling the wishes of the Admiralty many of his suggestions were sanctioned by them.

Various proposals were now made by the Admiralty to engage Bentham permanently in the public service, but he demurred, and ultimately was induced to refuse any appointment which should not constitute his individual responsibility. It was then proposed to create a new office for him, with suitable assistants, under the name of Inspector-General of Naval Works, and with a salary of £2,000 a-year. The Navy Board took alarm, and foreseeing that the institution of such an office would disturb the peace and quiet they had hitherto enjoyed, and feeling especially annoyed by the proposed salary being so much superior to what they themselves received, exerted all their influence to effect its diminution—they succeeded: the Inspector-General's salary was thus reduced to £750. An attempt was then made to change the title of the office; but on Bentham's written remonstrance it was retained. The reduction of salary being said to be on the ground of the impossibility of ever finding a successor of equal talents and acquirements as those that Bentham possessed, he offered to serve his country for a time gratuitously, leaving the salary to be determined according to the benefit he should effect in the naval service. It was finally settled that, in addition to the nominal salary, he should receive £500 a-year. He loved his country, and, convinced of the services he could render, he gave up the honours and riches that awaited him in Russia—amongst others an estate that was promised him on his return—as well as the facilities these afforded to him of introducing beneficial inventions, and determined to devote his energies to his native country, regardless of all pecuniary advantages.

The Inspector-General's office was not instituted till the Spring of 1796, but in the interval he had, during his frequent conferences with Lords of the Admiralty, exhibited such glaring instances of the weakness of sea-going vessels generally, and that consequent on the disregard of shipwrights to the commonest mechanical principles constantly employed in civil architecture, that their
Lordships authorised him, early in 1795, to build seven experimental vessels according to his own ideas. They were to be two sloops of war, four schooners, and a vessel to convey water in bulk to ships at sea; though, owing to the extra work occasioned by the war, these vessels were ordered to be built at private yards, and both ships and schooners were at sea the following year. The principal innovations in these vessels were the following:—

1. Diagonal tresses or braces. 2. Fixed instead of rocking bulkheads. 3. String pieces in lieu of knees, imitated from French examples. 4. Connecting the decks, sides, and lower-works with one another. 5. The omission of many weighty or costly parts, such as crutches, breast-hooks, carlings and ledges, footwallings and ceilings. 6. Straight decks. 7. Metallic tanks for preserving water sweet at sea. 8. Increased thickness of plank. 9. Metallic cannisters for powder. 10. Filling the magazine with water in the event of danger from fire. 11. Safety lamps. 12. Illuminators. 13. Sheathing nails of the same metal as the sheathing. 14. Sheathing nails wedge-shaped instead of tapering in both directions. 15. Suiting the kind of timber to the part in which it is employed, as fir for parts where strength depends on the longitudinal fibre, beech and elm for parts constantly immersed in water. 16. Dividing the timber used as beams so as to take advantage of its strength in vertical directions. 17. Bins for stores in midships, leaving free the sides of the vessel. 18. Walking height between decks. 19. Heavy ordnance. 20. Guns fixed without recoil. 21. Cheapness of structure. 22. Short screws. 23. Chain plates fixed in the thick strate of the vessel. 24. Pintles and braces, every set alike. 25. Mechanical apparatus for working rudder.

Some years after Sir Samuel invented and introduced coques, now so generally used; also bolts having heads and screw points, with appropriate nuts and plates, so that the bolt might be drawn tight at first, and afterwards continued so in case of the shrinking of the timber or plank. The bolt nails, now so universal, were also his invention and introduction.

From the very first the Navy Board and Dock-yard officers were inimical to these innovations. Reports were spread that vessels so constructed would not
be safe at sea, so that their crews were adverse to them, and their commanders were obliged to come into port whenever the least water had entered, though less than was constantly witnessed in other vessels. Dock-yard officers magnified the alleged evils, and caused any repairs to be more than ordinarily delayed and expensive. The General consequently abandoned some improvements, such as Captain Schank’s sliding keels, the advantages of which had been exemplified in the sloops, the Arrow and the Dart. The Dock-yard officers, ordered to state their value, reported a price not equivalent to half the most ordinary vessels, though it proved that not one of these officers had ever been on board of them, or had even ever seen a drawing of them. Had the General lived till now he would have had reason to exult in these experimental vessels, for by degrees all their peculiarities have been adopted; save short metal screws, step-shaped trenails, and screw pointed bolts, these inventions still abide their time.

On the General’s first authorised visit to the Dock-yards in 1795, the outline was sketched of his subsequent important improvements. His report to the Admiralty entered into the delays and cost consequent on the practice of sending off shipwrights to repair ships at Spithead, and the waste and embezzlement of stores thus occasioned. He proposed as a remedy the enlarging the basin and jettys of Portsmouth Dock-yard, the making single instead of double docks, deepening the entrance to the basin sufficiently to admit any sized ship that could enter the harbour. By these means he showed that as many as twelve ships of the line could at one time be fitted or repaired within the precinct of the Dock-yard, and under the inspection of its officers. His plans were adopted.

During the same authorised excursion he visited Plymouth Dock-yard, and indicated several improvements there, but they were not executed till after the Earl of St. Vincent’s visitation in 1802.

Appointed Inspector-General of Naval Works in 1796, his whole energies were exerted in the improvement of naval arsenals, not neglecting the introduction of his machinery, with steam power to give it motion. Lord Spencer, who
was most anxious that it should be erected, had already sanctioned the introduction of a steam engine at Redbridge, and the conveyance thither of some machines from Queen Square Place; but the engine was not ready till most of the experimental vessels were completed, wherefore the machinery was placed in store in Portsmouth Yard. Then there arose most violent opposition to the introduction of steam-engines in a Dock-yard—they would occasion strikes, set the yard on fire, &c., &c. His Lordship could not venture to authorise their introduction against such a host of opponents, but advised the General to introduce his machines by degrees. Little progress was, however, made before the year 1797, when the need of new pumps in Portsmouth Yard presented an opportunity of proposing a steam-engine to work them; and he further stated that the engine might by day give its force to working the machinery he then particularised. This proposal was acceded to, and additional machines were brought from Queen Square Place. Still, but small advantage was derived from the use of the machines, as the works in the Dock-yard were dispersed in many shops, under different masters, though in 1802 the Lords of the Admiralty witnessed its efficiency as recorded in their “Minutes of Visitation.”

It was in that year that the Inspector-General recommended a measure which had the effect of giving the whole merit of the Portsmouth machinery to Mr. Brunel. That gentleman presented himself to the General, soliciting his patronage of certain machinery for shaping blocks. Brunel was found to have considerable ingenuity, and was of pleasing manners; he had married an English lady, and his character was irreproachable. Bentham was fully engaged at that time by Lord St. Vincent, in organising a better mode of managing timber in the Royal Dock-yards, and it occurring to him that Brunel, being totally disengaged, would be likely to influence the public in favour of machinery for working wood, proposed that he should be engaged for that purpose, and recommended the adoption of his apparatus for shaping blocks, to which Brunel’s machines were solely confined. He was thenceforward often in Queen Square Place, viewing Bentham’s machines, and consulting with him as to the apparatus that would be required at Portsmouth for the entire confection of blocks. For all the
preliminary operations saws that were already at Portsmouth were employed, or others made like them according to the specification of 1793; Bentham having arranged that Brunel should be employed at Portsmouth to superintend the erection of block-making machinery, which of course caused him to be generally on the spot, he was supposed by the numerous visitors to have been the sole inventor of all the machines for working wood. Bentham, on his part, conceiving that a pleasing arrangement of engines for the confection of one single article would be the most likely means of conciliating public opinion in favour of machinery, caused several of his own machines to be removed, replacing them with those required for the block-making, and arranged the apparatus for giving them motion in his office. It will thus be seen how the notion originated that Brunel was the inventor of all the wood-working engines at Portsmouth, whereas every one of them had been specified by Bentham in 1793. Even the Crown Saw was supposed to be Brunel's, though so distinctly specified in the following words: "Instead of a cutter or cutters, the end of the tube itself may be cut into teeth like a saw."

In pursuance of Bentham's design to bring all ship-building works under Dock-yard control, he contrived a new mode of opening and closing the great basin at Portsmouth. It was by constructing its entrance of masonry in the form of a double inverted arch, and closing that entrance by a caisson, somewhat in the manner of a ship. What might be called the keal of the vessel, he planned to fit into the groove of masonry. To avoid the need of taking ballast in or out, or of pumping water enough to sink the caisson, he devised an elevated deck over which water could flow to sink the caisson, or run from it when it was raised, providing valves also to regulate the influx or efflux of water at pleasure, and a bridge of communication for the heaviest loaded waggons above it.

Another proposal of his in the year 1797 was to provide waterworks, which combined also means of extinguishing fire in whatever part of a building it might break out. This was proposed to be effected by pipes laid to every part of Portsmouth Dock-yard for instance, and having firecocks at convenient distances for the supply of water, and hose to screw easily on to the cocks; and further, for
the immediate supply of water, a cistern on some elevated building. The
efficacy of this provision was manifested on several occasions in Portsmouth
Yard early in this century, and some years afterwards similar works were ordered
for other yards. Unfortunately at Chatham the fire-extinguishing works had
been neglected, and were not had recourse to at the late conflagration, so that the
destruction of buildings and machinery was immense. At Pembroke Yard the
extinguishing works are habitually kept in repair, and at the breaking out of fire
they were immediately put in requisition, and by a hose screwed upon a fire-
cock the fire was promptly extinguished, the damage done amounting to less
than £30, whereas the fire at Chatham must have caused an injury of as many
thousands sterling.

Sir Samuel Bentham perceived that the mortar used in masonry was badly
mixed, to obviate this evil he invented the mortar mills now so generally used,
which ground the materials by a rotary wheel, and mixed them by machinery.

The cost of raising soil from under water was half-a-crown per ton. It was
not possible at that enormous expense to execute the many improvements he had
in view by deepening the water in harbours; he therefore investigated the
subject, and in April, 1800, proposed to the Admiralty a steam dredging machine,
which should raise soil from under water at the rate of two tons per minute;
stating at the same time the many uses to which such a steam dredge would be
applicable, both in public and private works. The machine he proposed and
gave drawings of, consisted of a chain of buckets revolving by the force of a
steam-engine placed on board the dredging vessel. The buckets were of a shape
to cut easily into clay, and to contain a large mass of that or any other soil, such
as mud, sand, or shingle. The efficacy of this invention has realised the most
sanguine hopes of its designer, and would alone suffice to rank its originator
amongst the most distinguished benefactors in mechanical science; but Sir
Samuel Bentham's claim to it has been doubted. Indeed, the late Mr. Rennie
does not seem to have discouraged the notion that the invention was his own,
and it is still frequently attributed to that eminent engineer; but official records
prove that Sir Samuel's steam-dredger was actually in use at Portsmouth two
years before Mr. Rennie proposed the application of a steam-engine to an
existing steam-dredger at Hull. Mr. Rennie might possibly have seen the drawings of Bentham’s steam-dredger, which he sent to the Commission for Metropolitan Improvements in 1801. Whether fifty-five years have elicited improvements on the original machine it would be difficult to determine from want of sufficient data. Bentham’s dredger, when used at Sheerness, raised soil at twenty-seven feet below water, working amongst sunken timbers at one penny per ton, including £1 10s. per day charged for wear and tear, &c., &c.

In connection with the steam-dredger were his barges for carrying the soil. One description of them was for let out the soil in deep water through the bottom of the barge; the other kind was for depositing it at or above high water for the formation of new ground. This kind of barge has not yet been made, though drawings of it no doubt exist.

The economy of steam as a prime mobile being at length acknowledged in 1801, Bentham proposed in September of that year the placing a steam-engine on wheels. By his plan the boiler was a wooden cask as being lighter, and it lasted above a score of years, though the iron fireplace had been several times renewed. This invention was soon adopted, both in public and private works. It was the origin of the many purposes to which moveable steam-engines are applied in workshops, for agricultural purposes, and, it may be said, even on railways.

To produce effects at the least cost constantly influenced the General, consequently as shallow docks were cheaper than deep ones, he was enabled, as soon as he had invented moveable steam-engines, to adopt his plan, submitted to the Admiralty in 1793, of rendering shallow docks as useful as deep ones. The efficiency of this expedient was first exemplified at Portsmouth, where the shallow docks within the basin were enabled to receive deep ships by pumping water into the basin as a lock; but in that instance pumps were already provided. It is in situations where the badness of the soil renders it difficult and costly to construct deep docks that shallow ones are the most desirable, and steam-engines on wheels could at little expense pump water into them, so as to float a ship sufficiently high for placing blocks under it.

Considering the great delay usual in building or repairing ships in bad weather he early investigated the effects of such docks as then existed, but it was
not till after his examination of those at Carlscrona (1807), that he could make up his mind as to the best mode of constructing them. He had learnt that at Carlscrona, where docks were covered by a roof supported on pillars, the draught of cold under the roof caused the timber of the ships to be riven, and was very injurious to the operatives, he therefore devised docks so covered and enclosed as to resemble the best workshops; they were perfectly well lighted, ventilated, and warmed when required by a mechanical contrivance, the stem was openable to let a ship in or out; moveable stages were contrived within these, and such machinery was adapted as would best aid in the works of a ship, and assist the men in lifting heavy weights. No such covered docks have yet been introduced either in Royal or private dockyards, though less commodious ones have been erected at a great expense.

Costly sheds of various descriptions have been constructed in Royal Dockyards for seasoning wood, but none have yet been found to accomplish their intended purpose, and large timber is left for seasoning on the ground for years. Sir Samuel had from a boy studied the different means employed for seasoning timber, and in the year 1812 he invented a building for the seasoning all the timber and wood necessary for the completion of a ship of the line, prefacing his plan with instances of the more or less durability of timber consequent on its exposure to the atmosphere, &c., and mentioning Messrs. Strutt's, of Belper, as the only apparatus for the artificial seasoning of wood. Sir Samuel further said, that the process to be effectual depended on the quantity of air admitted at a time, and on the degree of heat, as too strong a current caused the timber to be riven. The proposed design consisted of an under part of the structure, in which were arranged the fireplaces and the passages to them, admitting more or less air at pleasure; above this chamber was one for the timber to be seasoned, it was provided with apparatus for hoisting and receiving the logs, which apparatus ran upon a hanging railroad (believed to have been the first devised), whereby a single labourer was enabled to place upright the heaviest log, and from the peculiar form of the structure no space within it was lost. Detailed calculations of all expenses proved that by each such structure the saving would amount to £17,178 per annum, arising from the interest on the capital lying dead on the
timber as seasoned in the ordinary way. It was further shown that the cost of each seasoning house would be refunded in half-a-year. As yet no artificial mode of seasoning timber has been introduced in the Royal Dockyards, but many private persons have availed themselves of different means of drying wood.

An apparatus for examining ground under water was invented by Sir Samuel, and executed at Sheerness. It consisted of an iron cylinder of about six feet in diameter, one of them being added to another when required by the depth under water, the lowest cylinder of a form to cut into the ground; these cylinders when sunk had the water pumped out of them leaving the interior dry, in which a man descended to examine the subsoil. A wooden cylinder on the same principle was provided for Portsmouth harbour.

He also constructed foundation masses, consisting of a wooden platform upwards of twenty feet square, on which were built walls of brick or stone to a certain height, the mass was then launched, the walls carried higher, the woodwork strengthened by brickwork, and the interior angles also. When built to the required height the mass was sunk to its place, and a weight brought over it equal to the greatest it would ever have to bear. About 200 feet of the present Ordnance Wharf at Sheerness was formed of these masses at a lesser cost than an ordinary dam, and have to this day withstood the fury of the boisterous sea that often rages off Sheerness.

Egg-shaped drains were also invented by Sir Samuel, and first exemplified by him in Sheerness Dockyard. About half the length of this drain still remains, the rest having been taken up to give place to the new works there.

In the year 1793, when preparations were making for the erection of a Panoptican prison for a thousand convicts, the General designed a building in which only incombustible materials were to be employed. The parts where strength depended on tension, were to be of wrought iron; other parts, such as pillars, window frames, and sashes, of cast iron. He subsequently designed a Record Office for Portsmouth and other Dockyards entirely of incombustible materials. He proved, in the instance of a Store-house in Deptford Yard, that fire-proof structures could be erected at a lesser cost than combustible ones, and
designed a fire-proof Ropery for Plymouth Yard. In his plan for Sheerness Yard all the buildings were to be fire-proof.

Many other novel inventions are also mentioned in Sir Samuel's papers; for instance, the supporting decks by tubular pillars, some of them to serve as pumps, others as channels for air. Also the forming a ship's side double, to give strength with the least expenditure and weight of materials, the intermediate space serving as tanks for water, stores of various kinds, &c., &c.

It has already been said that, though Bentham's steam-engines and machinery had been successfully introduced at Portsmouth, he had also devised the manufacturing of copper sheathing and other works in metal on Government account, and the Lords of the Admiralty had left this difficult business to his own discretion, as also the management of a numerous body of millwrights; till in the Spring of 1805 the Inspector-General officially informed their Lordships that the new establishments at Portsmouth were brought to a state in which they might be placed under the regular management of the Dockyard officers, proposing at the same time the number, pay, and description of operatives requisite for carrying on the works. Their Lordships referred his proposal to the Navy Board, who stated that neither they nor the Dockyard officers were competent to carry on business of "so great a magnitude and consequent responsibility." Their Lordships therefore gave the entire management of the three new establishments to Sir Samuel Bentham, leaving them to his uncontrolled discretion in every respect. He forthwith repaired to Portsmouth, where he placed the three manufacturing establishments on the same footing as he had found the best conducted private ones, having ascertained in an extensive tour in the manufacturing districts on what depended their prosperity. The three new establishments were the Wood Mills, the Metal Mills, and the Millwright's Shop. Aware of the mischievous result of employing none but adult operatives, he had already engaged many boys, and when their strength was insufficient, he had, since the first introduction of his machinery in 1797, employed common labourers in lieu of skilled workmen. He appointed a master for each of the manufactories. Mr. James Burr for the Wood Mills, who had been trained to the use of his machinery at Queen Square Place, and who was retained in the
Inspector-General's office at Lord Spencer's express desire. These masters were at weekly in lieu of annual pay, to facilitate a change of them if needed. The operatives were also paid weekly instead of quarterly, as was the custom of the Dockyard, to the serious injury of the people, as it obliged them to have recourse to Dealers, as they were called, who provided the week's pay in the form of shoes or bread, if the dealer happened to be a shoemaker or a baker. Every operative had two different employs, the one working a machine, the other some handicraft, so that no machine was ever worse worked in the absence of an operative, and no man ever lacked work in case of injury to the machine he usually tended. Piecework was introduced whenever practicable, and no abatement was made, however great the operative's earnings; every operative when convalescent was allowed to repair to these establishments, to work according to his strength by the piece, thus avoiding the public-house and earning a trifle. Accounts were much simplified, no clerk having been employed in any of these establishments, yet, even a single pound of iron, or an hour's work of an operative was noted, a clerk in the Inspector-General's office verifying the accuracy of the figures, and he himself inspecting the accounts weekly. In fact these were model establishments, and some of their inventions have been imitated in dockyards, as that of paying the men weekly instead of quarterly. The results of these establishments have been highly beneficial to the public, were it only from their savings; those effected in the Wood Mills having amounted to nearly £17,000 per annum, and those in the Metal Mills to above £40,000, though copper bolts were not yet rolled when this account was drawn up.

Private interest has always been, and still continues to be inimical to the manufacturing on public account, and the General had in consequence continually to combat opposition to the Portsmouth establishments. But the late vote of the House of Commons against a manufactory of small arms has shown its mischievous effects on the community at large, for the authorities have been obliged to have recourse to foreign nations for a supply. The General from first to last had to refute private objections, to the Metal Mills especially; and it was asserted, even when the Wood Mills were supplying blocks for the whole Navy, that the quantity required could never be manufactured at Portsmouth, and that
the whole scheme was an idle fantasy of the projector's brain. Opposition to the
Metal Mills was still more violent, as it proceeded from many wealthy con-
tractors, and showed itself by statements to the Admiralty and the House of Commons; however, the investigation that it occasioned, though troublesome at the time, ended in a complete proof of the excellence of the mills, both in regard to their produce and their economy.

The millwright establishment was difficult to manage, so many injurious customs of the millwright had to be overcome:—they would not attend a regular call; were paid double for working overtime; would not suffer any but a millwright even to turn a grindstone for them; limited the number of apprentices to their calling, &c. &c.; but nearly all these prejudicial customs were done away with before Sir Samuel's last office was abolished.

A want of appropriate education for all ranks of persons in the naval service early engaged the General's attention; and, with the entire approbation of Earl Spencer, he devised the institution of naval seminaries at each of the principal dockyards. The pupils were to consist of three classes,—one of them for superior officers, both military and civil; a second class for the due education of warrant officers on shipboard, and of clerks and so forth in naval arsenals; another class for operatives. He proposed that, to promote genius, joined to industry and morality, pupils should at stated periods be promoted to the next class, and ultimately be eligible for the superior one, should they be worthy of it. Each seminary was to consist of a thousand boys, admissible at seven years old. These seminaries were to be self-supporting, partly by a small pay from each pupil, partly by their work. The then Prime Minister, when acquainted with the scheme, highly approved of it, and readily offered funds for the first outlay. The seminary for working hands was included in a plan for the reorganisation of the dockyards in 1800; the Comptroller of the Navy objected to it, but the Earl of St. Vincent, when he succeeded Earl Spencer at the Admiralty, was desirous that such institutions should be organised, but another change of ministry put a stop to it.

These seminaries were only a part of the fundamental change contemplated by the Inspector-General, who was requested by Earl Spencer to draw up a
scheme, in conjunction with the Secretary of the Admiralty, for the future organisation of the dockyards; the burden fell on the General, Sir Evan Napean having time for little more than running over the plans. It would be uninteresting to enter into particulars in this brief memoir; suffice it to say, that the General founded his plan on the introduction of individual responsibility, but at the same time imposing no duty on a man that he could not perform,—on the entire separation of the accountant from the operative business,—the giving to a chief operative officer the direction of all works,—the placing as the Eye of the Admiralty a superior naval officer at each yard, with power to commence or countermand any work by a written order, provided he informed the Admiralty of it the same day.

The Speaker of the House of Commons in 1800 intimated that the House was impatient for some report on the proposals of the Commissioners of Enquiry, and the Inspector-General was ordered to prepare one. It was hastily drawn up, but indicated that a fuller one was in preparation. This report was ready for signature, when the Earl of St. Vincent succeeded Lord Spencer at the Admiralty. Lord St. Vincent having been consulted by Bentham on the clauses of it, the Report was duly sanctioned by His Majesty.

This Report entered into the better management of timber, and the Admiralty ordered the Inspector-General to introduce the measures that had emanated from himself. He did so, to the annoyance of contractors, for they could no longer profit by vague terms in their contracts;—he introduced also the common receipt as a voucher, &c. &c.

In proceeding with the proposed plan for dockyard management, it appeared that the source of the evil must be sought for higher than in naval arsenals, that Board management was faulty, and that all under the Admiralty required amendment. The Comptroller of the Navy was of an adverse opinion, and in consequence the Admiralty determined on an official visitation of the naval arsenals. It was on this occasion that the General had an opportunity of showing the advantages of his machinery at Portsmouth, of explaining the improvements he had proposed for Plymouth Yard, which were all ordered, and of stating the advantages that would result from a gradual removal of Sheerness
Dockyard to the Isle of Grain, the works at Sheerness being in a state of decay, the prevailing winds frequently rendering its access difficult, the soil objectionable, &c. &c. On the other hand, the Isle of Grain was accessible from both the Thames and the Medway, was easily defensible, and had naturally many other desirable qualities as a naval arsenal. Mr. Bunce, architect in the Inspector-General’s office, was desired to examine the ground, and found that a short canal was requisite. The Isle of Grain was said to be for the time abandoned on that account, but the real reason was the death of Mr. Bunce, who died of a fever caught in the execution of his arduous duties. And thus, alas, was this plan given up.

Without enumerating all the minor improvements Sir Samuel effected, it may be as well to mention some,—such as the payment of sawyers according to the number of feet cut, instead of falsifying accounts of their work; the bringing to light the abuses of job-work, and the inefficiency of pay-books though kept at a great expense, and introducing in lieu an improved mode of keeping accounts; also the making use of existing works, as, for instance, converting a small camber, of which no use was made at Portsmouth Yard, into a dock for frigates, building store cellars over the reservoirs, &c. &c.

The General became more and more convinced of the need of a reform of general management; representing from first to last the delays, inconveniences, and cost arising from a want of cooperation of the several departments and managers of the different divisions in the naval civil works. For example, in the outfit of a vessel of war, letters had to be bandied backwards and forwards through the Naval and Ordnance Boards, and after their respective directions were obtained, the business was again divided amongst several head officers, having each of them a separate control. Thus the getting a vessel ready for sea depended on the officers in the dockyard, next on those in the Ordnance for the supply of guns, on the Victualling Board for a supply of victuals and water, and lastly, on the Port Admiral for its equipment of men. Bentham strenuously recommended that at each port one officer should be charged solely with the whole direction; nay, he even went so far as to suggest the amalgamation of the different Boards under one chief authority, a Minister of War.
At this period, Viscount Melville having succeeded the Earl of St. Vincent, commerce was greatly disturbed on the coast by French privateers, and vessels of war could not then be spared to protect our traders. The Inspector-General suggested a remedy, that of arming the coasting vessels, such as they were, in a novel and more efficient mode. He had powerful ordnance, fitted on the non-recoil principle, mounted on Berwick smacks, transports, and other small coasters. The result was most satisfactory, for the enemy's privateers were all beaten off. The advantages of this non-recoil principle having, after eight years' experience, been duly confirmed, the Admiralty issued orders that in future all carronades should be fixed on that principle under the Inspector-General's direction, but the Navy Board conceived that his interference was derogatory of their influence, and induced the Admiralty to rescind their order, alleging that they were themselves capable of fitting carronades. It proved otherwise, however, for some of the carronades they fitted could not be used without setting fire to the vessel that carried them. Thus it appears that the non-recoil system has been abandoned, although Sir Thomas Hastings, in his evidence to the House of Commons in 1848, stated that no doubt, in the event of war, small craft would be so armed.

We are now come to the forerunner of a great change in the Inspector-General's life, for when at Plymouth Dockyard in 1795 he received their lordships' commands to return immediately to town. On his arrival, he learnt from Lord Barnam that it was proposed to send him to Russia to build ships of war for the British navy: would he consent?—all should be done to gratify him; it was expected that his wife should accompany him;—no other man was so competent as himself. The General hesitated, but on the succeeding day accepted the mission, on the assurance that his whole expenses would be paid, including those of his family and suite. The arrangement being concluded, he was requested to point out a locum tenens, for whom he could be responsible. He proposed Mr. Goodrich, the mechanist, in his office; who was accordingly appointed, and satisfactorily supplied the General's place during his absence, except that Mr. Goodrich had not been informed with what had been privately arranged with the Admiralty. The General was furnished with instructions to
build several ships of the line and frigates; was provided with coqueing and other tools of his invention, and had a clerk, a shipwright, and three or four clever operatives. He engaged a surgeon at his own expense.

On his arrival at St. Petersburgh great was his astonishment to find that even our ambassador had not been apprised of his mission, and that our ministers had construed diplomatic assurances of readiness to oblige, as a full acceptance of their proposal to build ships of war in Russia, whereas the Government of St. Petersburgh were adverse to the measure. However, the General soon made acquaintance with the Minister of Marine, who authorised the building of ships for England in the Imperial Dockyard, provided that for every one laid down a similar one should be built for Russia, exhibiting all the General's improvements in naval architecture. He therefore purchased timber; when the Emperor Alexander, aware of its increasing scarcity, objected to its employment in ships for England, and in a council of his ministers, though contrary to their unanimous opinion, decided that no vessels for foreign countries should be constructed in the north of Russia. On apprising the General of this decision, he was told that there was abundance of timber near the Crimea, and that the Governor would allow him to make use of it for the construction of ships. But again the Emperor refused his consent, and Bentham informed the Admiralty of this decision, and sent home the assistants who had accompanied him. But having received instructions from our Government to do his utmost to gratify the Emperor, he had already engaged to superintend the building a School of Arts, and a Panoptican for it. The Russian Minister wrote to obtain a leave of absence for the Inspector-General, and he remained at St. Petersburgh until the end of the following year, 1807, when war broke out with England. The Panoptican was so far completed before his departure, that its effects were practically demonstrated; that is, that from a central chamber, 106 feet diameter, could be distinctly seen to the ends of five radial adjuncts, each of them above 100 feet long, and that two floors could be seen at the same time by the Inspector, who could, by a mechanical contrivance, raise his chair to the upper stories without the inmates knowing it.

The General having been honoured by the Emperor with a cordial leave-
taking, as well as many tokens of regard from distinguished men in Russia, was furnished with an Imperial man-of-war to convey him from Revel to Stockholm; being requested to inspect and give his opinion on the works constructing at Revel. It was then that he noticed the good effects of floating breakwaters, invented and used by Mr. Norbergh, a Danish engineer, for whilst a strong gale was raging without them, the water was perfectly smooth within their influence. The passage to Sweden was perilous, owing to the disposition and cut of the sails, and the inexperience of the captain; but he was, like most Russians, ready to follow good advice, and actually gave up the management of the ship to Bentham, after it had nearly run ashore on the Island of Borneo. Being out of her course for Stockholm he determined to make for Carlserona, where he had intended going to visit the great naval arsenal. He had letters for the authorities, and was received with all honours, the King of Sweden himself giving an order for him to see it. He had the happiness of meeting the illustrious designer of the works, the veteran Admiral Chapman, so highly honoured and respected. His house exhibited numberless proofs of the inventive genius of its master, the walls were of two strata, enclosing air between them for the exclusion of cold: he had even contrived minor inventions, such as the hanging window blinds, for his were drawn up simply by passing suspending cords over common pulleys.

Before quitting St. Petersburg the General had been informed, though it is true not officially, that the Admiralty Board had discussed his absence, and decided that they could no longer "do without him." Great was his astonishment therefore, on opening the first letter he received in England, to learn from them that his office had been abolished, and that he was thenceforward to be amalgamated with the Navy Board with an increased salary, and that his assistants were also to be attached to that Board. He remonstrated officially—but in vain; then enquired what sum would be allowed him as a retiring pension, but finding that it would only be two or three hundred a-year he was under the necessity of accepting the proposed seat in order to support his family. In his letter to Lord Melville, communicating this determination, he frankly told his Lordship, that this motive alone had made him accept an office in which he felt
convinced that his future exertions would be of little avail, though his best
endeavours should not be wanting for the advantage of the naval service.

His new office gave him the title of "Civil Architect and Engineer of the
Navy," an employment for which he had indeed manifested peculiar talents,
though nowise educated for it; but excluding him at the same time from all
interference in ship building, for which he had served a regular seven years'
apprenticeship, and had subsequently manifested extraordinary talents.

His passion for naval architecture still continuing, and, sensible of the
increasing scarcity of naval timber, he devised various modes of saving it by the
introduction of iron in its lieu, and in 1810 apprised the Admiralty, through the
Comptroller of the Navy, that he had done so—that he was ready, either in
conjunction with the surveyors of the navy or otherwise, to exhibit means by
which ships could be constructed wholly of iron, or partially by the introduction
of it for such parts as beams, &c. The Admiralty refused to listen to this
proposal. A guard-ship being about to be built for Chatham, Sir Samuel
proposed that it should be of iron, as thus it would be constantly under the
observation of the Dockyard officers, and the influence of that metal on the
compass, as well as other objections would be ascertained. But the Admiralty
would not give their consent; hence the introduction of iron in shipbuilding
has been abandoned to private enterprise.

The perfect ventilation of ships became again a question, and Sir Samuel
proposed effectual means of ameliorating it, which have never been adopted. He
stated that Hales' ventilator was still in use, by which means, though foul air was
extracted, even worse was driven in from the foul compartments of the vessel,
and therefore he recommended a second set of pipes for the admission of fresh
air; but as the efficacy of every ventilating apparatus depended on its frequent
use he suggested a tell-tale to ascertain it.

In the year 1811 the Admiralty sent an order to the Navy Board for the
erection of the Breakwater in Plymouth Sound. Sir Samuel was fully
acquainted with it, and with the several works which had been projected for its
improvement, having, when at Torbay in 1800, particularly discussed its features
with the Earl of St. Vincent, who said there was no other fault in it, except that
in some parts the bottom was rocky and apt to cut cables. Sir Samuel objected to the proposed breakwater for various reasons (imposing and useful as it appeared to be to ordinary observers), amongst others, it would destroy the Sound as a roadstead for ships to take shelter in, though there was no other place between Plymouth Sound and Spithead, where ships could run in stress of weather, Torbay being inaccessible with certain winds, whereas with others, ships could not sail from it. But if the Admiralty were determined to have a breakwater in the Sound, he proposed three different modes of making it, all of them admitting the free influx and efflux of the tide to Hamoaze, and allowing the water of the Tamar to find a free course to the sea. The kind of breakwater he preferred was a floating one, on the same principle as that he had seen at Revel, and like one he had caused to be used at Sheerness for the protection of masonry works. The Admiralty returned his proposal to the Navy Board, and when it was called for in the House of Commons, the Admiralty’s Secretary sought an interview with the member at whose motion it was to be produced, and prevailed on him to forego the most convincing paper. The present breakwater was commenced, and carried on for above forty years. It is believed to have been erected within its estimated expense of a million and a half sterling, but this sum does not seem to have included the assistance afforded by Devonport Dockyard and its officers, and many other expenses; at any rate the public are paying for the breakwater, and will continue to do so as interest of the money borrowed, no less a sum than £75,000 a-year, for smooth water obtained within its morings for about twenty ships of the line. The former safe anchorage in Causend Bay for a dozen ships of the line, has been destroyed by the rapidity of the current now passing through it; it is frequently far from safe for such ships to enter by the eastern channel left by the breakwater; within it ground is gradually depositing, and more trading vessels have been destroyed upon the breakwater than were ever lost in the Sound before its erection. Sir John Rennie is mistaken in his assertion that the lives of many of the seamen in Royal ships were lost previously to the construction of the breakwater, as also that many ships of the Royal Navy were formerly lost in the Sound, for on Sir Samuel’s previous and careful investigations it appeared that only one single frigate was
ever lost there, and that on that occasion the disaster arose from a careless neglect of shutting the port-holes of the vessel.

The Admiralty had determined to renovate Sheerness Dockyard rather than to remove it to the Isle of Grain, and ordered the civil architect and engineer to prepare plans. He therefore resided for some time in its vicinity, studying the nature of the ground, the prevailing winds and tides, and all other interesting particulars, and went also to obtain the necessary data of repairing ships of war, &c. Mr. Hall had, after a long delay, replaced Mr. Bunce, but being merely a "labourer in trust" at Deptford Yard, though fully competent to the examination of accounts and other routine business which occupied his whole time, he was totally devoid of architectural knowledge or skill. Sir Samuel therefore applied for the temporary assistance of an architect, whose great taste and skill were well known. The Admiralty refused, saying that dockyard works required no taste. Bentham therefore, at his own expense, engaged Mr. Charles Aiken, and other assistants, whose salaries for several months amounted to a greater sum than he himself received, but he had at heart the erection of a dockyard on a good plan, and which, though simple, would not be devoid of architectural symmetry and pleasing appearance; and in the beginning of the year 1812 he sent the Navy Board a plan for a new dockyard at Sheerness, which they transmitted to the Admiralty, who in two days decided against it. That it was a predetermination is probable, for, besides the well-known fact that a private engineer had of late engrossed their Lordship's ear, Sir Samuel's plan was prefaced with a statement of the "desiderata in a naval arsenal," which he printed and presented to each member of his Board, requesting them by letter to note their observations and objections in the blank pages. Now, it seems impossible that their Lordships could in a single day have come to a decision on the many points in question. The plan was indeed novel in most of its parts, and every detail was considered in all its bearings—first cost, cost in use, convenience, efficiency, &c., &c.; and the site proposed was also well weighed as to all its advantages or drawbacks. One of his objects in the arrangement of the plan, was the bringing the works most requiring inspection the nearest to the
officer charged with their supervision; briefly, it sought to spare the valuable
time of superintending officers, as well as of their subordinates.

Spite of repeated rebuffs Sir Samuel persevered in exerting his best skill,
when one morning, whilst engrossed in some new project of amelioration, he
received official notice that his last office was abolished! It appeared that the
First Lord of the Admiralty had applied to the Speaker of the House of
Commons the night before, for his assistance in determining what should be
done for Sir Samuel. The Speaker declined interfering, being unacquainted
with particulars, and moreover, from his well-known friendship for the dis-
missed one. By Lord Melville's desire he petitioned the Prince Regent for
compensation for loss of office, and remuneration for his services. The Prince
referred the petition to the Admiralty, and the Speaker was consulted. The
salary was to be continued as the compensation for the loss of a patent office; the
particulars of remuneration for services, acknowledged to be great ones, were
discussed. Sir Samuel had, on application from the Admiralty, furnished a
"statement of his services," in which nothing was inserted that could not be
proved by official documents. On referring to that statement it was found
difficult to affix a due amount of remuneration; at length, on coming to the
Metal Mills, "there," said Lord Melville, "Sir Samuel stands upon a rock." It
proved a slippery one, for under the pretext that it would be necessary to apply
to Parliament for so considerable a sum as a year's savings, effected by the
introduction of the metal mills, no remuneration was ever accorded to Sir
Samuel Bentham for any one of his services. This was of inferior moment to
himself, but it left his family wholly unprovided for after his death.

After the restoration of peace in 1814 Sir Samuel retired to France for the
economical education of his children. At Paris he enjoyed the society of the
most celebrated men for rank, literature, and talents; but he lost his eldest son,
and on account of his own health determined to seek an abode in the south of
France. At that time inns were comfortless abroad, and he resolved to travel
without having recourse to them. He contrived and had built one carriage as
his and his wife's bedroom, another for his daughters and their governess, his
remaining boy had the travelling coach. These carriages had a door at the
back, windows along the sides, and the driver's seat in front. They were the first of the kind, but served as a model for the omnibuses in Paris, which were afterwards introduced into this country. These continued to be used as sleeping chambers until he settled at Montpellier, and by night were kindly admitted into some gentleman's courtyard; as for instance, to that of the Prefet's in all préfectures, his friend, the Duke de Richelieu, having given him letters of introduction to all those he was likely to come across, and by day Sir Samuel and his wife were received as their guests. Such sleeping vehicles would be quite needless in these days, but omnibuses are likely to be used as public conveyances throughout Europe.

A remarkable feature in Bentham's inventions was the perfection of their machinery at their first construction. For instance, the first caisson in Portsmouth Yard answered all its intended purposes on its first trial; his first steam dredging apparatus never required alteration; and the same may be said of nearly all his improvements and inventions. He never attributed such unusual success to his own genius, but ascribed all merit to a careful previous consideration of the effects to be produced, and of the several means by which they might be attained. It was his invariable habit to draw up for his private use the desiderata of the object in view, were it a machine or a mode of management, and then to compare the merits of the several modes by which the end might be accomplished; his "Desiderata in a Naval Arsenal" may be cited as a good example of this.

Few of the improvements have been noticed which he classed under the head of management, yet no memoir of Sir Samuel Bentham would do justice to his exertions without mentioning them. One of the most important of his endeavours of this nature were his efforts to draw attention to the "value of interest on money." The nation is paying above £50,000,000 annually for interest on the national debt, yet no attempt was made in public departments to spare the people an increase of this burden by looking to the value of such interest on money. From the year 1795 to the close of his life in 1831, Sir Samuel embraced every opportunity of bringing forward the importance of this subject. His first effort was the composition of tables, exhibiting the loss
occasioned by delay in the execution of a work, a loss so enormous that, in the instance of a mast pond in Portsmouth Dockyard, it would, ere completed, have cost an outlay of £32,000,000. This was not a fabulous supposition, for he had at his own expense employed an actuary to make the calculation, as given in his Evidence to the Committee on Finance of 1798. Similar delays were habitual in the naval department; but he practically proved them to be unnecessary, for, whilst charged with the preparation of estimates, he only inserted such works as could be carried on simultaneously during the year without retarding one another. Costly errors of this nature he showed to have originated in the mistaken notion, that money would be more readily granted for carrying on a variety of works simultaneously, than for the completion of any one of them. He further advised, when cash could only be obtained by driblets, that it had better be put out at interest, till its aggregate would suffice to complete the work with the utmost practicable rapidity.

Bentham coined the word *interconvertability*, to designate that frequently the same article would serve for different purposes; exemplified, for instance, in the *Arrow*, one of his experimental vessels. Many of her sails and parts of her masts and rigging were alike, so that one of them might replace the other, and thus a much smaller stock of such stores was required. But he did not confine interconvertability to ships only, but extended it to stores in general, materials, buildings, &c.

Sir Samuel introduced a more efficient mode of paying artificers, who had hitherto received the same amount of wages, whatever were their age, capacity, or industry.

He showed that the time lost in mustering the operatives in dockyards cost the nation no less than £24,000 per annum, exhibiting a mode by which such expense might be avoided.

Incessant work was carried on in the Metal Mills without injuring the health of the operatives, by the simple expedient of changing the hands at one o'clock, in lieu of having a night set and a day set.

He exhibited the fallacy of book-keeping as practised in naval arsenals. The dockyard books, though kept at a great expense, failed to show the real cost
of an article, as the only efficient way was, as regards timber for instance, that every piece of wood should be traced to its final employment, which was done with much less trouble than the customary mode of book-keeping.

He represented the inadequacy of the usual mode of remunerating inventors, whether by granting them contracts for the improved articles, or by a reward in money, for by both these methods the inventor was frequently paid beyond the value of the improvement, sometimes insufficiently; he therefore proposed that an inventor should receive the amount of a year's saving arising from his ingenuity. On very many occasions he brought to view the mischief caused by want of due compensation.

Sir Samuel delighted in the inventive genius of others, and was ever prompt in bringing forward their improvements. Hence arose his introduction of Mr. Brunel, of whom he afterwards officially said: "In regard to the machinery, I was afterwards satisfied that Mr. Brunel had skill enough to have contrived machinery to have answered the same purposes, had he not found mine ready to his hand." So when the time came for giving him a year's savings made by the block machinery, the matter was referred to Sir Samuel. It was a difficult task, for, under the various particulars to be investigated, his own credit was involved. Most of the machines had been described in his specification of 1793; the savings of a manufacturer's profits had arisen from his own recommendations; the economical management was entirely his own; yet he disinterestedly recommended that the whole profits arising from the manufacture of blocks on Government account should be given to Brunel. And when a Ropery at Woolwich was determined on in 1803, Sir Samuel never spoke of it but as Grimshaw's patent, and that as the most perfect system he had ever seen; yet, when Mr. Grimshaw was engaged in its introduction at Woolwich, Bentham devised several improvements.

Great inventors have been inclined to attribute to themselves inventions of which they had given no hint,—not so Sir Samuel. He might have claimed the invention of steam navigation, for during his apprenticeship at Chatham he had devised and described a mode of propelling ships by the force of steam; and in 1731 he proposed to the Empress Catherine to take the blast in iron works
from air heated by the furnace; yet he never called himself the inventor of steam navigation, or of the hot blast, or of many other of the improvements he had hinted. And indeed, unfortunately for his family, others derived the profits of those inventions he did patent, for in 1795 he took a patent (No. 2035) for divers manufacturing processes to be executed in vacuo, of which all the particulars are described in the seventh volume, page 145, of the Repertory, the application of which in refining sugar is said to have realised to its adopter no less than half a million sterling. Not a single sixpence ever resulted to the General for this, or any other of the processes enumerated in his specification.

On his return to England in 1827 he had frequent intercourse with many of the Lords of the Admiralty, and addressed several proposals to their Secretary, or to the Council of His Royal Highness the Lord High Admiral.* Amongst these, there was a plan for the more prompt payment of the navy. The payment of allotments was also simplified, a partial adoption of which has been made this year (1855) in the Baltic fleet.

Finding that no means had yet been taken to ascertain the best form of sea-going vessels, he at length induced the Admiralty and Surveyors of the Navy to institute a series of experiments for that purpose; and to avoid the heavy expenses so frequently incurred by building large ships to ascertain the advantages of some particular shape, he proposed to commence with small models, then to proceed to boats, and so on to large craft. He was authorised to expend £50 in apparatus; his mechanical friend, Mr. Maudsley, entered heartily into the scheme, furnished several costly articles at his own expense, and consented to give the assistance of a young man studying under him, and who has since proved himself to be a most distinguished engineer. But his time was no longer at his own disposal when the apparatus was ready for experiments, and Sir Samuel applied for a young man from the dockyards. No one could be spared! And thus ended the ascertainment of the fittest form of vessels.

Lord Althorp having requested him to point out reforms in the civil naval service, Sir Samuel proposed a more efficient mode of appointing and paying

* Afterwards King William the Fourth.
clerks hitherto receiving the same salary, whether mere copyists, requiring nothing more than a fair legible hand, or the intellect and capabilities of a composer of official and other letters.

He proposed the employing, in times of peace, the then useless vessels of war for the purposes of transport and packet services, from which many benefits would result, such as the employment of officers on active service, saving the amount of their half-pay, &c. &c. By this alone the saving to the nation would amount to £1,000,000 per annum.

Amongst other suggestions, one of his latest was an urgent appeal to the First Lord of the Admiralty, to afford more appropriate education to all ranks of youth destined for naval service.

On the occasion of some extensive conflagrations in the metropolis, Sir Samuel contrived an application of the same fire-extinguishing works he had devised for the dockyards. His plan was presented to Sir Robert Peel, but he was of opinion that the "public mind was not yet ripe" for such an application of the water-works. It has since been most successfully introduced at Hamburg and in some English towns.

In private life Sir Samuel Bentham was beloved; he gave his children a good home-education, made them early his companions, and was rewarded by their true affection.

His Widow, M. S. B.
# List of the Late General Sir Samuel Bentham's Inventions

## Machinery, Tools, Implements.

<table>
<thead>
<tr>
<th>Description</th>
<th>Date</th>
<th>Voucher</th>
</tr>
</thead>
<tbody>
<tr>
<td>An improved chain-pump</td>
<td>1773</td>
<td>Ny. Bd. to S. B.</td>
</tr>
<tr>
<td>A machine for planing wood and forming mouldings</td>
<td>1781</td>
<td>S. B. to British Ambassador at St. Petersburg.</td>
</tr>
<tr>
<td>Pile-driving machine</td>
<td>1783</td>
<td>P. L. describing the machine.</td>
</tr>
<tr>
<td>A concealed way-metre acting in a carriage-wheel</td>
<td></td>
<td>P. L. describing the metre.</td>
</tr>
<tr>
<td>Improvement of planing and moulding making machine of 1783</td>
<td>1791</td>
<td>Patent, No. 1838.</td>
</tr>
<tr>
<td>A great variety of inventions for the working of wood, metals, stone, and other materials, viz.:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laminated Work.</strong></td>
<td></td>
<td></td>
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<tr>
<td>Wedges applied to the piece when thin parts of it are cut</td>
<td></td>
<td>In use at Q. S. P.</td>
</tr>
<tr>
<td>A saw formed of circular segments</td>
<td></td>
<td>S. B. Ady.</td>
</tr>
<tr>
<td>Different cutters for cutting circular grooves, dovetailed do.</td>
<td></td>
<td></td>
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<tr>
<td>Conical do. and fluted do.</td>
<td></td>
<td></td>
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<tr>
<td>Cutting rollers</td>
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<tr>
<td>A circular tool to cut mouldings</td>
<td></td>
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<tr>
<td>A circular plane</td>
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<tr>
<td>A tilting-bench, to form waves or other curvatures</td>
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<tr>
<td>A double cutter, for cutting both sides of a piece at once</td>
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<tr>
<td>Compound saws, or other cutters</td>
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<tr>
<td>The slide-rest</td>
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<tr>
<td>Tubular borers for various purposes, open at the end</td>
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<tr>
<td>Boring annular grooves</td>
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<tr>
<td>Spiral stem</td>
<td></td>
<td></td>
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<tr>
<td>The crown saw</td>
<td></td>
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<tr>
<td>Machine for making mortices, whether square, oblong, round, &amp;c.</td>
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<td></td>
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<tr>
<td>A rasping bench</td>
<td></td>
<td></td>
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<tr>
<td>A scoring cross</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A double lathe, or lathe with two hand-rails</td>
<td></td>
<td></td>
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<tr>
<td>A presenting bed</td>
<td></td>
<td></td>
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<tr>
<td>Machine for washing lace</td>
<td>1795</td>
<td>In use at Q. S. P.</td>
</tr>
<tr>
<td>Steam dredging apparatus</td>
<td>1800</td>
<td>S. B. Ady.</td>
</tr>
<tr>
<td>Floating steam-engine on a navigable vessel, for dredging purposes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam-engine on wheels</td>
<td>1801</td>
<td>Do. Do.</td>
</tr>
<tr>
<td>Engine for making coques</td>
<td>1801</td>
<td>Do. Do.</td>
</tr>
<tr>
<td>Coque sinking tools</td>
<td></td>
<td>Minutes of visitation of the Admiralty. Do. Do.</td>
</tr>
<tr>
<td>Treenail making tools and augers</td>
<td></td>
<td>Do. Do.</td>
</tr>
<tr>
<td>Rotatory tools, for forming the heads and points of treenails</td>
<td></td>
<td>Do. Do.</td>
</tr>
</tbody>
</table>
The heat of steam from salt beneficially applied to the heating  
a supply of brine  
Raising a double quantity of brine by making the upper part  
of the pipe double, with a piston in each pipe  
Panoptican, or inspection-house  
Fire-proof buildings  

Speaking tubes  
The improvement of Portsmouth Harbour  
Floating breakwater, to form a boat pond  
Waterworks combined with fire-extinguishing works  
Double drawbridge  

New combination of the materials used in the construction of  
a bridge  
Apparatus below the structure of a drawbridge  
Egg-shaped drains  

Covered docks  
Timber seasoning-houses  
Keeping timber dry instead of under water  
Apparatus for masting vessels worked by steam power ma-  

chnery  
Floating breakwater of wood  

Breakwaters formed of cylindrical masses, built afloat  
Breakwaters formed by a semi-subaqueous bridge  
Buoyant masses of cast iron for forming foundations  
Excavating under water in a harbour so as to procure deep  

water  
Naval basin and canal at Portsmouth harbour  
The construction of a double canal communicating with the sea  
Foundation masses of brick or stone to be floated to their places  
Masses pressed into bad ground  

A weighted probe to ascertain the weight that ground will  
bear  

Temporary exclusion of water to examine underground water-  
works  
Ventilation from underground  
Underground covered roads  
Watertight cylinder for examining ground under water  


Engineering and Architectural Inventions.

S. B. — Ny. Bd.  

Salt works.  
Do.  
Do.  

Jeremy Bentham’s works.  
Naval papers, official plans, and accounts.  
Q. S. P.  

S. B. — Ny. Bd.  
S. B. — Ady.  

Do.  

S. B., to select Committee of the  
House of Commons.  
Do.  
Do.  

Existing drain in Sheerness  
dockyard.  

S. B. — Ny. Bd.  
Do.  

Do.  

S. B. — Ny. Bd. — Model in  
United Service Institution.  
S. B. — Ny. Bd.  

Do.  

Plans for Sheerness Dockyard.  

S. B. — Ny. Bd.  
S. B. — Ay. Bd.  

Weale’s Quarterly Review.  

1811 Patent, No. 3429.  
200 feet of wall at Sheerness.  

Sheerness Dockyard.  

Do.  

S. B. — Ny. Bd.  

Patent, No. 3544.


Naval Architecture.

Amphibious carriage.  

Vernicular vessels formed of separate links so as to twist about  
in tortuous rivers  


S. B. to British Ambassador  
at St. Petersburg and used  
at Perme.  

Used at Prince Potemkin’s  
works, and to convey the  
Empress Catherine II. down  
the Dnieper.
Diagonal arrangement of the planks of a vessel | ... | 1789 | United Service Gazette.
Amphibious baggage-wagon | ... | 1794 | Used at Jassy.
Metal for the shell of a navigable vessel | ... | 1810 | S. B.—Ny. Bd.

Fixed bulk-heads—Diagonal trusses and braces—Thick strake pieces in lieu of knees—Timber butting against the ends of the vessel—Straight decks—Metallic tanks for water—Metallic cannisters for powder—Thick glass illuminators—Hawse holes and rudders at both the stem and head of a vessel—Chain plates fixed to the thick strake of the vessel—Copper pintles and braces, all alike—Mechanical steering apparatus—Safety lights—Step shaped treenails—Short metal screws in lieu of long bolts—Form of vessel

Coques for preventing the sliding of one part on another | ... | 1794 | Experimental vessels.
Screw-pointed bolts with plates, &c. | ... | 1802 | S. B.—Ay. Bd.
Bolt nails wedge-shaped | ... | 1805 | S. B.—Ay. Bd.
Metal used in a hollow form in lieu of a solid mass, and the vacuities used for receptacles for provisions, &c. | ... | 1808 | S. B.—Ay. Bd.
Hollow iron pillars to serve as ventilators, &c. | ... | 1810 | S. B.—Ny. Bd., also Mechanic’s Magazine, No. 1313.
Coating treenails, &c., with a pigment when inserted | ... | 1829 | Do. No. 1407.
Winches in lieu of capstan-braces | ... | Do. | Do.
Masts of a vessel to act as braces | ... | Do. | Do.

### Ordnance.

Connecting two pieces of ordnance together so that the recoil of one draws out the other | ... | 1787 | Naval Essays, Naval Papers, No. 7.
Non-recoil of artillery | ... | 1788 | United Service Journal.
Placing ordnance on ship-board in the intermediate spaces left by the guns | ... | 1829 | Do.
Dividing the aim of ordnance | ... | 1830 | Do.
New mode of fixing a small one with a large piece of ordnance

### Metallurgy, &c.

A new mode of converting iron into steel | ... | 1784 | S. B. to his father.
A new variety of Reaumur’s porcelain | ... | Do. | Do.
Mixture of metals so as to increase the hardness and strength of the alloy | ... | 1810 | Experimental vessels.

### Miscellaneous Inventions.

A chart of the absolute and comparative population of a part of Russia | ... | 1783 | Made for the Empress Catherine.
The performance of a great variety of operations in vacuo, specified as follows:—1. Preservation in point of substance. 2. Distillation. 3. Effectuation of contact. 4. Intromission into tubular or other cavities. 5. Impregnation. 6. Transfiction and Percolation. 7. Mixture. 8. Regulation of heat. 9. Exsication.
Improved means of protecting premises by a more efficient mode of placing the guards | ... | 1800 | Patent, No. 2035.
Giving two different employments to the same individual in the dockyards | ... | 1805 | Proposed Naval Seminaries.
and | ... | S. B.—Ay. Bd.

THE PADDOCK VIADUCT,

JOHN HAWKSHAW, F.R.S., ENGINEER.

[The great engineering works that have arisen during the railway era are comparatively unknown to the public eye. Their position is usually such as to leave them unseen by the numerous travellers who are carried across them at railway speed. In a few years, probably, some railway historian may think it worth while to give a history of those great modern engineering works which signalise the present age, and which display the power, wealth, and skill of this generation].

The Paddock Viaduct is built upon the line of the Huddersfield and Sheffield Railway, in a deep gorge at the village of Paddock, close to the town of Huddersfield.

The valley across which the viaduct is built is occupied by the Huddersfield Canal, the river Colne, and the turnpike road from Huddersfield to Holmfirth. In addition to which the viaduct had to be carried across a portion of the premises of a large mill.

The position of the navigation, river, and other works, required four large oblique openings for the central part of the viaduct.

The viaduct consists of fifteen stone arches, each of 30 feet span; one cast-iron bridge at the south-end of the viaduct, 47 feet span, and four central openings, each of 75 feet span.

These four central openings are crossed by six continuous longitudinal malleable iron lattice girders, supported on stone piers, each girder is 340 feet in length; and the whole of the longitudinal girders were made fast to the central pier, but rest upon bed plates and rollers on the other piers, and thus room is afforded for contraction and expansion.

Four of the longitudinal girders are placed under the lines of rails, the other two girders rise above the level of the rails, and form a fence to the viaduct.
These girders are tied together every 10 feet by transverse lattice bracing, which adds greatly to the stiffness of the structure.

Six inch planking is laid across the girders, upon which the rails are laid. The opening, 47 feet wide at the south end of the viaduct, is crossed by four cast iron girders, each girder is a single casting 55 feet long.

The total length of the viaduct is 1,040 feet, and the height is 84 feet. The malleable iron in the lattice work over the four central openings weighs 300 tons.

The viaduct was executed in 1848 and 1849 from the designs and under the superintendence of Mr. Hawkshaw, the engineer to the Company.

DESCRIPTION OF PLATES.

PLATE I.
An elevation and plan of the four central openings.

PLATE II.
An elevation of a portion of the outside girder.

PLATE III.
A transverse section and a plan of a portion of the girders showing the cross bracing.

PLATE IV.
A longitudinal section of a portion of girder is shown, section of angle irons.

PLATE V.
Plan of girder, and plan and section of the bed plate and rollers, section through angle irons, half size, &c.

PLATES VI., VII., AND VIII.
Plan, elevation, and sections, with details of the cast iron girder bridge over the 45 feet opening.
Paddock Viaduct.

Plan of Girder.

Sections through Angle Irons. (Half Size)

Plan of Bed Plate and Rollers.

Section through Bed Plate.

Scale of Feet.
PADDock VIADUCT.

ELEVATION OF GIRDER.

GIRDERs 55 FEET LONG (SINGLE CASTINGS)

PLAN

SCALE OF FEET.

TRANVERSE SECTION.

SECTION THROUGH THE ROD.

PLAN UNDER CODING OF PARAPET.

SCALE OF FEET.

John Backsham, Engineer.
PADDock Viaduct.

Elevation of Cast Iron Bridge.

Transverse Section.

Section through parapet.

Section through pilaster.

Scale of Feet.

For Elevation & Transverse Section.

John Hawkshaw, Engineer.
Paddock Viaduct.

Plan.

Scale of Feet.

John Hawkshaw Engineer.
THE LOCKWOOD VIADUCT,

JOHN HAWKSHAW, F.R.S., ENGINEER.

The Lockwood Viaduct is among the largest of those great works which have been called into being by the construction of railways, and was designed by and built under the superintendence of Mr. Hawkshaw, on the line of the Huddersfield and Sheffield Railway. It carries that railway across the deep valley at the village of Lockwood, about two miles from the town of Huddersfield, in the West Riding of the county of York.

The Huddersfield and Sheffield Railway extends from Penistone to Huddersfield, in a direction which causes it to cross nearly at right angles the ridges and valleys that form the rugged surface of that part of the West Riding, the character of which will be understood from the circumstance that in a distance of fourteen miles there are no less than five tunnels and four viaducts, the lowest of the viaducts being 80 feet high.

The Lockwood Viaduct consists of thirty-two semi-circular arches, each of 30 feet span, and of two oblique arches of 45 feet and 70 feet span respectively.

Its principal dimensions are as follows, viz.:

- Total length: 1,428 feet.
- Height to top of parapet: 136 feet.
- Height from bed of the river to the level of the rails: 122 feet.

The piers have a batter of one-sixth of an inch per foot. The highest pier is 7 feet 7 inches thick at the base; all the piers are 4 feet 6 inches thick at the springing of the arches. The outside width of the viaduct at the level of the rails is 28 feet, the inside width is 25 feet.

The viaduct is remarkable, not for its great size merely, but also as a good example of a style of masonry not usually applied to structures of such magnitude and lightness of proportions.
The stone of which the viaduct is built, was obtained from the adjoining cutting on the line of railway. It is a hard flat-bedded sandstone, varying from 3 inches to 12 inches in thickness, and it was important to adopt that kind of work which would admit of using stone of all sizes. This led to ashlar and coursed masonry being dispensed with, and the whole viaduct, with the exception of the oblique ribbed arch of 70 feet span (which is of ashlar masonry), is built of stone of all sizes, thick stones being placed in juxtaposition with two or three stones of inferior thickness, a style of masonry technically called by Scotch masons "snecked rubble."

Masonry built in this manner is greatly dependent upon care and skill in workmanship, and upon the good quality of the mortar. The mortar used for the piers and abutments was made from "Weldon wood" (a Yorkshire) lime; that used for the arches and for all the masonry above the piers was made from "Halkin mountain" (a Welsh) lime. The whole of the mortar was composed of one part lime to two parts sand ground under rollers. No cement was used in any part of the structure. Good sand being difficult to obtain in the neighbourhood, a considerable proportion of clean sandstone, previously broken into small pieces, was ground with the lime instead of sand. Powerful mills being used for the purpose. The stones used were not "dressed" in the ordinary sense in which that term is applied to masonry; protuberances were knocked off, and the ends of the stones roughly squared, and care was taken that as nearly as practicable the beds of the stones should be horizontal, and the joints vertical; but this style of masonry does not admit of great accuracy of pumallelism of beds and joints.

Masonry so constructed is not capable of bearing the same incumbent pressure as if built throughout of solid blocks of squared and chiselled stone, but it costs little more than one-half the price of solid ashlar masonry, and if carefully executed it may be applied in cases requiring considerable strength; as is instanced by this viaduct, for there are few more severe tests of strength than passing heavy trains at high velocities over lofty structures like that in question.

The oblique stone arch at the south end of the viaduct is 70 feet span, and
LOCKWOOD VIADUCT.

LONGITUDINAL SECTION.

SCALE OF FEET

John Hawkshaw Engineer

John W. S. London 1866
LOCKWOOD VIADUCT.

ELEVATION OF STONE RIBBED ARCH.

TRANSVERSE SECTION ON SQUARE

PLAN.

SCALE OF FEET.

Architect: Rennie; Engineer: Telford.
has a versed sine of 8 feet; it is built of five stone ribs, rising from as many
points in each abutment, the springing point of each rib being set square to the
line of thrust. These stone ribs are built of ashlar masonry. The remainder of
the bridge is of the same style of masonry as the other parts of the viaduct.

The viaduct was begun at the end of 1846, and was finished in 1849. The
foundations of all the piers are upon slate, and the pressure upon the base of the
piers is about eight tons upon each square foot. The total quantity of masonry
in the structure is 972,000 cubic feet. The cost was £33,000.

DESCRIPTION OF PLATES.

PLATE IX.
Plan and elevation of the Lockwood Viaduct.

PLATE X.
A longitudinal section of a portion of the viaduct

PLATE XI.
A transverse section of the viaduct, transverse section through arch, section through parapet.

PLATE XII.
Elevation, plan, and transverse section of the stone-ribbed arch.
DENBY DALE VIADUCT,

JOHN HAWKSHAW, F.R.S., ENGINEER.

The Denby Dale Viaduct is situate upon the line of the Huddersfield and Sheffield Railway at Denby Dale, and was constructed in 1847 and 1848, from the designs and under the superintendence of Mr. Hawkshaw, the engineer of that Railway.

It is a large timber structure, the two ends being formed of masonry, each end having two stone arches of 30 feet span. The intermediate part of the viaduct is of timber, supported on stone foundations: the stone-work being raised three or four feet above the surface of the ground.

Timber sills are bolted down upon the masonry by bolts passing through the masonry, and upon these sills the superstructure of the viaduct is placed.

DESCRIPTION OF PLATES.

PLATE XIII.

Shows the elevation and plan of a portion of the timber viaduct, and a transverse section of the timber framing is shown upon Plate XV. The upper part of the viaduct is shown with a longitudinal section to a larger scale on Plate XIV.

The whole of the timber is Memel. The framing is well secured by iron straps and bolts, and the vertical balks which rest one upon another are further secured by an oak dowel, 2 inches diameter, passing 8 inches into the ends of the two balks in contact.

The viaduct is 1,050 feet in length, and 120 feet high.
DENBY DALE VIADUCT.

ELEVATION.

PLANT.

SCALE OF FEET.

John Besley, London 1856

John Hawkshaw, Engineer

Dundas & Co. Ltd., London
DENBY DALE VIADUCT.

MODE OF JOINING PILES

LONGITUDINAL SECTION

SCALE OF FEET

John Hawkshaw, Engineer.
TITHEBARN STREET VIADUCT, LIVERPOOL.

JOHN HAWKSHAW, F.R.S., ENGINEER.

The Liverpool and Bury Railway, which has its station in Tithebarn Street, near to the Liverpool Exchange, in entering Liverpool had to pass over the Liverpool and Leeds Canal, and the canal wharfs of that Company.

It became incumbent on the Railway Company to construct their railway across the canal and wharfs with the fewest number of piers, and with flat girders, so as to leave the wharfs below as free as possible for the canal traffic. This arrangement left only 20 inches from the level of the rails to the underside of the viaduct; and, under the several limitations, which were fixed by Act of Parliament, the viaduct was constructed.

To comply with the conditions a number of flat malleable iron girders of large span were used, each made, as it regards the top and bottom of the girders, of boiler plates, but differing from the usual form of box girder in having lattice sides, which gives greater lightness of appearance, and still affords the requisite strength.

Transverse malleable iron girders are bolted to the under side of the large longitudinal girders upon which the planking is laid that carries the rails; and along the middle of the transverse girders, between the two lines of way, a small longitudinal girder is introduced, which is bolted down upon the transverse girders and greatly adds to their stiffness, and helps to distribute the weight of the passing trains.

The length of the principal longitudinal girders is 135 feet 3 inches, the extreme opening is 125 feet 11 inches.

The viaduct was executed in 1849, from the designs and under the superintendence of Mr. Hawkshaw.
The accompanying drawings show that portion of the viaduct which crosses the canal.

DESCRIPTION OF PLATES.

PLATE XVII.
Elevation of a portion of one of the main girders, a plan of the longitudinal and cross girders, and a section of the cross girders.

PLATE XVIII.
A transverse section of one of the main girders.

PLATE XIX.
An isometrical drawing of one half of a main girder.
TITHEBARN STREET VIADUCT.

ELEVATION OF GIRDERS OVER CANAL.

John Hankshaw, Engineer.
TITHEBARN STREET VIADUCT.

TRANSVERSE SECTION.

SCALE OF FEET.
A DESCRIPTION OF THE NEWARK DYKE BRIDGE,
ON THE
GREAT NORTHERN RAILWAY.

BY
JOSEPH CUBITT, C.E.

This bridge, for carrying the railway across a navigable branch of the river Trent, near Newark, was described as being erected at a point where the line and the navigation intersect each other at so acute an angle, that, although the clear space, measured at right angles, between the abutments, was only 97 feet 6 inches, the actual span of the girders was 240 feet 6 inches.

This structure consisted of two separate platforms, one for each line of rails, carried upon two pairs of Warren's trussed girders, each composed of a top tube strut, of cast iron, opposing horizontal resistance to compression, and a bottom tie, of wrought iron links, exerting tensile force; these were connected vertically, by alternate diagonal struts and ties, of cast and wrought iron respectively, dividing the length into a series of fourteen equilateral triangles, whose sides were 18 feet 6 inches long.

The top tubes rested upon the apices of equilateral, or A frames, fixed on the abutments; and each pair of girders were connected by a horizontal bracing at the top and bottom, leaving a clear width of 13 feet for the passage of the trains.

Each tube was composed of twenty-nine cast-iron pipes, of 1½ inch metal and 13½ inches diameter at the abutment ends, increasing to 18 inches diameter, with 2½ inches metal at the centre of the span,—the ends of the pipes being
accurately turned and fitted, so as to give exact contact of the surfaces, where they were connected together by bolts and nuts.

The lower tie consisted of wrought iron links 8 feet 6 inches long, of the uniform width of 9 inches, but varying in number and thickness, according to the tensile strain to which each portion was subjected; the abutment portions having each four links of 9 inches by 1 inch, and the centre piece fourteen links of 9 inches by \( \frac{3}{8} \) inch.

The diagonal tie links varied from 9 inches by \( \frac{13}{8} \) inch to 9 inches by \( \frac{3}{4} \) inch, and, in order to accord with the relative strains, were distributed in groups of four, for the first three lengths from the ends, and then in couples for the next four lengths, on each side of the centre.

The cast-iron diagonal struts had a section resembling a Maltese cross, the area being in proportion to the compressive force to which they were subject.

The bearing pins at all the intersections were 5\( \frac{1}{2} \) inches diameter, carefully turned and fitting into bored holes.

The links of the lower tie were supported in the middle of each length by a pair of wrought iron rods, 1\( \frac{1}{2} \) inch diameter, suspended from each side of a joint pin traversing the top tube; and by means of nuts and washers they could be made to bear a portion of the weight of the platform of the bridge.

The trusses were so arranged that all the compressive strains were received by the cast iron, and all the tensile force was exerted by the wrought iron; the proportions being such, that when the bridge was loaded with a weight equal to one ton per foot run, which considerably exceeded that of a train entirely composed of the heaviest locomotive engines used on the Great Northern Railway, no strain could exceed 5 tons per square inch of section.

The total weight of metal in each pair of girders, composing the bridge, was 244 tons 10 cwt., of which 138 tons 5 cwt. were cast iron, and 106 tons 5 cwt. wrought iron, which with 50 tons for the platform, &c., made the total weight of each bridge 294 tons 10 cwt., or 589 tons for the whole structure; and the cost, exclusive of the masonry of the abutments, and of the permanent rails, but including the staging for fixing and putting together and the expense of testing, was £11,003.
BRIDGE OVER NEWARK DYKE.
SIDE ELEVATION

These surfaces are to be charged in cutting the Bridge so as to fit well between the end flue.
BRIDGE OVER NEWARK DYKE.

SECTIONS ENLARGED TO \( \frac{1}{4} \) REAL SIZE

SECTION ON C.

SECTION OF JUNCTION WITH HANDRAIL

CROSS STRUT IN TOP OF GIRDER

JOINT PLATES FOR DIAGONAL TIES.

CAST IRON WASHER FOR JOINTS IN TOP OF GIRDER.

J. Cobett C.E.
BRIDGE OVER NEWARK DYKE.

MODE OF SECURING PLATFORM TO CHAIN
BRIDGE OVER NEWARK DYKE.

PIPEC IN TOP OF GIRDERS.

WROUGHT IRON TIES NEXT THE CENTRE OF GIRDERS

The calculated loads on the top and bottom of the girder will be the same as that of these ties.

SCALE.

John Weale, London 1866.
With a weight of 316 tons, equal to 1 ton per foot run, plus the weight of the platform, &c., as before, the ultimate deflection at the centre was $4\frac{1}{3}$ inches.

When the bridge was fixed in its place a train of waggons, loaded up to 1 ton per foot run, extending the whole length of the platform, caused a centre deflection of $2\frac{2}{3}$ inches.

The deflection caused by two heavy goods engines, travelling fast and slowly, was $2\frac{1}{3}$ inches; and that produced by a train of five of the heaviest locomotive engines used on the Great Northern Railway, was $2\frac{1}{2}$ inches in the centre.

**DESCRIPTION OF PLATES.**

**PLATE I.**
Elevation and plan, with dimensions.

**PLATE II.**
Half-side elevation of girder, with dimensions; half top plan.

**PLATE III.**
Transverse section, shewing opening; section of parts, with dimensions.

**PLATE IV.**
Section; section on A. B.; section on C. D.; half plan of cross girder; plan of end joint of top, with dimensions.

**PLATE V.**
Half plan underneath platform; cross section of bridge.

**PLATE VI.**
Detail; side elevation, with dimensions.

**PLATE VII.**
Sections; cross strut in top of girder; sectional parts, joints, &c., quarter real size.

**PLATE VIII.**
Section; platform; mode of securing platform to chain, &c. with dimensions.

**PLATE IX.**
Struts in sides of girder; junction of struts at centre of girder; sections, with dimensions.

**PLATE X.**
Pipes in top of girder; wrought iron ties next the centre of girder; plan, &c., with dimensions.
The following brief account of the Mountain Top Track, or the Railroad now in use across the Blue Mountain, in the State of Virginia, is taken from the Report of Mr. Ellet, the engineer under whose direction the work was laid out and constructed. This remarkable road is not intended for permanent use, but as a means of connecting the two portions of the Central Virginia Railroad which lie on the opposite sides of the mountain, during the construction of a tunnel through the mountain, which is destined ultimately to supersede the temporary work.

The total length of the Mountain Top Track, from the point where it commences to ascend the mountain on the eastern side to the summit, is 12,500 feet, or 2.37 miles; and in this distance an elevation of 610 feet is overcome.

The total length of the track, descending the mountain on the western side, is 10,650 feet, or 2.02 miles; and the track descends in this distance 450 feet.

The maximum gradient of this road, on straight lines, is \(5\frac{6}{10}\) feet in 100, or \(295\frac{6}{100}\) feet per mile.

The general gradient on straight lines is \(5\frac{3}{10}\) feet in 100, or \(279\frac{8}{100}\) feet per mile.

The minimum radius of curvature was intended to be, when the road was laid out, 300 feet; and this limit is, in fact, adopted very frequently. At one point, however, where the road rests upon a very steep slope of the mountain, it was found necessary, in order to avoid an unwarrantable expenditure, to reduce the radius to 275 feet.
The usual gradient on these abrupt curves is $4\frac{5}{10}$ feet in 100, or $237\frac{6}{10}$ feet per mile.

It was supposed by Mr. Ellet, in establishing the plan of this road, that the difference of 58 feet per mile between the gradient adopted on straight lines and that used on curves of 300 feet radius, would be an adequate compensation for the increased resistance due to the curvature. The result, however, showed that the engines labour much more in drawing their trains through the curves than on the steeper ascents of the straight lines; and we are informed by Mr. Ellet, that if he were about to construct a similar track now, where such curves would be inevitable, he would make the acclivity of the straight lines somewhat greater, and that of the curves less.

This road is worked altogether by locomotive engines, and has been used with entire success and great satisfaction to the public since the month of March, 1854. Its services will be required about two years longer, probably until the end of 1857.

The engines used upon this line are of various plans of construction, and built by several different makers. Those chiefly relied on are the connected six-wheeled engines of M. W. Baldwin and Co., of Philadelphia. These engines weigh about 50,000 pounds. They have $16\frac{1}{2}$ inches cylinders, and 18 inches stroke. The drivers are 42 inches in diameter. The water-tank and fuel are carried on the top of the boiler, so as to dispense with a tender.

The ordinary train behind the engine is three loaded eight-wheeled freight cars, each car weighing, with its burden, about 14 tons, or a total seldom less than 40 tons, and never exceeding 50 tons.

Great care is taken to avoid accidents. A good break is applied to every wheel. Powerful couplings connect the cars, which are also provided with guard chains. Powerful breaks are applied to the engines, which are also furnished with what is called the "Atmospheric Break," formed by opening a valve in the lid of the steam chest when the train is descending the mountain.

One of the ordinary freight engines of Messrs. Richard Norris and Son, of Philadelphia, has also been found to perform remarkably well on these abrupt curves and steep gradients. This engine,—the Charles Ellet, Jr.,—having
four drivers of 54 inches diameter and a truck, 14 inches cylinders and 26 inches stroke, a tank on top of the boiler, and weighing, without wood or water, 41,165 lbs., has ascended the mountain and drawn its train of three loaded cars, or 42 tons, up the grades and around the curves without difficulty. But this excellent engine was not designed to work on the Mountain Top Track, and is only occasionally employed in that service.

Although the working of this extraordinary road has fully satisfied the expectation of its projector, we are informed by Mr. Ellet that he would not resort to such extreme gradients and short radii, excepting in cases of very great necessity. He expresses the opinion, however, with much confidence, that lines for general traffic in mountainous districts, having ascents of 200 feet per mile, and radii of 400 feet, may often be constructed with great advantage, and, worked by the Baldwin engines, with entire safety.

The Virginia road, to which the above description applies, is used for the accommodation of a promiscuous and very considerable freight and messenger business.
PRELIMINARIES TO GOOD BUILDING.

First.—The projectors must, before seeking any designer, have so far ascertained what they want, as to be able to state clearly and finally—(1) How many apartments they mean to have, for what purposes, and of what capacity; (2) Which of the Five orders of Stability (hereunder to be defined) should be attempted; and (3) Which of the Four degrees of Beauty; that is to say, whether the building should have structural beauty alone; or should add, besides this, floral ornament; or, besides both these, animal ornament; or, besides all these, historic art.

Secondly.—It is absolutely necessary to have nothing to do with any designer who proposes, as a part of his design, any ornament that he could not execute with his own hand.

Thirdly.—For public buildings, the designers must at first, for a few years, be found by public and open competition, subject to the above condition; so that every competitor must produce, along with his design of the whole structure, a full-sized model or specimen of the most important or difficult ornament (whether it be a birth of Minerva or a brick moulding); and the selectors must bind themselves on no account to select one person's structure and another person's ornament, as no good work can ever be produced in this manner.

Fourthly.—No drawings of any kind must be allowed to be brought or displayed; as none are necessary, and all, except plans, are wholly deceptive and misleading. Each competitor must explain himself solely by a model, on a given scale, not less than a hundredth of reality, but as rough as he pleases.

Fifthly.—The instructions to competitors must state (besides the Requirements, the order of Stability, and the degree of Beauty) the three remunerations
to be made to the successful architect—(1) the fee for design alone, to be paid as soon as it is chosen; (2) the daily salary for superintendence, and how many days thereof he is to give; and (3) the second fee, on successful completion. All these must be kept distinct, named from the first, dependent solely on their judgment of the work required from him, and wholly irrespective of the cost of building.

Sixthly.—The selectors must bind themselves not to view the designs till they have first been examined by some person named (who ought eventually to be a public officer expressly charged with this duty), who is to reject any that do not fully comply with the instructions, and to give certificates to each designer who, in his opinion, has complied; and that these certificates shall afterwards be held valid evidence; and that if they, the selectors, should at any time during the erection be proved to have built contrary to their published instructions, they will be liable to pay to each and every certificated designer, for wasting his time, a sum equal to that offered as the fee for design alone.

Seventhly.—By public and open competition is meant, not only that all the world be free to compete, but that all who bear part in the expense of building may be heard if they will, before the selection. Therefore, in every case of public or municipal buildings, the models must be publicly exhibited, in a manner that may just pay the expense of doing so; and this for as long a time as possible pending the decision. Moreover, in the present state of the English mind, or in any similar one of general delusion as to the time required for real design, it would be necessary to protect the public against some effects of their hallucination, by such a rule as this:—that the amount of the fee offered for design alone be deposited when designs are called for, in some person's hands who is to pay it either to the chosen designer, or (if none be then chosen) to all of them jointly, as soon as the models have been as long under inspection as they were in their author's hands. The object of this would be not so much to ensure prompt decision, as to procure the allowance always, of at least as much time for design, as they mean to take for the easier and less important task of selection.

Without pretending to say whether these conditions are all that will be necessary to render real competitions possible, the writer would be understood to predict confidently that nothing less than these will ever again suffice (even could
GOOD BUILDING.

it be proved to have sufficed in any past time), and that the omission of any single one of these checks (except the last) will render the rest utterly nugatory. As for the farce now dignified with the name of competition, which, without taking part in, he has none the less attentively watched, it seems impossible among the whole range, even of nineteenth century insanities, to match its absurdity. But this concerns solely the paymasters. They must decide what is to their interest, and it is no affair of ours.

Let us observe, however, that the absolute necessity for obtaining the designers by competition, will not continue beyond the first generation who shall attempt true and honourable building; because, when any real designers are once found, the profession will be perpetuated, like others, by proper education; and the more surely so, because a nation that has suffered for so many ages from so great a want, will no sooner obtain the least glimmering of what true design means, and the contrast between it and our present engineering and architecture, than the whole importance of the thing will be recognised. Let men once taste of the tree of the knowledge of good and evil, instead of evil only, and they will provide for the future supply.

Real competitions, however, though the first, are by no means the chief essential towards good building. And they are as far from being the only one, as good Building itself would be from sufficing for Architecture. Still as it is allowed to be essential thereto (even by that most contemptuous decrrier of all things mechanical, Mr. Ruskin himself, who in the very first page he penned on the subject, says, "there can be no architecture which is not based on building, nor any good architecture which is not based on good building;") we may conclude it will be time enough to talk of architecture when we have some mere building passably sound and rational; that is to say, approaching in honesty and common sense to the worst examples of the most barbarous locality, in the worst period we can find, of the forty centuries preceding the present. And it will be time to inquire why we have not this, when it shall be historically made out that there ever was or could be any such, under conditions like ours, or without some such checks as are above proposed.

But we must come next to certain matters of taste, or ornamental architec-
ture, simply because they stand in the way of the mere "Good Building," which we make for the present the object of these enquiries. There are certain supposed aesthetic or architectural refinements, the dregs and settlement from all the imposture of the last three centuries, that must be looked in the face before we can regain a single step; things to be entirely abandoned,—which are unclean, and shall be unclean unto us,—and during the toleration of which, we distinctly challenge and defy any tolerators of them, by any expenditure whatever, with any genius whatever, though they had a Phidias, a Giotto, and a Michael Angelo rolled into one, or fifty of them, to obtain, by any number of trials, in any number of ages, a single work that shall not become, to the very next generation, either a laughing-stock or a curse. It seems to me that three rules laid down and strictly adhered to, would free us of the greater part of these things; and that, if fairly stated, there would be found a section of the public now ready to support an architectural (or engineering) schism, whose chief badges these rules should be.

First, then, nothing could be easier or more definite than to reject positively and at once, all features in plaster; that is, all use of it otherwise than as a flat surface, for cleanliness or protection. I am aware that such surface has been simply and unaffectedly adorned, in times of true art, by a particular kind of shallow stamping; but I think only on exteriors (where the retaining of dust is no disadvantage), and this only on buildings of timber, which must now be, in an old country, wholly out of date. However, there is no need to discountenance any plaster ornamentation likely to appear on exteriors, if we extend the above rule to the rejection of all external plastering whatever in towns; which I think is fair, because, though in rustic building, of great rudeness and flimsiness, external plaster may have an utilitarian object as a protection, it is matter of experience that in our towns it is never so used, but only for purposes of disguise that have degraded and utterly ruined the system of structure concealed by it. Let us then utterly abjure external plastering in towns, as well as all plaster features (i.e. projections), both external and internal. Do you say, a trade would lose employment? These proposals do not look to a general reformation, but only to a schism. The orthodox part of the public, who still continued to think
themselves benefited by the ornamental plasterers, would still find them employment enough; at least till they have time to learn some more useful craft. They must have learnt that of plain plastering already.

Secondly.—It seems equally easy to draw a circle round another vice, which I have not yet seen defined, but which is as deplorable in its waste of our resources as this of sham architecture; but more subtle in its fallacy; more ancient I think, in this country at least; more national to us; and holding the same place in our public building that the former does in our private. It may be called "Sentimental Materialism," and defined as "a display of certain materials solely for the sake of mental associations that happen to have adhered to them." The way that we know and prove them to be used solely for this, is by finding them obviously more costly at the spot where they are used, than some other material that is abstractedly a better one, i. e. more durable with equal beauty of colour, or more coloured with equal durability. The subtlety of the fallacy arises from its being so easily characterised as a "sacrifice of things costly because they are costly," and thus confounded with the "Lamp of Sacrifice" so beautifully defined by Mr. Ruskin, with which it has not the most remote connection. In fact, however, the above definition is not true, but the change of one word will render it so; as regards at least, the commonest, and by far the most widely spread form of this vice. It is, in its general form, a sacrifice indeed of things costly, because they look (not because they are) costly; and in the rarer forms, a sacrifice of them because they look antiquated, or churchlike, or suggestive by association, of some particular class of things. But observe that the baseness or dishonourableness of this principle, as regards the designer of the building, arises from its being a substitution of material for design,—a substitution of mere manual drudgery for mind,—and above all, a substitution of other men's labour for that which he is paid to do. The architects, says Ruskin, "can indeed raise a large building, with copied ornaments, which being huge and white, they hope the public may pronounce 'handsome.'" Now, why is whiteness conducive to this? Why must the plain walls of a public building in a brick town,—say a town of the most durable and most rich-coloured brick,—be disguised in freestone, both less durable and less coloured, at a greater expense?
To make the dead walling of any building, of a material different from the common one of the locality, without gaining either in solidity or beauty, seems to me a pure sacrifice of public money to private persons; and if the substituted material be a loss in both, both less durable and less coloured, then surely these persons had better have been 

**pensioned** to the same amount. But in London this is what we do with all public buildings. Church walls must (at present) be of "Kentish Rag," a worse walling material than any other used in London, and cut up with a precise and minute imitation of the worst kind of rubble-work. A few years ago, when the same spirit required them "stone-coloured," but had not advanced to actual stone, they had to wear an icy livery of the pallid Eastern Counties' brick: and public buildings in general, a skin of some perishing and dismal drab stone, brought 100 miles; while the brick it conceals is (if like that of the surrounding houses) more durable than any English stone, or even granite; more finely coloured than any but a few of the rarest marbles; very peculiar to the locality; and forming with common red brick (as probably the nearest gin-palace will exemplify) a chord of colour singularly fitted for our dull climate, and which the stone builders of half the world might envy. Just turn the eye to such a gin-palace after the portal of a church of the White-Brick period, in its present begrimed Quaker tone of colour; and say which ought to be the cheaper,—which should we bring from a distance at increased expense? It is not that it matters the least, observe, whether a plain unaffected building be of this colour or that; but the difference between bringing from a distance, red brick for the sake of its colour, or white for the sake of its stone-looking want of colour, is just this—that one shows a natural taste, the other a purely artificial and affected one. Similarly, where shall we find any natural or rational motive for carrying into a brick district a single block of common stone for plain wall-surface?—or, for vault-surface, if we had any?

This national fallacy of substituting material for design; sacrificing it in fact, not to the work but solely to the architect; has been equally corrupting and degrading in its effect on his art, whether the material so substituted be stucco or granite; though of course the former adds the evil of a similar effect on the mere builder-craft. Let us renounce it. Let us form a body from which, whosoever of
us proposes either of these things, may be sent to Coventry. Let us bring no stone into a brick town, except to carve it,—or except coloured marbles or granites be given us. We shall have more architecture, though less stone.

Thirdly.—We come to a vice more wide-spread and mischievous than either of these, and more subtle and difficult now to be eradicated; indeed, never to be so, nor even moderated to any useful extent, until there be some understanding and due contempt shown for it by the general public, and a watchful jealousy on their part, over any remaining symptom of it, or future return towards it, by professed reformers. Now I do not despair of seeing such an understanding, first, because this vice (of Architectural Mimicry) has, unlike the others, been perceived and fully despised by the more thinking part of them for at least a century past (as might be shown by a series of unmistakeable allusions and oblique satires in our best literature); and, secondly, because after a restrained and quiet progress all that time, it has, in the present generation, burst all bounds; outstripped in its exaggeration all possible satire; and, as if resolved to overawe the public by the sheer extravagance of its shamelessness, has swollen to a development that seems, like that of the indulgence system under a Leo and a Tetzel, ominous of speedy fall. Beginning from playthings and shows; creeping up through every grade of what should have been real and serious work; till it strides over all, and takes possession at once of the temple and the senate-house; it evidently can now go no further. There is no world left to conquer. As if to mark its day of triumph, the two great national works of the century, the British Museum and Westminster Palace, arise precisely in time to become the monumental landmarks how far it can go; that it can reduce the chief civic buildings of a boastingly "practical" nation, to build historical romances,—piles of petrified stage-property,—stone scenes, instead of canvass, for the performance of some drama, the one of Terence the other of Shakspere. Meanwhile the same gross non-perception of decorum, the same abuse of histrionic art, more proflanely misplaced, and penetrating to the ends of the earth, has at once made our places of worship the laughingstocks of our cities,

* The stone buildings of the middle ages were not in brick towns, but either in stone or wooden towns.
and the religion with which they are associated, in the eyes of the learned Hindoo and the simple Polynesian, a religion whose temples are toys.

Of the fallacy that lies at the root of all this, it is rather remarkable that the philosopher to whom we are indebted for the clear definition of it, seems himself by no means aware of the chief bearing of his discovery; nor so ready to carry it out to its legitimate lengths, as many of the architects themselves (the late Mr. Pugin and Mr. Kerr for instance) already were, at least in theory, from their mere feeling of the fallacy; long before having it put before them in the clear admirable formula that “to carve our own work, and set it up for admiration, is a miserable self-complacency, a contentment in our own wretched doings, when we might have been looking at God’s doings. And all noble ornament is the exact reverse of this. It is the expression of man’s delight in God’s work.” It is truly strange that Mr. Ruskin could write this, and in the same volume tell us how to make “battlements,” whose “use” should be to blend the light of a wall with the shade of a roof;—truly strange how he could so fearlessly and truly condemn on this score the whole system of the after-Gothic shrinework, its stones carved into miniature groinings, “gabelts,” buttresses, and pinnacles, and yet tell us “it is as lawful to build a pinnacle for beauty, as it is to build a tower for beauty.” It seems that his principle of not setting up imitations of our own work for ornament, extends only to imitations in miniature. We may copy them full-size as much as we like. We must not carve such ornaments, but may build them. We may spend on them the labour of hundreds, but not of one. According to Galileo, Nature’s abhorrence of a vacuum did not extend to one longer than 33 feet. Mr. Ruskin has not stated the number of feet which, when a mimic buttress or a mimic pinnacle exceeds, his abhorrence thereof ceases.

But no such limitation, we are convinced, will be acknowledged by most Englishmen once awakened to the sense of this monstrous delusion. On the contrary, they would rather pay for small mimic architecture than large, and rather tolerate it in another Beverley shrine, than another palace of Westminster. They will think poor Mr. Pugin, though not so philosophical, to have been practically nearer the mark in his rule (little remembered indeed by himself, and still less known as it deserves to be) “to decorate construction, and not to
construct decoration." This indeed is precisely what would follow, (and nearly all that would follow with our present kind of designers), from the strict carrying out of Ruskin's prohibition of all but natural objects as ornaments. For, as we should hardly choose elephants, leaves of fan-palm, or flower-spikes of agave, nor magnify other objects, like the Egyptians, our largest ornaments would be nearly sure to be of a single block, like those of the Parthenon and cathedrals; and not, as now, "constructed" decorations,—porticoes and peristyles, nave-arcades and their piers, buttresses and pinnacles, and whole chancels, if not towers.

However, the Ruskin formula carried to its full lengths, is the only one by which the public can protect themselves, in purse and in future credit, against this prodigious abuse. Designers must not be allowed any representations of building features as ornaments, either in great or in small built representations; or carved, or painted, or moulded, or stamped, even down to printed ones. They must not be allowed, either in what is called Architecture, or what is called Engineering, which at present uses them just as numerously, only not on so large a scale as churches and other playwork admit. But the difficulty of observing this rule, a difficulty quite peculiar to the age,—for nothing seems or really could be simpler and easier in itself than such a rule as "that ornament should be natural,"—the difficulty consists in this, that while every one can tell what is natural, very few can tell, in such works as ours, what is an ornament. The ornaments, being often the ugliest things about them, are regarded by the too simple beholders, to whom the whole is a mystery, as some wonderfully scientific necessaries, above their comprehension, but necessary (for how else could such ugly things appear?). We have engineering works, of which the whole visible face is pure ornament, which yet pass with the public as having no ornament on them. How many men in a million (not professed Engineers) know which of the buttresses of Westminster Abbey are ornaments? Two are so, and they are the only two that I know of in any work of the middle ages. How many know, that of all the buttresses jutting out round every church they have seen erected since they drew breath, not one is anything but pure ornament? Now in any past age, almost all the world, even unlettered peasants would have known this
(which now perhaps is not known to a single bishop, or one of the twelve judges). Thus it is to sheer loss of knowledge by the public, even the most educated,—it is simply to the heretofore unimaginable depth of ignorance to which over-division of labour has now reduced all alike, learned and unlearned, on this commonest of all "common things"—building; that its degradation is due; a degradation involving untold loss to every one, and inconceivable dishonour. Now it will be necessary to fine building, or architecture, that some rudiments of the matter should receive in common education, as Mr. Ruskin has suggested, an attention almost comparable with that devoted to grammar or spelling. But at any rate it will be necessary to mere Good Building (Architecture being for the present, and till that is attained, out of the question) that the thinking part of the public become able to apply his rule,—"all ornament to be natural." And this they cannot do unless able to distinguish, in ordinary buildings, what things are made for ornaments; which they never can without some little information (not more than might, I think, be impressed on the memory in a few hours) as to the different degrees or orders of Stability, (which, as already remarked, I shall divide into Five), proper to be attempted in their buildings, from the noblest to the cheapest; and the rules naturally arising out of each; just enough to enable them to know what features are unnecessary to each degree, or kind of building so as not to appear therein unless copied as ornaments from another kind.

The rules then, by which I propose that these various aesthetic obstacles to good building or engineering should be met, are these:

1. To project no stucco features, without or within: nor, in cities, external stucco at all.

2. To use no unnecessarily costly material except for a gain either of durability or colour, or to receive carving; and consequently, in brick cities, to use no common stone uncarved.

3. To imitate as ornaments nothing but natural objects. And to ascertain what are ornaments, we must first classify our buildings, according to their stability, into at least five classes, which we will proceed to define.
SUGGESTIONS FOR INCREASING,

IN SMALL SUMS,

The Circulating Medium,

WHICH SHALL BENEFIT, AT THE PRESENT JUNCTURE, THE MECHANICAL AND COMMERCIAL INTERESTS OF THE COUNTRY.

[The following ideas were recently submitted to Sir George C. Lewis, Bart., as Chancellor of the Exchequer of the present Government.* The original letter is given, but subsequently, however, to this communication, the subject has assumed a more interesting feature, arising from the pecuniary complication both in this country and in France; there undoubtedly is abundance of unrepresented and unemployed capital, made originally by manufactures and commerce, and by the natural productions of the earth; a proper disposition of which into small sums, would add much to the conveniences of trade, and in the disbursement of purchases and its facilities of payments, of weekly earnings. A paper circulation should alone represent positively created capital, and that within safe bounds, as now proposed to be regulated in the following letter. The only deviation, see postscript to the following letter. This divergence is proposed for the removal of a temporary difficulty, still on the security and accessible means of the country.]

Sir,

Having previously had the honour of addressing you as The Right Honourable the Chancellor of the Exchequer, I again take leave to submit a revised outline of a project for a more ready transmission of money than at present exists, as an auxiliary for increasing the currency, and for the transmission of small sums in any exact amounts that may be required under five pounds; for the ready substitution of silver change now in much need in retail

* The trade and commerce of a country are carried on, not by means of its paper money or its circulation, but by means of its capital; and when pressure falls upon the trading community it usually arises from some disturbance of the due proportion between the extent of trading operations and the amount of capital by which those operations are to be sustained. Changes in our currency laws, or fluctuation in the amount of our paper issues, can neither increase nor diminish the amount of capital. They may possibly exercise some slight influence upon the distribution of that capital, but this effect must be limited both in its extent and in its duration.—Mercator, Times, Dec. 14, 1855.
transactions; for removing the difficulties occasioned in the issue of Post-office orders, Scotch and Irish provincial notes, otherwise than in those kingdoms, in payments of money; and bringing under one permanent and secure head all transactions in small notes, and equalising the exchanges and value of money in the United Kingdom of Great Britain and Ireland, and facilitating all kinds of transactions under the said amount of five pounds, which, it is premised, would add considerably to the convenience of all classes, and add much to the revenue of the country.

By the establishment of billet banks, based on deposits of money made in exchange for billet notes, for transmission and payment, and, by such facilities, increasing the circulating medium.

It is therefore proposed that billet notes should be issued in England, Ireland, and Scotland respectively, emanating from either of the chief banks, at each of the three capitals; the issue to be made by government establishments to bankers, postmasters, and others which may here-after be organised, and who may be authorised so to do; the notes to be as promissory notes, printed and properly signed on bank-note paper, and numbered numerically in red for England, pink for Scotland, and green for Ireland, payable on demand at either of the three capitals named. The amounts to be written in sums varying from five shillings to one hundred shillings, each to have a penny stamp, a good designed stamp of the Royal Arms, conspicuously and well impressed on each note.

Bankers and issuers to charge a profit of one penny on each note in addition to the charge for the stamp on the billet.

The billet notes to be legal tenders representing moneys deposited in the hands of the government, and paid on demand in silver or gold at the banks of the red, pink, and green numbers in the government banks of London, Dublin, and Edinburgh. The banks—red, pink, and green,—each to make returns to the other every five days, or in any given time; the numbers issued being duly registered in the home London bank; the cashiers of the issue banks to sign their names, with the letters well and plainly written, under each of the numbers.

The protection from forgery would be a well-designed government stamp of the Royal Arms, very conspicuously stamped on the note, and the peculiar make of the paper, similar to that of Bank of England notes, together with the signature of the issuer.

Billet banks to be established, and the notes sold in every town in the empire.

Upon application being made to either of the three head government banks, forms here-after determined on to be filled up, and the amounts required on application to be paid in, with the payment for the amount of stamps.

The establishment and the legal currency of billet bank notes would be such a convenience to the public generally, and a boon to the country, particularly the trading community, as to subdue any impression of their being considered to be the imposition of a tax, or the reissue of the former one and two pound notes. Post-office orders, which are charged 3d. and 6d. are difficult in many instances to be obtained, especially in remote country places, and very frequently errors are made in ignorance of spelling and making out names, sometimes
requiring several days for correction of errors, to the loss and inconvenience of the recipients; and these money orders produce but little revenue to the country.

The objects to be accomplished by billet bank notes are—firstly, considerably increasing the revenue of the country, obviating present difficulties; secondly, the dilution of capital in smaller and more numerous investments; thus affording a great increase of those means which are now absolutely in requisition for the maintenance and encouragement of a trade much on the increase in smaller and less priced articles, advertised and put forth as priced lists.

Persons would be enabled, either personally or by letter, to procure from their bankers or from other agents, when required, any precise amount or amounts varied for facilities of change in payments.

- Billet notes passing current in all parts of Great Britain and Ireland, of 5s., 10s., 15s., 20s., £1. 5s., £1. 10s., £1. 15s., £2., £2. 5s., £2. 10s., and various sums intermediate and up to £5, would be made available in travelling, giving and taking change; the notes being light and more convenient than silver and gold; and would be received abroad as in the case of Bank of England notes.

Bank notes, in Scotland, of any of the banks, are preferred to gold or silver by the Scottish people.

A billet bank note intercourse with the Bank of France from five francs to one hundred francs, could be established so as to afford greater facilities between the two greatest Western European nations, determining the exchange of twenty-five francs as the £1 English sterling.

The issue of billet bank notes would enable manufacturers, contractors, builders, manufacturing engineers, and others, to pay their workpeople without that difficulty of obtaining silver, so often experienced, and remedying the frequent evil of paying workmen in public drinking-houses. Billet notes could be obtained in the town from bankers and others in exact amounts, to be paid to each person for wages; one draft on the bankers for the whole amount so to be obtained would save much time and trouble.

Bankers ordinarily make advances to merchants, manufacturers, contractors, and traders, on bonds and other securities lodged with them for the profitable purposes of carrying on trade, and the employment of the people. The issue of billet bank notes would be an additional advantage to them: 1st, by the interest derivable on the credit advanced; and 2nd, by the profit on each billet bank note so issued to their customers.

Retail shopkeepers, a very numerous class, would gladly avail themselves of billet bank notes in small amounts, for the advantage to themselves and the accommodation of their customers.

Postage stamps, employed as a means of payment, have become a great evil. Persons are burdened with them, frequently from necessity, who, not being vendors of stamps, have to dispose of them at depreciated prices. Thus the legislature and bankers suffer by an evasion of bank money orders and in receipt stamps, postage stamps in payment being considered an acquittance.

To render illegal the too frequent issues of IO U’s, as injurious to the revenue as they are insecure and dangerous in a trading community.

The consequent increase of the Post-office revenue, by the augmentation of letters, containing price-lists, and lists and catalogues generally, would follow the facilities afforded by the issue of small and convenient billet bank notes for buying and selling.
These ideas are thrown very loosely together. A system of management could be laid down if the project is entertained.

John Weale,

October 31st, 1855.

59, High Holborn.

P.S.—Moreover, as it is probable from the continuance of the war, government will still require, for use in the ways and means of the country, the aid of a considerable sum of money, twelve millions of pounds sterling could be raised within the empire, by a disposition of billet bank notes, divided in the following manner: six millions for England (Bank of England), three millions for Ireland (the Bank of Ireland), and three millions for Scotland (Bank of Scotland). The influences and interests of these great establishments in their several districts, would enable them to supply the funds required, and much relieve the present necessity of money for commercial purposes. Special bargains with these banks could be made for the purchase of the notes, which they could advantageously apply by an immediate issue to their customers and to the public; the notes in question being made legal tenders, and the representatives of money advanced to the government of the country. These issues, by the doubtless confidence in them, would facilitate trade, and remedy all the existing evils complained of, and neutralise, or partially subdue, the largely grown-up monied capitalist,* and render the government, in more intimate communication with the smaller capitalist, more independent of such monied monopolies.

* M. Rothschild, Frankfort, recently deceased, leaving for the disposition of his already enriched family, 30,000,000 guilders, two millions and a half of pounds sterling, made out of the necessities of governments and peoples.
OPINIONS OF THE PRESS
ON
MR. HYDE CLARKE’S NEW AND COMPREHENSIVE
English Grammar and Dictionary.


A Grammar of the English Language as Spoken and Written, with a Treatise on Comparative Philology. By Hyde Clarke, D.C.L. John Weale, 59, High Holborn.

This English grammar and dictionary, which are published together in one volume, reflect the highest credit upon the learning and industry of Mr. Clarke, and will, we are satisfied, come into general use. "New and comprehensive" are strictly appropriate words to apply to a dictionary which, within one volume of convenient size, contains at least 60,000 words more than any former dictionary, and which is constructed with reference to the spoken as well as the written language. Our standard dictionaries are founded, as Mr. Clarke justly remarks, too exclusively "upon literary considerations, under which a printed authority is required for a word;" and although this method is very suitable for a dictionary of classical Greek or Latin, we agree with our author that the English language may with advantage be otherwise treated, and "that the English people require something more than a dictionary of book words." The general requirements of the whole public, not disregarding even children or working men, have been considered by Mr. Clarke in this compilation; and the examination which we have made of its contents satisfies us that it is a most useful and praiseworthy undertaking, the success of which will, we trust, lead in future editions to a still further development of the same plan. Technical terms, ordinary abbreviations, even Latin or French phrases, which have been generally adopted into the spoken language of Englishmen, are added in considerable numbers to the more regular vocabulary, which is in itself extraordinarily copious. The grammar enjoys the same distinctive features as the dictionary, and is rendered peculiarly interesting by a very able sketch of comparative philology, and of the philological characteristics of the English language. It is quite impossible, in a limited space, to do justice to the peculiar merits of this publication; and we must rest satisfied, therefore, with a general recommendation of it, which will, we trust, have the effect of inducing our readers to examine it for themselves.—Morning Post, May 23, 1855.

The public is greatly indebted to Mr. Weale, and still more to the author, or this important acquisition to its philological stores. The dictionary is preceded by an excellent English grammar, in which the author has "thought it right to look rather to the spoken than the written tongue, and to seek his standard among that body of southern English among whom our greatest writers and speakers have arisen." A noticeable feature of the grammar is the author’s
careful abstinence from Latinisms, in order that he may be the more readily understood by children and working men. Of the dictionary itself, we feel no hesitation in speaking in the most laudatory terms. To self-teachers it will be especially valuable, while we are ignorant of any class which will not find it a serviceable handbook. Unlike abridgments which only give words which everybody knows, and standard dictionaries which omit spoken words which everybody wants to know, it is a dictionary of the English language, as spoken and written; and, by an ingenious arrangement, contains, in remarkably small space, at least 60,000 more words than any other dictionary yet published. The meanings, of which there are 10,000 additional for old words, are given by words of English or Anglo-Saxon root, in order to their being more readily understood.—The Sun, April 28th, 1855.

Most works in general literature are beyond the pale of professional criticism; the book before us is an exception. A dictionary is, or at least ought to be, a key or organon to the comprehension of the language of another. The reader who is imperfectly acquainted with a foreign tongue, reads dictionary in hand, and he has a right to find fault with his dictionary if he do not find in it an equivalent in the language he knows well, for every word in the language he knows but imperfectly.

We expect this information in a foreign dictionary; but in the case of English dictionaries we have been admonished by our great lexicographers to seek only for such words as they may have thought orthodox or classical. Now it happens that most of the great and the little affairs of this busy life are carried on in language not always orthodox or classical, according to the lexicographic standard. Since the immortal Johnson wrote, the social world has been revolutionised. Science, arts, commerce, in their accelerated march, have, in creating new things, new ideas, necessitated the creation of new words. It is of daily concern to every one to understand the meaning of these new words. They may not be classical; we may not find them in Addison or Pope; but we may suffer material damage and appear grossly ignorant if we do not understand them. The medical practitioner, for example, is now-a-days often brought to give evidence in a court of law. He gives it, as far as he can, in general expressions; but sometimes he must use technical expressions. The newspapers report everything; the trial may be one of universal interest; everybody reads it; but where shall the public find the explanation of these technical terms? On the other hand, the medical practitioner is equally interested in understanding the meaning of the law terms, without which no trial can be accurately reported. Again, every science, art, trade, or question, may be the subject of litigation or discussion; the papers are daily filled with terms very familiar to those who are engaged in the particular pursuits to which they belong, but often as mysterious as Sanscrit or Chinese to the rest of the world.

The Dictionary of Mr. Hyde Clarke is a master-key to the technical expressions peculiar to every art and branch of knowledge, besides being the most comprehensive dictionary extant of the English tongue, as it is spoken and written.

After putting the work to very severe tests, we confidently say that no one who consults it will be disappointed. It contains many thousand more words than any other dictionary. Not only is it deserving of the highest praise for its comprehensiveness, but it is worthy of study as an exercise in logic. We have been surprised and delighted at the terseness, conciseness, and precision of the definitions.

The great erudition, profound and wide acquaintance with dead and living tongues, and marvellous industry which Mr. Hyde Clarke is known to possess, have long marked him out as a man fitted to take rank with our standard lexicographers: this work is his indisputable title to that position. For comprehensiveness, for excellence in execution, for convenience of reference, and for moderation in price, his dictionary has no rival amongst those designed for the service of all, and for every day use. Every one of our readers who shall give it a place at his elbow will, we are sure, thank us for having introduced a most valuable friend.—The Lancet.
Mr. Hyde Clarke, one of our ablest philologists, only corroborates his reputation as a writer distinguished for the originality of his views, when he puts forth a dictionary remarkable for several points of novelty. One defect, which this new work is intended to supply, lies in the disregard with which most of our lexicographers have treated spoken language; yet it would seem essential that we should have some standard reference for the host of words arising out of the necessity of every passing hour, and for those forms of speech and idioms which, though they constitute so much of the staple of ordinary language, are usually unnoticed by grammarians. Following out this plan, Mr. Hyde Clarke has produced a dictionary whose practical value will be extensively felt. The mere fact of its containing 60,000 more words than any other dictionary in our mother tongue, must render it an important repertory of information for the numerous community of the Anglo-Saxon race, who contribute them from so many and such different quarters of the globe. The book itself has great intrinsic merit beyond the circumstance of supplying so much fresh matter, and will increase the already well-established reputation of the author. In the grammar prefixed to the work, is included a treatise on the comparative philology of fourteen tongues allied to the English, which will be found of great use to the student of languages, and which is the first of the kind on a comprehensive scale. We ought not to take our leave of this publication without a mention of the publisher, Mr. Weale, to whose efforts to produce a set of hand-books, remarkable alike for their cheapness and excellence, the cause of popular education owes so much. We trust he will be repaid with interest for the present cheap contribution to the literature of instruction, which ought to have a place on the shelves of every library, whether of the special or of the general reader; particularly, we advise every one of the extensive body of readers among the industrial classes to purchase it in preference to the older dictionaries of less comprehensive scope.—Bell's Weekly Messenger, April 7th, 1855.

This grammar, by Mr. Hyde Clarke, constitutes another instalment of the series of instructive books issued by Mr. Weale. To those who have devoted any attention to the study of the English language, the want of a grammar which might be recommended as at the same time interesting and yet erudite, and while thoroughly national, yet not unmindful of the connection our tongue bears to foreign dialects, is well known. The author has successfully endeavoured to supply this want; and has produced a treatise, which, being different from the meagre compilations to which the general student has usually been accustomed, affords a comprehensive view of our tongue and its co-relations, and a clear insight into its own peculiarities. The chapter on comparative philology, containing tables for turning English words into the corresponding words of other languages, is highly useful to those who are desirous of acquiring that kind of knowledge of English which will enable them to pass with greater facility to the study of its affinitive tongues. We perceive, by an advertisement prefixed to the work under notice, that the enterprising publisher is about to issue a new dictionary, by the same author; and we have no doubt that this arduous task will be completed by Mr. Clarke with the same success as has attended his labours in the present instance.—Bell's Weekly Messenger.

This is one of Mr. Weale’s new series of educational works, to which is prefixed a grammar of the English language by the same author, of which we have heretofore spoken. Though in a work of compilation like a dictionary, discovery and originality are not to be expected; nevertheless, great judgment, research, and taste are required to collect all the new words and terms constantly pouring into our language, to pack them into a reasonable compass, and to give well-poised definitions of them. How well the author has performed his part in these respects, may be gathered from his statement of having given, in a pocket volume of only 466 pages, no less than 60,000 words, or about 150 per cent. more than any other dictionary contains. To accomplish this, he has been obliged to exercise his wits in condensation, which he has carried to very great
lengths, without impairing perspicuity or the utility of the book. One feature we observe in this dictionary which we do not remember to have seen in any other; namely, the words are followed by the prepositions idiomatically used after them. The value of this to young persons, and the assistance it may sometimes render even to writers, is considerable. The work throughout has been creditably got up; no labour has been spared to make it complete of its kind; and no expense by the publisher or pains by the printers to render it worthy of the labour bestowed on its compilation, and of the patronage of the public.—*Hera- path's Journal.*

This is a very valuable dictionary, as it shows the mode of spelling the participles and perfect tense of verbs, a great desideratum, and the compound forms of words, and the sense in which they are used when united with their usual adjuncts. In this respect, the dictionary is more complete than any we have yet met with, in anything like the same size. It is preceded by a valuable grammar, in which the philology and comparative philology of the language are treated with much learning and clearness. The dictionary is very valuable, either for educational or practical purposes.—*Civil Service Gazette, May 19, 1855.*

It is an undoubted, indeed a very generally acknowledged truisum, that although many works of high merit, descriptive of the English language, are extant, consisting of reprinted editions of Johnson, Walker, Sheridan, and other eminent lexicographers, much want has long existed for a compilation which should meet the requirements of modern times, by the introduction of many words inadvertently omitted in all former editions, and the insertion of others which have been introduced to meet the march of science and improvement, and the intellectuality of the age. We are happy to find that this desideratum has now been accomplished, in the publication, by Mr. John Weale, of High Holborn, of a "*New and Comprehensive Dictionary of the English Language, as Spoken and Written,*" and which will form a Part of his Rudimentary Series. The commencement of the volume is occupied by a copious grammar of the language, including the ethnology and philology of the English tongue, a new theory and practice of English prosody, forming a complete and comprehensive essay on the subject, which must prove of great utility to the student, and an excellent volume of reference to the writer and general reader. The philological portion of the work embraces practical instruction on sixteen languages allied to the English, though the requirements of the author embrace as many languages and dialects as Mezzofanti. Our respected correspondent, Mr. Hyde Clarke, D.C.L., is the author of this novel publication—novel, inasmuch as he has boldly struck out a path of his own, and instead of a new edition, or abridgment of a Johnson or a Walker, Mr. Clarke has produced a work more explanatory of the spoken than the written and printed language of the population, and one in which everything is explained in common English, avoiding Latinisms, and thus rendering the whole most readily understood. The chief features of this dictionary are, that it contains above 100,000 words, being 60,000 more than any similar work yet published, and with 10,000 additional meanings for old words not hitherto given. The terminals of adverbs, adjectives, &c., are given separately, without repetition of the mother word—a plan which has effected much economy in space. The author, indeed, has introduced every possible improvement which could be devised to facilitate the study of the language, and in which we think he has been eminently successful. As usual, the publisher, Mr. J. Weale, has failed nothing in his general spirit of enterprise: the type and paper are unexceptionable, and the volume will, doubtless, not only occupy a place on every library table, but find, from its moderate price, a large circulation among the mechanical and working population.—*Mining Journal.*

Notwithstanding that it hardly comes within the professed scope of our publication, this Dictionary is so eminently deserving of notice as meeting the wants of every class of readers, that we cannot refrain from recommending it with
equal sincerity and warmth to our own. Its copiousness is almost fabulous, inasmuch as it contains at least sixty thousand more words than any dictionary that has yet been published. Of course, we do not pretend to have verified the fact by actual computation, and by collation also with other works of the same kind; but we can readily believe, after the examination we have given it, such to be the case. At any rate, we have put it to a very severe test, and it has stood it excellently well, inasmuch as we have sought out and met with, all the unlikeliest words we could call to mind, besides meeting others of the same kind which we were not looking for—words which we have never been able to find in any other dictionary, some of them not even in special glossaries of technical terms. There are a vast number of words which, though they have not yet been stamped by the literary mint-mark, or formally recognised as denizens of our language, have, whether rightly or wrongly, obtained currency in it, not only in familiar discourse, but also in the lighter and more popular forms of literary composition. It is precisely words of that class—and they have now become legion—which the mass of readers require to have explained to them—new-coined or newly-introduced ones, together with such as it is considered to distinguish as doubtful English by italicising them; which last term will serve as an instance in point, since no one can be at a loss for its meaning who has this dictionary we are now speaking of, to refer to.

Be it ever so copious, a dictionary of a living language can never be complete, because the language itself is continually receiving fresh accessions, some of which may, perhaps, die away and fall into desuetude, while others, though at first received doubtfully, become established ineradicably.

In spite of all we can do, neologisms will invade us; they can no more be repelled by merely protesting against them, than could the Atlantic be driven back by Dame Partington's mop. Every new discovery or invention brings along with it, not only new terms but new epithets, similes, and metaphors. The dramatist and the novelist help in the work of innovation. Sheridan's "Mrs. Malaprop," and Dickens' "Pecksniff," at first only proper names, have become very significant nouns; and when we say that both of them are included in the present Dictionary, we hardly need offer any other pledge of its comprehensiveness.

As may be supposed, we have not neglected to test it with regard to the terminology of architecture, and can vouch for its containing not a few exceedingly comprehensive terms; such as "Asstyrar," "Fenestration," and the like. Even "Roscoco," which we had despaired of finding in any dictionary, has been caught up and fixed. Neither is "Teocalle" omitted. What tends to render this book a most useful—almost indispensable vade-mecum to those who are unacquainted with other languages than their own—nor does its size or bulk disqualify it for a pocket companion—is its containing a great number of expressions and phrases which, although not English, are perpetually recurring in English conversation and writing. By way of an in ter omnium—"Fortiter in re" (which phrase itself is here explained), we may mention "Ecce signum," "Statu quo," "Sub judice," "Noli me tangere," "Au fait," "Hors de combat," "De trop?" and there we stop, lest we should be accused of dealing in de trop ourselves.

Another recommendation of this Dictionary is, that it explains, not only those common abbreviations which are familiar to almost every reader, but all that anywhere occur, and some of which are apt to puzzle even well-informed persons. It is a great advantage, too, that instead of being, as usual, put together at the beginning of each letter of the alphabet, they are placed in the strict alphabetical order of the letters which compose them; thus, K.P. comes immediately before 'Kraal;' and K.S.F., K.T., and K.T.S., between 'Kryolite' and 'Kufic;' and should any of our readers be at a loss for the meaning of those words and abbreviations, they will not on that account think the worse of the dictionary which interprets them, and a host of others.

Some will, probably enough, suppose that extraordinary copiousness in some respects must have been obtained by nearly equal deficiency in others; yet such is not the case. The abundance
of fresh words has not occasioned the omission of antiquated or even obsolete ones; neither have provincial words been overlooked. In short, all pains have been taken to render this Dictionary a complete key to our language, both as spoken and written—as it is employed in literary composition, or in familiar every-day converse; and pronunciation has been carefully marked, not only as regards accentuation, but different sounds of the same letter, as when C takes that of S, or G that of J; also the distinction between the hard and soft Th.

Very truthfully may we affirm this dictionary to be an equally remarkable and serviceable production. Besides painstaking industry, it displays earnest and scrupulous diligence. It is anything than the work of a drudge; for prodigious as the labour must have been, it has evidently been a labour of love. A boon it certainly will prove to readers of every class, and must soon come to be considered indispensable for every printing-office, if not every reading-room also. Some trifling errors have no doubt unavoidably crept in, and some omissions have occurred;—strange, even marvellous, would it be were it otherwise;—but future editions will correct the former and fill up the latter. That there should be so few of either the one or the other, is even now scarcely less marvellous: and what is not least of all marvellous, is the exceeding low price at which the book is offered to the public—for the expense of bringing out such a mass of closely-printed letter-press must have been enormous. With this remark, we take our leave of a production that cannot fail to obtain for the name of Hyde Clarke a prominent place among those of our English lexicographers and philologists.—_Land and Building News_, May 1, 1855.

Mr. Hyde Clarke has favoured the public with an important contribution in the present work. The labour bestowed upon its production has obviously been very great, and we may candidly say, that the quantity of work which Mr. Weale has turned out in this volume for 3s. 6d. may well challenge comparison with the cheapest publication of the day. We cannot understand how the book has been produced at the price. An enormous sale can alone reward the enterprise of the publisher.

We have, however, rather to do with Mr. Clarke than with Mr. Weale. Mr. C. very justly remarks in his introductory preface, that his “labours have been such that any one can ensure, and few can appreciate, as to which each will indulge his own fancies, and whereunto the critic is just as likely to object for what is new and special, and for what is erroneous or deficient.” We readily admit the truth of this proposition.

It is an important consideration to economise space in a work of this kind, and we will venture to suggest a principle which might, as we believe, be practically adopted in the dictionary before us with the greatest advantage. Nouns should stand alone with their meaning, and mere ordinary compounds of the same noun should be omitted. Take, as an example, the word gold: in the work before us, we have it, “Gold, n., precious metal, gold coin, money, wealth, a bright yellow colour, name of an English clan.”

Thus far, we have found fault with Mr. Clarke, not for having come short of his work, but for having done too much—a very pardonable fault, which many of his readers, and many of his purchasers (and we sincerely hope these may be numbered by scores of thousands), will, doubtless, believe; and were it not that we entertain a very strong opinion that no foreign word should be used by an English writer or speaker in cases where an equivalent is to be found in his native tongue, we probably might think so too; but we dread the evil effect which the wholesale admission of foreign words into an English dictionary cannot fail to exercise upon a language already sufficiently complicated in its construction and its roots.

To turn from this view of the work before us, to the more gratifying task of recording our opinion of the book generally. We have found much pleasure in following Mr. Clarke in many authors whose pure English style is unquestionable, as well as in the more obscure and less popular language of our great writers of the Elizabethan period, and it has afforded us satisfaction to recognise good old Saxon words restored, and reinstated in their just and due place, honour, and degree! In truth, we have been perfectly
OPINIONS OF THE PRESS.

Now, however thankless the task of grammar-writing may be considered generally, this author deserves high praise for the masterly manner in which he has performed his present undertaking.

Paucity of space permits us to say in this number but few words of detail on his able and meritorious performance. A glance, though but cursory, has, however, enabled us to see and say how he has dealt with some of his subjects. For instance, we see that he has treated—

Ethnology—entertainingly, yet excellently.
Philology—pleasantly, yet philosophically.
Orthoëpy and Orthography — originally, yet ordainantly.

The Parts of Speech—particularly sensibly.
Syntax—succinctly and synthetically.
Prosody—pleasantly, and anything but prosaically. And, finally,

Figures of Speech and Figures of Thought—feelingly, yet forcibly and fluently.

There is, perhaps, no subject that requires more abundantly the labour of practical and keen analysis than the English tongue, the history, formation, and sources of which the author most attractively illustrates.

In an educational point of view, this work deserves the applause of all friends of progress; since, in leading the student by comparison and analysis to examine that with which he should be most familiar—his mother-tongue, it tends to develop his powers of judgment, and to foster a taste for study and research.

That Mr. Hyde Clarke fully recognises the importance of the mission such a work is destined to accomplish we clearly see. He has not scorned to adapt it to such as find in the terms Ethnology and Philology words lacking a plenitude of meaning, but places side by side pure Saxon exponents—"Folk-knowledge" to the one, and "Speech-knowledge" to the other; examples which the curators of our museums and public institutions will do well to follow.

Another salient feature is the recognition of the importance of the spoken as well as the written tongue; a distinction rarely made yet most patent. To the former, Mr. Clarke assigns the first importance, at least for purposes of historical investigation; and most properly, for in the oral tra-

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"As this is a work which will go into the hands of children, and of working men among others, the writer has, so far as he can, put everything in common English, and shunned Latinism, so that he may be the more readily understood."
ditions of the people, strange as the fact may appear, the character of a tongue is found more strongly and permanently fixed than in the lettered records of its scribes.

This work will, we believe, become to the young as important a step in their educational career, as it will not fail to be to the adult reader seeking to familiarise himself with the vernacular of these realms.—The Artizan.

This work is one of the marvellous results of the high intellect of the age, being combined with, instead of depending upon, the spirit or the capital of the booksellers. Here is a book which, if printed in the type of Lindley Murray's octavo, would of old have cost 10s. 6d. or 12s. It is published for 1s. As it is stated to be intended for self-teaching, we must in all honesty say that it must be the self-teaching of rather advanced scholars in our present imperfect system. More children could not comprehend the chapter on comparative philology, though it would be readily apprehensive to the somewhat cultivated intellect. The grammar is a most valuable adjunct to our elementary works on teaching; at the same time the "proficient" student will find it extremely valuable. He will here discover how much he has to learn, even to understand and speak correctly in his own tongue. It is a work resulting from a profound examination of the world's language—the deep learning and philosophical research—the refined taste and musical ear—are all brought to bear in explaining the origin, rule, order, and completion of our language.—Hampshire Independent.

Had this dictionary been a new edition of any previous one, or an abridgment of any existing work, we should have passed it over without notice. Indeed, there are abridgments enough in existence, and most of them scarcely exceeding the requirements of the schoolboy. Mr. Clarke's work, however, is (as far as such a work can be) a new and original dictionary of the English language, in which the author has included not only all the words contained in previous dictionaries, but has actually added about 60,000 more words—that is, he has nearly doubled the number of words previously included by any other author. Mr. Clarke states, that his dictionary includes more than 100,000 words, reckoning the number by the same standard as in other dictionaries.

This result alone is an extraordinary achievement in lexicography; but what renders it the more important, is the fact, that the additional words, now admitted for the first time into a dictionary of the English language, are precisely those words for which a dictionary of reference is most required.

He appears also to have noted an infinity of words, for which printed classical authority cannot be produced, and which have, therefore, not yet found their way into the standard English dictionaries.

With our language, in its present state of development, it happens that there has become interwoven into our ordinary conversation, and we daily see, reproduced into the newspapers, words and expressions derived from almost every language of importance under the sun,—words which, although they are not English by origin, have, by use and prescription, become as it were naturalised amongst us. These words of foreign origin, which, in spite of philologists and lexicographers, English journalists will print, English orators will pronounce, and which the English people persist in using in ordinary conversation, still retain their foreign garb, and occasionally prove most troublesome and puzzling.

Mr. Clarke rightly marks these words as foreign by the use of an italic type; but this class of words, expressing generally ideas for which we have no English synonym (at least without re-
Who was that worthy individual who declared a dictionary to be the most excellent book for reading in the whole range of literature? for, begin where you will, leave off when you will, you never break in upon the continuity of the story, never lay down the book in the middle of a subject—a recommendation which will apply to scarcely any other production of literature, save perhaps a directory. These remarks are merely preliminary to the notice of a certain dictionary—a really new one—which has just fallen under my eye, and the sooner that the reader makes acquaintance with it also the better will it be for him. Let no one presume to speak lightly of the lexicographical labours of burly old Samuel in the last century, or of Webster or Richardson in this. All honour to such worthy pioneers in clearing the way to our more thorough knowledge and appreciation of our mother tongue! Indeed, Dr. Richardson's English dictionary is not only a super-excellent work in its way, but it is a really pleasant book to look into. Every page is studied with apt quotations in prose and verse from the works of the great hierarchs of our language. Still, nearly all our dictionaries are dictionaries of printed words rather than of spoken words; of words drawn from classical precedents rather than from every day usage; and surely, while every merely vulgar or slang word ought to be excluded from the national lexicon, every truly nervous, expressive epithet, which passes among us in our ordinary lingual intercourse as current coin, ought to be exalted to a place therein. Here has long been a desideratum, which Dr. Hyde Clarke has at length stepped forward with the laudable attempt of supplying us. Mr. Weale, the eminent publisher of scientific and architectural works, has from time to time presented to the public a series of most excellent and very cheap rudimentary treatises or handbooks on the various sciences and arts, and other branches of human knowledge. But a dictionary was needed towards imparting anything like completeness to his admirable set of handbooks; a dictionary that should be conceived in the same excellent spirit as all the rest of the series, be as economical in price and as original in idea as the nature of the work would admit of. With abridgments, stereotyped and
otherwise, we have been dosed long enough; but as Dr. Clarke says, truly enough, "It is the fault of abridgments [of dictionaries] that they give the words every body knows, and do not give the words that are not known, or not well known."

Again: "A great merit, and thereby a deficiency, in our standard dictionaries—so far as their general use by the population is concerned—is, that they are founded on literary considerations, under which a printed authority is required for a word; the word, too, is critically examined before it is admitted; it may be absolutely rejected, or it may lie for years under the interdict of the censors."

"The English people require something more than a dictionary of book words." In short, in a country like ours, where a more real freedom of thought, speech, and publication exists than in most other states on the globe, our dictionaries will soon fall behind the wants of the age, if they confine themselves to the task of enshrining such words only as the scholar in his closet refines, polishes, and sets in his contributions to the jewel house of our literature. The English language has attained to a degree of importance far beyond that to which the most prismatic clippings and chippings of the study could elevate it. This is due to you, and such as you, Mr. Editor. "It is," says Dr. Clarke, "the growth of the newspaper press which has given this importance to the English oral language, the influence of which cannot long be neglected. While the lexicographer is hesitating, weighing, suspending, harshly rejecting, or tardily admitting, a language is being worked out which will react again upon our literature. The periodical press, hardly dignified with the name, much less with the honours of literature, though it embodies some of the most classical compositions in our language, is not accepted as an academic authority; and yet the Times ought to be as eligible an authority as some book long since defunct, and known only by its epitaph, or the title on its coffin plate. The periodical press forms, nevertheless, the connecting ink between the written and the spoken language, between the artificial polish of Macaulay and the rude utterance of the boor." Every reader will indorse this dictum of Dr. Clarke. Seeing, then, that he knows what was wanted, the next im-

portant question is—has he produced what was wanted? He has, and that in so novel, serviceable, and compact a form, that, impossible though the labour may seem, he has contrived to give in the compass of a three-and-sixpenny volume, a dictionary comprising a larger number of words than any other dictionary in the language; besides which, he has included compound words and colloquial phrases, such as we have no right, with our preconceived notions, to look for in a dictionary, but which being there are the more welcome, for that they were not altogether expected.

Yet let it be said, while there is nothing in this book either mysterious or enigmatical, it is not a book that will always reward the gropings of a stupid man, or the careless search of a lazy one. You must have your eyes about you when you seek Dr. Clarke's aid. His necessarily confined space has led to the adoption of many ingenious devices on his part, but his dictionary has no difficulty or peculiarity about its abbreviations and compressions which a careful perusal of his preliminary remarks will not enable an intelligent reader to comprehend.

Let a few specimens, culled at random, suffice. Here is the word "Call," for instance. Of course, the initials v, a, n, stand for verb, adjective, noun, and so on.

"Call, v, name, summon, make a short visit, require payment on shares; n, a cry, summons, divine inspiration, an instalment on shares, instrument for calling sailors or birds, or worrying actors or members of parliament, speculation on the Stock Exchange; — ed, a, named, &c., divinely directed; — ing, a; — ing, n, act of making a call, employment, religious profession; — er, n; — bird, n, a bird taught to draw others into a snare; — boy, n, a boy on a steamer who repeats the captain's orders, a man in a theatre who calls the actors; — again, repeat a call; — aside, withdraw; — away, summon away; — back, revoke; — before, summon; — down, invoke; — forth, induce to come out, summon; — for, demand; — in, invite, summon together, resume; — names, apply abusive epithets; — off, summon away, divert; — over, repeat; — on, solicit, visit; — out, challenge, holo; — upon, visit, implore, require payment of instalments; — round,
go and visit; —to, hollo to; —up, invoke, bring into view; —of the house, reading the list of the members to mark those absent; —over the coals, to an account."

Here the dash (—) represents the initial syllable, the syllable in capitals the remainder of the word, and the italics the compound words. No signification is attached to the words, which explain themselves thus “—er,” as above, so obviously means “caller,” that to add after it "one who calls," would have been but to waste that space which Dr. Clarke has been forced to economise with so miserly a hand. The Doctor has in his book dared to include many words which would have frightened Dr. Johnson into fits, had such words been in common vogue in his day. Here is one:

“Burke, murder secretly by covering the mouth, or to obtain the body for dissection; stop a subject without opportunity of inquiry.”

Pity that the author’s limits would not allow him to give to his readers the origin of such words as this; for many of the generation sprung up since “Mr. Burke,” by the performance of those notable exploits of his which brought him to the gallows, and added one more expressive word to our language.

Dr. Clarke has very properly inserted many words of foreign growth not met with in ordinary dictionaries, but which very frequently turn up in newspaper articles and the like. These words he distinguishes by italics, in which character he also prints such words as are idiomatic. Two or three of these may be selected.

“Dubash, n, interpreter, steward.

“Effendi, n, lord or master, Turkish high civilian.

“Gurry, n, a Hindoo fort.”

Under the word “Ireland,” we find, inter alia—

“Young Ireland, Hiberno-Celt, who wishes to instal the reign of Brian Boroo in Ireland and the United States.

“Old Ireland, Hiberno-Celt, who follows O’Connell.”

Of another class of entries in this dictionary, the following will serve as a sample:—

“Rowland for an Oliver, tit for tat.”

This should be Roland, by the bye.

—Preston Chronicle, September 29.

In this double volume Mr. Hyde Clarke has exhibited his erudition, and it will increase the reputation he already enjoys as a sound thinker and practical grammarian. The views expressed are not clouded in doubtful language, but are so prominently presented, that they seem well adapted for the intended purposes, viz., self-teaching and schools. With these works in their possession, the most uneducated could not fail to make progress, the full explanations and the arrangement conducing to render them available to all classes of students, whether juvenile or adult.—Banker’s Magazine, Dec. 1855.
The following suggestions for publishing a New Directory for the East Indies are submitted for Mr. Wealc's consideration by J. H. Miller, of Moulmein:—

The Directory of the late Captain Horsburgh, although containing mostly all that is required for the safe navigation of the Indian seas, is not adapted to the present wants of navigation, principally because the work is more extensive and consequently more costly than what is required by a great majority of ships trading to India at the present time. The writer is of opinion that a smaller and cheaper work might be published, that while it contained all that is really useful for navigation, might also embrace much that has been overlooked in other works, and be at a cost within the means of everybody, say at twenty to twenty-five shillings the copy.

2nd. The work being intended for India should commence at the Cape of Good Hope, and extend to the east coast of China, including all the Malay Archipelago, and Islands within these geographical boundaries; a chapter on Australia might also be added, and one simply stating the best routes to be pursued through the North and South Atlantic Oceans to and from the vicinity of the Cape of Good Hope.

3rd. Most of the Directories extant contain a great deal of matter that is of little or no use to the navigator; for example, lengthened discussions on the means employed, and the authorities for determining the geographical position of the principal ports, and descriptions of the trade and produce, which are not even entertaining to the great bulk of shipmasters, and at the present time entirely out of his legitimate calling; all such should be omitted, and a simple statement of the latitude and longitude given from the best authorities, directions for making the port, and such local matters about watering, supplies, &c., as come strictly under the duties of a shipmaster.

4th. At ports and places less frequented by Europeans, of which there are many in India, geographical position, positive or approximate produce, articles in demand for trade or barter, as well as a description of the natives, their habits, tempers, and prejudices, &c., would all be most desirable to know; in this Catalogue Madagascar, Sumatra, Borneo, the Anduman and Nicobrue groups, and the other islands on the east side of the Bay of Bengal are mostly all purely native, and at many of them a vessel may stop on her voyage for trade or refreshment if they were better known.

5th. A chapter on Winds, Currents, Meteorology, as likely to be experienced in different parts of the Indian seas, to which might be added an account of the various nautical and other instruments in use at sea, and the mode of using them; also the management of a ship under circumstances of difficulty, especially in hurricanes.

6th. The assistance of an experienced practical seaman would be requisite to plan out and superintend the work to insure its being made useful.
Should it be undertaken the writer of this would be happy to furnish such information as he has acquired in upwards of thirty years' navigating in India, and on his return to India collect and forward such as he might be able to obtain from other sources from time to time as collected.

J. H. MILLER,

Montrose, vice Calcutta,

or, for the next year, at

Milton, by Markinch,

Fifeshire, N.B.

London, July 24th, 1855.

ICE BREAKERS.

I was desirous of getting such information from the United States as might be useful to us, or suggestive to our Shipbuilders for present employment. I wrote to an eminent American friend, an engineer of some standing, who has sent the following reply:—

"It gave me much pleasure to receive yours of the 12th ult., and to know that you were still engaged in your publication enterprises.

"In regard to Ice-breakers for ships and steam-boats we have none that can be considered successful; the most usual plan is to put on a false bow, having great rake and flare, so as to run upon the ice and break it down by its weight (the bow is of course protected by iron). A better plan for our light draft river boats is to have the bow so made as to run under the ice after the manner of a plough; in this case there is less difficulty in breaking it, as the ice is not sustained by the water.

"There have been several plans tried for sawing and breaking up the ice in front of the vessel, but I do not know of any of them which have proved successful.

"New York, November 3rd, 1855."

"CHARLES W. COPELAND."

VINES.

BARON DE FORRESTER having completed his tour through Portugal, we give the result of his observations regarding the effects of the Grape-malady in the Wine-growing districts:—

The Grape-malady or Vine-disease has been general in every part of Portugal since the year 1853, and during the present year its ravages have produced almost a total extermination of the fruit. From the river Minho to the Tagus, but especially in the wine districts of the Bairada, Buceias, and Lisbon, it may without exaggeration be declared that scarcely a perfect bunch of grapes was produced this year, and that at the vintage season instead of the vineyards being thronged with cheerful people gathering the fruit, in many parts we observed that goats, hogs, and cattle, were feeding on the vines. There is literally no wine for the ordinary consumption of the Portuguese people, neither is there wine in any of these extensive districts for distillation.
The stocks of old Lisbon wines are much reduced, and their value increased, at the lowest

calculation, 100 per cent.

Of Figueira wines the stocks are altogether exhausted, and the same may be said of the Muscat

wines of St. Ubes.

South of the Tagus, in the provinces of the Alemtejo and Algarve, the grapes were likewise
destroyed.

In the Port wine districts the Grape-disease developed itself in the month of July, and destroyed

between that month and the middle of August about one-half of the fruit, and the heavy rains in the

month of September nearly completed the destruction of the remainder, so that, according to the

Baron's calculation, not more than 8,000 pipes of wine, and those of most inferior quality, were

obtained.

The wines accumulated in the Alto-Douro (or Wine Company's district) consist principally of the

total stock of wines on the 1st of October last for exportation in Villa Nova hardly amounted

to the one year's production of the Port wine vintage of 1847. Of this stock a very large proportion

consists of wines of the vintages 1850, 1852, and 1854, which, notwithstanding their very doubtful

quality, cost the holders more than double the price at which far better wines were shipped from

Oporto four or five years ago.

Choice old wines in general stock may be estimated at about 10,000 pipes, the average value of

which in the Oporto market rules from £50 to £80 per pipe. This peculiar and limited stock of old

Ports it is perhaps unnecessary to remark, can never be increased in quantity, but must daily increase

in value, such wines being from five to twenty years old.

Of vintage wines, for shipment as such (and these are principally of the year 1853), the quantity

cannot be estimated at more than 15,000 pipes.

The stock of Brandy in Villa Nova on the 1st of October last was reduced to one-fourth of an

average quantity, and its value increased four-fold.

As Alto-Douro wine-growers, our own individual stock (with the exception of our choice wines

of vintage 1853) is almost reduced to our reserves of former years. We therefore, for the present,

limit ourselves to the shipment of our ports of vintage 1853, and to the sale of our assorted stock of

wines in bond.

As there were no grapes in 1854 and 1855 worth our making into wine (either on account of

their inferior quality or their high price), of course we did not venture to purchase wines made of such

grapes by others, preferring to continue to limit the business in Ports to wines exclusively of our

own making.

The distress in the wine-districts of Portugal may be more easily imagined than described, and

more especially so in the rugged and rocky mountains of the Port wine demarcation, which being an

exceptional territory, adapted almost exclusively to the cultivation of the vine and the olive, is

incapable of producing corn.

From this narration of facts the wine merchants of this country will be able to form their own

opinion as to what may be the probable future state of the Port wine trade.

We think that it may not be out of place to mention here that a silver medal of the first class has

been awarded to Baron de Forrester for his Port wines exhibited in the Universal Exhibition at Paris.
**AMERICAN PATENTS.**

The United States Commissioners of Patents, through the intercession of my friend, Joseph Henry, Esq., Secretary of the Smithsonian Institution at Washington, has done me the honour to present for my use, through the Legation, one of the copies (in 3 vols. 8vo.) presented to Congress, described and indexed, of all the patents granted in 1854. Together with their specifications, one of the volumes contains about 1500 illustrative diagrams, showing the inventions in a neat outline, and sufficiently clear to make out the several objects patented. The following very short abstract will be considered interesting, and any one desirous may have access to these volumes by favouring me with a personal application.

**United States Patent Office, January 31, 1855.**

Sir,—I have the honour to submit the following report for the year 1854.

The condition of the office at the present time, and also as compared with previous years, will be seen in a general way by reference to the following statements, numbered 1, 2, 3, and 4.

No. 1.

**Statement of Moneys received at the Patent Office during the year 1854.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received on applications for patents, reissues, additional improvements, and extensions, and on caveats, disclaimers, and appeals.</td>
<td>$134,125 00</td>
</tr>
<tr>
<td>Received for copies, and for recording assignments.</td>
<td>13,664 84</td>
</tr>
<tr>
<td>Amount reimbursed to patent, per act August 4, 1854.</td>
<td>16,000 00</td>
</tr>
<tr>
<td></td>
<td>163,789 84</td>
</tr>
</tbody>
</table>

No. 2.

**Statement of Expenditures from the Patent Fund during the year 1854.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries</td>
<td>$51,000 85</td>
</tr>
<tr>
<td>Additional compensation, per act April 22, 1854 (including six months in 1853)</td>
<td>8,827 59</td>
</tr>
<tr>
<td>Temporary clerks</td>
<td>32,750 86</td>
</tr>
<tr>
<td>Books for the library</td>
<td>3,772 28</td>
</tr>
<tr>
<td>Contingent expenses</td>
<td>32,539 78</td>
</tr>
<tr>
<td>Agricultural statistics, and purchase of seeds</td>
<td>2,538 00</td>
</tr>
<tr>
<td>Librarian</td>
<td>700 00</td>
</tr>
<tr>
<td>Payments to judges in appeal cases</td>
<td>475 00</td>
</tr>
<tr>
<td>Refunding money paid by mistake</td>
<td>302 00</td>
</tr>
<tr>
<td>Refunding money on withdrawals</td>
<td>34,139 96</td>
</tr>
<tr>
<td></td>
<td>167,146 32</td>
</tr>
<tr>
<td>Excess of expenditures over receipts during the year.</td>
<td>3,356 48</td>
</tr>
<tr>
<td>Excess of withdrawals this year over last</td>
<td>10,673 32</td>
</tr>
</tbody>
</table>

No. 3.

**Statement of the Patent Fund.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount to the credit of the patent fund, January 1, 1854.</td>
<td>$28,950 00</td>
</tr>
<tr>
<td>Amount paid in during the year 1854, including $16,000 reimbursed by the act of August 4, 1854</td>
<td>163,789 84</td>
</tr>
<tr>
<td></td>
<td>192,739 84</td>
</tr>
</tbody>
</table>

From which deduct—

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of expenditures during the year</td>
<td>167,146 32</td>
</tr>
<tr>
<td>Leaving in the Treasury, January 1, 1855</td>
<td>25,593 32</td>
</tr>
</tbody>
</table>
Table exhibiting the Business of the Office for Fourteen Years, ending December 31, 1854.

<table>
<thead>
<tr>
<th>Years</th>
<th>Applications filed</th>
<th>Caveats filed</th>
<th>Patents issued</th>
<th>Cash received</th>
<th>Cash expended</th>
</tr>
</thead>
<tbody>
<tr>
<td>1841</td>
<td>817</td>
<td>312</td>
<td>493</td>
<td>$40,413</td>
<td>$83,085</td>
</tr>
<tr>
<td>1842</td>
<td>761</td>
<td>291</td>
<td>517</td>
<td>36,503</td>
<td>31,241</td>
</tr>
<tr>
<td>1843</td>
<td>819</td>
<td>315</td>
<td>531</td>
<td>35,313</td>
<td>30,776</td>
</tr>
<tr>
<td>1844</td>
<td>1,045</td>
<td>380</td>
<td>502</td>
<td>42,509</td>
<td>36,344</td>
</tr>
<tr>
<td>1845</td>
<td>1,216</td>
<td>452</td>
<td>502</td>
<td>51,076</td>
<td>48,340</td>
</tr>
<tr>
<td>1846</td>
<td>1,272</td>
<td>448</td>
<td>619</td>
<td>50,264</td>
<td>46,158</td>
</tr>
<tr>
<td>1847</td>
<td>1,531</td>
<td>533</td>
<td>572</td>
<td>63,111</td>
<td>41,878</td>
</tr>
<tr>
<td>1848</td>
<td>1,628</td>
<td>607</td>
<td>660</td>
<td>67,376</td>
<td>58,965</td>
</tr>
<tr>
<td>1849</td>
<td>1,955</td>
<td>595</td>
<td>1,076</td>
<td>80,752</td>
<td>77,716</td>
</tr>
<tr>
<td>1850</td>
<td>2,193</td>
<td>602</td>
<td>993</td>
<td>86,927</td>
<td>80,100</td>
</tr>
<tr>
<td>1851</td>
<td>2,238</td>
<td>760</td>
<td>869</td>
<td>93,738</td>
<td>86,916</td>
</tr>
<tr>
<td>1852</td>
<td>2,639</td>
<td>996</td>
<td>1,020</td>
<td>112,886</td>
<td>95,816</td>
</tr>
<tr>
<td>1853</td>
<td>2,673</td>
<td>991</td>
<td>938</td>
<td>121,287</td>
<td>132,869</td>
</tr>
<tr>
<td>1854</td>
<td>3,324</td>
<td>868</td>
<td>1,902</td>
<td>163,789</td>
<td>167,146</td>
</tr>
</tbody>
</table>

From this last statement, it appears that 3324 patents have been applied for within the past year, which is an increase of 651 over the applications of the previous year.

The number of patents issued in 1854 is nearly twice as great as in 1853.

The number of cases in the office awaiting examination on the first day of January, 1854, was stated, in the report of last year, to have been 592. Owing to an imperfect mode of computation, this number was found to be incorrect. An actual count showed that there were really 823 cases on hand and undisposed of at the commencement of the past year. That number is now reduced to 89, so that the work of the office can hardly be regarded as being at all behind hand. Applications are now acted upon within a very few days after being made.

The receipts of money from all sources, during the past year, amount to $163,789, and the whole expenditure has been $167,146. This exceeds the receipts by $3,356. Among the receipts is included the sum of $16,000, refunded to the Patent Office for expenses incurred, partly in 1853 and partly in 1854, for fitting up the rooms of the new building, and for other similar purposes, so that the revenue arising from fees alone during the year 1854 has been only $147,789. This falls short of the actual expenditure by $19,356.

This excess of expenditure has resulted, partly, from the additional compensation allowed by the act of 22d of April, 1854, to clerks and other persons employed in the office; in accordance with which, the sum of $8,827.59 has been paid during the past year, as appears from the foregoing statement No. 2.

The expenditures have also been very much augmented during the year by the necessity of repairing a large number of the models in the office, and also of cleaning, varnishing, and removing them to their new receptacles.

The crowded condition in which it has heretofore been necessary to place them had resulted in numerous and great injuries, which it was incumbent on the office to repair. They will be, in a great degree, exempt from such injuries in future.

But the largest item of extraordinary expenditure has resulted from the augmentation of force necessary to dispose of the accumulation of arrearages before mentioned.

The number of cases now on hand is less, by 734, than that which existed a year previous.

The fees of these 734 cases (amounting to more than $20,000) were received in 1853; the labour has been performed, and the expense incurred, in 1854.

The entire income which has resulted from all the cases disposed of during the past year, has been greater than the whole expenditure of that year.

The report for the year 1853 was illustrated with wood engravings, which, though somewhat imperfect, are believed to have added much to the value of that report, by rendering it vastly more intelligible than it could otherwise have been made. Steps have more recently been taken to improve still further in this particular, by providing copper-plate engravings for this purpose. A conditional contract has been made with a competent artist, which, if approved by Congress, will render the report for the year 1854 highly creditable to the office, and eminently useful to the public. I feel great confidence that the advantages resulting from these illustrations will fully justify the increased expenditure thereby rendered necessary.
At the present time, the laws of Canada do not permit our citizens to obtain patents in that province under any circumstances; which causes great inconvenience and loss to our inventors. All machines invented here, can be made and used in Canada without any license from the American patentee; and the products of those machines can, with little trouble or expense, be brought into our markets to compete with like commodities manufactured here by persons who are obliged to pay for the right to use the patented machines for that purpose. This operates like a discriminating tariff against the home manufacturer, which cannot but be prejudicial to his interests.

Reliable information of a private character has, however, been received, to the effect that the Canadian Parliament is taking steps to remove this cause of complaint. A bill was introduced into that body at a recent session (which has been adjourned over to some time in the present month), and is still pending, which contemplates allowing American inventors to obtain patents in Canada; and the only cause of doubt as to its becoming a law is believed to grow out of the enormous fee demanded by this office from all Canadian inventors. The proposed modification in our rate of fees, would doubtless be followed by the desired change in the Canadian law. This would remedy the difficulty complained of by our inventors above alluded to, so far as future patentees are concerned, and might perhaps do so in relation to patentees of a previous date.

It may be thought that we shall best attain our object by retaliatory measures. Such a course would be calculated to arouse angry and hostile feelings, rather than to lead to any final advantage to either party.

A course dictated by kindness and liberality, will soon dissolve the barriers which make nations strangers and enemies.

We can well afford to lead the way in a course of measures which will contribute no inconsiderable share towards rendering us and our Canadian neighbours practically one people.

Very respectfully, yours, &c., &c.,

CHARLES MASON,

Commissioner.

PATENTS OF 1854 CONSIST OF

Class I.—Agriculture, including instruments and operations.—172 Patents granted.

Class II.—Metallurgy, and manufacture of metals, and instruments therefor.—165 Patents granted.

Class III.—Manufactures of fibrous and textile substances, including machines for preparing fibres of wool, cotton, silk, fur, paper, &c.—168 Patents granted.

Class IV.—Chemical processes, manufactures, and compounds, including medicines, dyeing, colour-making, distilling, soap and candle making, mortars, cements, &c.—90 Patents granted.

Class V.—Calorifics, comprising lamps, fire-places, stoves, grates, furnaces for heating buildings, cooking-apparatus, preparation of fuel, &c.—111 Patents granted.

Class VI.—Steam and gas engines, including boilers and furnaces therefor, and parts thereof.—83 Patents granted.

Class VII.—Navigation and maritime implements, comprising all vessels for conveyance on water, their construction, rigging, and propulsion, diving-dresses, life preservers, &c.—57 Patents granted.

Class VIII.—Mathematical, philosophical, and optical instruments, including clocks, chronometers, &c.—27 Patents granted.

Class IX.—Civil engineering and architecture, comprising works on rail and common roads, bridges, canals, wharfs, docks, rivers, weirs, dams, and other internal improvements, buildings, roofs, &c.—83 Patents granted.

Class X.—Land conveyance, comprising carriages, cars, and other vehicles used on roads, and parts thereof.—98 Patents granted.

Class XI.—Hydraulics and pneumatics, including water-wheels, windmills, and other implements operated on by air or water, or employed in the raising and delivery of fluids.—73 Patents granted.
Class XII.—Lever, screw, and other mechanical power, as applied to pressing, weighing, raising, and moving weights.—39 Patents granted.

Class XIII.—Grinding mills and mill-gearing, including grain mills, mechanical movements, and horse-powers, &c.—64 Patents granted.

Class XIV.—Lumber, including machines and tools for preparing and manufacturing, such as sawing, planing, mortising, shingle and stave, carpenters' and coopers' implements.—163 Patents granted.

Class XV.—Stone and clay manufacturers, including machines for pottery, glass-making, brick-making, dressing and preparing stone, cements, and other building materials.—48 Patents granted.

Class XVI.—Leather, including tanning and dressing, manufacture of boots, shoes, saddlery, harness, &c.—47 Patents granted.

Class XVII.—Household furniture, machines and implements for domestics purposes, including washing-machines, bread and cracker-machines, feather-dressing, &c.—82 Patents granted.

Class XVIII.—Arts, polite, fine, and ornamental, including music, painting, sculpture, engraving, books, paper, printing, binding, jewelry, &c.—108 Patents granted.

Class XIX.—Fire-arms and implements of war, and parts thereof, including the manufacture of shot and gunpowder.—37 Patents granted.

Class XX.—Surgical and medical instruments, including trusses, dental instruments, bathing apparatus, &c.—22 Patents granted.

Class XXI.—Wearing apparel, articles for the toilette, &c., including instruments for manufacturing. —28 Patents granted.

Class XXII.—Miscellaneous.—58 Patents granted.

Extensions for 1854.—21 Resumed.

Disclaimers for 1854.—11 Patents.

Additional improvements granted in 1854.—45 Patents.

Designs patented for 1854.—65 granted.

* * * Names of Patentees, and their residences, with dates when the patents were granted, are very satisfactorily registered and inserted in this work.