PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

VOL. V.

Vols. I. and II. of the "Professional Papers" having been for some time out of print, and much inquired for, it is intended to publish, in the course of the present year, a second edition of the two Volumes.

Of Vols. III. and IV. some few copies still remain, and may be had at the following prices:

Vol. III.	£1 5 0
IV.	1 8 0

PAPERS

ON SUBJECTS CONNECTED WITH

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OF THE

CORPS OF ROYAL ENGINEERS.

R. E.

VOL. V.

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LIST OF PLATES.

INTRODUCTION.

SINCE the publication of the Fourth Volume of the PROFESSIONAL PAPERS, at the Meeting of Subscribers which took place in February last, a Resolution was passed, increasing the Annual Subscription from 10*s*. to 15*s*. The circumstances which compelled me to submit such a proposition to the Meeting I shall now proceed to detail. In the Introduction to the Third Volume I mentioned that an agreement had been entered into with Mr. WEALE, the effect of which was to improve the appearance of Volumes III. and IV. in every way. I did not at the time give the details of the agreement, which I shall now state for the information of my Brother Officers, and for the purpose of explaining how the addition of 5*s*. per annum to the previous Subscription became unavoidable. Mr. WEALE agreed to take upon himself all the expenses of engraving Plates, Printing, Binding, &c.; in fact, every expense connected with the Work, after the Papers and Drawings were put into his hands,—to give me 250 copies of the Work for distribution among the Subscribers, and to allow me to purchase 250 more copies at 25 per cent. below the retail price;—in return for which he was to have the copyright of the Work.

The number of Subscribers to whom copies must be furnished amounts to between 450 and 500; and I have hitherto availed myself of the permission to purchase the 250 copies, in order to have a few spare copies to distribute to young Officers who may wish to complete their sets. The retail price of Vol. IV. being 28*s*., the cost of the 250 copies amounted to £262. 10*s*., which exceeded by some pounds the amount of the Subscriptions, leaving nothing for a variety of trifling expenses, as postage, carriage of parcels, &c., or for the cost of preparing Drawings for publication; so that had I continued to carry on the Work on the same terms as before, giving to every Subscriber a book worth 28*s*. for his Subscription of 10*s*., the publication fund would soon have been bankrupt. I therefore felt myself compelled to submit to the Annual Meeting the proposal before mentioned, that the Subscription should be raised from 10*s*. to 15*s*., and this was unanimously agreed to.

The effect of the increase in the funds is visible in the present Volume, as I have been able to employ Draughtsmen to prepare Drawings of various Machines, well worthy the attention of my Brother Officers, but which, without such increase, I should never have been able to procure. The number of Plates has also been increased far beyond those of any preceding Volume; and I hope now, with the means at my disposal, to keep the Volume always up to the present standard. There may be many instances also in which Officers having objects of interest in their immediate neighbourhood, will not have time or opportunity to make the necessary Drawings: in such cases I should be too glad to defray the expense of employing Draughtsmen to execute those Drawings on a scale proper for the Work; and by so doing I hope to secure reports and descriptions of various works useful to us in every point of view.

With regard to the Papers contained in this Volume few remarks are necessary. It will be seen that there are two Plates containing plans and sections of works at the Island of Ascension: I hoped to have been able to give in this Volume the conclusion of the Paper commenced in Vol. IV. by Captain BRANDRETH; but he not having been able (owing to the multiplicity of duties thrown upon him in his present situation under the Admiralty) to complete the letter-press, I have inserted the Plates in this Volume, as they were already printed; and the letter-press will be given in the next.

I have in conclusion only to assure my Brother Officers that no effort on my part shall be wanting to make our Papers a repository of valuable professional information; but as a Work of the extent of the present Volume can only be kept up by the efforts of a body of men, each of whom will devote a portion of his time for the purpose, I must call upon my Brother Officers for all the assistance that their very varied duties well enable them to afford.

W. D.

Woolwich, Dec. 31, 1841.


Forte Diamante
Canale di Tre
Forte del Pelio
Mᵉ Spino
Fratelli
Romignano
Canale di Cica
Begado
Molini
Beghe
Sperone
S.Bart
Torbella Rio
1632
Anno
Nuovo
J. Bigato
S.Antonio
S.Pantaleo
Recinto
Castellazzo
Acq
Torre
Torre Cost
nell'
Costrutto
Torre
Torre
Torre
F.S.Giorgio
Castelletto
Le Tenaglie
Crocetta
Recinto
antico
Darsina
Arsenale
Porto Franco
Mandraccio
S.Teodoro
PORTO
Passo di S.Lazzaro
Belvedere
S.Martino
Permontane
Molo vecchio
Scoglio Campana
Passo nuovo
Molo nuovo
S.Pier d' Arena
Lanterna
Map of
GENOA AND ITS


Forte della Sommità della Croce
S. Eusebio
BISAGNO
T.
Monlesignano
Forte del Monte de Ratti
Ratti
Acquedotto
Figari
Pedegni
Forte Richelieu
Forte di Què
Camaldoli
Quezzi
Valle del Vento
Forte di S. Tecla
Chiapella
raisi
Madonna del Monte
F. Olivella d. Albaro
Vernazza
Pᵉ Rotto
S. Martino d. Albaro
Paverzano
S. Fruttuoso
Le Freccie
Torre
S. Agata
Pᵉ di S. Agata
Torre
S. Elena
S. Luca
Beverato Paradiso
Borgo Pilla
Pᵉ Pilla
S. Franco d. Albaro
S. Mra del Campo
BISAGNO
S. Giuliano
Boccadasse
Carignano
S. Vito
Lazzeretto
Batt. della Torre d'Amore
Batt. S. Nazario
Batt. di Vagno
RIVIERA DI LEVANTE
NVIRONS.

THE Sketch of the LINE OF WATER COMMUNICATION FROM LAKE ERIE TO MONTREAL has been so incorrectly reduced from the original Drawings, as to make it necessary that another should be prepared forthwith; but as it was not desirable to delay the present Volume for this purpose, the present Map has been inserted, and a correct one will be furnished to Subscribers hereafter.

PROFESSIONAL PAPERS.

I.—*Notes on Genoa and Lyons. By* T. K. STAVELEY, ESQ., *late Captain Royal Engineers.*

NOTES ON GENOA IN 1839.

WHEN the British troops under Lord William Bentinck, in conjunction with the fleet, advanced to the attack of Genoa in 1814, the French were driven in from their advanced position in front of San Martino d'Albaro, and the high ground on the banks of the Bisagno, within short range of the city walls, was speedily occupied.

Demonstrations were made of erecting batteries, and other steps taken, which, added to symptoms of insurrection on the part of the inhabitants, caused the French to evacuate the town by the opposite gate, and the British troops took possession of the place. Since that time, or soon after the Congress of Vienna, Genoa and its territory became an important acquisition to the kingdom of Sardinia, both in a military and territorial point of view; and that power is so sensible of its value, that no expense has been spared to increase its strength as a fortress, and improve it as a first-rate maritime city.

As the situation and plan of Genoa are well known, it will only be necessary to describe what has been done since 1816 to the fortifications and to the city itself.

Two new forts have been constructed beyond the Bisagno, at the distance of about 2000 yards from the city lines.

The first is at San Giuliano on the sea side, and the second a little in the rear of San Martino d'Albaro. It is called Olivete, and commands the great post road from the Riviera di Levante.

These two forts are respectable both as to size and profile, and if we can judge from certain *external appearances*, contain bomb-proof redouts or barracks. The ditches are deep, and the escarps generally high; but, as is often the case in small works, the flanking defences are not so good as might be desirable. This is obviated in some places by a zigzag counterscarp, having a passage behind it, loop-holed for musketry. The ground in the immediate neighbourhood of these forts being much enclosed, and intersected by garden walls and other cover, great care has been taken to protect the guns on the ramparts from rifle fire; and this is done by a screen of masonry.

Had these two works been in existence in 1814, our troops would have been most effectually prevented from approaching to bombard the town, as they form a continuation of the chain of forts from Santa Tecla.

Fort del Monte de Ratti appears to be a perfectly new work, occupying the summit of the ridge above Fort Richelieu: it is capable of containing a considerable garrison, the barracks being extensive. It is an irregular pentagon, having three long and two short faces.

These are all the new forts of any consideration to the east of the city. On the west is La Crocetta, built on the ridge just above San Pier d'Arena, and below Le Tenaglie, with which it is connected by a covered way. This work has bomb-proof cover for troops.

In addition to these exterior advanced forts, towers are erected on several points in front of the old lines of 1632, as also on the mountain ridge of Monte de Ratti, looking into any hollows or approaches unseen from the line walls or forts.

They will have one gun on the summit, and the entrances and base are protected by machecoulis, for throwing grenades.

On the old ramparts several new works are constructed, by enclosing two bastions and a curtain to the rear, where the width of the ridge will allow of it. Such are Il Begato and Castellazzo; the one 600, the other 1000 or 1200 yards below the Sperone. All these mountain forts are necessarily of a similar construction, viz., good walls, not always well flanked, but they have generally good defensive barracks within, serving as an interior defence for the garrison.

Castelletto and San Giorgio are two new works erected on commanding points or bastions of the *city walls*, and are defensive barracks for the garrison, or a species of citadel. The latter is a large quadrangle of several stories in height, bomb-proof, and mounting guns on the summit platform.

In addition to the works enumerated above, all the numerous old forts (with the exception of Quezzi) have been placed in good repair, or are in course of repairing, and loop-holed flanks have been constructed on the old lines, wherever considered necessary.

In the city itself great improvements are in progress; new and wide streets communicating with the port, a handsome bazaar on the quay, new city gates, and a theatre: these, with a bridge over the Bisagno, which is commenced, attest the anxiety of the Sardinian Government to improve Genoa, and restore its former splendour.

THE ENTRENCHED CAMP OF LYONS.

The accounts received of the fortifications lately constructed at Lyons have been various and contradictory: in fact, there is nothing more difficult than obtaining correct information on this head. So few persons interest themselves in the subject, and so very few know any thing about it, that nothing less than a personal visit is satisfactory.

From one gentleman I learned that the forts were directed against the citizens only, who were suspected of being riotous and disaffected. Another informed me that they have been constructed to enclose certain suburbs in the octroi of the city. A cursory glance at the accompanying Map of Lyons Plate II. will show that the new forts are eight in number, extending in an arc on the left bank of the Rhone, crossing that river, to the left bank of the Soane, and that they form a permanent entrenched camp, covering the great roads from Piedmont and Switzerland to the city of Lyons. The forts are not yet completed (1839), but they are sufficiently so to furnish a correct idea of the works themselves, and of the system employed in their construction.

The ground on the left bank of the Rhone, on which the six following forts are built, viz., Colombier, de la Motte, Villeurbanne, de la part Dieu, des Broteaux, and de la Tête d'Or, is flat, and covered with the suburbs of La Guillotiere and Les Broteaux; a great part of it, as far as the gravel banks, liable to be flooded by the Rhone, on the melting of the snows. The two remaining forts of Montessuy and Caluire occupy the ridge between the rivers Rhone and Soane, and cover the approaches to the city on that side.

Fort Colombier is on the gravel bank before alluded to, and just without the line of casual inundations. It is a square redoubt, having defensive barracks to the rear. The system employed is a modification of Carnôt's, viz., the revêtements detached, but the loop-holes about 10 feet above the bottom of the ditch.

The flanking defence is worthy of observation. At the north and south salients, which are very acute angles, are small projecting demi-bastions, having two guns in casemates in the flanks, and arched recesses in the faces of the main work, to see to the foot of the escarp at the dead angles and unflanked faces.

The wall is about 18 feet high, and the ditch, when revetted, will be about 60 feet wide.

Such is the general plan of the smaller description of forts on the dry gravel beds.

Advancing towards the Fort des Broteaux the ground is very low and subject to inundations. The ditches of these forts are wet, and the exterior line of rampart is without revêtement. The interior is raised, and similar in construction to Fort Colombier.

Many of the minutiæ in these works could not be observed, as they are not yet completed. Forts Montessuy and Caluire are large square forts with bastions and interior defensive works. They are constructed with the detached revêtement, which is a simple wall 3 feet thick, and the loop-holes are from 6 to 9 feet apart, much too great for a close and effectual fire.

The flanking fire is from loop-holes for musketry only, and if the length of the line of defence, and the general distance between the loop-holes, be considered, these forts must be pronounced as very imperfect. The masonry also is very coarse and ill done, and altogether they are inferior works. One fort only remains to be mentioned, St. Irenée. This is a small redoubt of little importance, and not connected with the general lines of the Camp Retranché.

The only additional remark on the execution of the work of the several forts was, that the earthen slopes of the parapets and ramparts were inoculated with grass, and not regularly turfed with sods.

This may be considered as a very short and imperfect account of so im-

THE FORTIFICA


VAISE
SERIN
Fort St Jean
Gare de Vaise
Roche Cardon
S A O N E R
COMNE DE LA CROIX ROUSSE
Cimetiere de la Croix Rousse
Rue St Pothin
Ch. du Bois
Rue de l'Enfance
Rue de Cuire
Cuire
Ch. de la descente du Rue
LA CROIX ROUSSE
Grande Rue Coste
Ch. de la Croix Rousse
Chemin de Vin
Route Departementale No. 1
Ch. de Vaise à St. Rambert
la Clavagne
Ile Barbe
Fort de Caluire
St. Rambert
ST. RAMBERT
Caluire
Ch. de la Croix Rousse à Caluire
Rillieux
Fort de Montessuy
F
LES BROTEAUX
Fort de la Tête d'or
la Tête d'or
Bois de la Tête d'or
Charpennes
Mon Geriend
PLAN OF FORT COLOMBIER
aaaa Openings for Grenades
Scale 100 Yards to an Inch.
Scale 10 Feet to an Inch.
GENERAL SECTION OF THE RAMPART & DITCH OF FORT COLOMBIER

portant a work of fortification as Lyons; but more could hardly be said on the subject, unless details were entered into which are well known and common to certain systems, as Carnôt's, Montalembert's, &c. I do not presume to offer to my former brother officers my ideas of the strategic merits of the place in question as conducive to the general defence of the country; yet, at the same time, I cannot resist the impulse of saying that such positions as those of Lyons, permanently fortified beforehand, chosen within the frontier, on the great leading communications, would prove more efficient than the projected fortifications of Paris.

T. K. STAVELEY.

NOTE on No. II. Vol. iv.

For the following amendment to the description of "*the old Fortifications of Verona*," given in vol. iv. page 10, of Professional Papers, &c., I am indebted to Lieut.-Colonel Duplat, R.E.

On General Von Scholl, of the Austrian Engineers, receiving orders from his Government to place Verona in a state of defence against a coup de main in the least possible time, the old bastioned works on the right bank of the river, covering the city towards the west, and the main roads from Peschiera, Mantua, and Legnano, occupied his particular attention. The faces of the bastions had been blown down and destroyed by the French, previous to their retreat from Lombardy, but the curtains were left entire.

As the readiest method of effecting the required object, the ditches of the works were advanced, and the earth taken from them was added to the bastions, thus covering all the ruins, and forming a regular slope towards the country. At the base was built a detached escarp according to Carnôt's system. The same was executed on the flanks, except that the escarps were advanced a sufficient distance to allow of a passage for troops and artillery into the body of the place, and they are constructed with orillons at the shoulders, in which are the sally-ports.

The counterscarp in front of the curtains was formed "en contrepente," and the ditch is sufficiently wide to allow of large bodies of troops being formed in close column, ready to advance on a given signal.

To prove its efficiency, at an experimental manœuvre executed by the Austrian troops cantoned in Verona, 50,000 men were marched out and formed in order of battle in front of the works in 8½ minutes.

The General was at that time perfectly aware of the experiments at Woolwich on the breaching the detached escarps of Carnôt from a distance; but this is most effectually provided against by the narrow ditch and the height of the crest of the glacis.

T. K. Staveley.

II.—*Part of a Report on the last* 150 *miles of the Great Fish River, South Africa. By Lieutenant* NELSON, *Royal Engineers.*

HAVING been intrusted with the arrangement of a small reconnoissance ordered by His Excellency Major-General Sir G. Napier, as well as engaged in the execution of a part of it, what I have now to offer is the General Report on the whole length examined, and the Special Report of my own portion; the rest is not in my possession.

I am not only in hopes that these, as well as the appended Table of the rate of fall of the Fish River, will be interesting to some of my brother officers, as specimens of the various duties required at our hands in the colonies; but I also trust to elicit observations generally on the various modes in which Reports may be framed, as well as to point out some connexions that exist between the simpler matters of Geology and Military Topography.

Before entering on the subject of the Paper, it may be as well to state that the Report was ordered by the then lately arrived Governor, Sir G. Napier, with reference to his own views of the somewhat difficult question of protecting the eastern frontier of the Cape from the aggressions of the Kafirs along an irregular boundary, the extremities of which are at least 90 miles apart in a direct line; and which, so far from possessing natural defences, is either so thickly clothed with extensive bush on each side or very near it, that every facility is as much afforded to these predatory savages, as a "covered way" of entrance and exit at pleasure, as is possessed by rabbits in a warren. The bush cannot be cut down, it is too extensive; it cannot be burned, from the succulent nature of much of the vegetation; and the difficulties of an efficient occupation, with limited resources, are very considerable.

During the time that I was engaged on this reconnoissance, two farms were attacked; one a mile in my front, the other some distance in the rear. These Kafirs have not only the most systematic mode of plundering herds by introducing trained decoy cattle, but they have a peculiar facility in rushing through the thorniest bush, scarcely less than that of the wild animals, such as the hyæna, leopard, &c.

Several Dutch words are retained, as having appeared in the original as current local expressions; such as karroo, krang, &c., &c.

The Report was, of course, accompanied by an atlas of plans and sections.

Royal Engineer Office, Graham's Town, July 3, 1838.

SIR,

In submitting the following Report on that portion of the Great[1] Fish River assigned to me,—extending from the old post at De Bruin's to Fort Brown, and lying on the direct Kafir route from the Zuur Berg to the Koonap,—I beg leave, before I enter on more detailed statements, to offer a few remarks on the general relations of the four points of Report with reference to this locality, which will serve as a preface to the whole reconnoissance.

GROUND AND RIVER.

1. Drifts.[2]
2. Banks.
3. Bush.
4. Suitable spots for locating Hottentots.
    1. As an agricultural arrangement.
    2. As a military one.

GENERAL REPORT.

I. GROUND AND RIVER.

1. The Fish River is the drain, as it were, to the great valley formed by the two parallel high grounds of the Botha's hill range and the Vis Rivier Rand: the average width from crest to crest of this valley is about 12 miles. The former line, traced by Botha's hill, Governor's Kop, Waay-plaats, and Mount Donkin, is the southern boundary; the latter is the northern limit, as far as the junction of the Fish and Koonap rivers, continuing from that point to the sea along the range marked by the Grass-Kop.

2. Spread over the bottom of this valley is a mass of karroo, or a diluvial deposit, sometimes 50 feet thick, of clay and gravel, the former composing the upper beds; and

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[1] 'Great' only in contradistinction to the 'Little' Fish River, a tributary that joins it some few miles above the commencement of the part reconnoitered.

[2] Fords. Vich drifts, cattle fords.

the latter the lower ones, resting immediately on the slate (which is the rock of the district), from far above my work to the sea.

3. It is in this karroo that the channel of the river lies for a considerable part of its length: wherever it (the karroo) has any breadth, the course of the stream immediately becomes serpentine; where there is but little scope for this, it resumes a straighter direction.

4. At its junction with the Koonap, the Fish quits the regular valley with its broad karroo bed, and does not return to it until it has made a détour along the bottom of a deep and narrow by-valley in front of the Grass-Kop, and then rejoins it at the kranz,[3] above Committuy's; from thence they continue together as far as Trompeter's Poort; there the valley narrows so as to terminate the karroo, and the river runs along the bottom of a deep valley, and over rather a steep descent and rocky bed to its estuary.

X *a*. GROUND, RIVER, AND DRIFTS.

5. Drifts are formed either by naked out-crops of the slate, as at *a b*, or by the same, as at *c*, covered with gravel washed out of the lower karroo beds, either directly by the stream, or by its very numerous tributaries, the land streamlets, which, when they have nearly reached the river, cut the yielding karroo down to the rock in gullies frequently of extraordinary size, bringing down the gravel with them.

6. As long as the current has a straight course, and no out-crops of rock to check its progress, its momentum carries every thing onwards; but as soon as the velocity is reduced, either by a sudden turn of the river, or by a ledge of rock, the gravel is then thrown down, and such a drift as *c* is the result.

7. Hence, drifts may be looked for with confidence at the principal turnings of rivers; they may be expected below any sudden hook of less importance, and will be very generally found close to the slotes or before-mentioned gullies, cut in the banks by the descent of the land streams.

Further, as these principal turnings are invariably, on this river, marked on the re-entering side by kranzes, and the minor and sharper ones are frequently occasioned by rocky projections from these cliffs, *to ride to the nearest kranz* is an excellent rule for finding the nearest cattle-drift, provided that the bush along the river edge be practicable.

8. With reference to 6, the certainty of meeting one in the straighter parts (even of the serpentine reaches) is by no means so great as when the bending is more abrupt, or where the river winds more considerably.

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[3] Kranz, cliff or bluff.

x *b*. GROUND, RIVER, AND BANKS.

9. The kranzes, where such occur, by no means invariably form the river bank; between many of them and the stream is frequently a narrow strip sufficient for a cattle-track, and along the face of such as slope at the base, from the softer nature of the rock having yielded to the weather, bridle-paths are readily practicable.

10. It is this soft description of rock (or shale) which forms drifts along certain portions of the river, not at points, but for lengths, and up the face of which, as a bank, there is but little difficulty in driving cattle.

11. Hence, a kranz is no certain mark of impassable bank; and as no other description of obstacle in this country offers itself as insurmountable, as the total length of kranz is but small compared with that of the river, and as what defence it does afford is rendered all but useless by the drifts that (par. 7) are sure to be near, if not close to it, it would seem that this relation of ground and river to bank reduces the feasibility of the project of rendering the banks impracticable at a moderate cost. In rock it would be extremely expensive, and, as above, of no great utility: in karroo, very expensive as a first outlay, from its extent, and not much less so subsequently, from repairs to the weathering of the banks, and to damage done by Kafirs, who soon effect, at any point, the rude ramp necessary for their purposes.

x *c*. GROUND, RIVER, AND BUSH.

12. As the ground to be reported on extends for only a mile on either side of the river, it lies, generally speaking, low in the Great Valley, seldom including more than the minor features of the hill ranges by which it is formed. Par. 1.

13. With the exception of kranzes, of small pointed hills, and narrow valleys, I have generally observed this rule,—*the steeper the ground, the thicker the bush:* thus, no ground is so open as along the summits and contiguous upper parts of the high grounds, as also the broader valley bottoms. It is to the intermediate and steeper portions that bush is confined, especially in kloofs,[4] and the edges of the abrupt banks of the river, in both of which the water keeps the vegetation in vigour. Hence, on this head, as far as concerns *extent*, this reconnoissance will be deceptive, if considered as relating to the whole Fish River bush; generally speaking, it refers only to the narrow strip along both sides of the river at the bottom of the Great Valley, amounting to, perhaps, not one-fifth or one-sixth of its width.

x *d*. GROUND, RIVER, AND HOTTENTOT LOCATIONS.

14. The upper beds of karroo being sandy clay (par. 2) or loam, they afford a soil

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[4] Kloof, 'ravine,' sometimes means valley.

that if watered is a most grateful one; if not, one that remains irredeemably barren and useless, except as a sheep pasture.[5]

15. The same cause[6] that placed the gravel beds under the loam limits also the general extent of the gravel to those parts of the Great Valley lying nearest its head, and below them deposits of loam may be expected; the whole gradually thinning out as they approach the estuary.

16. Hence, projects of locating Hottentots, in an agricultural point of view, are less likely to be successful on the higher than the lower parts of the river, from the greater expense of leading off the water for irrigation, or else in damming it up to avoid the disadvantage of a long channel. By par. 4, none can be satisfactorily located below Trompeter's Poort.[7] A thin deposit having found its way down the by-valley (par. 4) between the Koonap junction and Committuy's, the lower part of this has been selected as the site of a settlement, with the additional advantage of a treble chance of water, in case of drought from the sources of Koonap, the Fish, and the Kat; it being situated immediately below the confluence of the two latter.[8]

17. Further, with regard to the defence; where there is the greatest extent of ground for pasture and cultivation, *i. e.*, in those parts where the river winding through the broader parts of the karroo creates most drifts as it sweeps and turns (pars. 3, 7, 8), it is there where, those drifts laying the frontier most open, that a proportional attention to the defence is required; an additional reason for the greater eligibility of the lower rather than the higher parts of the river for these Hottentot locations.

a. DRIFTS.

ab. DRIFT AND BANK.

18. Drifts being formed by out-crops of slate (par. 5), as many may be expected as there are strata appearing at the surface. Hence, such are all but innumerable in the dry season, when the channel is more like a chain of pools, or an old bad road, than a river course; and when, were it not for the banks being thickly bushed (par. 13), the stream might be passed at any point. Should the water be at all high, it is only by these ridges that troops can pass encumbered by arms that prevent them from swimming,

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[5] The pasture on which sheep are chiefly fed in this part of South Africa is not grass, but a variety of low slender shrubby plants, growing in tufts on this dry meagre-looking soil; nevertheless these animals thrive satisfactorily.

[6] Gravity,—that threw it down as a diluvial deposit earlier than the lighter matters of clay and sand, which were carried further down the valley by the water as mud.

[7] The location at Kafir Drift is not in the valley, but at the old post bearing that name.

[8] Notwithstanding the facilities of irrigation afforded by this judicious selection, and by the thinness of the karroo, the Hottentot gardens, however flourishing, are always liable to be ruined by *one night* of the hot winds.

and which wet renders ineffective. It is different with the Kafir; his assegais are at least no hindrance to swimming, and are not injured by water. He avoids the waggon-roads and their drifts, if possible, because on them he may be more easily traced; nor would he be likely, for the same reason, to take to the smaller ones, were not the banks there easier of access *on the Kafir side* than at other points.

19. It is this facility of *getting out of the water* that makes the drift with reference to Kafir and cattle: when pressed, he will *drive down* almost any bank, work through any bush, and swim the river with his booty; but it is the steepness of the opposing bank that checks him, especially when crossing by swimming.

20. A drift, then, with regard to Kafirs, is where the *banks* permit their driving cattle readily across; the bottom is not of such importance to them.

A drift, with regard to troops and waggons, is where the *bottom* must be considered as well as the banks.

21. Hence the Kafir has a serious advantage over the soldier and the colonist in the celerity and security of his motions with regard to passing the river; and taking the latter part of par. 11 into account, it would seem far more difficult to deprive him of that advantage than to raise our condition to an equal footing by multiplying our communications.

a c. DRIFT AND BUSH.

22. As observed in par. 18, the bank-bush forces the Kafir to the drifts; in this instance bush is a protection to the colony, though in general it is far otherwise.

a d. DRIFT AND HOTTENTOT LOCATIONS.

23. In addition to what is advanced in par. 17, I have only to observe, that when the strata slope in the direction of the stream, the hint of the out-crops retaining the gravel (fig. *c.* par. 5) should be used in selecting them as the foundations of any dam that may be hereafter projected for irrigation, not only from their suitable form for stability, but from the river being shallower, and there being thus a more economical arrangement.

b. BANK.

b c. BANK AND BUSH.

24. Where there is but little karroo to form a bank, as in the by-valley between Koonap junction and Committuy's, there is but little of the protection alluded to in par. 22.

c. BUSH.

See paragraphs 12, 13, 22, 24.

d. HOTTENTOT LOCATIONS.

See paragraphs 16, 17, 23.

SPECIAL REPORT.

DRIFTS.

25. In discovering these for the length of the 41 miles reconnoitered by me, I used first the experience of the proprietors of the ground, as best qualified for knowing, and most interested in giving information respecting them. I then added from my own observation such as had escaped their memory; but numerous as the drifts pointed out are, I cannot pretend to say that no more exist. The thickness of the bank-bush rendered such certainty impossible under the limitation as to time in which the reconnoissance was effected. I believe the only way to discover every drift, were such a proceeding worth the expense, would be the somewhat dangerous process of kedging down the stream when the floods are sufficiently high to allow of the use of a boat.

> Report.—In my 41 miles of river are 63 drifts, of which 8 are for waggons, 55 are vich-drifts; also 2 open lengths at miles 23 and 31, not very well defined, but not exceeding a mile at each place.

BANK.

26. The karroo bed is, in my portion, from 30 to 53 feet in depth.

The average cross sections of the channel in the straighter parts may be taken as varying from 50 to 30 feet in breadth below, 50 to 30 feet in depth, and 50 to 30 yards in breadth above. The proportion of bank absolutely impassable to Kafirs driving cattle is not one-sixth of the length reconnoitered; hence

> Report.—Scarping the river bank at a moderate expense is impracticable in my ground.

BUSH.

27. On the banks of the river it consists almost entirely of willow and mimosa; elsewhere, chiefly of the same mimosa, boerbontje, euphorbia, and speckboom. It is in no instance impassable on emergency, as the bush grows in clumps, and it is not *through* but *round* them, by the narrow tracks separating them from one another, that a passage is effected in bush.

28. The main Kafir tracks in my ground are along the crest of the Vis Rivier Rand (par. 13), from whence a striking view is obtained of the system followed by the natives, of making these their principal routes in such places. There are numerous tracks also along the bushy plateau half-way down the south side of the hill immediately overhanging the left bank of the river; these communicate with those on the hill top, and lead by Skelm's Drift, either eastward, away towards Lower Koonap and the Xingxore Kloof, or else south-east, across Skelm's Hoek to the drifts on the Fish River just below Fort Brown.

REPORT.—29. The character of my ground as liable to be infested by Kafirs cannot be better given than by stating that the line along which it lies is marked at 2 miles from the western end of my work by the noted valley and bandit cave called Hell, and at the eastern extremity, by Skelm's Hoek or Rogue's Corner.

HOTTENTOT LOCATIONS.

30. From a length of 32 miles of this river, which I levelled in 1837, the average fall is 10 feet per mile. In my district I do not estimate it at above 8 feet.

I have also stated (pars. 2, 26) that the karroo may vary from 50 to 30 feet in thickness. Taking 40 as an average, it would thus require $\frac{40}{8} = 5$ miles of conduit to irrigate it in most parts, or else a dam that would raise the water to that height at once. Both are, I presume, out of the question; and were they not, there is but little Government ground left, except what is so close to Fort Brown as to reduce what value might be placed on a location as a defensive measure materially, to say nothing of the distance to which the line along which I have worked falls to the rear of the frontier.

REPORT.—I do not consider Hottentot locations advisable in my ground on any account, economic or military.

I have the honour to be, Sir,
Your most obedient humble servant,
R. J. NELSON,
Lieutenant Royal Engineers.

To Captain Selwyn, Commanding Royal
Engineer, Graham's Town.

Tabular and approximate Report on the Fall of the Great Fish River, referred to par. 30, *obtained by rough sections taken with Lieutenant-Colonel* BLANSHARD'S *water-level.*

Stations.	Lengths in miles levelled.	Falls in feet.	Rate of fall.		Remarks.
			ft. ⅌ mile.	or 1 : *n.*	
At Double Drift.	10·5	185·5	17·75	1 : 302	
,, Trompeter's Drift.	7·62	76·5	10·0	528	
,, Hermanus Kraal.	6·12	43·25	7·0	754	
,, Committuy's Drift.	7·44	31·0	4·25	1242	
	31·68	336·25	10·6	1 : 498	
DETAIL LENGTHS.					
Trompeter's *b c.*	0·75	,,	34·5	1 : 153	
Double Drift *fg.*	2·72	,,	32·0	165	
Do. *a b.*	0·55	,,	15·5	341	
Do. *b c.*	1·29	,,	15·5	341	The decimals are carried out to some length; one that would have been unnecessary had it not been done to avoid confusion in the calculations.
Do. *g h.*	0·5	,,	14·0	377	
Do. *c d.*	3·16	,,	13·0	406	
Do. *d e.*	1·31	,,	11·75	450	
Committuy's *b c.*	0·69	,,	11·5	459	
Hermanus Kraal *a b.*	1·25	,,	10·0	528	
Trompeter's *a b.*	6·87	,,	7·25	728	
Double Drift *ef.*	0·97	,,	6·75	782	
Hermanus Kraal *b c.*	4·87	,,	6·0	880	
Committuy's *a b.*	1·88	,,	3·75	1408	
Do. *c d.*	4·87	,,	3·25	1625	
	31·68	,,	,,	,,	

R. J. N.

Graham's Town, June, 1837.

III.—*Memorandum of the Operations for removing the Wreck of the 'Equitable,' in the Fultah Reach of the River Hoogly. By Captain* W. R. FITZGERALD, *Bengal Engineers.*

THE barque *Equitable*, 420 tons burden, outward-bound to Sydney, laden with wheat, rum, &c., was wrecked in the Fultah Reach of the River Hoogly on the 4th October, 1839, in consequence of having grounded upon a newly formed sand-bank in the middle of the channel. The strength of the freshes down the river at the time was such that she was immediately thrown on her beam ends, filled with water, and sunk. After a few slight changes, she ultimately assumed a position in the bed of the river, distant from the nearest bank about 700 feet, and the depth of water over her hull varying, according to the state of the tide, from 15 to 30 feet, while in her immediate vicinity it ranged between 36 and 51 feet.

As she was found to be a serious obstruction to the navigation of the river, several attempts were made to break her up; but, being a strongly-built vessel, these proved unsuccessful, and it was ultimately resolved upon to effect her demolition and removal by the use of gunpowder.

In order to render the subsequent details of the means adopted for ensuring the desired object clear to those who may not be conversant with the subject, it may be stated in general terms that the plan first decided upon was to lodge against the vessel a charge of powder enclosed in a water-proof cylinder, and ignited by means of a train contained in a linen hose protected by a leaden pipe of the necessary length.

The cylinder was capable of containing about 2400 lbs. of powder, the charge it was considered advisable to employ: its shape was that of a large cask with a slight bulge, and it was strongly bound with iron hoops. An exterior casing of sheet lead, carefully soldered at the joinings, fitted closely over all, and every means were taken to provide against the possibility of leakage.

In the event of any accident happening to the leaden pipe, it was of importance that the water entering in consequence should not be able to communicate directly with the powder in the cylinder; and to prevent its doing so a priming tube, capable of containing sufficient powder to ensure its bursting on ignition, and communicating with the main charge, was employed. The tube was made of spelter, carefully soldered, and of the form and dimensions shown in Sketch No. 1. About an inch from its upper end, Plate III. a leaden flange 4" in diameter, with a collar beneath $1\frac{1}{2}$" in diameter, was fastened on, while, to admit of the tube being introduced into the interior of the cylinder, an aperture of the same diameter as the collar was cut in the centre of the bulge. The use of the flange and collar will be better understood after some further details have been given.

A length of 60 feet of patent milled lead pipe was employed for protecting the powder hose, and as this was only procurable in India in pieces of 15 feet, great care was necessary in forming the junctions, so that they might be at once strong and water-tight. The interior diameter of the pipe was $\frac{3}{4}$ths of an inch, and the thickness of the lead rather more than $\frac{1}{8}$th. Before used it was tested by closing one of its ends and filling it with water while in a vertical position.

In order to ignite the powder in the priming tube, a linen hose, $\frac{1}{10}$th of an inch in diameter, and loosely filled with Dartford powder, was employed. To regulate its rate of burning it was tightly tied at intervals of 6", and to prevent its falling down into a heap after ignition, it was attached at the same intervals to a pewter wire, which was found by experiment capable of resisting the heat of the powder without fusing, and which, previous to the hose being lighted, was securely fastened to some object outside the pipe. At the lower extremity of the hose, about 2 feet protruded without wire, to admit of easy insertion into the priming tube, while the upper extremity was fixed to a piece of wire which crossed the diameter of the pipe near its mouth, as represented in Sketch No. 2. Air-holes were pierced through the pipe in the immediate vicinity of this junction.

To fix the leaden pipe securely to the cylinder, and to guard against all risk of water penetrating to the charge through the line of junction, the following arrangements were adopted. A brass union joint was procured, the different parts of which are represented in section and elevation in Sketch No. 3. The part marked A, after the coupling screw C had been placed on it, was firmly and carefully soldered to the lower end of the leaden pipe. The priming tube above described having been introduced into the interior of the cylinder through the aperture prepared for it, its flange formed a washer for that part of the union joint marked B, and by the same screws both were firmly attached to the cylinder. On this being done, a circular disc of sheet lead, with an aperture in the centre to admit of its passing over the screw of B, was placed over the whole, and well soldered to the casing of the cylinder; between these fittings red lead was used as an additional precaution against leakage. When it became necessary at the time of making the final arrangements to connect the pipe with the cylinder, the parts A, B, were placed in contact with a leather washer well soaked in oil between them, and the coupling screw C was brought home by means of a wrench. The joint thus formed was perfectly secure and water-tight.

The loading of the cylinder was then effected by placing it on one end, and filling it through an aperture 1″ in diameter in the other. When the whole charge was introduced a wooden plug was driven tightly into the hole, and a circular piece of lead 9″ in diameter soldered over it to the covering of the cylinder.

The loaded cylinder was afterwards slung under the bows of the *Vulcan* anchor vessel, and dispatched down the river on the morning of December 2, 1839.

Subsequently, from a consideration of the position which the cylinder, after it had been lowered to the wreck, would occupy, and also from an impression that the nature of the bed of the river might tend to cause it to slip, a rectangular wooden frame-work, of size just sufficient to admit of the cylinder resting inside of it, and having legs 6″ long at its angles, was lashed firmly on beneath the cylinder.

While the various arrangements detailed above were in progress, several preparatory subaqueous and other experiments were tried with tubes of different kinds and hoses of different diameters—a common hooka snake, about $\frac{1}{8}$th of an inch in diameter inside, and coated exteriorly with dammer, was filled with powder and fired. It was found that, though a considerable length of it ignited, its strength was not sufficient to enable it to resist the explosive force of the powder. The employment of a water-tight snake of larger diameter than the above, with a very small hose, was, however, suggested as worthy of trial. Leaden pipes, similar to that used for the actual experiment, with hoses of mealed and grained powder, $\frac{3}{16}$ths of an inch in diameter, tied to garden lines at intervals of 6″ throughout their length, were also tried, and the results of these experiments led to the reduction of the diameter of the hose to rather less than $\frac{1}{10}$th of an inch, the use of larger ones being invariably followed by the bursting of the pipe.

The morning of Friday, December 6, 1839, was fixed upon for the first attempt, and by nine o'clock the *Vulcan*, with the powder on board, was moored directly over the wreck in such a position that on the cylinder being lowered it would rest against or be very close to the deck of the *Equitable*, and between her fore and main-masts. The lowering having been successfully effected, the *Vulcan* slipped from her moorings, the old boat, to which the pipe was firmly lashed, was properly stationed, and the arrangements for firing alone remained to be completed. A piece of portfire, calculated to burn ten minutes, was then fixed in the mouth of the pipe, the match attached to it was ignited, and the party allotted for this last duty rowed off. The portfire burned freely, but as the proper time elapsed without any result following, it became necessary to ascertain the cause of the non-ignition. On examination it was found that the portfire had become extinguished, apparently from the thickness of the case, before communicating with the hose. This was rectified by applying and igniting a fresh portfire, calculated to burn six minutes, from the lower end of which a portion of the covering had been removed. This communicated with the powder hose in due time, and the latter burned so freely as to encourage hopes of ultimate success. After a short while, however, a slight explosion was heard, and from past experience it was suspected to indicate the bursting of the pipe: no smoke issuing after it, proved that the hose had been extinguished, and, on returning to the boat, 30 feet of the pewter wire was found projected from the pipe by the force of the powder.

In the afternoon of the same day the cylinder was raised, and, as anticipated, it was found the pipe had been burst at about 25 feet from its mouth, and the water having forced its way through the priming tube, the powder in the cylinder was destroyed. Had it been in our power to have obtained pipes of an inch, or an inch and a half in diameter, there is every reason to infer that, as in other instances, so in the present, the result would have been successful. There is, however, the less cause to regret this deficiency of resource, as there is but little doubt that in future this plan will seldom, unless under peculiar circumstances, be resorted to.

SECOND ATTEMPT.

A second attempt with the same quantity of powder as before having been resolved on, it was determined to employ the galvanic battery as the means of effecting the ignition, instead of the leaden pipe and powder hose.

The arrangements for rendering the cylinder water-tight continued as in the first experiment, and the battery, and the details of the apparatus immediately connected with it, were as follow:

The battery employed was formed of twelve rectangular copper cells, 15 inches square by 1 inch interval between the sides, and each cell was provided with a little cup for containing mercury.

In each cell was placed a zinc plate enclosed in a case of pasteboard with wooden edge pieces, and provided with a copper wire $\frac{1}{12}$th of an inch in diameter and 8 inches long.

The battery cells were separated by thin pieces of wood, and all secured in a box. When it became necessary to complete the connexions, the wire from the zinc of the first cell was led to the copper of the second, and so on through the series.

The battery was charged by pouring a saturated solution of sulphate of copper into the copper cells, and a dilute solution of sulphate of soda into the pasteboard cases, so that each zinc plate was in contact with the sulphate of soda, and each copper surface with the sulphate of copper solution. It was previously found that with dry conductors of 150 yards in length, this battery would keep an inch of platinum foil $\frac{1}{10}$th of an inch broad at a white heat just short of fusion for several hours. The details of the apparatus connected with the battery were—

1. A circular piece of teak-wood (Sketch No. 4), having two grooves cut in it opposite to each other for the reception of the copper conducting wires which were to communicate from the interior with the exterior of the cylinder, was tightly driven into the hollow part of an iron tube previously heated. On this being done, the whole was plunged into water; the metal contracting on the wood with its inlaid wires fixed it firmly and securely, so as

to prevent at once the probability of leakage and the risk of derangement of the apparatus from accidental strains.

2. A thin piece of platinum foil connected the two extremities of the wires to be placed within the cylinder; and as these projected some inches beyond the teak-wood, leaving the foil exposed to the risk of fracture, a copper case, closed at one end with a plug, was passed over them, and firmly fixed to the iron tube. A cartridge of mealed powder was placed in immediate contact with the platinum, and the interior of the copper case was charged with about ¾ of a pound of fine Dartford powder, so that on the circuit being completed, the ignition of this would burst the case, and communicate with the main charge.

3. An iron flange about 4″ square was screwed on the iron tube. The part below the flange being introduced into the interior of the cylinder, the flange with two washers beneath it, one of leather and the other of felt, well covered with white lead, was strongly and securely fastened by means of four screws with leather washers to the cylinder, and over all a piece of lead about a foot square, with an aperture in the centre, and cut to admit of the outer part of the iron tube passing through it, was carefully soldered to the casing of the cylinder.

4. The conducting wires issuing from the extremity of the teak-wood outside of the cylinder were attached, as shown in the Sketch, to a cross piece of wood, and were protected at their points of issue from the risk of contact with each other by a covering of melted sealing-wax.

5. As the tube projected fully 6″ beyond the cylinder, and the teak about 7″, a rough wooden case was lashed over all to protect the wires. The loading having been effected, the aperture closed, and the wooden frame-work fitted as before, the cylinder was again slung under the bows of the *Vulcan*, and dispatched down the river on Thursday, December 12, 1839.

6. The most serious objection to the use of the galvanic battery in a river subject to such strong tides and currents as the Hoogly, is to be found in the difficulty of managing the length of wire absolutely necessary for ensuring the safety of those engaged in the operations. To obviate this, a mechanical arrangement, which admitted of the boat containing the battery being moored directly over the wreck, was brought into play; and though the adoption of this plan involved the loss of the boat, &c., this was considered of little

moment in comparison with the greater certainty of success thereby secured. By this means the main conductors passing from the surface of the water to the cylinder were reduced to about 40 feet in length. Each was composed of three strands of copper wire about $\frac{1}{16}$th of an inch in diameter, twisted so as to form a rope, and at intervals of about 6″ they were kept apart by cross pieces of wood about 4″ in length. This was the only precaution adopted, preparatory experiments having satisfactorily proved that any insulation of the wires for so short a distance by water-proof coatings was unnecessary.

The arrangements for completing the circuit, as also those for breaking it again, so as to remove all risk of danger in returning to the spot, should any accident delay the explosion, were as follow. Wires, as represented in Sketch No. 5, passed through two adjoining pieces of wood about 3″ long and $1\frac{1}{2}''$ deep into four glass tubes, partially filled with mercury; above these, fixed by means of a small wooden frame-work, was placed an old watch, for the minute hand of which a thin piece of copper was substituted. This was fixed on the arbor of the hands so as to cross the dial, and each extremity of it carried, suspended from a short arm, a copper wire bent, as shown in the figure, the legs at one end dipping into two of the mercury tubes, those at the other into the remaining two. The lengths of the legs A, designed for completing the circuit and effecting the ignition of the powder, were so regulated that the copper hand to which they were attached being set to any specified number of minutes, they would not come in contact with the mercury in the tubes till that time had passed, while those at B were arranged so that if the specified time elapsed and no explosion followed, four minutes afterwards the copper hand, in traversing the dial, would raise them out of their mercury, break the circuit, and render it perfectly safe to return to the battery to ascertain, and, if possible, remove the cause of failure.

On the morning of Saturday, December 14, 1839, the day fixed for the second attempt, additional means were taken to strengthen the conducting wires at their points of issue from the iron tube, so as to provide against accidents during the lowering of the cylinder. The thin wires were attached to others with three strands, and afterwards placed in opposite grooves in a circular piece of wood, a hollow bamboo was driven down over this on to the projecting part of the iron tube, and another piece of wood with proper grooves was driven into the upper end of the bamboo. These arrangements removed all strain from the thin wires, and threw it on the others which were more calculated to resist it.

The *Vulcan* having taken up her position, the lowering of the cylinder was commenced about half-past 2 P. M., just at low water, though the force of the under current was even then such as to sweep the cylinder below the bows of the *Vulcan*, and away from the wreck, requiring it to be raised again. The second attempt, when the under current had slackened, succeeded, and the cylinder was placed, as in the former case, resting against or very near to the deck, and between the fore and main-masts of the vessel. The *Vulcan* having slipped from her moorings, the boat with the battery, &c., firmly fixed to it, was moored head and stern over the wreck. All the arrangements of the wires being completed, the watch was set to cause ignition in twelve minutes.

At the expected time the connexion took place, and instantaneous explosion followed. A dark and discoloured mass of water of a globular shape at its base, rose rapidly from the bed of the river, and from its centre a bright and feathery column shot out, to an estimated height of 130 feet, the diameter of the base of the whole being about 100. Its duration was not more than a few seconds. Scarcely any noise accompanied the explosion, no smoke was apparent, and in the boats and on shore only a very slight concussion was felt. On approaching the spot, fragments of the wreck, casks, boxes, wax candles, and quantities of wheat, &c., were seen floating in every direction, and on subsequent examination it was found that the portion of the vessel aft from between the fore-mast and the main-mast had been broken up and scattered in different directions into deep water, leaving the fore part but little injured by the explosion.

In effecting this successful result the most important assistance was derived from the services of Professor O'Shaughnessy, and Lieutenant R. Baird Smith, of the Engineers, who was appointed to assist in the operations. By the former the galvanic battery was supplied, the ingenious apparatus necessary for obviating the supposed difficulties connected with its employment at a distance contrived, and the mechanism for the explosion arranged, while the latter superintended the execution of all the other details, not only on this but on the former occasion also. The nautical arrangements were completed in a most satisfactory manner by Captain Bowman, second assistant to the master attendant, and Lieutenants Bĕcher and Alexander, of the Engineers, were present during the operations and afforded assistance when required.

THIRD ATTEMPT.

On the 14th January, 1840, an attempt was made to blow up the remainder of the *Equitable* with a cylinder charged with 2050 lbs. of powder, but owing to some untoward circumstance it did not succeed. The galvanic battery employed was in good order, the conductors were 150 feet in length, and had one wire insulated throughout, 120 feet of it being covered with pitched corks, while the remaining 30 feet were protected by means of rope yarn saturated with tar and covered with wax cloth. They had been tested a short time before the cylinder was lowered, and found to be perfect in every respect, still when the circuit was twice completed at the time of the experiment the powder in the cylinder would not ignite. The conductors were then reduced to about 40 feet in length, and again tried, but with the same result.

It was deemed advisable after these failures to raise the cylinder. This was effected with great difficulty, after it had been twenty-six hours in the water, owing to its slings having become entangled in the wreck. On examining it previous to opening, it appeared that the protection which had been given to that part of the priming apparatus which projected exteriorly, had been knocked off in raising the cylinder, and the priming apparatus itself much strained, and afterwards that the powder in it was slightly damped, but the powder in the cylinder was as dry and as serviceable as when it was put in.

What the cause of failure actually was it is very difficult to imagine; but as there was a small portion of the conducting wires unprotected just at their junction with the cylinder, it is not improbable that metallic contact had been established at this intermediate point in the circuit, and this idea is further confirmed by the report of the divers, who found a large quantity of iron about the bows of the vessel. The damping of the powder in the priming tube, it is almost certain, could only have occurred at the time when its exterior head was injured; since, had there been any original defect in this apparatus, the water must, in twenty-six hours, have forced its way to the powder in the cylinder.

FOURTH ATTEMPT.

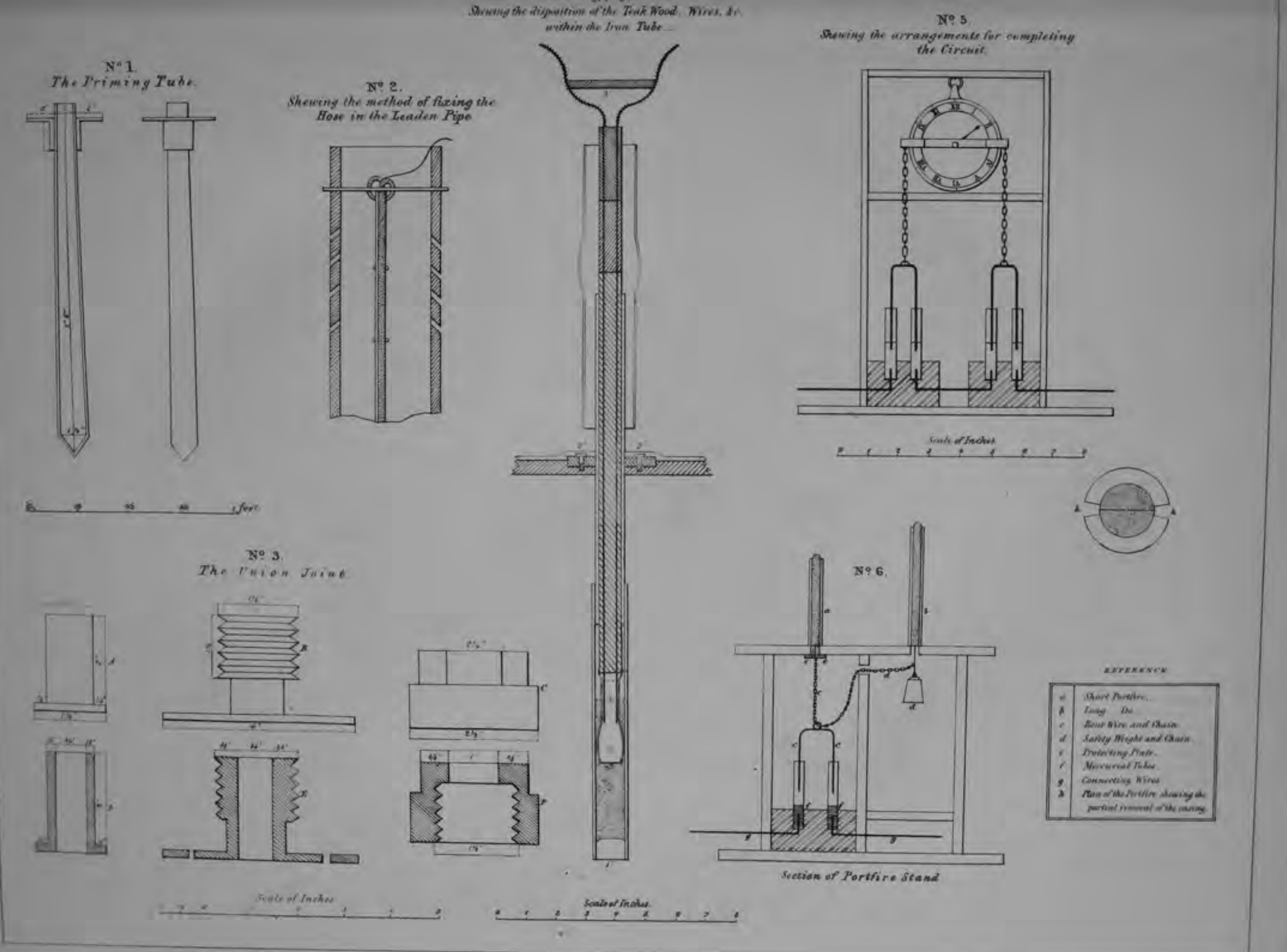
As it was determined to use the same powder without either addition or alterations of any kind, the priming tube, on the return of the cylinder to Calcutta, was inserted without the removal of the powder, care being taken to avoid all risk of accident while the external soldering was in progress. When this was finished, the wires were tested by a galvanometer to ascertain whether the interior circuit was complete, and satisfactory evidence of this having been obtained, the cylinder was again slung under the bows of the *Vulcan*, and dispatched to Fultah.

The galvanic battery, watch, &c., having, as was before stated, been expended on the occasion of the successful attempt on the 14th December, 1839, from the boat in which they were placed being moored directly over the wreck, the arrangements adopted on the 14th January were adhered to on the present occasion, not only with the view of endeavouring to save the battery and apparatus employed, but also of determining with some degree of accuracy the limit of danger from the explosion of large charges of powder under water. The conductors employed were consequently the same length as before, namely, 150 feet, which it was conceived would admit of the boat being placed beyond the risk of destruction, without incurring any serious chance of failure from the strength of the current of the river, or other contingencies, to which a greater length might have exposed them. This course was considered the more advisable, for, although the prior experiments of Colonel Pasley in England had satisfactorily proved that under favourable circumstances ignition could readily be effected at any distance within 500 feet, no direct attempt had ever been made to determine the maximum range of the destructive effects of the explosion. The conductors were made (as suggested by Professor O'Shaughnessy) by passing one wire through corks, subsequently covered with hot pitch and cloth, the other wire fastened outside remaining uninsulated. A length of about 30 feet went down perpendicularly with the cylinder, and the remaining 120, after passing over a floating spar, were carried to the boat in which the battery and the portfire stand for completing the circuit were placed.

The arrangements for connecting the conductors with the battery, and interposing the portfire stand in the circuit, will readily be understood by a reference to the Sketch No. 6. One end of one of the main conducting wires was attached to the zinc extremity of the battery, the other was fixed to one of the protruding wires of the stand; the remaining wire of the stand was then connected with the copper end of the battery, and the circuit was broken only by the interval between the wires in the two mercurial tubes. To complete this in any specified time was the object of the portfire stand. The bent wire *c*, *c*, suspended with its legs in the glass tubes *f*, *f*, was attached by means of a metallic chain and hook to a loop of readily combustible string passing through the composition of the shorter portfire *a*, from which the casing had been partially cut away, as shown at *h*, *h*. The portfire, on burning down, destroyed the string, caused the wire to fall, and thus completed the circuit. Should ignition fail to follow, the portfire *b*, calculated to burn a few minutes longer than the first, had a weight *d*, *d*, similarly attached to it, which, on falling, drew the bent wire out of the tubes by means of the connecting chain, and thus broke the circuit. The portfire stand was suggested and contrived by Lieutenant R. B. Smith, and its capability of answering its intended purpose was fully tested by frequent experiments before the day of the explosion. It was slightly improved from that used on the 14th of January, by the addition of a small copper plate for the portfire to rest on, in the centre of which a small hole had been perforated for the string to pass through, to which the wire or weight was suspended. This copper plate was added to prevent any of the composition of the portfire, just as it burnt out, from falling into the glass tubes, which was found to be the case on the former occasion, and which, with this improvement, was effectually prevented.

Had the success of the experiment on the 14th January depended on the action of the smaller portfire, it would have been complete, as a test applied at the time showed; and although the weight acted as intended on the first trial, by drawing the wire out of the tubes, yet it is necessary to mention that on the second and third attempts it failed in doing so, not from any fault in the design of the apparatus, but from the manner in which the longer portfire was attached at the moment, a properly prepared one not being at hand to apply.

On the 28th January, 1840, the day fixed for the explosion, the cylinder was lowered just at low water: the arrangements previously described having been effected, the two portfires were lighted, the shorter one for completing the circuit being calculated to burn five minutes, and the longer one eight.



N° 1.
The Priming Tube.

N° 2.
Shewing the method of fixing the Hose in the Leaden Pipe

Shewing the disposition of the Teak Wood, Wires, &c. within the Iron Tube.

N° 5.
Shewing the arrangements for completing the Circuit.

N° 3.
The Union Joint.

N° 6.

Section of Portfire Stand

REFERENCE

a	Short Portfire.
b	Long Do.
c	Rear Wire and Chain.
d	Safety Weight and Chain.
e	Protecting Plate.
f	Mercurial Tubes.
g	Connecting Wires.
h	Plan of the Portfire shewing the partial removal of the casing.

Exactly as the five minutes elapsed the explosion took place, and the result was as perfect as could have been anticipated. An immense mass of water was thrown up, the fall of which completely obscured the firing boat from sight. The surface of the river was afterwards seen literally covered with fragments of the wreck, and numerous small fish and two porpoises, picked up by the boats, suffered from the effects of the explosion.

The firing boat (which was a small and rickety fishing dingy), with the battery, &c., notwithstanding its imminent danger from the turbulence of the waves, was seen in perfect safety after their subsidence, and every thing on it, as well as the main conductors, were thus saved. Its distance from the centre being about 120 feet, its total obscuration would give a diameter of 250 feet for the falling waters, and the ascending column was estimated at about 100 feet in width, and 130 in height.

The limit of actual danger with a charge of 2050 lbs. of powder, in a depth of 30 feet of water, may, from such experience as this single instance authorizes, be calculated at something beyond 120 feet. At 200 feet it is conceived that a person in a substantial boat would be perfectly safe alike from the effects of the waves and the fragments of the wreck; but should it be considered advisable to dispense with the self-acting apparatus, it is however recommended that for charges of the above description the main conductors should not be less than 250 feet in length.

It may be useful here to state the specific quantities of the materials employed on this occasion in making the solutions for the battery, and from the admirable manner in which they acted they can with confidence be recommended. The proportion of sulphate of copper to water was as 1 to 3 by weight, and the solution was prepared in a copper vessel. Of the sulphate of soda the proportion was as 1 to 8 by weight also, the solution being dilute. Batteries charged with the above solutions were found to be in perfect action in five minutes, and one continued most powerfully excited for 9½ hours, at the expiration of which time it had not apparently lost any of its igniting effects on the platinum wire.

The expense attendant upon all the operations herein detailed is briefly stated below, viz.:—

FIRST ATTEMPT.

	R.	A.	P.			
2450 lbs. of powder	522	10	8			
Quick match	37	10	8¼			
Portfires	3	4	11½			
Leaden pipe	127	5	9			
Sundries	62	0	0	753	0	0¾

SECOND ATTEMPT.

2408 lbs. of powder	513	11	3½			
Cylinder	50	0	0			
Galvanic battery, watch, boat, &c.	138	4	0			
Sheet lead	102	11	0¾			
Sundry stores	125	10	8¼			
Sundries	43	4	9	973	9	9½

THIRD ATTEMPT.

Sundries	57	13	6	57	13	6

FOURTH ATTEMPT.

2050 lbs. of powder	458	10	8			
Cylinder	45	0	0			
Sheet lead	103	0	5½			
Sulphate of copper, &c.	138	4	6			
Sundry stores	21	2	3¼			
Sundries	65	10	0	831	11	10¾
Total Co.'s Rs.				2616	3	3
Or				£261	12	6

The effect of the last explosion upon the wreck of the *Equitable* has been reported by Mr. Chalke, the commander of the *Pilot*, who was deputed subsequently to examine the bed of the river by the master attendant, as follows:— "The deepest water is where the wreck was. The soundings are particularly uneven, varying from 4 to 6 fathoms and upwards. I took great pains in sounding over this spot, and am led to conclude that the last explosion so completely scattered the vessel that there is nothing remaining of her to obstruct the navigation of the river; the fragments are scattered in every direction. This I ascertained by heaving the lead myself at slack water, when I had an opportunity of letting it drop two or three times in one place. The divers' report corresponds with the same."

The removal of all obstruction to the navigation of the river having been thus successfully completed by the destruction of the *Equitable*, it remains only to repeat the remarks of a former paragraph in favour of Lieutenant R. Baird Smith and the co-operation of Captain Bowman, and also to mention that the useful services of Sergeant Longhurst, of the Sappers and Miners, were obtained by permission of the Chief Engineer; and it is satisfactory to be enabled to add, that, during these operations, no accident of any kind whatsoever occurred.

NOTES.

NOTE I.

The arrangements adopted by Colonel Pasley on the occasion of the successful destruction of the brig *William* in the Gravesend Reach of the Thames were generally followed in the first attempt to destroy the *Equitable*. As, however, no peculiar advantages were connected with the buoy-like shape which Colonel Pasley selected for his cylinder, and as its construction involved resources in workmanship and materials which it would have been difficult for us to command, the common barrel form was preferred, and was found equally effective and convenient. Farther, the leaden enclosure was applied exteriorly instead of interiorly as in Colonel Pasley's operations, and from the accounts which have just reached India of his more recent experiments on the *Royal George*, it appears that he has now adopted the same plan. It will readily be observed that the exterior coating is both more simply applied and more effective in preventing leakage than the interior one, which, in the event of the seams of the cylinder admitting the water, would immediately yield to the pressure and collapse on the powder.

NOTE II.

After the failure on the 14th of January, much inconvenience was experienced from the difficulty of replacing the priming apparatus in the cylinder, when the latter was charged, owing to the resistance of the powder; and, as during operations of this kind many circumstances may occur under which the power of readily effecting such an adjustment would prove of considerable advantage, the following construction of the priming apparatus, which seems calculated to answer this purpose, is suggested for practice on future occasions. In order to preserve the vacant space required for the conducting and igniting portion of the apparatus, the protecting case should be made a fixture within the cylinder. Beneath the flange of the igniting apparatus, which should be carefully soldered to the iron tube, a fine screw of about an inch in length should be adapted to a corresponding screw at the mouth of the protecting case; by these means the igniting apparatus could be taken out and replaced without difficulty.

NOTE III.

A considerable portion of the apparatus on which the successful effect of the galvanic battery in subaqueous explosions depends, is necessarily concealed from sight, and it must always be satisfactory to ascertain, prior to the actual trial, that none of this has been injured. Colonel Pasley recommends that this should be done by decomposing water introduced within the circuit through which a galvanic current has been made to pass, but an easier and perhaps more certain way is to employ a galvanometer; and as this instrument is seldom to be met with in its perfect form in India, the following simple substitute, constructed for these operations by Lieutenant Smith, will be found to answer every practical purpose. A piece of copper wire, about one-twelfth of an inch in diameter, and 12 or 14 feet long, was coiled on a rectangular wooden frame-work 6″ long, 3″ broad, and 1″ deep, care being taken to preserve the metallic coils throughout from mutual contact. The magnetic needle of a small theodolite was then mounted on the point of a common needle fixed in a thin wooden stand. On placing this within the frame-work with the coils of wire passing above and below it, and directing a galvanic current, excited by the insertion of a circle composed of a single piece of copper and zinc, each being 2″ long by 1″ broad, into a glass of slightly acidulated water, immediate deflection of the needle follows. It is only, therefore, necessary to introduce the apparatus to be tested into the circuit, and if it affords an uninterrupted path for the current, the same deflection will occur.

NOTE IV.

Of the different forms of conductors which may be employed, there is, perhaps, no one preferable to that suggested by Professor O'Shaughnessy. When the vertical depth bears a small proportion to the horizontal distance, the buoyancy of the insulating material ensures facility of management, and preserves the wires in the horizontal portion from contact with a large mass of water. In cases where the vertical depth and consequent pressure of the surrounding water is considerable, the porosity and lines of separation of the corks would not admit of that perfect insulation which under such circumstances it is desirable to ensure. The only inconvenience experienced in using it during these operations arose from the liability of the corks to break and leave the wires exposed. On all occasions, however, this form might be used for the floating portion of the conductor, the vertical part being insulated in some more perfect manner. For the latter a form of conductor employed during some recent experiments in Fort William, where perfect insulation was absolutely essential, would perhaps be as convenient as any other. Each wire was carefully covered with rope-yarn, and over this was laid a coating of water-proof composition made of dammer and grease; the two insulated wires were subsequently lashed together with yarn, and a second water-proof coating applied; a single rope about half or three quarters of an inch in diameter was thus formed, and the efficiency of the conductor was tested by immersing 500 feet of it in water to some depth, and igniting powder with an indifferent battery of 15 or 16 cells. During the same experiments the great superiority of a conductor composed of several strands of wire over one of a single wire of an equal diameter was frequently observed: owing to its want of flexibility, numerous fractures of the thick wire took place, while the strands of the thin wire were never, with a single exception, found to yield.

NOTE V.

The solution of sulphate of copper employed in the concluding portion of these operations was scarcely thoroughly saturated. Turner, in his 'Elements of Chemistry,' states the proper portion to be one part of sulphate of copper to two of hot water, whereas three parts of water were used in preparing the solutions for the batteries during the experiments to which this note refers. It must, however, be stated that the measurements were not very rigidly made, nor is it necessary they should be, as the most effective method of preparing this solution is to throw in the sulphate of copper till the hot water refuses to dissolve it farther, and on cooling, the surplus salt will be again deposited in crystals, and thus recovered for future use.

NOTE VI.

Practical Directions for the use of the Galvanic Battery.

In using the form of the galvanic battery described in the text, there are a few precautions to be observed, on which its practical efficiency is to some extent dependent, and it has therefore been considered advisable briefly to advert to them in this note. Before the pasteboard cases are placed in the copper cells, it is necessary that they should be well soaked in the solution of the sulphate of soda with which they are subsequently to be filled. The solution of sulphate of copper should occupy about three-fifths of the containing cell, and on the pasteboards being introduced, the sulphate of soda should be poured in till the remaining portion is filled to within about an inch of the mouth, care being taken that the solutions intermix as little as possible. The battery having thus been charged, the small cups should then be partially filled with mercury, and the connexions completed throughout the series. The action of the battery may be readily tested by fixing a short piece of platinum wire or foil to a copper wire, and directing the current through it; the intensity of the ignition of the former will furnish an indication of the heating power available. Should it appear that this effect is not proportional to the size of the battery employed, it is probable some accident has taken place, by which part of it has been nullified: to ascertain the locality of the interruption, one end of the testing wire should remain connected with one of the poles of the battery, while the other with the platinum should be brought in contact with each cell successively. By thus traversing the battery from one end to the other, the cause of the diminution of the heating power will seldom escape observation. The terminations of the connecting wires should invariably be kept clean and bright, and in general it is advisable to amalgamate them. Faraday recommends that this should be done by placing a few globules of mercury with a little grease on a piece of cloth or leather, and rubbing the wires till the adhesion of the mercury is effected. When it is desirable to increase as much as possible the effect of the battery, the zinc plates should also be amalgamated. This is done by washing them with a very weak solution of sulphuric acid, and then applying the mercury. Great care must however be taken in handling zinc plates thus treated, as they become extremely brittle, and break with the utmost facility. The mercury employed in these manipulations frequently becomes impure, and to fit it for use again it should be strained through fine cloth or leather. The utmost care is required in connecting the conductors with the battery, or with each other, to make the surfaces of the wires at the junctions as clean as possible, as much of their efficiency depends on this being done. The twisting at the junctions should never be less than six or eight inches in length, and the more perfect the contact ensured, the less is the prejudicial effect of many connexions.

NOTE VII.

Actual experience alone can give any correct idea of the difficulties attendant upon new operations of a practical character, even when prosecuted under every advantage which unlimited resource and superior agency can command. The deficiencies in these respects which have hitherto accompanied undertakings of the above description in India, have always given a degree of uncertainty to their results, and prepared the minds of those engaged for occasional failures. The two unsuccessful attempts which occurred during these operations were not therefore altogether unanticipated, and a knowledge of the many sources of accident which existed will ensure for them the indulgent consideration of those who have obtained experience under analogous circumstances.

IV.—*Madras Lighthouse. Report of Progress in the Execution of the new Machinery and illuminating Apparatus for the Madras Light. By Captain* SMITH.

To the Acting Chief Engineer, &c., &c., &c.

SIR,

In pursuance of a recommendation from the Madras Government, my services were, in March, 1835, directed to this undertaking, by a summons from the Honourable the Court of Directors E.I.C., who called for a detailed account of the project which had been submitted by me, and an explanation of the novelties introduced in it; and, for whose further satisfaction and that of the Board of Control, models in illustration and estimates of probable cost were prepared. In addition to this, the opinion of a committee of the Elder Brethren of the Honourable Trinity Corporation was taken, whose report being favourable, the scheme was finally sanctioned; though, from the delays inseparable from protracted correspondence, its execution was not ordered till January, 1836.

The interval occasioned by this delay was not, however, lost, as I availed myself of the opportunity to make inquiries as to the best establishments for the execution of the apparatus, in comparing their styles of workmanship and prices, and in studying various minor details which admitted of modification or improvement without affecting the general project.

These inquiries led to some alterations, the most important of which were—an improved construction of the argand lamps—the substitution of plated for brass reflectors—an enlargement of their size, and reduction of their number—and a new disposition of the whole upon the frame, whereby a much superior compactness and strength was obtained, with an increased facility of access to its various parts. As these alterations will be more clearly understood from a comparison of the apparatus, as it has now been completed, with the original project, I shall take the liberty of subjoining a brief description of it, as the readiest mode of bringing them to your notice.

But it is right to state, in the first place, that the final determination of the nature of the optical instruments to be employed was not made till after a full examination and inquiry into the practicability of those further discoveries which have recently attracted attention, more particularly the French lenticular and zonal dioptric apparatus,—the oxy-hydrogen, or lime ball light, proposed by Lieutenant Drummond, and the use of gas as a substitute for oil.

The principal objection to the French lenses I found to consist in the great uncertainty and apprehension entertained regarding the security of the focal light, which is generated by a large and complicated lamp governed by clockwork, and which at the time I made my inquiries had never been tried in England, and was considered liable to serious objection. Nor did the advantage gained by the increased power of the French lens, (being derived from the contraction of the duration of the flash,) appear to me to be of so much importance in a climate like that of India, as it might reasonably be supposed to be in situations where it is so frequently required to penetrate dense fogs; whence I was led to the conclusion that if a sufficient intensity of light were obtained by the concentrating power of the apparatus used, a more useful effect would be produced by giving the greatest possible *duration* to the flash or interval of light, than by sacrificing this important desideratum to obtain a superfluous degree of brilliancy. The experience which has since been gained regarding the use of these instruments has justified the above conclusions, much complaint being made of the shortness and suddenness of the flash exhibited by them; for, although the ray of light cast by the lens is three times more vivid than that of the apparatus designed for the present work, it is only visible during 5 seconds; while the latter will have a mean duration of not less than 24″, which will occasionally extend to 48″. I ought not to omit to add also, that the French lens apparatus would have been much more expensive, both in first cost and in annual outlay. Mr. Fresnel's beautiful dioptric zonal arrangement was liable to the same objection as that above stated, arising from the great difficulty and risk attending the central lamp; and as it exhibits merely a *fixed* light, would be, I considered, unsuited to the exigencies of the present work, to which it seemed to be indispensable that some marked distinguishing character should be given.

Having, from the above causes, been compelled to lay aside all thoughts of the use of dioptric instruments, my attention was directed to the oxy-hydrogen light, and to the substitution of gas for the argand lamp. The former of these I found to be subject to difficulties, which, after repeated trials and many costly experiments, had been found to be insuperable by the parties expressly engaged to overcome them; and the latter, though less hazardous in application, had been found liable to serious risks, and to be complicated and troublesome in management, at the same time that its advantages were considered doubtful. Feeling, therefore, the great importance of avoiding the risk of future derangement, as far as possible, by a fastidious attention to the simplicity of the means made use of, I felt satisfied that the apparatus hereafter described would be approved of, and would most effectually secure the objects aimed at.

As the work consists of several distinct parts, viz.: the lantern—the reflector frame—reflectors—lamps—and the machinery, I shall proceed to describe them separately.

The new lantern is entirely composed of gun metal, and consists of a twelve-sided polygon, of which nine of the faces or sides are transparent, and the remaining three blanked by the insertion of copper plates in lieu of the squares of plate glass. The interior diameter of the lantern is 9 feet, and its height 4½ feet, exclusive of the roof, which is of the form of a pyramid, and is surmounted by a turn cap and cowl. An exterior balcony is necessary in order that the windows may be accessible from without, for the purpose of cleaning, &c. Of this, for economy, the skeleton only has been prepared (of iron) with a view to the completion of the rest with wood. The diameter of the lower curb of this skeleton frame is 12 feet. Into the upper curb of the frame of the lantern is fitted a cross, consisting of a couple of iron bars intersecting one another at right angles in the centre of the lantern, on a level with the upper curb, and steadied by iron stays to four of the rafters. This cross carries a plate and friction rollers for the support of the spindle of the reflector frame. The floor of the lantern being the platform upon which it is erected, eight large and eight small ventilators have been provided for the admission of the air below, and capable of being opened or closed from the inside.

The whole of the parts of the lantern are packed separately from the machinery, in order that it may be unnecessary to disturb the latter until after the lantern has been completed, and is ready to receive it.

The reflector frame consists of a strong wrought-iron turned spindle, to which are affixed the supports for fifteen reflectors, in two tiers, eight above and seven below; these reflectors are so disposed as to point in the direction of five faces of an octagon, three reflectors on each, which three reflectors are parallel to one another, and are therefore seen at the same time, constituting a *flash* when the revolution of the apparatus brings them in direct opposition to the eye. The light thrown by these three reflectors is emitted in the form of a conical beam, whose sides are inclined at an angle of 18°. Hence, as the different sets of reflectors, (being ranged on the faces of an octagon,) cast their light in the direction of the perpendiculars to these sides, which are inclined to one another at an angle of 45°, it follows, that at any given time there are 18° of the horizon out of the 45°, which are covered by the spread of rays; and, consequently, on the revolution of the machine, the duration of the flashes would bear to that of the eclipses, or dark periods, the proportion of 18 to 27 (equal to $45° - 18°$), or as 2 to 3. As the nature of the motion is, however, reciprocating instead of rotatory, the above ratio merely expresses the *average* proportion of the light and dark intervals, which are themselves variable, according to the position of the spectator; and as the rapidity of movement is so adjusted that the luminous beams cast by the reflectors sweep round the horizon at the rate of 90° in 2 minutes, it follows, that the duration of the flashes will vary from 0″ to 48″, and that of the eclipses from 0″ to 72″; the sums of the durations of light and darkness, however, in every position bearing the constant ratio before stated, viz., as 2 to 3. The reflectors being fixed to the reflector frame, as before described, become capable of rotation round the spindle as an axis; the upper neck of the spindle being engaged by the set of friction rollers before spoken of, and its lower end turning on a pivot fixed to the frame of the machinery, beneath the level of the floor of the lantern. By means of a spring clutch, this part of the apparatus may be disengaged from the wheel-work which moves it, and made to revolve independently for the convenience of cleaning the reflectors, trimming the lamps, &c.

The reflectors are all similar, being paraboloids of 3 inches focus, and of the breadth of 21 inches over the lips, by a depth of 9 inches. They are manufactured, by hammering, from flat discs of rolled copper and silver, and afterwards highly polished. By the mode in which they are fixed to the frame, each reflector carries its own lamp, the burner of which is adjusted to the focus of the parabola, the chimney passing through an opening in the upper part of the reflector. Of the effect or illuminating power of the beam cast by the combined operation of the three instruments whose united beams constitute one flash, as before explained, in comparison with that of the apparatus at present in use in the lighthouse, I am unable to give an exact estimate, having no precise knowledge of the comparative illuminating powers of the argand lamp, and the common wick and tumbler lamp now employed; but from an experiment which I made previous to my leaving India, I have reason to believe that the former is not less than 2¼ times as powerful as the latter, a proportion which is certainly not too great, if assumed in reference to the *average* illuminating power of the two lamps; the latter being subject to great diminution, while the former is nearly uniform.

Admitting 2¼, then, to be the ratio of the illuminating powers of the argand and common wick lamp, it may be demonstrated, that the additional effect gained by the action of the nine looking-glass reflectors, as at present applied to the twelve lamps in the lighthouse, is equivalent merely to an augmentation of their power of not more than ⅙; making the total effect of the twelve lamps as great as that of fourteen would be, or equal to 6·22, &c., argand flames.

The effect of the parabolic reflector is to produce a beam of light which is feeble at first, and gradually increases in intensity till it reaches its maximum of illuminating power, which remains unaltered during a few seconds of brightest effulgence, and then gradually decreases in vividness. The illuminating power of the beam at the point of maximum effect is equal to that of 130·43 unassisted argand flames; thus, the comparative power of the brightest period of the flash cast by the combined operation of *three* reflectors, is to that of the present apparatus as 391·3 to 6·22, or as 62·9 to 1; but although this estimate rather falls short of than exceeds the actual ratio of the augmentation which the illuminating power of the light will receive from the improved means to be applied to it, the effect upon the eye may be less striking than this statement of it might lead one to anticipate; the vividness of a travelling beam of variable intensity appearing much less than that of a fixed light of equal power.

With regard to the construction of the lamps fitted to the reflectors, being sensible of the great importance of securing their durability, and guarding against derangement in every particular, I spared no pains both in studying the greatest possible simplicity in their contrivance, and also in providing against the operation of the usual destructive agents. In the first respect, being dissatisfied with the action of the pattern first tried, a series of experiments was undertaken, in the course of which various experimental new burners were manufactured and submitted to trial, which finally led to the adoption of one which has fully satisfied my expectations. This contrivance, which from its simplicity will be readily understood on inspection, possesses the advantage of a motion for raising the wick quite distinct from the body of the lamp, so as, in case of its derangement, to admit of its being thrown aside, and a spare one substituted. The burners also are secured against the usual corrosion at the point where the flame rises, by being tipped with platina; and as a further security against a failure of the means for generating the light, a complete set of spare lamps, of a commoner kind, with iron tubes, has been provided, to be called into use in event of the first requiring a general repair.

The machinery adapted to this apparatus is so designed as to communicate a *reciprocating* motion to the frame, causing it to pass and repass over an angular space of 90°. The different faces of illumination being, as before stated, inclined to one another at the angle of 45°, there would have been an effectual provision for the supply of light to every point of the horizon embraced by the rays of the two extreme faces, had 45° been the limit of the arch traversed; but I was induced to prefer the wider sweep, through the quarter circle, by considering that the action would be more certain were each point in the azimuthal circumference exposed to the light of two sets of rays; while the further advantages would be gained,—1st, by the facility which such an arrangement would afford for varying the flashes by the use of crimson shades, should such a distinction ever become necessary hereafter; and, 2ndly, by the greater regularity of the periods of light and darkness, of which the duration of every *alternate* series is thereby rendered *constant*.

The machine consists of a train of wheels of strong construction, which are kept in motion by a weight, and regulated by fans, capable of adjustment to the required velocity; and the reciprocating or *reverse* movement is effected by the alternate action of two vertical bevelled wheels upon an horizontal one of double their diameter, fixed upon the spindle of the reflector frame. The certainty of this movement at the periods of the successive engagement and disengagement of each vertical wheel in turn (the vertical wheels turning on the same arbor, and taking into *opposite* sides of the horizontal wheel, half of each of their circumferences being without teeth,) is ensured by a contrivance designed for the purpose, and consisting of a cycloidal *cam*, or snail, of a double curvature, which acts upon a radial pin projecting laterally from the side of the horizontal wheel above alluded to. This addition has the effect of obviating the possibility of the reversing (vertical) wheel failing to become engaged at the proper moment, and gives certainty to its action.

With the view of obviating unexpected difficulties, I made a point of causing the whole apparatus to be erected and kept in motion (day and night) for about two months previous to its dispatch; during which time it was inspected by various scientific gentlemen, including the Deputy-Master and several of the Elder Brethren of the Trinity Corporation, who have evinced their approval of the scheme by the erection of a harbour light upon the same principle at South Stack.

As the work may now be so soon submitted to your inspection, I shall refrain from troubling you with any further details, as the above description will, I hope, suffice to convey a general idea of the mode in which the project has been carried into execution; and I hope also to satisfy you, that every security for the continued regularity and permanent efficiency of the machine, which its nature allowed, has been provided. I shall therefore merely add, that although in compliance with the original plan and the intentions of the Government, the work has been so constructed as to be suited to erection upon the site of the present light, (with the modifications noticed in my first Report upon it,) yet that it may be also fitted to any new building; and, as the former plan would confine its range to limits far within the bounds of its capability, it would be a great pity were the present opportunity of adding to its height, and thereby increasing its usefulness, allowed to pass unimproved. Hoping, therefore, that in consonance with this opinion, you may be led, on the final execution of the undertaking, to give your recommendation to a measure so essential to its complete success,

I have the honour to be,
Sir,
Your most obedient servant,
(Signed) J. T. SMITH,
Captain, Corps of Engineers.

No. IV. *continued.—Essay on the Method of Illuminating Lighthouses, with a Description of a Reciprocating Light. By Captain* J. T. SMITH, *Madras Engineers*, F.R.S., &c. *Being the substance of a Paper read by him before the Institution of Civil Engineers, with some additions.*

(Extracted from the Reports, &c. of the Corps of Engineers, Madras Presidency.)

THE subject of improvement in the construction of lighthouses having recently occupied a considerable share of the public attention, and its close connexion with the maritime welfare of this commercial nation rendering every step towards its accomplishment a work of utility, even should it fail to deserve notice for its scientific interest, I am induced to lay before the Institution the following brief description of an apparatus of a novel kind, which has recently been constructed under my superintendence for the Madras Government, with a view to its being sent out to that Presidency, and erected in Fort St. George.

The advantages which were contemplated by the alterations which I have succeeded in bringing to perfection in the apparatus above alluded to, have no reference to any modification of the means employed for the original production of the light, but more particularly to an economy introduced by a more effectual distribution of it, by whatever means it may have been generated. This saving is effected by a contrivance so simple in its operation, and at the same time so obvious when explained, that I should not have ventured a description of it were I not in hopes that it might be beneficial to others that the practical success of the experiment should be made known, and desirous also to introduce it, as a new principle of illumination, to a place beside the two established systems, from both of which it differs, and which are now so well known as the *fixed* and *revolving* lights.

The new apparatus to which I allude, and which it is the object of this Paper to describe, I have named a *Reciprocating Light*, the motion which is impressed upon it being of that description; but as my account of the contrivance itself would be incomplete, were I not also to explain the motives which led me to propose it, and wherein consists its difference from, and advantages over, the existing systems for which it is proposed as a substitute in some cases, I shall, before entering upon a more detailed explanation of it, venture to premise a few remarks as to the general principles of illumination, which will, I hope, have the effect of rendering my meaning more clearly intelligible.

In *fixed* lights, as is already well known, the distribution of light is effected, according to the system hitherto adopted in England, by means of Argand lamps, and a number of parabolic reflectors placed round the circumference of a circle, facing outwards, and so disposed with respect to each other that each reflector is pointed towards a different part of the horizon, a very small portion of which is illuminated by it; the tendency of the reflector, from its peculiar shape and catoptric properties, being to collect the light of the lamp placed in its focus, and propel it in a dense beam along its axis, or in the direction of the point immediately in front of it, to a very small space on each side of which its effects are confined. This space or breadth of the luminous beam is usually calculated at $7\frac{1}{2}$ degrees on each side of the axis, or 15 degrees in all;[1] consequently the number of reflectors required to fill the whole circumference of the horizon with light ought not to be less than $\frac{360^\circ}{15}$, or 24°. If a part of the horizon only require illumination, a smaller number, in proportion, is sufficient.

A *revolving* light may be explained by first supposing the above system of reflectors to be mounted in a frame which is connected with machinery suited to give it a revolving motion. It is plain, that if the entire system proper for a fixed light were thus made to rotate, a spectator would still see an uninterrupted beam of light,[2] since the diverging rays from the twenty-four

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[1] This is not the entire space filled by the light of the reflector, which, in fact, spreads through about 18 degrees; but the illuminating power on each edge of its beam being very feeble, it is usual, in arranging the disposition of a fixed light, to allow one reflector for every 15° only, so that the beams cast by them overlap, as it were, at their junction, and, by uniting their effects, partly compensate for their want of intensity.

[2] In the case here referred to, the beam would be uninterrupted, for the reasons given; but it would not be *uniform* in intensity. For the tendency of each reflector being to collect the greatest quantity of light close to its axis, and proportionally less and less as we recede from it, its effects become weaker towards the edges of the space filled by its beam, so that the light is much more

reflectors filling up the entire circumference of the horizon, as before explained, the effect of each, as seen during the revolution by a spectator from a distance, would not cease till that of the succeeding one had commenced.

If we now suppose, that instead of the complete system above referred to, every alternate reflector be removed, the disposition of the remaining ones being unaltered, it will be obvious that the appearance produced would undergo a very marked change; for now, on the light of any one reflector ceasing to be visible, the illumination would not be kept up, as before, by the action of a succeeding one, but an interval of darkness would ensue, corresponding to the blank left by the removal of its adjoining reflector; and the effect of the system after this alteration, as viewed during rotation, would be that of a series of bright and dark periods, which constitute the "flashes" and "eclipses" peculiar to the revolving light.

This principle is striking and effective, as well as economical, when compared with the fixed lights; for it will be readily understood from what has been above explained, that if the eclipses and flashes be of equal duration, only half the number of reflectors and lamps required by a fixed light become necessary for the illumination of a complete circumference of the horizon; and it will be further obvious, that if, as is usually the case, the dark periods or eclipses be made of a *longer* comparative duration, the number requisite would be still further diminished: for instance, if the eclipses were proposed to be of double the duration of the flashes, then, instead of removing every alternate reflector, as in the case above alluded to, the plan adopted would be to remove two and leave the third, thus reducing the number from twenty-four, indispensable to the fixed principle, to eight only.

There is, however, one circumstance attendant upon this contrivance which in many situations detracts greatly from the superiority it would otherwise possess over the fixed light, and this it is the object of the improvement which I have introduced to obviate. This defect consists in the useless expenditure of effect which is occasioned by a revolving light sweeping the *entire* circumference of the horizon, when placed in a situation where only *half* of it requires illumination. When a lighthouse is situated upon a line of coast, as most are,

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feebly seen by a spectator situated on the line opposite the junction of two reflectors, than when immediately in front of either of the mirrors themselves; and hence the effect of the revolution of such a system would be to produce an undulating appearance, unless great rapidity of motion were imparted to it.

it is plain that no real benefit can result from illuminating the land side; and consequently, in such a situation, that portion of the lantern which looks inland, in lieu of being cased with glass, is always "blanked" by inserting copper plates, to avoid expense, risk of breakage, &c.

Now when a light upon the *fixed* principle is established in such a situation, the effect produced is precisely proportioned to the means employed, and none of the light is lost,[3] since none of the reflectors are pointed inland; but in a revolving light, on the other hand, this adaptation of the means to the end to be gained cannot be applied, for while the revolution continues complete, the reflector, which at one time points to seaward, *must* a few minutes afterwards be directed towards the land, or rather against the *blank wall* which closes the lantern on that side; so that, while one half of this system is fulfilling the purpose for which it is intended, the effects of the other half are absolutely thrown away.

This is of more importance when, instead of each flash being produced by a single reflector, as in the above supposition, a number are combined (pointing in each direction) to augment the vividness of the beam. In this case the total number employed being greater, the absolute loss is thereby enhanced. In the new apparatus recently constructed for Madras, it was determined to group three reflectors together to produce each flash; and it was also decided that intervals of darkness, of double the durations of the periods of light, should be allowed to intervene to form the eclipses.

These conditions would have required, (by the present system of revolving lights,) agreeably to the explanation above given, that 8 sets of 3 reflectors each should be used, or 24 in all; but being struck, while preparing the design for this apparatus, with the manifestly unprofitable result of such an arrangement, and being very desirous from other attendant circumstances to diminish the number of reflectors and lamps as far as possible, without decreasing the predetermined results, I was naturally led to inquire into the possibility of obviating the evil; and after some consideration it occurred to me that this might be very easily and simply effected by merely stopping the revolution of the apparatus after it had traversed a certain portion of the circumference, and

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[3] This regards the azimuthal distribution only, as it would be tedious and out of place here to take into consideration the vertical divergence of the rays; since, as this divergence is the same in both cases, the argument is in no respect affected by its operation.

then *reversing* the motion so as to cause it to reciprocate backwards and forwards, and thereby confine the action of the reflectors disposed towards the sea to that side only; thus obviating the necessity of placing any mirrors or lamps whatever on the side facing the land. I have been enabled by this means to fulfil the conditions proposed at $\frac{5}{8}$ths of the expense which would have attended an adherence to the revolving principle, and the saving might have been further increased to nearly one half, had I not been anxious to avoid the possibility of any defect in the distribution of the light near the coasts, by extending the limits of the illuminated arc to four points of the compass inland on each side.

The contemplation of the efficiency of this scheme as a means of illumination, apart from the contrivance by which it is carried into effect, is based upon considerations of so obvious and plain a kind as to need no explanation; nevertheless it would not be right for me to quit this part of the subject without pointing out a peculiarity in its effects, which, though far from decreasing the value of the system when judiciously applied, is not the less worthy of notice, as it shows the necessity of exercising a proper discrimination in its adoption, and, it cannot be denied, tends to circumscribe the sphere of its usefulness by excluding it from those situations, where, from the multitude of beacons thickly studding a dangerous coast, and the difficulty of impressing a distinguishing character upon each, it becomes necessary to have recourse to an observation of the length of the eclipses, or the time elapsing between the periodical recurrence of the flashes, as a means of enabling the mariner to determine the particular light which he is approaching, and without which the protection derived from it would be comparatively of no value.

From the variety of modes of distinction at present in use in the British lighthouses, it has hitherto, I believe, been unnecessary to rest entire dependence upon the differences in the periods of revolution, and it is no doubt wise to delay doing so as long as possible, that mode of discrimination being the least secure, and open to various objections. Should it, however, at any future time become indispensable, it will introduce an obstacle to the reciprocating system, to which that auxiliary characteristic cannot be applied; for although the total quantities of light and darkness seen by a spectator in every position are *constant*, yet, from the peculiar nature of the motion, the durations of the flashes and eclipses vary with every new position of the observer,—

a circumstance which, if not understood, might lead to mistake and fatal consequences.

These remarks, however, it ought to be added, apply only to those cases where, from the existing number of similar works, it becomes important to avoid the danger of confusion, and cease to be applicable to this plan when it is proposed to adopt it in situations sufficiently remote to be secure from the liability of incurring that evil. In the present case, for instance, the reciprocating light to be erected at Madras will be the only moving light on the whole coast of India, and hence cannot possibly be mistaken for any other at present in existence; but I consider it would be equally safe to introduce the system wherever the determination of the precise periods does not enter as an indispensable condition; and in such situations it will be strongly recommended by its economy, as the annual saving effected by it will be found to be well worthy of consideration, in addition to its being attended by other advantages, such as reduction of weight and bulk, superior cheapness in *first* cost, and diminution of the labour requisite to keep the apparatus in order, &c.

DESCRIPTION OF THE RECIPROCATING MACHINE.

Having thus given an outline of the nature and peculiarities of the system above described, it only remains for me to add a few remarks regarding the arrangement of the machinery by which the movement is effected.

The mechanical problem of resolving a continued circular motion in one plane into a reciprocating circular motion in another, is one attended with so little difficulty, and the solution of it must be so readily familiar to many of the Members of the Institution, that I should be wrong to detain them a moment upon the subject, were it not for the purpose of briefly noticing one of those little difficulties which frequently step in between the design and successful accomplishment of a new undertaking, however simple in its original plan, and of taking the opportunity to describe the mode by which that difficulty has been very satisfactorily overcome, as an assistance to others who may engage in a similar undertaking.

After much thought upon the subject, and an attentive consideration of several plans, which I either met with in mechanical publications, or which suggested themselves to me, and some of which were tried on a small scale by models, I selected one which appeared by far the most promising, from the simplicity of its action, as well as from its requiring only workmanship of a kind well understood. This contrivance will be most easily explained by first adverting to the means by which a continued revolving motion may be communicated to a reflector frame.

To effect this the whole of the reflectors are fixed in their proper positions in the frame, the parts of which are connected with a central spindle placed vertically, and to which motion is communicated from a machine of common construction, (moved by a weight and regulated by fans,[*]) by means of a couple of bevelled wheels, one of which is fixed on the vertical spindle just mentioned, and hence revolves in a horizontal plane; the other turns in a plane at right angles to the above, its arbor or axis being also at right angles with the spindle (fig. 1), and this latter wheel being also connected with the Plate IV. train of machinery, communicates to the reflector frame a continuous rotatory motion.

Now, if instead of this *single* vertical wheel, acting continually on one side of the horizontal one above mentioned, we conceived *another one* similarly situated on its opposite side, and engaged in the teeth on its margin; and if we moreover imagine that these two wheels are mounted on the same arbor, and consequently turn in the same direction, it will be evident that they would, if successively engaged, produce *opposite* motions in the spindle and the apparatus; but that, if both were engaged at the same time, no motion at all could be effected, since, by their opposite tendencies, they would act against each other.

This successive action is therefore effected by fixing both of the wheels upon the arbor in the same manner as if they were singly employed, and then cutting away the teeth of the alternate semi-circumferences of either, so that, while those of one are engaged and produce motion in one direction, the blank circumference of the other is presented; and the moment the former ceases to act, the teeth of the latter come into play, producing an opposite movement (fig. 2).

This apparatus, upon execution and trial, was found to produce the intended effect very steadily; but I soon observed, upon studying its action care-

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[*] The machinery attached to the apparatus belonging to the Madras Lighthouse is upon the common *principle*, though differing entirely from the pattern usually adopted in England, various alterations having been introduced in order to accommodate it to the position and circumstances under which it was to be applied.

Plate II.

fully, with the express object of searching for any latent cause of future derangement, that, however satisfactorily it might act when well set up, it would be incapable of withstanding the effect of those disturbances which long friction and wear of the parts, or accidents and ill-treatment, might subject it to, and without a perfect security against which I should have felt it unsafe to dispatch it to so distant a settlement. The reason of this will be seen by a reference to fig. 3, which represents A B C, the horizontal bevelled wheel, and E D F, one of the vertical wheels above alluded to, at the very moment when the last tooth of the latter is escaping from its engagement with the former, and when the change in the movement is about to take place. Now the conditions of the light demand that there should be no material loss of time in reversing the motions, that is, that the movement from Q to A in the upper wheel should commence in not more than a second or two after that in the direction of Q to B, caused by the action of the wheel E D F, has ceased. Moreover, it will be plainly seen, that as the change of motion which ensues after the tooth P has quitted its hold, causes the whole of the teeth from P to S immediately to return in the direction of K, passing over the head of P, there would be some risk (more particularly if by any derangement the wheel B C A should have become swayed out of its proper position, and its edge fall below the line H K,) of these teeth striking the top of P on their return; or, what would be as bad, of their failing to disengage it at the proper time, which could not be prevented unless, before this return movement commenced, the top of P had dipped sufficiently below the line of their path H K to be out of the reach of such an accident. But it unfortunately happens that at the point where the tooth P is situated, the dip below the horizontal line, occasioned by the curvature of its path, amounts to little or nothing, (being represented by the versed sine of the angle formed by the radius drawn to it, with the vertical C G,) and is hardly perceptible until it has reached a considerable distance from the vertical position; so that, before it would have amounted to $\frac{1}{8}$th of an inch, which I satisfied myself would be sufficient to place the security of the movement beyond the reach of probable accident, the delay or loss of time would have amounted to not less than 7 or 8 seconds. It occurred to me, however, that if I could make the final connexion between the wheels by means of a tooth situated on part of the wheel F D E endowed with a more *oblique* motion, it would then be in my power even to increase the clearing space above mentioned, if necessary, without the sacrifice of any material delay.

Such a tooth I accordingly set about to design, and, after a few trials, succeeded in cutting out the model of one which completely effected my object. It is represented in fig. 3 by dotted lines, and ought more properly to be termed a *cam* or *snail*, as it acts upon a short straight pin Q projecting from the side of the horizontal wheel, and communicates to it precisely the same motion as it would receive from the teeth, which now become unnecessary, and might be entirely removed. In order to ensure the exact equivalence of the motion to that for which it is substituted, and to cause the cam to follow close to the circumference of the upper wheel, its edge has a double curvature, that of M N, which is seen in the figure, and a similar one in the plane at right angles to this, whereby the upper part of the snail is bent more and more away from the eye of a spectator viewing it as represented in the figure. Its face is also twisted in a spiral direction, in order to accommodate it to the varying inclination of the radial pin it acts on. The adoption of this simple contrivance has completely obviated the difficulty which seemed to stand in the way of perfect success; and since it has been applied, although the interval elapsing between the motions is only 2 seconds, I have found the apparatus to work so completely free from the risk I was apprehensive of, that I have as yet found it quite unnecessary to do more than merely file the tops of the last two teeth, sufficient space having been gained by that means. It may perhaps be advisable to remove a little more previous to transferring the machine to the unskilful management of the natives, to whose care it will hereafter be intrusted. Plate IV.

I should not, however, have been satisfied with the security of this movement, unless, in addition to its freedom from the chance of derangement by the ordinary effects of wear and long-continued use, it had also been rendered exempt from the probability of disturbance by accidental mismanagement.

In order to understand clearly that precaution is requisite in this respect, it is necessary to return to fig. 1, and consider in what manner the apparatus for a continued rotatory motion differs from that required to produce a reciprocating or reverse one.

In considering the operation of the two wheels represented in fig. 1, it will be obvious that, as the effect to be obtained is *continuous*, the parts which are engaged together to produce it are never freed from their action upon one another; whereas, in the apparatus represented in the second figure, it will be equally plain that the horizontal wheel upon which the motion is impressed must be entirely set free from connexion with its driver on the one side, before it can yield to the impulse of that on the other. At the instant of time, therefore, after the action on one side has ceased, and *before* the teeth on the opposite margin have become locked together, it will be seen that the upper wheel is entirely free from connexion with either of its two drivers; and, were it not for the snail about to come into operation, would be capable of a complete revolution round its axis, *independently* of the drivers, which, though thus prevented in one direction, can still take place in the other; namely, towards the point to which the snail would impel it.

Plate IV. In fig. 4 the light and shaded parts represent the two opposite margins of the horizontal wheel, and parts of the two drivers acting upon them; that which is shaded being the one nearest the eye, the plain one that which acts on the farther side of the spindle; and on this the snail and the pin it acts upon are represented by dotted lines, as if they were seen *through* the rim of the wheel A B C. This diagram is supposed to represent the machine at the moment when the snail M N has ceased to act upon the pin Q, and when it has dipped a small space below the level of its under surface; but before the snail T V, which acts in the direction of the arrow behind the spindle W C, comes into operation. At this moment, therefore, the apparatus being freed from its connexion with the snail M N, is prepared to take the motion which would be communicated by the snail T V, and were it to be accidentally touched, might be made to turn in the direction of the arrow till the pin X was stopped by the *back* of the snail T V. Such a derangement is very unlikely to happen, it is true, since, in order for it to take effect, it must be caused by a pressure applied in the right direction, and at the critical instant of the passage from one motion to its reverse. Nevertheless, as such an event, if it did happen, would throw the machine out of gear, and cause it to stop, I thought it would be well worth while to adopt any expedient which would prevent the possibility of such an accident, and after some trials contrived the following plan, which is very simple, and answers the purpose most effectually.

The operation of the snail M N does not cease until the opposite one T V has nearly reached the pin X: when M N has ceased to act, therefore, the apparatus, though free, can only move in one direction, that shown by the arrow; and this is the direction in which it must move when the snail T V comes into play. What is wanted, therefore, is merely such a stop as shall

FIG 1.

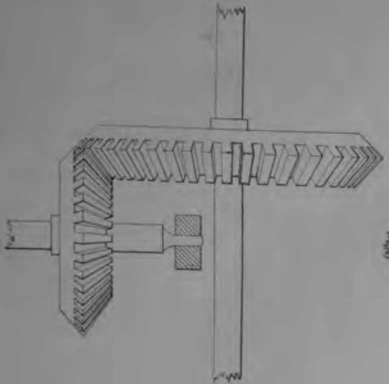
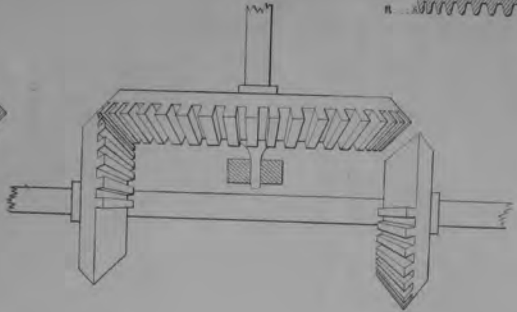


FIG. 2.



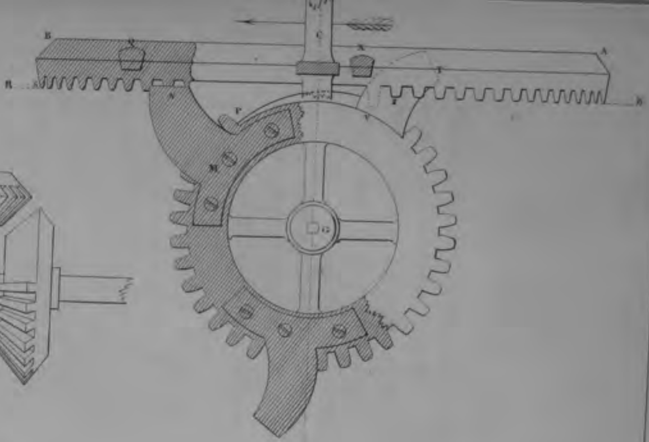


FIG 3.

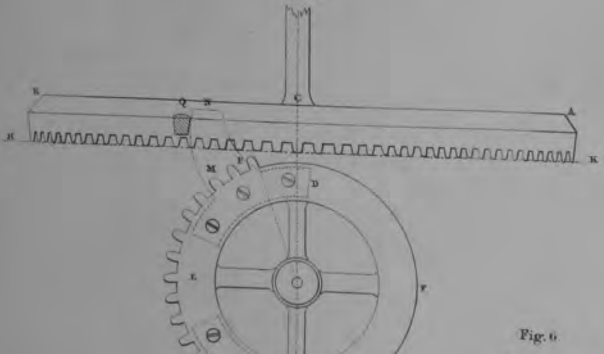


FIG. 5.

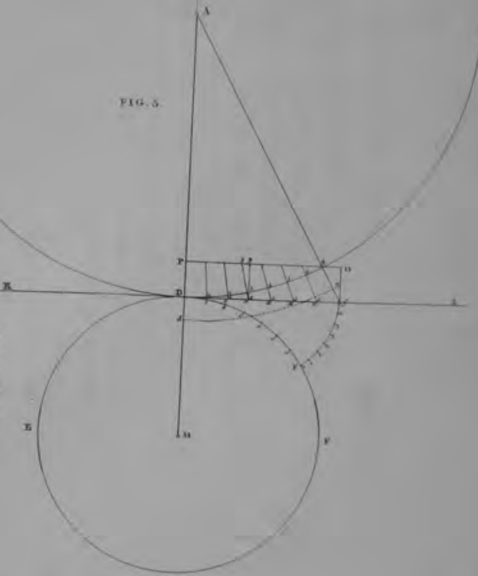


Fig. 6

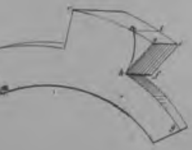


Fig 7

prevent its moving away *from* the snail. This is effected by elongating the first tooth brought into action by the snail, and which is shown on the figure by Z, and causing it during the previous motion, or whilst the snail M N is in action, to pass over a flat spring P Z, which lies along the upper margin of the driving wheel, and is released at the instant that M N is disengaged. This flying up, opposes an obstacle in front of the tooth Z, which makes it totally incapable of motion without carrying its driver with it, and thus prevents their relative situations being changed.

APPENDIX.

DESCRIPTION OF THE METHOD OF CUTTING THE CAMS.

THE determination of the curves for the different parts of the cam, described in page 49, having been a problem requiring some thought, and the practical method then adopted being of a general character, capable of application to other circumstances, and therefore likely to be generally useful, I shall here endeavour to describe, as concisely as lies in my power, the method by which it was effected, though the subject is necessarily difficult of explanation, from the various motions to which it is necessary to refer, and from their taking place in different planes.

To facilitate the exhibition of this part of the subject, it may be advisable first to consider what is required, with a view to the separate examination of each of the desiderata, and a synthetic mode of determining the compound form to be obtained. In order to this I have represented in fig. 5 the paths both of the horizontal and the vertical or reciprocating wheels, as they would be seen in their respective planes; having ventured, by what must be substituted for perspective, to delineate their exact geometrical proportions in each plane, though both are exhibited in one view. Were the subject not a mere diagram, it would be an incorrect representation of an oblique view of both the planes in which the wheels move; but as it is, being intended to show the relative changes brought about by the motion of each wheel in regard to the straight line which defines the intersection of their two planes, which line is, for both, correctly represented by K L, I am enabled by this arrangement to bring them into juxtaposition, and thus to place their connexion clearly before the eye.

Plate IV.

It may here be proper to state that the line K L, in fig. 5, indicates the intersection of a horizontal plane touching the lower surface of the pin Q of figures 3 and 4, with a vertical plane corresponding with the outer surface of the reciprocating wheel, and touching the root of the pin as well as the margin of the wheel into which it is fixed.

This plane also coincides with the inner surface of the cam, at its origin from the margin of the wheel E D F; for the margin of the horizontal wheel is flush with the outer surface of the vertical wheel E D F, or, in other words, touches the plane in which that surface is contained; and the projection of the pin beyond this margin determines the breadth of the cam, which is merely affixed by screws to the face of E D F.

In fig. 5, therefore, let B D C represent the margin of the horizontal wheel, of which A is the centre, D the place of the pin D *d*, E D F the vertical wheel. Now the object to be attained is to fix on the point D of E D F a piece of such a shape that it shall act on and impel the pin D, so as to produce a motion in the wheel B D C precisely the same as if the two bevelled margins rolled over one another. Referring to the lower half of this figure, and carefully recollecting that it represents the *vertical* plane, in which view the path of the pin D *d* is defined by the straight line K L, it will be seen that while the motion of the radius of which the pin D *d* is a part is along the line D L, the point D of E D F travels along the curved path D 1, 2, 3, 4, 5, 6, F. Hence, while the former has continued within the horizontal plane, the latter has dipped below it. The cam must therefore *rise* above the circumference E D F, and that in such a manner as continually to cut the horizontal plane at the very point the radius A *d* would have reached; which points, for the successive positions of the radius A 1, A 2, A 3, 4, &c., are shown by the letters x 1, x 2, x 3, and so on. To fulfil this condition, the edge of the cam must be shaped in the curve represented by F, 0, 1, 2, 3, 4, 5, 6, *f*, the method of describing which will be presently explained; it being merely necessary to add in this place that the zero point is in contact with K L, and with the radius, when in the position A D, the point 1 when it has shifted to the position A 1, the point *f* with the position A *f*, &c. It is thus shown, that with reference to the vertical plane the anterior face of the cam must necessarily possess the rake or curvature F *f*; and in regard to the horizontal plane also it may easily be deduced by a similar reasoning, that a lateral bend is equally required, in order to compensate for the increasing deviation, as regards this plane, of the path of the wheel B D C from that of E D F (which latter is now represented by the line K L). The same opportunity may also be taken, whilst referring to this plane, to show in what manner the anterior face of the cam requires a spiral twist in addition to the two curvatures above described; for if D *d* represent the position of the pin when at the point D of the wheel B D C, it will be evident, on considering the position of the vertical wheel and its projecting cam, that at this point that part of the cam in contact with D *d* (viz. its root F *o*) must coincide with D *d*, or be *square* to the circumference of the wheel to which it is attached. When the radius, and with it the pin, have, however, moved onwards a little, for instance to x 5, it is seen that its position is now *oblique* to the circumference of E D F, which is here represented by K L; that part of the cam, therefore, which is in contact with the radius at this point must be shaped with a corresponding obliquity, in order that it may fairly coincide with the pin; and this obliquity continually and regularly increases from the bottom upwards, like the spiral face of the thread of a screw.

In order now to obtain this complicated form practically, the first step was to prepare and fit on to E D F a piece of wood of sufficient bulk to include the whole piece afterwards to be cut from it; and this was merely of the shape of a circular segment, to the central part of which was superadded a die of a concentric figure, but much enlarged in width, the whole being of the form shown in fig. 6. Having previously determined the angle D A *g f* (fig. 5), through which the cam was to act, the height *b c* (fig. 6) of this additional piece was found by measuring the height F *f* (fig. 5) of the corresponding curve; the breadth *d e* by the corresponding *f g*. These dimensions being obtained, *f k*, *e d* and their opposite sides were cut at right angles to the plane of *a b c*, and, in fact, all the corners were square. The segmental part *a b k g* was suited to be fixed to the face of the vertical wheel by screws. The next step was to obtain the curve *k h*, and the mode of doing so will be easily understood after what has already been explained, by referring to fig. 5. Having laid down a diagram representing the wheels B D C, E D F of their full dimensions, and drawn the line K L, a number of equal and very small parts was set off from D to *g* on the circumference of B D C, and a similar and equal series on the circumference E D F. These were numbered on each 0, 1, 2, 3, 4, &c., from the point D both towards *g* and F; also radii were drawn from the centre A to the different divisions on the line D *g*, and their intersections with the line K L marked with the corresponding numbers *x* 1, *x* 2, *x* 3, and so on. A piece of transparent paper being now cut a little larger than the circle E D F, was secured to it by a pin passing through the centre M, round which the paper could turn; then, having drawn a line M D, and fixed the point D on it as the place of the origin of the cam, this line was turned gradually round in the direction of F, until the point D was successively brought to the divisions on the circumference of D F, numbered, as above mentioned, 1, 2, 3, &c. At each of these divisions the line M D was prolonged in the direction of the corresponding division *x*. Thus, when D arrived at No. 1 division of D F, it was lengthened by the addition of a little line joining it to *x* 1; when it arrived at No. 2, the *lengthened* M D was further extended by being joined to *x* 2, and so on. The curve F *f* thus obtained was easily transferred to the model (fig. 6), and the superfluous wood *k h i e f* cut away; *h i* being made parallel to *d e*, or square to the face of the wheel. The next step was to delineate and cut out the spiral twist of the face whose edge was just found. In order to do this it was necessary to mark off on the model the different divisions 1, 2, 3, 4, &c., of the curve F *f*, obtained during the last process, and by carrying parallel lines across the newly formed face of the model, to obtain the corresponding points on the opposite or *inside* of the block. Having then laid down on the plan (fig. 5) the whole breadth of the cam by the line O P parallel to K L, the distance O *g*, representing the twist at the point *f*, was first measured and marked off from the top of the curve on the inner face of the cam, in the direction of a line which would be cut on it by the horizontal plane when the point *f* is lowered so as to be on a level with it. The reason of this will be more clearly comprehended by remembering that the curved face of the cam had been cut square all the way down, and that the line O G (of fig. 5) represents the substance necessary to be removed from a *square cut* face to make it coincide with the radius. The same process was applied also to each of the other divisions marked down the inner curved edge of the face, by dropping perpendiculars from each, as that shown at x 3, and setting off the difference Y Z thus found. When all these were completed, the points thereby fixed were united by a curved line, which showed the proper inner boundary of the face; and the only point necessary to be attended to in reducing it to form was, that the corresponding points in the inner and outer curves should be joined by straight lines.

There now only remained to determine and shape the lateral bend, and this, with the assistance derived from the previous operations, was easily contrived. If P g f D (fig. 5) represent the plan of the top of the cam after the face has been properly formed, and we have a pin of the length of D d or g w only, it is plain that the part w f is superfluous, and that by laying off either of the distances g w or f w on the anterior face, from the proper edge, we should have the position of w for that point of the face. The same was repeated at the different points from top to bottom, with this variation only, that in every one except the uppermost both the inner and outer distances have to be laid off. When this operation had been completed, it was found that the edges corresponding to the circumference of B D C (fig. 5), and of a point a quarter of an inch beyond it, which was the length of the pin, were traced down the face by the two curves shown in fig. 7. The superfluous matter x x having been cut away, the model was completed. From this castings were made in gun metal, which, being finished and fitted to the wheels, were found to answer perfectly. Each of them, when correctly placed, exactly followed, and remained in contact with the pin, whilst the wheels turned one another by their teeth, showing that the effects are the same, and that the two may be either made to move together, or be substituted one for the other.

The investigation of the theory of excentric cams or wipers of this kind cannot be too strongly recommended as an exercise to the mechanical student. When we recollect that by the aid of such an instrument alone a machine may be constructed *without any other parts whatever*, capable of mechanically signing one's name, we cannot fail to be struck with the variety of applications to which its services may be rendered available.

No. IV. *continued.—On a New System of Fixed Lights. By Captain* J. T. Smith, *Madras Engineers,* F.R.S., &c.

The preparation of this volume affords a favourable opportunity of giving some account of the successful trials which have been lately made under my superintendence, of a new system of lighthouse illumination, which, although possessing but little claim to scientific notice, may not be the less acceptable to the practical engineer, to whom, more especially to those who may be engaged on such subjects in this country, it will, I feel confident, render extensive and valuable assistance.

The new arrangement which is here referred to was first suggested in studying the best means of constructing a small light to be hoisted on a flag-staff, to answer the purpose of a lighthouse; in considering how to produce a maximum effect in which, I was led to the trial of a new kind of reflector, whereby an imitation was attempted in catoptrics of the very beautiful dioptric arrangement, designed by the illustrious Fresnel, and now well known as a fixed light of the first order on the coasts of France.

The results of a trial of this instrument being as favourable as I had expected, the advantageous consequences of the use of many in combination next occurred to me, and an opportunity presenting itself in a call which was made for a temporary improvement of the Madras light, a cheap apparatus was constructed upon the plan indicated by the theory of this contrivance, and has been fully successful in its results; other combinations have therefore been since recommended and executed, so that the suitableness of the plan to various opposite circumstances has been fully and satisfactorily ascertained.

The motives which induce me to recommend the system now to be described to the notice of my brother officers in this country will, however, be best understood and appreciated if I give a sketch of the difficulties which it has been designed to contend against. I may, therefore, before entering upon a description of the contrivance itself, point out what these are, and notice the great difference which exists between the circumstances attending the illumination of our coasts in India, and the corresponding provision in Europe, and the many obstacles which present themselves to our availing ourselves here of the improved means already adopted for that purpose in those countries where beacons have been so long established.

The first of these arises from the much inferior place in the scale of importance which this subject occupies in this part of the world, and in consequence the much smaller degree of attention to which it is considered entitled. The rugged and inaccessible nature of the coasts of Britain, and the great value and magnitude of the property constantly at hazard in the busy trade along her shores, naturally induce a vigilant watchfulness over the efficiency of the lighthouse department, and supply abundant means for its maintenance, which is accordingly supported by a Corporation possessing a princely fund, in the disposal of which they are ever ready to meet the claims of the maritime community upon whom they depend, with a liberality worthy of the objects desired.

In this country, although the gradual increase of our commerce, and the growing importance of the coasting trade, have latterly awakened the attention of Government to the subject of coast illumination, and led to the consideration of means for its improvement; and although we have been taught by the frequent losses of property, and the disastrous accidents which have accompanied them, that the strongest interests, as well as the loudest claims of humanity, are linked together in supporting the appeals for its establishment upon a liberal scale, the position we occupy is very different from that which I have just adverted to. The great length of our shores in comparison with the present value of the maritime traffic along them imposes too heavy a burden upon the resources of that rising interest to permit of the application of more than a very partial and imperfect remedy for the deficiencies which are continually presenting themselves; and the claims which are constantly made on this behalf not being balanced against the profits of the tax raised in its support, as is the case when the department is placed under a separate management, each new claim is entertained as a fresh burden upon the resources of the state, which it is thought necessary to treat upon terms of the strictest economy. While therefore, in England, the accordance of a grant as large even as £150,000 for a single lighthouse is obtained when the occasion demands it, without any very extraordinary difficulty, and the expenditure of £15,000 to £20,000 upon objects of less importance may be heard of as of frequent occurrence, we have in this country to confine our wants within, not only the tithe, but even the hundredth part of such a proposal, or for ever sacrifice the chance of any improvement at all; and the engineer officer, in preparing his design for a work of this character, is bounded as to his estimates within limits which in Europe would be scouted as altogether impracticable.

The influence of this limited economy upon the resources of the engineer is twofold; first, by confining the amount of his expenditure towards the improvement of his apparatus, and secondly, by contracting the space also in which he has to dispose of it, in consequence of the small size of the building which he can afford to erect for its exhibition. The last is the most serious difficulty of the two, because an accommodation to circumstances by a sacrifice of the cost is in the one way possible without so great a diminution of effect, by discarding the expensive material used in England for instruments of this kind, and turning to account the cheapness of labour in India: but the loss of space brings with it evils which it seems almost impossible to get rid of upon any system of illumination hitherto known; and this I shall presently explain, as it was this obstacle to the adoption of the usual modes that compelled me to devise a new principle, such as that which it is the object of this Paper to describe. The difference in character and objects, which essentially recommend the plan I have adopted, will be practically exemplified by the circumstance, that whereas the instruments employed at home are usually provided for a complete circle of the horizon at a cost of from 10,000 to 20,000 rupees, independently of the cost of the tower, and require for their disposal the space afforded by a circular lantern of from 6 to 13 feet diameter, those which I have to describe have been constructed at charges varying according to power from 100 to 1000 rupees, and may be contained within limits ranging from a diameter of 6 feet down to the size of a cylinder of 1½ foot diameter and 2½ feet high.

I hope I shall not be misconstrued to state by the above, that when confined within the very limited dimensions I speak of, the apparatus would be equal in effect to the splendid and expensive instruments elaborately fitted up in the lighthouses on the coasts of England, or to recommend the use of them as substitutes when the more expensive and efficient means are attainable;

I merely wish to express in this place, that an efficient light (such, for instance, as to be clearly visible in the most unfavourable of the above suppositions at a distance of fifteen or twenty miles,) may be constructed within the dimensions stated,—a convenience not attainable by any other system that I am aware of; and that an engineer may thus be enabled to erect an efficient beacon under circumstances which before would have been entirely impracticable. I shall hereafter proceed to show that the proper application and extension of the same principle, when required on a larger scale, will be accompanied by effects much superior to those produced by the finest catoptric English lights, and that in a particular which has hitherto been little regarded, and is deserving of the first attention.

I have had occasion, in the earlier part of this Paper,[1] to describe the nature of the apparatus which has hitherto been universal in the English fixed lights, which I have there spoken of as comprising a series of parabolic reflectors placed circularly, facing outwards, and so disposed with respect to each other, that each illuminates a certain angular portion of the horizon, within which its effects are wholly confined.

The essential character of this system, therefore, is, that the whole circle of the horizon is divided into a number of separate sections or angular spaces, each of which is lighted exclusively by its own distinct reflector, and receives no light whatever from the other instruments in the apparatus; when, therefore, any given portion of the horizon has to be illuminated, it is indispensable to apply as many reflectors as may be indicated by the number of degrees comprehended by the space, divided by the number of degrees filled by each reflector, the omission of any one of which would be inevitably accompanied by the production of a dark space, within which the lighthouse would be altogether invisible.[2]

In designing an apparatus on the above plan, therefore, if the lantern is unavoidably limited to very small dimensions, we are compelled, owing to the necessity of using many reflectors, to reduce their size so much as almost to take away their whole efficiency; or another expedient may be resorted to, that of diminishing the focal distance of the mirrors, and thereby increasing the

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[1] Page 42.

[2] It is unnecessary here to notice the direct unassisted light of the lamps, as this is so feeble in comparison with that by reflection.

lateral space through which they act, so as to cause a smaller number to suffice; or both these expedients may be adopted in combination.

The former of these plans is attended with considerable loss of efficiency, which affects the useful results in a high ratio, the illuminating power of reflectors varying according to the square of their linear dimensions. The latter involves great difficulty in the manufacture of the instruments, besides a great sacrifice of the rays of light, which by the wide divergency given to them, both in the vertical as well as the lateral direction, are made to expand in the form of a pointed conical beam, and thus cause as much loss by the dispersion of the rays into the upper regions of the air, as they effect gain by increasing their separation in a lateral direction.

Nor are even the above accommodations sufficient to meet the necessities of the case, when the limits are as small as some of those before referred to. When the size of the lantern is contracted to a less diameter than 4 feet, the adoption of reflectors, even at any sacrifice, becomes very difficult; the great heat thrown out by a number of lamps, and the crowding of the space by them, their reflectors, and reservoirs for oil, opposing almost insurmountable obstacles to success.

Moreover, the gradual reduction of the size of the mirrors, and the consequent diminution of the aid of reflection, necessary in the accommodation of the above system to narrow dimensions, signifies the abandonment of those advantages upon which the efficiency of the light so highly depends; and the final term in this progress of degeneration ends in the catoptric power being reduced to nothing, and the lamps being left to their own unassisted powers, of which the augmentation by scientific means becomes impracticable.

These difficulties were presented in an aggravated form in the proposition which was ordered to be carried into effect for converting the flag-staffs at the various ports into beacons for the guidance of vessels into their harbours, by hoisting a lantern to a sufficient height to give it the necessary command. This had already been attempted before my attention was directed to the subject, by means of a lantern containing merely a single lamp, in which the Argand principle had been aimed at, though unsuccessfully, owing to the want of chimneys, which are not procurable at out-stations. On the occasion of a light of this description being lately called for, I was requested to study the subject, with a view to render the project more effectual, by improving the power of these small instruments, and the following considerations led me to the scheme I have since adopted.

In the reflectors now employed on the coasts of Great Britain, and in fact in all those in common use, the principle of construction is that of giving to them the property of collecting the rays which emanate from a central point, and propelling them all in parallel lines in the direction of the axis of the mirror, which is a line perpendicular to the middle point of its surface. This property, which is usually aimed at in all mirrors, however faulty their real figure may be, is correctly attained by shaping them in the form of a paraboloid, that is, a solid generated by the revolution of a parabola round its axis. The mathematician who is already familiar with this property of the parabola will be aware that it is due to the nature of the curve, and to the circumstance, that in solids of rotation all the sections through the axis are similar to one another, and similarly situated with respect to the axis of rotation; and hence, that as the property of each curved section is to return the rays in directions parallel to its own proper axis, which axis is in this case common to all, being also the axis of rotation, the result is that all the rays radiating from the focus are propelled in a direction parallel to this common axis and to one another.

The necessary consequence, therefore, of the use of reflectors of the above form, if the light emanated from a focal *point*, would be, that the emergent rays being strictly parallel, would merely fill in space the capacity of a cylinder of the sectional area and form of the end of the reflector; and before these instruments were generally known, and had been submitted to trial, an unpropitious result from the use of them was predicted by the late celebrated Dr. Robison, from the apprehension, first, that owing to the small area which would be covered by the section of this cylinder of rays, which he anticipated would be formed, it would be extremely difficult to point it in the proper direction, so as to catch the eye of a mariner on the horizon; and, secondly, that an almost infinite number would be requisite to fill the circumference of the surrounding space at the requisite distance. That distinguished philosopher had omitted to take into consideration the natural divergency of those rays, which, owing to the flame of the light being *larger than a point*, were necessarily situated *out* of the focus, and which, consequently, on emergence, form the same angle with the axis after reflection, which they subtended before impact with a ray proceeding from the point of reflection to the true focus. Had it not been for this last unlooked-for circumstance, these instruments, however interesting from their elegant application of scientific truth, would have been entirely useless as a practical means of illumination, and would have fully verified the unfavourable doubts entertained regarding them. But to return. I have now to explain in what way a modification of these properties has been effected, so as to bring about the results which were had in view.

It will be observed that by the above construction the rays emanating from the focus are collected in every direction, both vertically and laterally. The first is evidently a desirable object, since it is obvious that all rays which emanate in directions however slightly inclined to the horizontal line, either upwards or downwards, can never reach it, except they be restored to the proper course by reflection; but, in regard to the lateral divergency, it is plain that no object whatever is gained by collecting them, since this very collection introduces the difficulty felt in the narrowness of the space filled by each reflector, and has to be compensated for and neutralized by the inconvenient and expensive necessity of multiplying the number of the instruments employed, and with them the number of lamps, reservoirs, and, in fact, all the other parts of the apparatus.

It occurred to me, therefore, that if an instrument could be devised capable of collecting the rays of light emanating from a central point *as regards their vertical divergence only*, leaving their lateral diffusion untouched, I should then be able to effect a condensation of the beam to the utmost useful extent without the introduction of the accompanying evil just pointed out, and that the application of such an instrument to a light whose agency was required to be seen throughout a wide space of the horizon, must effect the maximum of advantage of which its use was susceptible.

In M. Fresnel's beautiful dioptric light before alluded to, the principle here spoken of is carried into effect by placing the light in the centre of a cylinder formed by a series of separate zones of glass placed one above the other, each so shaped as to possess the property of refracting to the horizontal direction the rays impinging upon it from the central lamp. A vertical section of one of the sides of this cylinder, therefore, presents the appearance of a wall of prisms, which has the same property in dioptrics as was before stated to be peculiar in catoptrics to the parabolic mirror, namely, that in the plane of this section all the rays emanating from the central or focal point are refracted to the horizontal line, that is, a line perpendicular to the wall of prisms at its middle point.

This horizontal line, parallel to which the rays are collected, is in the parabolic mirror made the axis of rotation, and thus, as before explained, by becoming the common axis of all the sections, the whole of the rays become parallel to it, and to one another. In M. Fresnel's dioptric arrangement, instead of making this line the axis of rotation, in which case the prismatic section would by its revolution be formed into a polyzonal lens, a line perpendicular to it, and parallel to the section, is made the axis, and the rotation of the section round it forms the cylinder, as shown in fig. 4, where the axis Plate V. is represented by $g\,h$. Here it will be quite obvious, that as the sides $c\,d\,c'\,d'$ have the property of collecting all the rays emanating from the focus f on both opposite sides, and further, that the same sections are exhibited by cutting the cylinder in any other direction, it follows that the whole cylinder possesses the property of condensing all the beams proceeding from the focal point, as regards their vertical divergence only; and that as regards their circular dispersion, that is, their divergence from one another in the horizontal plane, they remain unaffected, and like mere unreflected rays, equally diffused.

In attempting to imitate this in catoptrics, it will be manifest, from what has before been explained, that for the wall of prisms we must substitute the parabolic section; and it is necessary to remark also, that it is essential that the axis of rotation of the cylinder to be formed should pass through the focus of the section, that is, through the focus of the parabola. The axis of rotation, therefore, becomes the parameter of the curve, or the focal ordinate; and were the dimensions similar to those adopted in all Fresnel's dioptric zones, whose focal distance is 3 feet, and the refraction confined to the lower part of the sphere of rays emanating from the light, by cutting off from the solid formed by the revolution, that portion which approaches the axis and occupies a vertical situation in respect to the light, a bulged cylinder would also be generated, fig. 5, which would much resemble a wine cask. But in the small reflectors which I am now speaking of, the whole of the curve intercepted by the parameter is used, instead of merely the zone, whose section is $a\,b$; and the figure produced by its rotation is that shown by the dotted lines, the shape of the instrument itself being very like an empty canoe, or the half of a nine-pin.

There is one great disadvantage in catoptrics, which will not fail to have already occurred to the mind of the intelligent reader, viz., that we cannot in this case, as when refracting the rays through a series of transparent zones, use the entire cylinder; one half of it is necessarily sacrificed in consequence of its interference with the efficiency of the other half, and hence it is impossible by this plan to take advantage of more than one half of the radiant light, and no reflector of this kind can fill more than 180° of the horizon.

This is no doubt a serious evil, theoretically, when we consider the economy of the rays of light, the object of which is, of course, to arrest every individual pencil of the luminous matter, and turn it to good account. But, practically, it is not of so much consequence, except in those situations in which more than a semicircle of the horizon is required to be lighted, which rarely happens, except in the few cases where a lighthouse has to be established on an island. Under such circumstances the beneficial effect of a set of reflectors of the character above described would be smaller, and the advantages of their use less, in comparison with a refracting apparatus in which the sacrifice above mentioned would be avoided, in the ratio of one half.[3]

As most lighthouses stand on the edge of a coast, and require only the means of illuminating one half of the circumference of the horizon, this drawback to perfection in the theoretical efficiency of this scheme is rarely felt in practice; and even then, the advantages of its adoption are so many and so great, that it is of little importance when compared with them; nor are we altogether without a remedy, for unless the size of the reflectors be very small, a partial recovery of the hemisphere of lost rays may be easily effected by means of the adoption of a small hemispherical reflector, represented by *a b c* in fig. 6, in front of the lamp, and pointed inwards, as there shown. This arrangement, which has been suggested for the common reflector by Mr. Barlow, has the effect of returning all the diverging rays which would have

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[3] The same objection would also be applicable to a *set* of dioptric lights, such as, for instance, a system of M. Fresnel's catadioptric lights of the fourth order, if used circularly, to illuminate a complete horizon; in which case one half would interfere with the other. But a very efficient application of the system which I have proposed would be made by a series of these instruments, each backed by a hemispherical reflector, for the purpose of returning the rays which would be lost owing to the above cause, back again through the front, and thus doubling the radiation in that direction. Thus furnished, each of these instruments would be for all purposes one half more effective than a reflector. I have, however, addressed my remarks principally to the latter, they alone being capable of being manufactured in India.

been diffused in front back again through the focus into the corresponding directions of the opposite hemisphere, whence they are diverted into their proper courses by the parabolic mirror.

The reflectors which have been hitherto used by me have been principally of the dimensions of 2 feet in height by 1 foot breadth, and 3 feet by 1½ foot; that is, of 6 inches and 9 inches focal distance. When the size of the lantern of a lighthouse will admit of it, it would be more effective, as well as economical, to use larger dimensions. The lamps which are fitted to the reflectors are necessarily of a peculiar kind; for on considering the properties of the double curve used for reflection, which it will be recollected is a parabola vertically, and a semicircle in its horizontal section, it will be observed that all the reflected rays must pass through the axis of rotation, that is, through the parameter of the curve, the middle part of which is the focus, and contains the lamp, which, were its construction such as is commonly adopted, would very probably fill up a large portion of its height by its own body, drip-cup, and chimney; and thus, since the *whole* of the rays are obliged to converge and pass through this axis, they would nearly all meet with obstruction, and the entire efficiency of the instrument be destroyed. It is therefore indispensable that the burner and all the solid parts of the lamp inside the reflector should occupy as little bulk as possible; and although the use of a chimney would be less open to the same objection, yet since, in spite of its transparency, it could not fail to be some interruption to the free passage of the rays, and might very probably interfere with their correct diffusion, it would be highly desirable that it should be dispensed with. This desideratum is still further enhanced by the great difficulty and constant trouble which would accompany the attempt to keep up a constant supply of such fragile articles; the delay and uncertainty in procuring which, and the great inconvenience which would be met with in providing for the wants of numerous out-stations, would impose an unceasing and vexatious trouble upon the Marine department.

Many different kinds of lamps and burners have been tried, with a view of combining the desiderata above noticed. I shall here merely give a description of that which has been hitherto found most successful. In those last constructed, a cistern *a b* is fitted at the back of the reflector, into which drops a fountain reservoir similar to those used with the common Argand lamps, and furnished like them with a valve, &c. Plate VI. fig. 5.

A feeding pipe for supplying oil to the burner passes from the lower part of

Plate VI. the cistern (fig. 4), through the head of the reflector, to the focus. This pipe is open at the top, and is about $\frac{3}{8}$ or $\frac{1}{2}$ an inch broad by 1 inch deep. Towards its extremity, where it is united to the burner, it is closed at top, and its form Plate V. is changed to a tapering one (fig. 9), the object of which is to prevent the formation of a shadow in the lower parts of the reflector. When it reaches the focus it is joined to the burner, which is a flat one, placed transversely across this pipe, and is $\frac{1}{4}$ inch in length (in the direction of the feeding pipe), 3 inches in breadth (measured transversely to ditto), and an inch in height. The outer lip of this burner is $\frac{1}{4}$ inch below the inner one, so that the two sides appear with a slope. In other respects it is a mere empty trough. In order to secure and adjust the wick, a thin but stiff plate of brass, measuring in breadth 3 inches (which is the breadth of the burner), by 1 inch in height, is turned up at one of its broad ends, so as to form a circular hinge, which nearly fits the interior of the burner, and while the whole plate is quite moveable, (there being no pin to the hinge,) keeps the lower part of it in contact with the front edge of the trough. In the middle of the front of the brass plate is provided a socket, into which fits transversely a small piece of clock spring, bent into the form of a curve extending outwards, so that when the plate, or "wick-holder" as it may be called, is fitted into the burner, this spring keeps its upper edge pressing against the inner edge of the burner. This tends to steady the wick, which is merely a slip of the common cotton manufactured for that purpose, wove in lengths of 50 or 100 feet by 3 inches broad, from which wicks of an inch long are cut, and merely secured in the burner by the pressure of the spring plate just described. A fresh wick is used daily, and the renewal takes place when the wick-holder is removed for the purpose of cleaning the lamp, which is effected with ease, in consequence of the removal of the wick-holder and the simplicity of the parts. To guard against any accident occurring to the spring it is made moveable in the socket, which joins it to the wick-holder. Should it therefore be broken or get out of order, it may be withdrawn, and a spare one substituted.

In these lamps the oil is regulated so as to stand at the level of the outer edge of the burner, and when thus trimmed, and the wick smoothly cut and evenly adjusted, they will burn with a clear steady flame for 5 or 6 hours without being touched. This is without the assistance of any chimney. The breadth of the flame is 3 inches, and the height about $1\frac{1}{4}$ inch, and I have ascertained by experiment that the illuminating power is equal in average effect to that of the Argand lamp used in the British lighthouses. The consumption of oil is rather less, being about 1⅓ pints of cocoa-nut oil in 12 hours.

In speaking of the comparative illuminating powers of the Argand and the above flat-wick lamp as being equal, I ought not to omit the distinction which exists between their intensities. The Argand lamp (such as is used by the Trinity Corporation) has a flame of 1 inch diameter and 1¾ height, that is, showing a surface of 1¾ square inches in any horizontal direction. The flat burner lamp exhibits a flame of 3 inches by 1¼ height, or 3¾ square inches; but it must be observed, that in the former every part of its surface exhibits the light of a double sheet of flame, which, being shaped like a hollow cylinder, is doubled in every aspect; every square inch of the visible flame of an Argand lamp is therefore equal in illuminating power to two of the simple flat burner I have just described, or, in other words, its intensity is twofold greater; in addition to which there is a superiority in the combustion, when aided by the current of air induced by the chimney, which further assists in making up for the difference of surface.[4]

The flat burner lamp may indeed be considered as simply the circular flame of the Argand spread out, the length of its wick being very nearly the same as that of the circumference of the latter, and consequently the consumption of oil and illuminating effect is very nearly the same also. What little difference there is arises from the combustion not being quite so rapid or intense in the flat as in the circular flame, for want of the chimney; but a saving in expenditure arises from there being no loss from the evaporation of unconsumed oil, which latter circumstance, added to a small difference in size in favour of the flat burner, compensates for its deficiency in regard to the first point mentioned.

It thus appears that the intensity of the lamp here spoken of is only one half of that of the Argand lamp generally used on the coasts of Great Britain; and this regulates the intensity of the whole light, since the vividness of the superficial area of the mirror filled by the rays, as seen from any position,

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[4] Were the heights of the two flames equal, and the intensities of the single sheets of flame also of the same value, then the superiority of the circular over the flat-wick burner would have the ratio of the circumference of a circle to its diameter, or be as 3·14 to 1, which ratio would exhibit their relative average intensities; but the difference of height and other practical circumstances reduce this ratio to the one before stated, which corresponds more nearly with experimental results.

could not exceed that of the original radiant, even were the reflection perfect.

In this climate the want of intensity, when the *illuminating power* is the same, is of less consequence than in England, where a light is so frequently required to pierce the dense fogs which hang round their coasts: were it desirable, however, there would be no difficulty in doubling it by using two flat burners, one behind the other; but it is doubtful whether, even with this addition, the combustion would be so perfect as to produce the brilliant white flame seen in the well trimmed Argand lamp, to effect which a glass chimney would be necessary. But though the intensity of the light is only one half, it must not be forgotten that the illuminating power is equal to the standard above taken, owing to the difference of size of the two flames, as above explained; and in the same way it may be demonstrated, that, though the intensity of the reflected light bears the same ratio, yet the illuminating efficiency of a series of mirrors of the construction I have described is not only equal to that of an equal number of the old form, but, from a circumstance I shall now explain, much superior.

This circumstance is, that from the nature and shape of the flame, and the properties of the new reflector, none of the light is wasted; the reflection tending to propel the rays in a thin sheet, whose effects, could they be exhibited by a screen opposed to them on the horizon, would be to form a circular zone or band of light encircling the mirrors, which is obviously the most useful possible disposition of the rays; while the common parabola, whose theoretical tendency is to propel them along its axis, practically disperses them to the form of a cone or pyramid, expanding in all directions, whose section would be similar to that of the focal light, which would be a rectangle of greater height than breadth. With the instruments now universally adopted in England, the form and dimensions of this pyramid are such that the outside rays are projected in a direction which at the distance of 20 miles raises them upwards of 5 miles above the horizon, the intermediate rays falling at proportionate distances. From this cause, as may be conceived, much of the useful effect is lost.

A single reflector of the kind I have described, when used in the back of a small lantern, suffices to answer the purpose of a beacon, which is seen equally in all directions through half the horizon, to the distance of 15 or 20 miles in this climate, according to its elevation. The visible appearance to a spectator in any direction is that of a bar of light similar in shape to the front face of the reflector, only narrower, its breadth being somewhat more than the breadth of the flame, as seen from the same point, and its height the whole height of the reflector.[5] When two or three are combined, they ought to be ranged parallel to one another, if intended for a lighthouse on the coast; and circularly, if meant to give light to an entire circumference of the horizon, as when placed on an island. When the reflector is of the size of 2 feet in height by 1 foot in breadth, its power, as obtained by experiment, is equivalent to a multiplication of the effect of the lamp in its focus by 10 or 12; when of 3 feet by $1\frac{1}{2}$, it is (as I calculated) increased to 15 or 16: that is, a lamp to which either of these reflectors is applied is equal in illuminating power to 10 or 15 similar lamps unaided by reflection. Theoretically, the superficies of the illuminated part of the reflector may be calculated to be $\frac{2}{3}$rds of the area expressed by the breadth of the flame, multiplied by the height of the reflector, which would, with the small reflector, give $\frac{2}{3}$rds of 3×24, or 48 square inches, as compared with the area of the flame (or $3\frac{3}{4}$ inches), and a comparison of these relative superficies gives 12·8 as the ratio of augmentation; but this, leaving no allowance for the practical loss of light in reflection, is rather confirmatory of the first than of the second of the experimental results above quoted, and that, as being the lowest, may be safely depended on.

In a number of these reflectors combined, the effects of all are added together, and this with the admirable advantage, that any trifling inequalities in the distribution by one mirror are corrected and equalized by all the rest. This is a point of great superiority in comparison with the British system of reflection, which, as will presently be shown, fails to produce a nearer approach to equality in its effects in various aspects than such as is expressed by the ratio of 1 to 8, while this system can be demonstrated to produce a larger effect with the same number of mirrors and the same expenditure, in conjunction with the long desired property of an absolute equality in distribution.

I have just had occasion to state that a great irregularity exists in the distribution of light by the old reflectors, the illumination being very much weaker as seen in the direction of a line passing through the junction of two

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[5] If the distance be small, this is distinctly seen; but farther off the appearance is that of a ball of fire, like the common reflector: in this case a strong magnifying power would exhibit the real figure of the light.

reflectors, than from the point immediately opposite to any one of them; and the inequalities in the value of the illuminating power are so great, that it is in some points less than *one-eighth* of what it is in others. This inequality is due to a cause capable of easy explanation, though it would lead me too far at present to enter upon it; I may, however, say, that the principles are such that they may be reduced to calculation, which calculations are verified by experiment.

In order to establish a comparison as to the absolute powers of the two systems, let us compare the effects of 12 of the Trinity House reflectors, which is the number requisite to fill half the horizon, with 12 of the "periscopic" kind, if I may so term them. The former are circular, and 21 inches over the lips, the latter 18 inches in breadth by 3 feet in height.

The *maximum* effect of each of the common reflectors is represented by the area of its end, or 346 square inches, which is the area of the circle of flame which it will exhibit in the most *favourable* position; and this has to be multiplied by 2, making it equal to 692, to account for the relative intensity of its light as compared with the "periscopic" reflector.

The above is a calculation of the most favourable appearance of a series of 12 reflectors in any aspect, because only one can be seen at once, and the numerical measure above stated is that applicable to the most favourable view of it.

On the other hand, a series of twelve 3-feet "periscopic" reflectors exhibits in one view 12 bars of light, each of which measures ⅔rds of 36 × 3, or an area of 72 square inches, making altogether 864 inches, whose intensity is represented by unity. The relative illuminating powers, therefore, of the two systems are, of the common reflectors 692, and of the new ones 864; but the above is a representation of the *maximum* effect of the common parabola, and it has been found that the *minimum* is less than ⅛th of this. The average effect is, therefore, only 4½ 8ths of the above, or to be expressed by 4½ 8ths × 692, or 389, whilst the average effect of the periscopic light is still represented by 864, the illuminating power being the same in all directions. With mirrors, therefore, of 3 feet by 1½ foot, an improvement is effected in the available power expressed by the ratio of 864 to 389, besides the independent advantages resulting from equality in distribution.

But the superiority of this principle will be still more plainly exhibited when it is carried into effect by means of dioptric instruments, because, in respect to them, a comparison can be made, accompanied by the use of the same radiant in both; and the adoption of the hemispherical reflector with them economizes a large number of rays which would otherwise be lost. To test the system fairly, it would be proper to construct instruments suited to it; but I have little doubt of the result of a trial of 24 common parabolic reflectors against 24 of M. Fresnel's semi-catadioptric lights of the fourth order, each supplied with Argand lamps, and the latter backed by hemispherical reflectors as proposed (Note, p. 64). The result of this experiment would, I have little doubt, show that the effect of the latter, while absolutely constant or uniform in all directions, would be superior to the *maximum* effect of the former, which would be found to range through all the gradations of illuminating power, varying from the nearest condition of equality with the dioptric lights of which it might be capable, down to the very low measure of reduction (⅛th) before stated.

Now it is the uniformity of effect in all directions which is by far the most valuable attribute, coupled with sufficient illuminating power, which can be possessed by any fixed light; and the high character which the French dioptric lights deservedly bear in this respect has, spite of disadvantages, forced them upon the notice and approval of the scientific authorities previously enlisted in support of the old system, and cleared the way for their introduction and general use. The grand objection, however, which was long urged against the French system, and is still the most formidable argument against it, was derived from the obvious hazard and constant uncertainty accompanying any system which is entirely dependent upon any single instrument, more especially when that is complex and liable to get out of order. The entire illumination in a French dioptric light being derived from a single large lamp placed in the centre of the lighthouse, it is evident that any accident occurring to that lamp would at once immerge the whole horizon in darkness, an accident which might be attended with the most fatal results. By the British system (in fixed lights), the horizon being divided into numerous separate compartments, each independently illuminated by its own light, the danger of any total eclipse is of course diminished in proportion to the number of sections which are combined to make up the whole circumference; and though the chances of accident are also increased by multiplying the number of lamps, yet their greater simplicity, and the much smaller risk to be incurred by the solitary failure of a part of the system, have been held to provide so much greater security for the general usefulness of the beacon, that the abandonment of that advantage has been looked upon as a very dangerous risk, and, in spite of the benefits held out by the dioptric theory, accounted a fatal bar to its adoption.

But it will be observed that the arrangement which is proposed in this Paper, though possessing to the full extent the characteristic advantage of the French light as respects uniformity of distribution, possesses a tenfold superiority over even the British system in regard to the certainty of its effects. By the old parabolic system the evils of a failure are small, but the chances are numerous in proportion to the number of lights; and hence the abstract chance of danger is the same as if the whole were illuminated by one lamp (were it possible); for the same evil, though of only one-tenth the magnitude, when repeated ten times, may be accompanied by as disastrous consequences as the single occurrence of the larger risk; and this argument would completely do away with the objection to the French system, were it not counteracted by the more forcible consideration of the greater simplicity and superior intrinsic security of the Argand as compared with the large French lamps, which alone constitutes the real difference between their respective merits in regard to the point in question.

But in the system which has been described in this Paper, it will be observed, that as the illumination in every part of the horizon is made up by the combined effects of the whole of the reflectors constituting the series, not even the smallest part of the horizon can be eclipsed without the simultaneous failure of the whole of the lamps; an accident, the chances against the occurrence of which are not merely in the simple ratio of the number of lights used, but are represented by the *power* of the ratio which expresses the chance of failure of a single lamp, whose index is the number employed.

Were the probability of the failure of any single lamp, therefore, even so great as to be represented by the fraction $\frac{1}{100}$, the chance of an obscuration of the whole system would be no greater than $\frac{1}{100000000000000000000}$, a probability which might be fairly considered indefinite. The only evil consequence which could, therefore, be ever apprehended would be the diminution of the effect by an occasional failure, which would reduce the illuminating power by $\frac{1}{10}$th; the danger of any portion of the horizon being at any time eclipsed being altogether annihilated.

But important as are the various advantages attending the arrangement which I have here proposed as regards the means hitherto commonly adopted for illumination, they are surpassed by the larger benefits which will be derived from it when more powerful and expensive means of combustion are resorted to. The grand desideratum in the present stage of our progress, as regards coast illumination in Great Britain, has been the means of condensing light in heavy weather; in other words, the discovery has long been sought for, of a mode of occasionally substituting a small and intense radiant for a larger and more feeble one. But great difficulty must ever oppose the accomplishment of this end, as long as the lateral dispersion is dependent upon the size of the flame, as the more intense flame being smaller, must fail to fill the space in divergency of its larger substitute; and the vast expense attending the indispensable use of so considerable a number of such costly lights would also offer a serious obstacle to its adoption. The proposed alteration of system by which any one optical instrument thus intensely illuminated may, when necessary, be made to act in lieu of the whole of the ordinary combination, seems to present the means of setting aside a difficulty which might have been a fatal hindrance to success; and I cannot conceive that its advantages can long be overlooked, more especially if the experiments which have been made towards the introduction of the Drummond and Bude lights be strenuously persevered in.

It is indeed the peculiarity of the system I have above attempted to describe, that, whatever be the radiant made use of, the total amount of illuminating power can at all times be proportioned to the exigencies of the situation or circumstances; for the effects of each reflector or dioptric apparatus of however large a series being similar to that of all the others, and with them equally diffused over the whole semi-circumference, it remains merely to determine the *intensity* by the nature of the means of ignition adopted, and the illuminating *power* by the number employed. In a considerable series, therefore, in which the means of supplying oxygen to the lamps is provided, as in the Bude lights, a most valuable property would be gained, which has never yet even been proposed for any lighthouse, viz., the faculty of increasing the intensity at pleasure, and of varying, at the same time, the amount of the illuminating power, to an extent far beyond what can ever be practically desired.

These views refer not, however, to the particular application which has been noticed as desirable in this country: here a low intensity is sufficient, from the favourable nature of the climate; and the apparatus I have described is valuable from many local considerations. We are here, moreover, as yet but on the threshold of improvement, and it is to other more advanced countries that we have to look for those expensive modifications, which I have above referred to, as necessary for the full devel̆opement of the advantages of which the plan is susceptible.

In the above suggestion of a trial of 24 of M. Fresnel's catadioptric lights of the 4th order against 24 reflectors of the common kind, that number has been proposed in consequence of 24 reflectors being necessary to fill an entire circumference with light; as the best method of making a practical trial, both as to the comparative powers of the two lights in various aspects, and also as to the nature of the distribution by each, would be to mount each side by side on a frame capable of rotation, and then to view them both together whilst revolving. I am not aware whether the experimental establishment at Purfleet, belonging to the Honourable Trinity Corporation, affords the means of making the trial in this manner; but if not, the interest which would attach to the subject, as well as the valuable consequences which promise to flow from it, would amply justify some expense to be incurred for the purpose.

In the construction of new dioptric instruments for the purpose of applying them in combination, it will be observed that the "useful effect," that is, the power as compared with the expense, is increased in proportion to the size of the instruments made use of; the only limits are the evil consequences arising from the too great diminution of the vertical divergence, and the necessity for adapting the dimensions in reference to the number employed and the size of the lantern in which they are to be placed. From what I know of the space afforded in some of the first-class lighthouses on the coasts of England, I should be of opinion that instruments of 3 to 5 feet in height by 15 to 28 inches diameter might be advantageously adopted; and of these a much smaller number would suffice to produce the same effects as are now derived from a large number of reflectors, both being lighted by the same lamps.

In this country it appears to me that a much smaller illuminating power answers every purpose, and I do not think that it will be found necessary in any situation, where the climate is such as it is on the Coromandel coast, to employ a larger number than six 3-feet reflectors for a semi-circumference of the horizon. The Madras light, which for the last 50 or more years consisted of 12 large lamps, aided by 9 plain reflectors, has been recently improved by the substitution of 4 lamps and small sized reflectors (of 2 feet by 1 foot), and the effect is found to be at least fourfold superior to what it had ever been previously;[6] although, when carefully managed and attentively watched upon the old system, it had been occasionally praised as a good light. A series of 9 large reflectors, for a complete circle of the horizon, has been very recently constructed for an insular light off the port of Coringa, and I have no doubt will be found to be abundantly sufficient in power. No accounts have yet reached me of its erection and performance.

In fitting up a set of instruments for a complete circle of the horizon, it is preferable to use an even to an uneven number, as in the case last alluded to; because, in a circular series of an even number of terms, each reflector is backed by a fellow in precise opposition to it, and these two, considered together, exactly fill up the whole circumference of the horizon between them, and create an uniform distribution of the light throughout it. Each pair does the same also, with the advantage, that the diameter joining the spaces filled by the two opposite reflectors falls in a different direction in the second pair from that of the first, and that of a third and fourth are also different; the effects of all the different pairs of reflectors thus, as it were, "breaking joint" with one another,—an arrangement which contributes to the utmost perfection in the distribution of the light. Each pair, also, taken separately, is complete in its effects, so that a modified application of the system may be made by reducing the number used, by pairs, which could not be done when the reflectors are not exactly opposed to one another, because, the circumference being not quite filled by any two in such a disposition, a third is necessary to complete the distribution. Thus, if a partial employment of a circular series of 12 were desired, the efficiency would be quite complete if either 12, 10, 8, 6, 4, or 2 were used; but if only 11 composed the series, then either 11, 8, 5, or 3 must be employed. The one would allow of 6, the other of only 4 variations in power, and the distribution would also be more perfect in the former case.

In Plate No. VI. is given a representation of the first trial which was made towards the construction of a flag-staff light. The arrangements for the

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[6] The light is, upon the whole, more than five times superior to what it was, but this is in part due to other improvements—in the ventilation, the glazing, &c.

lantern have since been very much improved, and the lashings which are there represented as necessary to secure the lantern to the mast have been dispensed with by a simple and self-acting contrivance.

A *double* light of this kind, with small sized reflectors, has also been constructed for the port of Masulipatam, and this, with a view to increase the effect, has its two reflectors furnished with lamps, whose burners are of greater breadth, and, consequently, increased power. The same purpose might have been answered in a greater degree had the lamps been doubled, but this was not thought to be required, and was therefore avoided, with a view to save unnecessary complication.

In the construction of the reflectors the material which has been generally used has been, for those of the larger size, a white kind of brass, containing a larger proportion of zinc than usual, and for the smaller, plated metal. All that have been as yet made use of have been supplied by Messrs. Gordon and Co., from templets prepared by myself, and I have found the figure which was given to them very correct, and the surface, more especially of the brass ones, tolerably perfect. Plated metal reflectors are kept in condition by the use of a soft polishing powder, consisting of prepared chalk, brick-dust, or any such substance, reduced to an impalpable powder, and supplied by means of chamois leather. The best and simplest mode hitherto tried for giving a lustre to the brass reflectors is a native process, which consists, in fact, of the application of fine corundum powder. Each lighthouse is furnished with one large and two or three smaller pieces of the corundum stone, and in order to apply them to use, the larger is placed on the floor, and a few drops of oil being poured on it, a smaller one is applied to it, and gently ground upon it for a few seconds, after which the oil assumes the appearance of a white cream; this is applied to the surface of the reflector, and rubbed over it with a piece of common serge. After the requisite effect has been produced, which is judged of by occasional examination, and by the change of colour which takes place in the oil (turning black), it is removed, and the surface wiped as clean as possible with a cotton cloth, and afterwards finally polished with powdered ashes of cow-dung, shaken on through a muslin bag, and chamois leather.

With these simple means the apparatus is easily kept in condition, even by natives; and the brass reflectors are perhaps better suited to their use than plated ones would be, if they are necessarily intrusted to their sole management. I have not had an opportunity of yet trying the comparative efficiency of the two metals, but I am of opinion, from what I have seen of both, that, practically, there is not so much difference as might be anticipated. It is true, that under the best management a higher lustre and a better reflection might be produced from the silver than brass; but under native management, I think it is probable that in practice they would either employ the former with a very imperfect surface, or make so much use of the polish as very speedily to remove the plating altogether. It is a great advantage in the use of a solid metal for reflectors that the continued use of the rubber rather improves than injures them, and in all arrangements in which a provision is necessary to be made for the continued service of natives, we cannot take too much pains to secure the fulfilment of our intended objects by leaving as little to their judgment or care as possible.

Before concluding this Paper, I may refer to a caution which is important, both in regard to this as to every species of light, but which is apt to be neglected in consequence of its connexion with the efficiency of the light not being apparent: I allude to the indispensable necessity of a careful provision for the free circulation of air through the building, without which precaution the lamps are apt to burn badly and smoke, and this is generally attributed to their faulty construction, the quality of the oil, &c. The usual plan for effecting the circulation is to provide a turn cap and cowl for the roof, and to form apertures in the floor; but in the latter, one meets with two difficulties: first, if the apertures are too large, the air in the interior of the room is liable to be affected by gusts of wind; and, secondly, during the monsoon, apertures of any kind afford entrance to myriads of insects, which clog the oil, and would entirely suffocate the lamps. I have hitherto found these difficulties completely obviated by perforating the floor of the building by a very great number of small holes of about 1 inch diameter, in each of which a small tin tube of 3 or 4 inches length, bent in the middle at right angles, was affixed from below. These prevent the glare of light from being seen at a distance, and the apertures therefore do not attract the insects, and they have been hitherto found quite effectual in excluding them. Had any further inconvenience been still felt, I had intended to have protected the mouth of each tube by a cover of wire gauze, but this has been found unnecessary at present. The number applied to the floor of a lantern of 6 feet diameter is about three or four dozen, but I am not sure that even more might not be applied with advantage.

No. IV. *continued.—Description of a New Hydro-Pneumatic Lamp.*

By Captain J. T. Smith, *Madras Engineers*, F.R.S., &c.

1. The following is an account of a new species of lamp made up under my superintendence, of which I am induced to offer a description, both because it is in itself curious, and because the various arrangements combined by it form an useful exhibition of the hydrostatic principles upon which these instruments are dependent for success.

2. My object in setting about this undertaking was the desire of constructing a lamp which should fulfil those conditions in which its light is required to radiate equally in all directions, throughout an *entire* circumference of the horizon; and I had more particularly in view its application as the means of generating light for the beautiful catadioptric lighthouse apparatus invented by M. Fresnel, or for a catoptric substitute for it which I had devised, which I was of opinion would be useful in many situations in India. These conditions require that the burner of the lamp should be supplied with oil from a source *below* its own level; since, were it otherwise arranged, there would necessarily be either a reservoir on the same level with the burner, which would itself intercept the rays tending towards the horizon in some or other meridian; or, were the reservoir of supply placed above, there must be a pipe passing down from it, and feeding the burner from below, which pipe would in the same way form an obstacle to the passage of the light in some direction.

3. M. Fresnel's catadioptric apparatus to which I allude consists of a spheroid made up by the superposition of a number of circular zones, each of which has the property of refracting the rays of light which impinge upon it from the focus in the centre, so as to bring them to parallelism as regards their vertical divergence, but which, by reason of their circular figure, and because their exterior and interior surfaces are parallel, or rather concentric, do not in any way act upon the rays as regards their divergence in the hori-

zontal plane; from which properties the result ensues, that the whole of the luminous beams are flattened into a circular *sheet* of light, instead of the cylindrical or conical beam produced by the common reflecting paraboloid; and, if there be no interruption to the passage of the rays, the illumination produced is of exactly equal intensity in every direction, a property of the greatest value in lighthouse illumination.

4. The supply of the burner of a lamp by means of a reservoir placed altogether above its level, and communicating with it by a pipe, as above described, is undoubtedly a practicable plan; nor is the obstruction occasioned by the pipe a very serious objection, when it is adopted in the interior of a large lighthouse, as it may be conducted down one of the stanchions supporting the roof, and thus occasion no additional interruption to the passage of the rays; but in a smaller lantern this is obviously impracticable, both from the want of space for a reservoir within the roof, the want of size in the stanchions for the protection of a pipe of proper capacity, and the difficulty of guarding against the effects of the heat, should the reservoir be brought too near the influence of the current of hot air proceeding from the burner. Besides which, whatever be the space at command, there is a great practical evil in the want of compactness in the apparatus, owing to the parts being detached from one another, instead of the whole instrument being (if one may use the expression) "self contained," whence its erection and adjustment must in many cases be intrusted to others, and may chance to fail, spite of the utmost care and attention in the maker.

5. These reasons have long since led, in the French lighthouses, which are now all lighted by radiation from a single focal lamp, to the use of a pump for feeding the burner from a reservoir below. This pump is moved by clock-work upon precisely the same principle as Carcell's lamp, and it is the complexity and liability to derangement of this part of the apparatus which has long proved the greatest obstacle to the general introduction of M. Fresnel's very elegant and effective system of illumination.

6. Other means have also been devised for accomplishing this object, and numberless patents have at various times been taken out, both in France and England, for self-supplying lamps of different kinds, and upon various principles; but, with the exception perhaps of Mr. Parker's Argyle lamp, all have been found inefficient and useless in practice, and have been long since quite forgotten. One may indeed occasionally meet with a stray

invention of this kind, but they are very rare, and but little known even by makers in London, being absolute mysteries to all others except those to whom they belong. Of the best of these contrivances which I have met with I shall here mention a few, by way of pointing out their defects, and thus exhibiting the difficulties to be overcome in their construction; and I shall then proceed to show in what manner these difficulties are met and overcome by the apparatus I have to describe.

7. Mr. Parker's Argyle lamp, which I have just mentioned as one of the most successful speculations in this way, is constructed, I have no doubt, upon the same principle as the one I shall have to describe; but the necessity for closely packing all the parts together, and of reducing the dimensions to such a size as to suit it to table purposes, have given it a complexity which renders it difficult to understand and manage properly; whence very few indeed of those sold by him have ever had a fair trial, and having often, perhaps, failed through the stupidity and want of attention of ignorant servants, have ruined the character of his invention. There is, besides, an important deficiency in them which is essential to complete success, owing to their being provided with no means for adjusting themselves to temperature, so that a lamp removed suddenly from a cold room near a hot fire is liable to overflow and be put out. In addition to which it is a practical inconvenience that a great part of the oil put into it can never be removed, except by taking it to pieces and unsoldering a plate of metal covering an aperture left for that purpose.

8. Mr. Marcell's lamp, in which the oil is expelled from a reservoir up the tube for supplying the burner by means of air condensed by a syringe, is liable to the above defect of want of adaptation to different temperatures, just referred to in regard to Mr. Parker's; and the expansion which occasions overflow being that of condensed air, the effect of heat is so sudden that the oil sometimes rushes out in a jet, inundating the table, and perhaps discharging its contents upon persons in its neighbourhood.

9. Another kind of lamp is that in which an outer column of a heavier fluid balances an inner one of oil, which, according to the difference of their specific gravities, is of greater height, and thus stands some distance above the level of the reservoir. The French make use of an hydrostatic lamp of this description, in which a solution of sulphate of zinc is used as a balance; and many other fluids have been tried, all subject to the same defects. These

are, first, that since it is absolutely essential to the well burning of a lamp that the oil be continually maintained at the precise level in the burner (called the "flow") to which it has been adjusted by the maker, any change in the specific gravity of the oil used introduces a corresponding change in the "flow," which, if not met by a corresponding adjustment, would completely ruin the effect. Secondly, that the balance, even if it should be correct at first, does not *continue* completely to answer the intended purpose of raising the oil to the required level, since, as the quantity of the latter diminishes and gives place to the balancing liquid, the height of that liquid as a column is necessarily lowered, and with it the height of the oil it counterbalances: thus, after burning a short time, the lamp becomes dim, and in a few hours would go out, were not the evil in some measure extenuated by forming the upper part of the balancing column of very large area, so as to enable it to supply a considerable quantity without a very serious depression. This will be more easily understood by reference to figure 1, Plate VI. where $a\,b$ represents the surface of the column of any heavy fluid, whose altitude is measured by the height $c\,d$. This at first balances a taller column $h\,e$ of oil, the point h being that at which the consumption ought to take place. After a quantity of the oil, however, has been removed at h, it is evident that, as its place must have been supplied from below with oil forced up by the pressure of the column $c\,d$, its abstraction must have been followed by a lowering of the surface $a\,b$ to some other level, such as f. But the column $f\,d$ is no longer a balance for $h\,e$, and will only support a shorter column, such as $g\,e$. Again, there is another cause for a gradual falling off in the effect, arising from the shortening of the *potential* altitude of the column $c\,d$, as part of its fluid rises in the pipe $h\,e$; for the total heights of the two columns being in the constant inverse ratio of the specific gravities of the two fluids, the excess of the lighter one, or the space $h\,a$, bears a constant ratio to the length of the column $c\,d$, as long as the whole of that column operates as a balance; but when a part of its effect is neutralized by the counterbalance occasioned by the ascent of a portion of it in the opposite leg, say, for instance, to the point i, the differential space $h\,a$ will be diminished, till it be in the same proportion to the remaining or potential part $f\,k$ of the column $f\,d$, as it before bore to its entire length.

10. The necessity for the constant maintenance of the flow of the oil at the exact point suited to the burning of the lamp has been the grand impediment

in all the hydrostatic contrivances of this kind which I have seen, no method having been discovered of freeing them from the defects just referred to, so that the lamps supplied by them necessarily lose their efficiency for want of a full supply, after burning for a short time. In regard to those lamps also in which the oil is forced up the tube of supply by the pressure of confined air, or by any other means, there is the same difficulty, owing to the gradual depression of surface of the oil to be raised, and the consequent continual variation of the potential altitude and pressure of the column to be overcome. This was one of the first obstacles which opposed itself to the construction of the lamp now to be described, and the mode by which it was overcome will be best explained in a detailed description of the whole contrivance.

11. The principle of the lamp is the well known one of the Hungarian machine, or of Hiero's fountain; and as this has already been pointed out by scientific authors as applicable to the purpose for which so many other schemes have been tried in vain, it is the more surprising that it should never hitherto have been rendered practically available. In its simplest form the following is the theory of its action: A (fig. 2) is a cistern open at the top, and communicating by the pipe *b* with a close vessel C, which latter is air-tight. There is a communication also from C to another vessel D, also air-tight, but containing the fluid to be raised up the tube E, which is inserted at the top of it, and dips into the fluid very near to its bottom. The bottom of the tube *b* being recurved, and of very small diameter, permits the water from the reservoir A to flow into C without suffering the air to escape. A condensation therefore takes place in C, and also at the same time in D, by communication, and this condensed air pressing on the surface of the fluid in D causes it to rise up the tube E till the pressure of the raised column E is equal to the pressure of the descending column *b*. In constructing a fountain upon this plan, a jet is substituted for the pipe D E, and the issue of water is prevented until previous condensation has taken place to the full extent. It is evident that the jet will merely continue to play as long as the water in the cistern A lasts, or until either the vessel C has become full, or that at D empty; and as it gradually reaches this termination, it is not of any great consequence whether the perpendicular rise of the stream be somewhat diminished or not; but in adapting the principle for the supply of oil to an Argand lamp, it is of so much consequence that, as the consumption takes place, the "flow" should be invariably maintained at the exact level suited to it, that

Plate VI.

the $\frac{1}{10}$th part of an inch either in excess or defect would make a serious difference in regard to its efficiency. Thus specific contrivances become requisite, to obviate the various causes of irregularity before referred to, which necessarily increase the number of parts, and give it an appearance of complexity; and this evil was unfortunately very much further enhanced in the pattern I caused to be made, from my desire to accommodate all the parts to the external figure I had assumed, and also to conceal the internal structure from the scrutiny of those to whom it was to be exhibited.

12. A representation of the lamp is given in Plate V., which contains (fig. 1) the elevation, and (fig. 2) the section. In the latter,[1] A is a reservoir, upon the principle of the bird-cage fountain, having a vent at a. This reservoir fits loosely into the upper half of the head of the pillar, being of a round form, but pierced in the centre by a circular aperture, through which passes a large thick pipe shown at D ($x\ w\ y\ z$), having a stop-cock and joint just above it, by which it is connected with the vertical tube $p\ r$ (fig. 1) supplying the lamp, and which latter I shall call the "supply pipe." When the reservoir is to be charged with oil, and the lamp used, the joint is unscrewed, and the reservoir A, after being filled, is dropped into its place over the pipe D and the stop-cock, and rests securely upon a partition forming the top of another close vessel C, presently to be described, (into which the pipe D also passes). By means of this reservoir A, and its vent a, a constant supply of oil is kept up in a tube B, and this is invariably maintained at the precise level of a, as long as the oil in the reservoir lasts. The tube B descends down the shaft of the column, and is soldered into an air-tight vessel represented by F, with which it communicates by an opening, which will be more particularly described hereafter, but the essential property of which is, that it permits the oil to flow *into* the vessel B, but will not suffer any air to pass *out*. Therefore, on pouring oil into the tube B, it will descend and continue to flow into the vessel F, till the air, finding no escape, becomes so much condensed as to resist the inward pressure of the oil composing the "balance column" B, and then no more could enter. Should any part of the air thus compressed be by any means suffered to escape, the consequence would be that, the tension of the remainder being

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[1] It ought to be especially mentioned that in the section the oil is shown occupying different parts; that mode having been adopted in order that its passage from one to the other might be more distinctly traced.

diminished, it would no longer resist the balance column B, which would again force its way into F until equilibrium were restored. It must be recollected also that the tension of the compressed air is always *exactly* equal to the pressure of the balance column B; and therefore, as long as the altitude of that column is, by means of the fountain reservoir and its vent a, maintained invariable, this tension will be absolutely *constant*. Now the condensation extends to the top of the air-tight vessel C, with which a communication is open through the condensed air-pipe m and the large inverted tube $x\,y\,z\,w$, through which latter a pipe n called the "supply pipe" passes, reaching so as nearly to touch the bottom of C.

13. Hence the pressure generated in the vessel F causes the oil to rise up this pipe n to a height exactly equal to the "balance column," where it is constantly supported at a point so adjusted as to be the proper "flow" of the lamp attached to it. To obviate the difficulty which has been before referred to (in par. 10), arising from the gradual depression of the surface of the oil in C, by its continual abstraction to supply the consumption of the lamp, the following contrivance is adopted. The condensed air does not communicate directly with the whole interior surface of the oil, but the pipe conveying it passes up through the bottom of the vessel C into the wide tube $x\,y\,z\,w$ before alluded to, which is 1 inch internal diameter, and is soldered air-tight into the cover of C, descending within $\frac{1}{10}$th of an inch of its bottom, and rising a couple or more inches above it. This tube ($x\,y\,z\,w$) I shall call the "cap." The condensed air first communicating with the interior of this cap occupies its whole contents, driving out the oil up the supply pipe to make room for it. The whole interior of the cap, therefore, is filled with condensed air, down to the level of a notch or vent at x, at which point it can escape into the upper part of the vessel C. Hence the surface of the oil underneath the cap, including that which surrounds the bottom of the supply pipe, can never rise higher than the level of the vent x, at which level it constantly stands, subject to the invariable pressure of the tension of the air in the vessel F. Whenever more oil is required to be forced up the supply pipe to feed the consumption by the lamp, it is not raised by lowering the surface x, for this would be impossible; but the instant that a sensible diminution takes place in the gravity of the supply column, the expansion of the condensed air superincumbent upon the oil in the vessel C, forces it up the tube from the body of the vessel, to supply the deficiency,

while a corresponding expansion of the condensed air in the cap forces a bubble of air by the vent x, which restores the condensation; the tension of the air in the cap being restored by a transference from the vessel F, whose tension is repaired by the entrance of oil from the balance column B. Thus will it be seen that while the tension or raising force is maintained constant under all circumstances, as explained in paragraph 12, the weight of the column of supply, or force to be *overcome*, is also at all times precisely the same; since it is always expressed by the height of a column of oil standing at a fixed level above the surface at x, which surface is subject to no change, as long as the supply of oil in the reservoir lasts.

14. In this form the lamp was first made and experimentally tried, and in so far as the above theoretical explanation is concerned, it was found to answer its intended purpose perfectly. In order to make sure that the supply was constantly maintained, and at exactly the same level when the whole quantity was nearly exhausted, as at first, I fitted a brass tube to the connecting screw p at the top of the stop-cock, and having first made it somewhat too long, cut it off at the precise spot at which the water (with which the experiments were first made) stood. By now tightening the connecting screw p a little, the water stood with a convex elevation in the centre, of a semicircular form; a little bit of flannel being now placed on the top, and allowed to hang over on each side, so as to act as a syphon, drained the reservoir *completely*. The same effect was produced when the water was drawn off by a small syphon, the short leg of which dipped only the $\frac{1}{100}$th part of an inch into the top of the pipe; showing that the balancing power of the hydro-pneumatic series did not fall off, even at the very last, to such an extent as to shorten the column raised by $\frac{1}{100}$th of an inch.

15. At the time these experiments were made, however, I was led by them to discover a practical defect, to which I lost no time in applying a remedy. Previous to my observation of the evil occasioned by it, the bottom of the "supply pipe" had been made to terminate on a level with the vent x, and thus situated it answered its purpose fully, and drained the oil entirely down to that level; but the moment this was done, the condensed air gaining access to the bottom of it, rushed up the pipe, carrying the water or oil with it, spirting the whole of its contents about, while it gave vent to the whole of the condensed air in C and F. The remedy for this was very obvious, and was easily effected by prolonging the pipe, so that its lower end was much below

the level of the vent x, and this was done by forming a little well in the bottom of the vessel C (represented by $v\,u\,w$), which allows the bottom of the pipe to descend an inch or more below the point where it before terminated. As the tension of the condensed air is invariable, it is plain that, after the oil has been expended to the level of x, no more can be driven by it up the tube for the reason before explained, viz., that by the further descent of the surface x the potential altitude of the supply column would be increased, and its weight would thus be caused to exceed the pressure acting upon it. After making this slight alteration, therefore, no fault nor inconvenience from the above cause was met with; but there was still another practical difficulty to be overcome, which was found more formidable, arising from a cause which I have before mentioned as the chief defect in all the lamps yet made in which condensed air is used,—their want of adaptation to changes of temperature, and of which I had hitherto been ignorant.

16. All the experiments above detailed were only such as were of short duration, and when perfect success seemed by them to have been attained, the next step was to fit a burner to the apparatus, and, by using oil, to try its effects as a lamp. This was accordingly done, and the whole appeared at first to act perfectly. The various reservoirs being large, the lamp burned with great steadiness until the supply was exhausted, which generally required about 21 hours; but, after many repetitions, it was found that there was some latent cause of *irregularity* in its effects, since, though always equally charged at the first lighting, the supply sometimes only lasted 12 or 14 hours, and sometimes even less. The cause of this was discovered by my happening on one occasion to be present during the burning of the lamp, and hearing a bubbling noise in the inside, which lasted for a few seconds and then ceased. Up to this time the pipe B had terminated in the interior of the vessel F by a recurved jet of the form shown at f (fig. 2), and on investigating the cause of the accident, I found that the air vessels having become heated, the tension of the contained air had become so much increased as to overcome the pressure of the "balance column" B, which, giving way, had released the whole of the imprisoned air, after which a fresh descent of oil followed, to restore condensation. The most obvious mode of remedying this evil was evidently similar to that applied to prevent the discharge spoken of (par. 13); but upon considering this I perceived that such a remedy would entirely vitiate the principle of the contrivance, the grand object of which was to

Plate VI.

maintain the pressure *invariable* at all times, while the plan referred to would merely provide a check upon the consequences of its increase, by creating an extra resistance to act against it in its more compressed state. What was required was plainly some mode by which, on the occasion of exposure to heat, the vessel F might be made to *relieve* itself of its superabundant air, so as to prevent the tension ever rising, and yet not suffer more to escape than was necessary for that purpose; and the mode by which this was finally accomplished is the following:

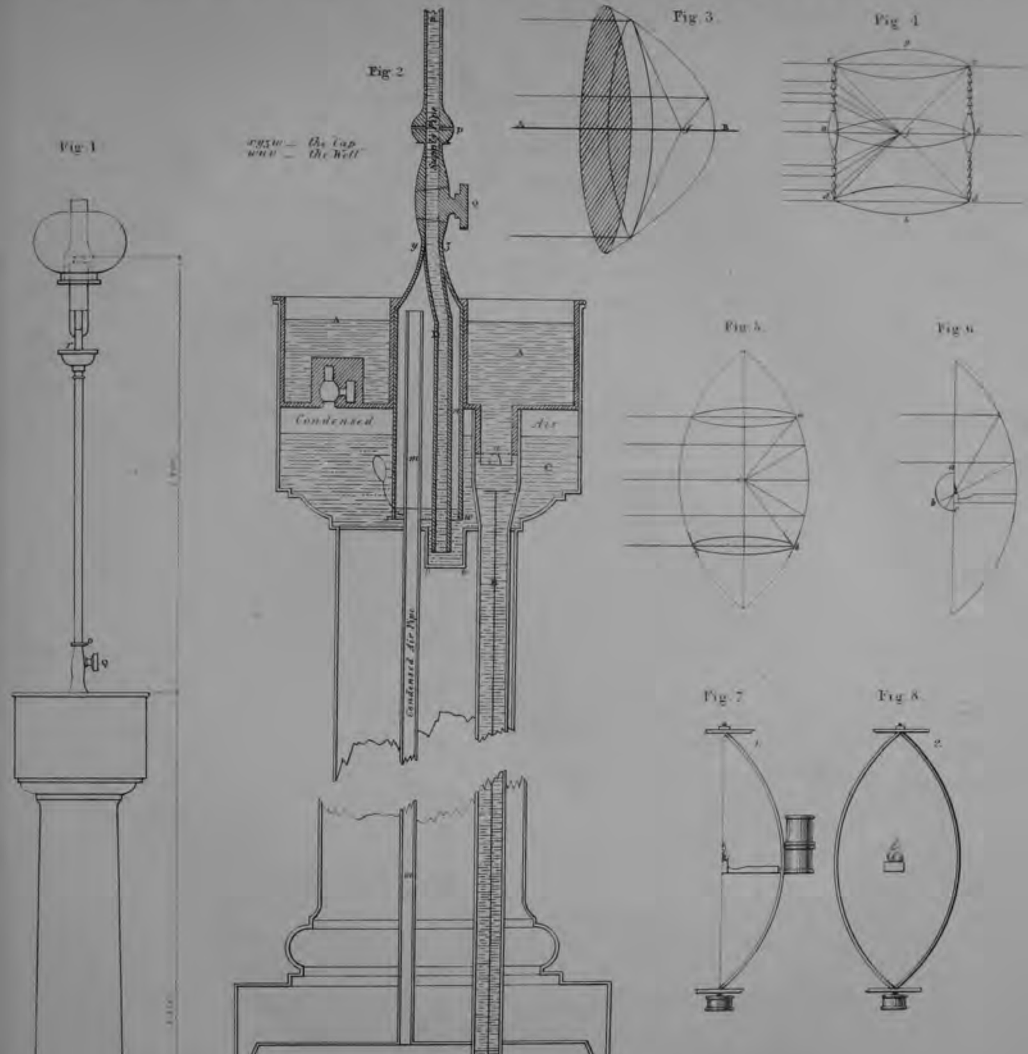
17. The tube B was taken out, and a new one inserted, which was of 1 inch diameter, and divided along its whole length into two semi-cylindrical spaces by a partition which fitted loosely into its place, and was soldered in at one or two points down the tube, having considerably large interstices between it and the sides in the other parts: thus, in spite of the partition, there was a free communication between the opposite portions of the tube, which was further increased by punching holes of $\frac{1}{10}$th of an inch diameter, about 1 inch apart, all the way down the partition. The object of this scheme was to prevent any bubbles of air, in their escape from F through the tube B, filling the whole of its interior, and thus relieving the air vessel F from the weight of oil pressing into it; while there should still be a free communication between the opposite parts, to allow the place of any bubble entering at one side to be immediately filled, as it passed upwards, with oil from the opposite side of the partition. At the foot of this new tube B a new arrangement was substituted for the recurved jet before applied; the pipe was closed at the bottom, and a vertical slit or opening cut adjacent to it on one side, in front of which a trough or cistern was formed by soldering on a piece of tin in advance of it, to which the same plate that closed the tube also formed the bottom. This arrangement is represented in the section and elevation exhibited in fig. 3, Plate VI in which *b d* represents the trough, *a e* the vertical slit or opening, and *c f* the partition or diaphragm crossing the tube, which, for the further security of free communication between the two parts, does not reach the plate closing the bottom of the tube, but stops short at *c c c*, about $\frac{1}{2}$ an inch from it. The upper edge of the slit or aperture *a* is curved, and the highest point of this curve is exactly $\frac{1}{8}$th of an inch below the lip *b* of the trough in front of it. When the lamp is charged, and during its operation, the oil entering by the aperture *a* flows over at *b* into the air vessel; but when any expansion from heat takes place, no sooner has the increased pressure driven the oil to the depth of $\frac{1}{8}$th

of an inch below its usual level, than it finds an escape through the aperture *a*, and up one division of the tube B. By reason of the partition above described, it is incapable of filling the whole tube, and thus keeping the passage open, so as to escape altogether; and as the oil occupying the trough is never relieved from the weight of any part of the balance column, which is maintained unchanged by the pressure from the *hinder* part of the tube, the level of the oil at *a* is restored the moment the escape of air has been sufficient to compensate for the increased tension, and every thing proceeds as before. On the application of cold instead of heat, the tension of the compressed air in F being merely diminished, no consequence ensues, except the descent of a small quantity more of oil into the vessel to restore equilibrium, so that thus the instrument is capable of adjusting itself to whatever changes of temperature it may be subjected.

18. This is the last alteration which has been found necessary to the final completion of the apparatus; and as it has now been subjected to many trials, and long continued experience, which have fully established its efficiency, I may venture to recommend it with confidence wheresoever it may be of use. The total height to which the oil is raised above the level of the reservoir of supply is about 2 feet 6 inches. This is very much more than would probably be ever required in practice, but I was desirous in the first exhibition of the scheme to anticipate all possibility of objection as to its capability of meeting the most difficult cases. The same principle indeed may be applied indefinitely, and the oil supplied at any height and in any quantity whatever, provided the different parts of the apparatus be made sufficiently capacious and strong.

19. In order to apply a test to its capability of bearing sudden additions of heat, I made many endeavours to cause it (had it been possible) to release its condensed air, by wrapping long strips of very hot flexible zinc plate round the various parts of the column; but although, previous to the alteration, a discharge of the confined air might have been produced by the mere application of the warmth of the two hands, no effect was occasioned afterwards beyond the successive release of a few small bubbles; and no kind of irregularity has ever since been observed in its action. It was for two or three months daily lighted at dusk, and burned till near midnight, at Mr. Deville's establishment in London, and whilst there inspected by many who were curious about these subjects. My intention in constructing it was to have

ELEVATION AND SECTION OF A NEW HYDRO PNEUMATIC LAMP.



DRAWINGS OF A FLAG STAFF LIGHT *Constructed for* THE PORT OF COCHIN.

FRONT VIEW.

Fig. 6

BIRDS EYE VIEW OF TOP.

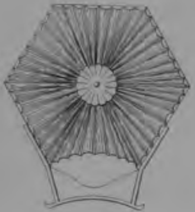
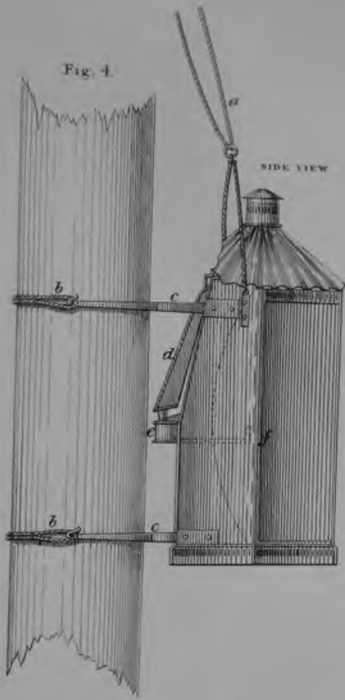


Fig. 4.

SIDE VIEW



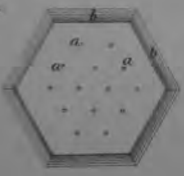
- *a* *Haul yards for hoisting and supporting the lantern*
- *b* *Lashings for do*
- *c* *Arms for securing it in an upright position.*
- *d.* *Oil reservoir*
- *e* *Cistern*
- *f.* *The burner*

BACK VIEW

Fig. 5

il reservoir
istern for do
l cover to protect the Cistern. b
ins for supporting the reservoir

PLAN OF THE BOTTOM



ir holes
Passage for the air to
a side grating

Fig. 1.

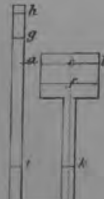


Fig. B

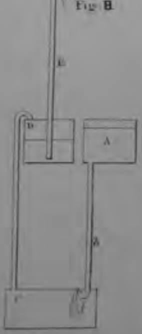
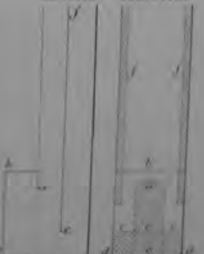


Fig. 3.

SECTION ELEVATION



FEET

exhibited it to the Honourable Trinity Corporation, to whom it was a desideratum, and by whom various unsuccessful projects for the same purpose had already been rejected; but the very great pressure of other business under which I laboured at the time of its completion occupied my attention so fully whilst in London that I had no opportunity of carrying this purpose into effect.

No. V.—*Remarks and Experiments on various Woods, both Foreign and Domestic. By Lieutenant* NELSON, *Royal Engineers; the late Captain* YOUNG, *Royal Engineers; Sir* ROBERT SEPPINGS; *Captain* SMYTH, *Royal Engineers; and Lieutenant* DENISON, *Royal Engineers.*

THE experiments on the strength of various descriptions of timber, both Foreign and British, as shown in the following Tables, have been made at different times by Officers anxious to establish something like a term of comparison between the timber generally employed in our different colonies and that in common use at home: the necessary experiments on the latter have been carefully made by Mr. Barlow and others, and the values of the constant multipliers determined accurately on a mean of many experiments.

In arranging these experiments, I have kept those of each individual distinct, but at the conclusion I have added a Table containing an abstract of all the results. The first column of this Table contains the names of the different woods experimented upon; the following ten columns contain the specific gravities and values of $S = \frac{l\,W}{4ad^2}$, as determined by five different observers; and the two last columns show the mean of the quantities thus determined.

I have taken the results of Mr. Barlow's observations from the second edition of his work on the strength of materials, and I am disposed to place the greater confidence in the results shown in the before-mentioned columns of mean values, from their near coincidence with those determined by so well known and so accurate an experimentalist.

Notices on various Sorts of Timber. *By Lieut.* NELSON, *Royal Engineers.*

WHEN I first commenced these Notices, they referred exclusively to such timber as was used at Bermuda in the Admiralty and Ordnance departments, with a view of ascertaining the merits of each description, and of being thereby able to reject such as rendered the 'Charge' and 'Demand' unnecessarily complicated.

During the course, however, of the many tedious and laborious experiments requisite, different friends kindly favoured me with contributions of materials and verbal information. What I am now enabled thus to offer, as obtained from various persons, and at different places, is only a partial completion of a scheme which stood originally thus.

To obtain information with reference to—

1st.

Strengths (to be exhibited in a tabular form).	Transverse (S).	The strain acting collectively on the fibres, and at right angles to them.
	Longitudinal (C).	The strain acting in the direction of the fibres, to snap them across: commonly called 'Direct Cohesion.'
		The strain acting also in the direction of the fibres, but separating them by sliding off one part of the wood from the other.
	Lateral.	The strain acting in the direction of the fibres, to crush the wood, and destroy this lateral cohesion: supposed to be the same as C.

2ndly. Such remaining considerations as

- Texture.
- Weight.
- Durability.
  - Decay from moisture.
  - ,, dry rot.
  - ,, marine animals.
  - ,, land do.
- Economy.
  - Immediate expense.
  - Convertibility and waste, with reference to departmental purposes.

I soon found, however, that such a project was not to be executed by persons liable to such frequent changes of place as the Officers of our corps: it would require the long-treasured and oft-repeated observations of the resident for years[1] to do full justice to the matter. The following must therefore be considered only as a humble contribution to the General History of Woods, and be received at such value as may be allowed after reading the above respecting the circumstances of the experiments.

In addition to my own, consisting of—

The Transverse Strengths of 21 sorts of timber, obtained from 3065 deflexions separately noted during the trial of, altogether, 94 specimens;

The Direct Cohesive Strengths of 20 of the above, obtained from 158 specimens;

And such other information as I could obtain,—we are enabled, by the kindness of Mrs. Young, to bring forward the general notes and records of experiments of our late brother officer, Captain Young, R.E., at Demerara;

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[1] No one can engage in such experiments without soon observing the very arbitrary values assigned to the deflexions, &c., &c., where only a few minutes can be allowed between the successive additions to the straining power. I am not, however, aware of any advisable medium between this extreme and that of conducting the whole in a perfect and leisurely manner. But, to do this, let us reflect on the length of time required to report completely on any one subject, when each weight is allowed the full time of many days to produce its final effect,—the hours occupied altogether in unloading and reloading in every instance,—to watch the state of elasticity, neutral axis, &c.,—and in registry, reflection, and computation: if, as might well be the case, several months would elapse ere we could thus do justice to but one specimen tried in but one way, where would be the end of the expenditure of time and money, when we connect the above with all the following, as varying factors of combination?—*e. g.*

The different points to be ascertained,—when the specimen is fixed at one, or supported at both ends, and these last fixed or free,—when the weight is at the centre, or when uniformly diffused, &c.

The unequal strengths of specimens from the same tree, as taken from heart or near sap, from top or butt.

The numerous varieties there are in that species.

The many genera and classes of the same, in a botanical sense; all liable to be affected by differences in country, climate, and locality; and some by the ignorance or dishonesty of contractors.

And where, after all, the equivalent benefit for *thus* pursuing a subject so fluctuating in the values of its detail results? Experiments on a tolerably extensive scale, with reasonable guards, are surely sufficient for practical purposes.

as well as those made by him subsequently at Bermuda, by order of Lieut.-Col. Tylden, R. E., who was not then acquainted with the results of my own performances. Lastly, I have obtained a series of experiments made by order of Sir Robert Seppings on 22 sorts of wood, conducted by Mr. Moore, Timber Measurer, Chatham Dock-yard. Twelve pieces of each kind were broken; only the extremes and averages of each set are now given, and on these averages, for want of details, S has been computed.

EXPERIMENTS ON TRANSVERSE STRENGTHS.

The specimens selected may be generally taken as the average of the usual qualities supplied to the Admiralty and Ordnance. They measured about 5 feet or 6 feet in length, and 2 inches[2] in breadth and depth. This series was conducted much in the manner described by Mr. Barlow.

To prevent any variation in the distance between the supports by the crushing of the edges of the trestle-heads, small iron plates were screwed to these last, one on each, just where the piece to be tried would rest. The trestles were, furthermore, kept steadily in their places by means of battens.

Unless otherwise specified, the points of support were 4 feet apart. The ends were free. The deflexions were read off to within $\frac{1}{100}$th of an inch. The weights were suspended at the centre, and added successively at intervals of about 4 minutes: they were usually $\frac{1}{4}$ cwt., sometimes $\frac{1}{2}$ cwt., according to circumstances; but all were carefully determined and regularly noted.

REMARKS ON THE TABLES.

Column 1.—The number of the experiment, for reference.

Columns 3 and 4.—The average of the depths and breadths, taken at the ends and centre of each piece to hundredths of an inch; and here I must observe, that in the exhibition of so many decimals, I lay no claims to hyper-accuracy, but do so to show that no pains were spared, and to give greater facilities in the detection of error.

Column 5.—Could time have been allowed, a much smaller weight would, no doubt, have done; still, however, all the experiments were carried on under like circumstances, and therefore their relative value remains perhaps unaltered. Where it occurred, the weight at which warning was given is noted, as affording a better datum for S to those who wish to be nicer in their computations.

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[2] Given with greater precision in the Tables.

Column 6.—This is, like column 5, apt to be so arbitrary, that as a corrector for those who care to calculate the representatives of elasticity, I have added

Columns 7 and 8, as well as the 2nd series of weights in column 7, showing what produced a deflexion of $\frac{1}{100}$th of the length of the specimen between the props; as for instance in No. 1, the deflexions became quite irregular after 1·25 in., produced by a weight of 1405 lbs., whilst 569 lbs. gave a deflexion of ·48 in., being $\frac{\text{48 inches, the distance between supports}}{100}$. These last are tolerably exact.

Column 10.—The value of such researches as these depending so greatly on the care and industry of the experimenter, I have thought it only due to the work to exhibit the number of weights added successively, stating that not only was the deflexion noted at the time of so doing, but that I preserve the original papers carefully, to meet any observations with which my readers may be pleased to favour me.

	No. of experiment.	Specific gravity.	Transverse dimensions.		Breaking weight.	Ultimate deflexion.	Weight giving a deflexion $= \frac{1}{100}$ length.	Weight at which the deflexions ceased to be at all uniform.	Corresponding deflexions.	Value of S from formula $S = \frac{W\,l}{4\,a\,d^2}$	No. of weights applied successively.	Detail Remarks.	General Remarks.
			Mean depth.	Mean breadth.									
			in.	in.	lbs.	in.	lbs.	lbs.	in.				
AFRICAN.	1	984	2·038	1·991	1741	1·9	569	1405	1·25	2527	62	Bent with great uniformity; gave warning at 1629 lbs. The 62nd weight remained on 5 minutes before it broke, and in so doing gave a beautiful exhibition of the neutral axis at about $\frac{2}{3}$ depth above the lower side.	The so-called African Oak or African Teak. All considered as choice specimens. S, from Mr. Moore's experim^nts = 2522.
	2	1007	2·027	2·013	1825	1·8	592	1601	1·45	2648	65	Gave warning at 1853 lbs.	
	3	1040	2·017	2·0	1797	1·9	639	1545	1·25	2650	63	Gave warning at 1741 lbs.	
	4	1004	2·021	2·013	1685	1·7	604	1573	1·5	2459	59	Gave warning at 1657 lbs.	
	5	964	2·01	2·0	1981	2·2	631	1461	1·25	2942	65	Broke without warning: an excellent specimen.	
	6	914	2·063	1·985	1181	1·6	391	1013	1·25	1677	41	Gave warning at 1153 lbs.: a very dry specimen, which was evidently beginning to fail, though there was no dry rot.	
		985								2484			
ASH. American.	7	618	1·98	1·98	1101	2·0	390	642	·8	1702	21	Good specimen; gave warning at 1017 lbs., then fell rapidly, and broke at 1101.	Mr. Barlow's English Ash, specific gravity 760, gives S = 2026.
	8	580	2·0	1·85	803	1·8	298	478	·8	1300	16	Tolerable specimen; gave warning gradually at 751 lbs.	
	9	636	2·0	1·85	1017	3·0	271	534	·925	1649	19	Do., as No. 8.	
		611								1550			
BEECH. American.	10	762	2·05	1·98	1241	2·7	428	697	·85	1790	24	Tolerable specimen; gave warning at 603 lbs.	Mr. Barlow's English Beech, specific gravity 696, gives S = 1556.
	11	788	2·0	2·0	1073	1·9	416	642	·775	1609	20	Good specimen; gave warning at 1017 lbs.	
	12	765	1·98	2·0	1157	2·6	428	534	·625	1770	24	Do., broke well and gradually.	
		778								1723			
BIRCH. Black American.	13	764	2·0	2·0	1521	1·7	540	1241	1·275	2282	30	Very good specimen; warning at 1270 lbs., broke suddenly at 1521 lbs.	
	14	646	2·0	1·98	1297	2·8	390	697	·875	1965	26	Good specimen; broke suddenly at 1297 lbs.	
	15	720	2·0	2·0	1017	2·7	487	642	1·1	1525	24	Do., broke with a long scarf, and gradually.	
	16	634	2·0	2·0	1129	2·5	536	803	1·17	1693	25	Do., broke well, but with little warning.	
	17	645	2·0	2·0	1185	3·3	470	642	1·1	1777	25	Do. Do. Do. All taken from the same piece.	
		682								1848			

	No. of experiment.	Specific gravity.	Transverse dimensions.		Breaking weight.	Ultimate deflexion.	Weight giving a deflexion = $\frac{1}{100}$ length.	Weight at which the deflexions ceased to be at all uniform.	Corresponding deflexions.	Value of S from formula $S = \frac{W l}{4 a d^2}$.	No. of weights applied successively.	Detail Remarks.	General Remarks.
			Mean depth.	Mean breadth.									
			in.	in.	lbs.	in.	lbs.	lbs.	in.				
CEDAR.—Bermuda.	18	..	2·55	1·575	1064	1·7	354	672	1·04	1403	20	4 feet 6 inches between the supports; young wood; felled only 4 months; cut and seasoned only 2 weeks: a tolerably clean specimen; gave warning at 952 lbs.	All may be taken as good characteristic specimens.
	19	..	2·536	1·55	1100	2·1	510	672	·09	1494	22	4 feet 6 inches between the supports; not quite so clean a specimen as No. 18; but both good average subjects. This was intended as an experiment with the ends fixed, but the nails drew before it was half loaded: it is therefore considered as having the ends free; warning at 896 lbs.	
	20	714	2·0	1·98	642	1·3	412	422	·52	973	12	A knotted piece, but not more so than is usual with this wood. At 478 lbs. cracked at a small knot 4 inches from the centre, and afterwards broke there.	
	21	777	1·98	1·94	857	1·2	368	857	1·2	1352	17	Clean specimen for cedar; little warning, broke well.	
	22	752	1·96	1·96	1101	1·8	312	697	1·07	1755	21	Not so good as 21, but better than 20.	
		748								1395			
CEDAR. Guadaloupe.	23	739	2·0	1·9	1353	2·6	412	857	1·07	2136	27	Clean specimen; broke with a good scarf, but no warning.	
	24	754	1·96	1·95	1241	2·3	480	803	0·92	1988	25	Do. Do. Do.	
	25	776	1·95	1·95	1241	2·2	417	751	0·92	2009	25	Do. Do. Do.	
		756								2044			
ELM. Canada.	26	703	2·046	2·008	1377	3·1	230	761	0·9	1966	38	The great uniformity of texture in this wood presented no irregularities for comment during the straining.	
	27	700	2·05	2·037	1265	2·5	486	649	1·5	1799	35		
	28	712	2·037	2·03	1321	3·5	483	673	0·8	1891	36		
	29	685	2·03	2·025	1265	3·5	451	621	0·74	1819	35		
		700								1869			
	30	854	2·0	2·0	1330	3·0	390	857	1·75	1995	27	Good piece, but with a small knot 12 inches from centre; gave warning at 1129 lbs., broke at 1330 equally at the knot and centre.	Mr. Moore's experiments give for Hiccory S = 2192, sp. gr. = 758.
	[illegible]	[illegible]	1·98	1·97	857	1·2	390	590	·7	1332	16	Indifferent specimen; $\frac{2}{3}$ths sap.	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	·975	[illegible]	[illegible]	Good specimen; warning at 642 lbs.	Capt. Young's experi-

	No. of experiment.	Specific gravity.	dimensions.		Breaking weight.	mate deflexion.	deflexion = $\frac{1}{100}$ length.	flexions ceased to be at all uniform.	Corresponding deflexions.	from formula $S = \frac{W l}{4 a d^2}$.	No. of we[...] plied succ[...]	Detail Remarks.	General Remarks.
			Mean depth.	Mean breadth.									
			in.	in.	lbs.	in.	lbs.	lbs.	in.				
LIGNUM-VITÆ. White American.	34	1110	2·02	2·0	1129	1·5	569	1017	1·075	1660	22	Tolerable piece, though somewhat worm-eaten; gave warning at 963 lbs.	A so-called Lignum Vitæ; *perhaps* only a local name. An experienced workman at Devonport calls it Sabaco wood.
	35	1054	2·08	1·98	1689	1·3	649	1465	1·1	2366	33	Good specimen, but broke short without warning at a worm-hole; but for this, it would have borne 1 cwt. more.	
		1082								2013			
MAHOGANY. Nassau, or Horseflesh.	36	788	1·82	1·82	478	1·2	170	478	1·2	991	9	Looked well, but broke short at 478 lbs.	Mr. Moore's Honduras Mahogany, with sp. gr. 531, gives S = 1503.
	37	834	1·93	1·9	1353	1·6	427	642	·75	2294	28	Good specimen; gave warning only at 1297 lbs.; broke suddenly at 1353 lbs.	
	38	815	1·89	1·82	534	1·2	190	310	·8	1972	10	Broke at a knot 6 inches from centre.	
		812								1752			
MANGROVE. Black Bermuda.	39	1122	2·0	1·95	1017	2·7	316	642	1·1	1565	19	Good specimen; broke very gradually at a small knot 6 inches from the centre.	
	40	1134	2·1	1·98	1129	2·5	367	803	1·17	1545	23	Little warning, but broke well, though not so well as 39.	
	41	1099	2·01	1·77	1185	3·3	306	642	1·1	1988	24	Do. Do.	
		1188								1699			
MANGROVE. White Bermuda.	42	846	2·1	2·08	1630	2·9	510	803	·75	2132	39	Good specimen; warning at 1157 lbs.; somewhat disturbed on the trestles by a slight warp, which also gave an unequal bearing.	
	43	1011	2·03	2·0	1240	2·15	450	803	·875	1829	26	Good specimen; warning at 963 lbs.; broke at a small knot.	
	44	995	2·1	2·1	1540	2·0	483	803	·775	1995	35	Do., warning at 1240 lbs.	
		951								1985			
OAK. White American.	45	716	1·93	1·92	1300	2·0	370	751	1·025	2181	30	Good specimen; warning at 1240 lbs.	Mr. Barlow's Canada Oak, sp. gr. 815, has S = 1766. Mr. Moore's American Oak, sp. gr. 815, gives S = 1699. Bad as the character thus given of American White Oak is, it is hardly more than it deserves.
	46	..	1·95	1·92	963	2·0	331	478	·75	1582	18	Broke soon at a knot; no specific gravity mentioned, 46 and 47 having been at first supposed to be too unsatisfactory; they were, however, recorded, as No. 50 did not give a very much better result.	
	47	..	1·93	1·93	803	2·0	426	642	·775	1342	15		
	48	666	2·05	2·03	1120	1·9	286	590	1·0	1580	22	Good-looking specimen, but slightly tainted with dry rot; broke with little warning.	
	49	600	2·00	2·03	1297	2·0	349	478	·65	1916	26	Do. Do. broke with a long scarf.	
	50	600	2·17	0·86	534	1·8	211	366	·9	1582	10	A slab specimen from 48.	
		645								1699			

	No. of experiment.	Specific gravity.	Tranſverse dimensions. Mean depth.	Tranſverse dimensions. Mean breadth.	Breaking weight.	Ultimate deflexion.	Weight giving a deflexion $= \frac{1}{100}$ length.	Weight at which the deflexions ceased to be at all uniform.	Corresponding deflexions.	Value of S from formula $S = \frac{W l}{4 a d^2}$.	No. of weights applied successively.	Detail Remarks.	General Remarks.
OAK. Basket, American.			in.	in.	℔s.	in.	℔s.	℔s.	in.				
	51	937	1·83	1·69	910	3·5	244	478	1·15	1929	17	Fair specimen; warning at about 400 ℔s.; broke with a long scarf.	
	52	947	1·81	1·68	697	3·6	207	310	1·6	1339	13	Broke at a large worm-hole, to which this wood seems to be subject.	
	53	937	1·8	1·6	803	3·0	..	478	1·3	1859	15	Do. These 3 specimens were all from the same log.	
		940								1709			
OAK. English.	54	1033	2·002	2·009	1265	2·2	430	873	1·0	1885	45	These, from 54 to 59, were given as very choice specimens of Oak for treenails; the wood was rather green, though 3 years felled; the pieces were riven, and merely planed down to the dimensions given, so as to interfere as little as possible with the longitudinal fibres.	
	55	992	2·033	2·017	1265	2·3	474	873	0·95	1821	45		
	56	997	2·023	2·029	1265	2·2	462	761	0·84	1829	45		Mr. Barlow's English Oak, sp. gr. 934, S = 1672. Mr. Moore's English Oak, sp. gr. 810, S = 1919.
	57	1066	2·027	2·013	1181	2·0	513	733	0·72	1714	42		
	58	1085	2·008	2·021	1209	1·9	408	733	0·87	1780	43		
	59	1030	2·019	2·027	..	..	..	..	..	..		Broke at 929 ℔s., omitted therefore in S.	
		1034								1806			
	60	835	1·95	1·93	1265	3·3	337	481	0·65	2070	45	These two, 60, 61, were in all respects the same as 54 to 59, except that they were well dried.	
	61	879	1·98	1·94	1377	2·7	392	397	0·45	2173	46		
		857								2121			
	62	831	2·017	2·0	1181	2·3	424	593	0·7	1742	41	Nos. 62 and 63 were both of good well seasoned wood, but sawn instead of riven.	
	63	836	2·025	2·008	1041	2·1	381	565	0·75	1517	43		
		834								1629			
OAK. American. m, or Live Oak.	64	1120	2·029	2·004	1041	1·8	338	313	·86	1513	28		The nearest to this, in Mr. Moore's Tables, is English Oak, sp. gr. 810, S = 1919; all the rest are inferior, as far as S is con-
	65	1230	2·025	2·015	1433	2·4	424	565	·67	2080	35		
	66	1121	2·046	2·039	1265	2·3	393	313	·74	1780	32		
	67	1141	2·029	1·99	1489	3·8	429	313	·7	2181	36		
	68	1140	2·042	2·023	873	1·8	347	257	·62	..	24	Evidently a bad specimen, though it looked well.	
	69	1209	2·025	2·017	1209	2·2	368	453	·58	1756	31		

	No. of experi-ment.	Specific gravity.	dimensions. Mean depth.	Mean breadth.	Break-ing weight.	mate de-flex-ion.	deflex-ion $= \frac{1}{100}$ length.	flexions ceased to be at all uniform.	Corres-ponding de-flexions.	from formula $S = \frac{Wl}{4ad^2}$.	No. of wei plied succ	Detail Remarks.	General Remarks.
PINE. White American.			in.	in.	lbs.	in.	lbs.	lbs.	in.				
	70	422	2·01	2·0	910	1·8	316	534	·75	1351	16	Good clean specimen; broke short without warning.	The average of Mr. Moore's six North of Europe Firs is, sp. gr. 587, S = 1387.
	71	450	2·0	2·0	910	1·7	343	590	·8	1365	16	Do. Do.	
	72	432	2·0	2·0	910	1·8	357	590	·85	1365	16	Do. Do. All these from the same log.	
	73	480	2·008	1·99	1041	..	..	..	..	1557	28	Do. } No remarks made at the time of experiment.	
	74	480	1·98	1·97	985	..	..	..	..	1531	27	Do.	
	75	453	2·0	1·99	1041	..	..	..	..	1569	28	Do.	
		453								1456			
PINE. Red American.	76	568	2·0	1·98	1157	2·1	369	642	·8	1753	23	Snapped at the centre, though there was a knot 8 inches from it.	Although the colour of this wood quite supports the name given, yet it must not be confounded with the Pitch-pine or Torch-wood, which is still redder, being far more resinous, and, as I apprehend, much stronger. Mr. Moore's Red pine, sp. gr. 521, S = 1289. Mr. Barlow's Red pine, sp. gr. 657, S = 1341.
	77	656	2·0	2·0	1420	2·5	459	590	·6	2130	32	Good clear specimen.	
	78	639	2·0	2·0	1300	2·1	459	963	1·125	1950	28	Do., but broke remarkably short, and without warning.	
		621								1944			
SNEEZEWOOD. South African.	79	1080	1·975	1·97	2001	3·3	602	1768	3·05	3908	82	Supports 5 feet 0·2 in. apart in the clear; weights used were shot averaging 24·04 lbs. each; warning at 998 lbs.	A fifth experiment gave S = 2942; such strength as this Sneezewood possesses is very rare. These four experiments were made at Cape Town by order of Colonel Lewis, R. E.
	80	1080	1·975	1·97	1568	2·5	374	1359	2·19	3062	64	Do. Do. Do. Broke short and suddenly.	
	81	1054	1·237	1·008	576	1·9	..	..	..	3301	94	Supports 2 feet 11·31 in. apart in the clear; weights used were shot averaging 6 lbs. each.	
	82	1050	1·25	1·0	522	..	..	..	..	2949	86	Do. Do.	
		1066								3305			

	No. of experiment.	Specific gravity.	Transverse dimensions.		Breaking weight.	Ultimate deflexion.	Weight giving a deflexion $= \frac{1}{100}$ length.	Weight at which the deflexions ceased to be at all uniform.	Corresponding deflexions.	Value of S from formula $S = \frac{W\,l}{4\,a\,d^2}$.	No. of weights applied successively.	Detail Remarks.	General Remarks.
			Mean depth.	Mean breadth.									
			in.	in.	lbs.	in.	lbs.	lbs.	in.				
TEAK.	83	622	2·029	2·022	845	1·5	306	593	·92	1218	31	Broke very short without warning; evidently tainted with dry rot.	These having been given as choice specimens, I have reported their behaviour under straining just as it occurred. It would seem that Teak is liable to dry rot in this country. Mr. Barlow's Teak, sp. gr. 745, S = 2462. Mr. Moore's Teak, sp. gr. 709, S = 1964.
	84	721	2·025	2·013	1517	1·6	543	1349	1·27	2205	54	Broke without warning, but in long scarfs reaching ½ or ⅓ way on each side.	
	85	733	2·025	2·011	1489	1·5	616	1321	1·16	2167	53	Do. Scarf on one side reached ¼ way.	
	86	748	2·013	1·991	1321	1·5	563	1153	1·08	1965	48	Warning at 1209 lbs.; broke well at the centre; slight signs of dry rot.	
	87	793	2·029	2·012	1545	1·8	..	1321	1·35	2239	55	An excellent piece, yet it broke without warning; no dry rot.	
	88	719	2·002	1·973	1433	2·4	468	845	·9	2175	52	All heart pieces, though slightly knotted; which, however, did not much affect the breaking. All were slightly touched by dry rot, especially 88.	
	89	657	2·023	2·017	1097	2·4	316	565	·87	1595	39		
	90	732	2·025	1·979	1209	1·7	446	761	·85	1789	44		
	91	744	2·017	2·015	1181	2·1	391	593	·74	1729	38		
		719								1898			
YELLOW-WOOD. West Indian.	92	946	1·98	1·98	1185	1·6	342	857	1·075	1832	24	Indifferent specimen, rather curved, and much shaken; broke short without warning, with a good scarf.	
	93	926	2·0	1·98	1833	1·7	497	803	·925	2776	35	Do., though better than 92; warning at about 600 lbs.; good scarf.	
	94	906	1·97	1·95	1073	1·3	369	642	·775	1702	20	Do. Do. Do. Much shaken. All three were cut from the same log.	
		926								2103			

EXPERIMENTS ON DIRECT COHESIVE STRENGTH.

The apparatus used was a lever of the first order. I determined on this as the simplest, and least liable to errors of friction, though somewhat tedious and laborious in the using.

The power was 10 : 1, on a flat iron bar 11 feet 9 inches long, 4 inches deep, and about ¾ths of an inch thick, working edgewise on a knife-edge pivot and metal sockets in an opening across the head of a strong trestle, which stood about 3 feet 6 inches high.

Each specimen was about $\frac{6}{10}$ths of an inch square, and strained between the shorter end of the lever and a ring-bolt screwed into the sleepers of the floor.

The weights consisted of the longer arm of the lever, equivalent to a dead weight of 728 ℔s., after proper deductions for the *et cœteras* of the apparatus; of ½ and ¼ cwts. until an approximation was made to the requisite power; and then grape shot, each at an average acting as 11·33 ℔s., placed lightly in a strong canvas bag, suspended with the other weights at 10 feet from the pivot.

REMARKS ON THE TABLES.

Column 1.—The same subjects having been used for both 'Transverse' and 'Cohesive' experiments, references are made by number and specific gravity to show which of the specimens, from the former series, were cut up to supply the latter; of course only the sound portions were selected: their average specific gravity is assumed at that of the piece from which they were taken.

Column 2.—The number of the experiment, for reference.

Columns 3, 4, and 5.—The mean breadths and depths are averages of those dimensions at the ends and centre of each piece, taken to hundredths of an inch; the mean area of the transverse section is the product. And here, again, I must observe, that "in the exhibition of so many decimals, I lay no claims to extraordinary accuracy, but do so to show that no pains were spared, and to give greater facilities in the detection of error."

Column 6.—The weights at which the specimen broke; less would doubtless have done in many instances, could time have been allowed; though the reduction need not be so great as in the like case with 'Transverse' experiments.

Column 7.—Column 6 × $\frac{\text{1 square inch}}{\text{area of section}}$.

Column 8.—Approximate proportion of the breaking weight, given by dividing by it the weight where warning was first given. In many instances no warning occurred, and in these cases a blank is left. These fractions are offered as sufficient approximations.

Column 9.—The utmost weight at which there is any ground to hope that ordinary specimens of the wood will stand, when exposed without any disturbance to a pull in the direction of the length *only*. It must be taken as the best judgment I could form from column 8 and the other observations made in the course of the experiments.

	No. of piece and average specific gravity.	No. of experiment.	Mean transverse dimensions. B. in.	D. in.	Mean area of transverse section. in.	Breaking weight. lbs.	C. Computed breaking weight per square inch. lbs.	Extreme practical limit of C. Approximate proportion.	lbs.	Remarks.
AFRICAN.	No. 1. 982	1	·6	·605	·363	5208	14347	23/36	9000	Judging from such specimens as pulled through the head rather than break, the cohesive strength in that sense seems to be about 500 lbs. per square inch.
		2	·605	·605	·366	4088	11169	7/8		
		3	·605	·605	·366	4088	11169	7/8		
		4	·605	·605	·366	3698	10103	5/6		
	No. 2. 1007	5	·605	·592	·3581	3528	9851	5/6		
		6	·605	·605	·366	4102	11207	5/6		
		7	·605	·605	·366	4088	11169	7/9		
		8	·608	·608	·3696	4901	13260	2/3		
							11536			
ASH. American.	No. 9. 636	9	·6	·607	·3642	3088	8478	..	4800	
		10	·605	·613	·3708	4051	10925	5/6		Mr. Barlow's English Ash, sp. gr. 760, C=17337
		11	·608	·615	·3739	4142	11077	4/5		
		12	·585	·575	·3363	2528	7517	7/9		Mr. Emerson's do. C= 6070
		13	·615	·615	·3782	2528	6684	..		
		14	·593	·61	·3617	2675	7395	8/9		
		15	·588	·61	·3586	2387	6656	4/5		
		16	·597	·6	·3582	2580	7202	5/6		
		17	·62	·62	·3844	3473	9035	..		
							8330			
BEECH. American.		18	·588	·598	·3516	2958	8319	..		
		19	..	..	..	..	..	..		Crushed.
		20	·61	·61	·3721	3755	10091	..		Mr. Barlow's English Beech, sp. gr. 696, C=9912
		21	·607	·603	·366	3687	10073	..	8000 if there be no crushing force.	Mr. Tredgold's do. sp. gr. 696, C=2360
		22	..	..	..	..	..	..		Crushed.
		23	·63	·612	·3855	3687	9564	..		
		24	·598	·612	..	..	..	..		Crushed.
							9512			
BIRCH. Black American.	No. 17. 645	25	·603	·575	·3467	2567	7404	5/6	4250	
		26	·612	·59	·361	2086	5778	9/10		Mr. Emerson's Birch, 4290
		27	·628	·56	·3516	2460	6996	5/6		
		28	·627	·597	·3743	2823	7512	11/12		
		29	·601	·597	·3623	1904	5255	3/4		
		30	·595	·597	·3552	1848	8809	..		
							6959			

	No. of piece and average specific gravity.	No. of experiment.	Mean transverse dimensions.		Mean area of transverse section.	Breaking weight.	C. Computed breaking weight per square inch.	Extreme practical limit of C.		Remarks.
			B.	D.				Approximate proportion.		
			in.	in.	in.	lbs.	lbs.		lbs.	
CEDAR. Bermuda.	No. 21. 777	31	·578	·593	·3427	2975	8680	..	3000	
		32	·61	·593	·3617	1662	4594	..		
		33	·615	·601	·3696	2839	7681	..		
		34	·61	·608	·3708	3405	9182	$\frac{14}{17}$		
		35	·578	·603	·3485	1662	4769	$\frac{2}{3}$		
		36	·625	·622	·3887	3711	9546	$\frac{5}{6}$		
		37	·61	·6	·366	3300	9017	..		
							7638			
CEDAR. Guadaloupe.	No. 24. 754	38	·587	·595	·3294	3473	10604	$\frac{7}{9}$	7500	
		39	·6	·566	·3396	2900	8539	..		
		40	·603	·595	·3587	3495	9743	$\frac{7}{9}$		
		41	·615	·575	·3587	3875	10802	$\frac{10}{13}$		
		42	·59	·582	·3433	3421	9965	$\frac{9}{11}$		
		43	·578	·565	·3265	2900	8882	$\frac{6}{7}$		
		44	·607	·61	·3702	3308	8936	$\frac{9}{11}$		
							9497			
ELM. Canada.	No. 29. 685	45	·593	·582	·3451	3528	10223	Records lost.	8000	
		46	·58	·597	·3346	4734	14148			
		47	·587	·58	·3404	4500	13219			
		48	·605	·578	·3496	4263	12193			
	No. 26. 703	49	·597	·575	·3432	4399	12817			
		50	·6	·578	·3468	4852	13990			
							12765			
HICCORY. American.	No. 33. 856	51	·583	·618	·3602	3518	9766	$\frac{11}{13}$	8000	
		52	·583	·61	·3556	4135	11628	$\frac{4}{5}$		
		53	·566	·59	·3339	3859	11557	$\frac{10}{13}$		
		54	·593	·575	·3409	4022	11798	$\frac{3}{4}$		
		55	·595	·595	·354	3648	10305	$\frac{5}{6}$		
		56	·595	·588	·3498	3893	11192	$\frac{10}{13}$		
	No. 30. 854	57	·63	·608	·383	4372	11420	..		
							11095			
LIGNUM-VITÆ. American.	No. 34. 1110	58	..	..	..	..	..	..	10000	Failed.
		59	·61	·61	·3721	4881	13129	$\frac{19}{20}$		
		60	..	..	..	..	..	..		Failed.
		61	..	..	..	..	..	..		Failed.
		62	·612	·608	·372	3518	9428	$\frac{3}{4}$		Faulty piece.
		63	·623	·6	·3728	3518	9428	$\frac{3}{4}$		Ditto.
		64	·625	·607	·3793	4638	12244	..		No warning.
							11057			

	No. of piece and average specific gravity.	No. of experiment.	Mean transverse dimensions. B. in.	Mean transverse dimensions. D. in.	Mean area of transverse section. in.	Breaking weight. lbs.	C. Computed breaking weight per square inch. lbs.	Extreme practical limit of C. Approximate proportion.	Extreme practical limit of C. lbs.	Remarks.
MAHOGANY. Nassau, or Horseflesh.	No. 36. 788	65	·61	·607	·3702	2641	7133	$\frac{3}{4}$		
		66	·597	·605	·3611	1838	5090	$\frac{3}{4}$		
		67	·613	·603	·3696	1838	4972	$\frac{3}{4}$		
		68	·612	·61	·3733	2070	5545	..	3000	
		69	·595	·613	·3647	1288	3532	..		
	No. 38. 815	70	·605	·573	·3465	2398	6920	$\frac{3}{4}$		
							5532			
MANGROVE. White Bermuda.	No. 42. 846	71	·601	·607	·3648	4441	12173	$\frac{9}{10}$		
		72	·557	·62	·3453	3648	10564	$\frac{9}{10}$		
		73	·617	·62	·3825	3081	8054	..		
		74	·622	·608	·3781	2627	6948	..		
	No. 43. 1011	75	·583	·608	·3544	3608	10180	..	5000	
		76	·615	·613	·3769	4577	12143	$\frac{9}{10}$		
		77	·605	·622	·3763	3655	9712	$\frac{9}{10}$		
		78	·605	·628	·3799	4543	11958	$\frac{9}{10}$		
		79	·6	·597	·3582	3518	9793	..		
							10169			
OAK. White American.	No. 45. 716	80	·59	·595	·351	4414	12547	$\frac{9}{10}$		Mr. Barlow's Canadian Oak, sp. gr. 872, C=11428
		81	·598	·595	·356	4890	13736	$\frac{6}{7}$		
		82	·587	·597	·3504	3201	9107	..		
	No. 49. 600	83	·598	·542	·3241	2958	9126	$\frac{4}{5}$	6000	
		84	·59	·585	·3451	2958	8578	$\frac{4}{5}$		
		85	·597	·598	·357	3088	8646	$\frac{4}{5}$		
		86	·588	·607	·3569	2755	7719	$\frac{7}{8}$		
	No. 45. 716	87	·608	·627	·3812	3523	9241	..		
							9750			
OAK. Basket, American.	No. 51. 937	88	·582	·566	·3294	3528	10710	$\frac{6}{7}$		
		89	·607	·573	·3478	3716	10684	$\frac{7}{9}$		
		90	·628	·583	·3661	3353	9158	..		
		91	·542	·61	·3306	3557	10759	$\frac{5}{6}$	6000	
		92	·585	·697	·4077	3365	8253	$\frac{10}{11}$		
		93	·608	·547	·3325	2769	8297	$\frac{7}{9}$		
		94	·602	·603	·363	4129	11374	..		
							9891			

	No. of piece and average specific gravity.	No. of experiment.	Mean transverse dimensions.		Mean area of transverse section.	Breaking weight.	C. Computed breaking weight per square inch.	Extreme practical limit of C.		Remarks.
			B. in.	D. in.	in.	lbs.	lbs.	Approximate proportion.	lbs.	
OAK. English. Riven and green.	No. 55. 992	95	·6	·605	·363	3376	9300	$\frac{3}{4}$		
		96	·585	·59	·3451	3528	10223	$\frac{3}{4}$		
		97	·587	·59	·3463	3376	9748	$\frac{3}{4}$		
	No. 56. 997	98	·588	·595	·3498	2968	8484	..	6000	
		99	·597	·59	·3522	3489	9906	$\frac{6}{10}$		
		100	·6	·597	·3584	3455	9640	$\frac{3}{4}$		
		101	·597	·605	·3611	3376	9349	$\frac{3}{4}$		
							9521			
OAK. English. Riven, and dried *rapidly* to $\frac{2}{3}$rds weight.	No. 55. 992	102				2355				From 102 to 119 were to ascertain the effects of drying the specimens, either quickly or slowly. No dimensions are given for these, it having been thought sufficient to have them cut to a $\frac{6}{10}$ths inch gauge by a very expert workman. A comparison of experiments 54 to 61, 'Transverse' series, with experiments 95 to 119 of the present, gives S in favour of the dried specimens; but C in favour of the green ones: though taking only from No. 102 to 119, the subjects that were dried rapidly were feebler than those done very gradually.
		103				2188				
		104				2109				
		105				2585				
		106				3009				
	No. 56. 997	107				2634				
		108				1848				
		109				2819				
		110				2894				
		111				1702				
						2414				
OAK. English. Riven, and dried *very gradually* to $\frac{2}{3}$rds wt.	No. 55. 992	112				3235				
		113				3485				
		114				2408				
		115				3648				
	No. 56. 997	116				2800				
		117				2500				
		118				2800				
		119				2000				
						2859				
OAK. English. Sawn and seasoned.	No. 62. 831	120	·605	·605	·366	3376	9224	$\frac{3}{4}$		'Riven and green,' beats 'sawn and seasoned,' with reference to both S and C. The uninjured state of the grain has, I apprehend, more to do with the strength than the condition as to dryness. Tredgold's English Oak, sp. gr. 830, C=3960
		121	·595	·605	·3599	2315	6432	$\frac{7}{10}$		
		122	·605	·605	·366	2725	7445	..		
		123	·593	·6	·3558	2315	6506	..	5500	
	No. 63. 836	124	·598	·61	·3647	3213	8809	$\frac{7}{11}$		
		125	·6	·605	·363	2963	8162	$\frac{7}{10}$		
		126	·6	·59	·334	2408	6802	$\frac{5}{8}$		
		127	·585	·6	·351	2408	6860	..		
							7530			

	No. of piece and average specific gravity.	No. of experiment.	Mean transverse dimensions.		Mean area of transverse section.	Breaking weight.	C. Computed breaking weight per square inch.	Extreme practical limit of C.		Remarks.
			B. in.	D. in.	in.	lbs.	lbs.	Approximate proportion.	lbs.	
Oak. Holm, American.	No. 65. 1230	128	·598	·6	·3588	3528	9832	Records lost.	4000	
	No. 67. 1141	129 130	·603 ·59	·6 ·608	·3618 ·3587	2688 4113	7429 11466			
	No. 68. 1140	131 132 133	·57 ·627 ·597	·603 ·577 ·573	·3437 ·3617 ·3420	3111 2128 2128	9051 5883 6222			
							8314			
Pine. Red American.	No. 76. 568	134	·585	·607	·355	1528	4304	$\frac{2}{3}$	3000	Mr. Barlow's New England Fir, sp. gr. 553, C=9947
		135 136	·587 ·582	·6 ·592	·3522 ·3445	1925 1868	5467 5422	$\frac{5}{9}$ $\frac{5}{9}$		
	No. 78. 639	137	·587	·59	·3463	1748	5047	$\frac{5}{8}$		Mr. Tredgold's Yellow American, sp. gr. 460, C=3900
		138 139	·587 ·588	·59 ·64	·3463 ·3763	1975 2449	5703 6508	$\frac{9}{8}$ . .		
							5408			
Pine. White American.	No. 71. 450	140 141 142 143 144 145	·62 ·607 ·63 ·635 ·607 ·627	·625 ·602 ·627 ·635 ·625 ·617	·3875 ·3654 ·395 ·3968 ·3793 ·3868	1424 1204 1555 1397 1295 1408	3674 3295 3936 3520 3418 3640	$\frac{5}{7}$ $\frac{2}{3}$ $\frac{6}{11}$ $\frac{5}{7}$ $\frac{10}{13}$ . .	2200	
							3580			

Sneezewood. I had not the apparatus in South Africa for ascertaining this point; but whilst trying the strength of a model of a trussed roof in this wood, it took 1566 lbs. to *slide off* the shoulder of a king post to which the tie beam was strapped. The section at this point was 1·05 in. × 1·21 in., or 1233 lbs. per square inch of cohesive strength in *that* sense.

	No. of piece and average specific gravity.	No. of experiment.	Mean transverse dimensions.		Mean area of transverse section.	Breaking weight.	C. Computed breaking weight per square inch.	Extreme practical limit of C.		Remarks.
			B. in.	D. in.	in.	lbs.	lbs.	Approximate proportion.	lbs.	
TEAK.	No. 83. 622	146	·583	·596	·3474	2188	6298	Records lost.	4000	Judging from such specimens as pulled through the head rather than break, the cohesive strength in that lateral sense is about 400 lbs. per square inch. The value given to C is very low; but with the liability of this wood to fail when it once leaves India, I dare not rate it higher.
		147	·622	·57	·3545	2300	6488			
		148	·573	·583	·334	1750	5239			
	No. 84. 721	149	·575	·615	·3536	4321	12220			
		150	·617	·58	·3578	4231	11825			
	No. 86. 748	151	·613	·577	·3537	2688	7599			
		152	·615	·585	·3597	3784	10519			
							7170			
YELLOW-WOOD. West Indian.	No. 94. 906	153	·61	·582	·355	3528	9938	$\frac{5}{6}$	4500	
		154	·615	·575	·3536	2968	8393	..		
		155	·62	·582	·3608	3365	9326	$\frac{5}{7}$		
		156	·595	·603	·3587	2408	6713	..		
		157	·602	·61	·3672	2968	8082	..		
		158	·577	·595	·3404	3500	10282	..		
							8774			

Notices on Timber of various Sorts. Extracted from the Papers of the late Captain YOUNG, *Royal Engineers. By Lieut.* NELSON, *Royal Engineers.*

THESE records of experiments at Demerara and Bermuda, and the remarks accompanying, were evidently not arranged by Captain Young for publication. Hence I am unable to state the details of his process, beyond mentioning that it was of the usual description for ascertaining the transverse strengths of timber.

From Nos. 1 to 40.

The ends were free; the scantling of the pieces, as well as the distance between the points of support ('effective length'), will be given in the Tables; weight applied at centre.

From No. 41 to 46.

One end fixed; scantling 1 inch; weight 15 inches from point of support; and deflexion measured from that at which the weight was suspended.

All that I have done is to arrange to a certain extent and compute the value of S.

There is one somewhat important hint to be gained from these experiments,—of the misproportioned results likely to be given by using very small scantlings in such cases. Compare, for instance, Nos. 20, 21, 22, with the remaining Cedars; Nos. 31, 32, 33, with the other Red Pines; and more especially the 10-feet specimens in the Demerara series, with the smaller ones in the same. It occasions a feeling of alarm when one thinks of the probably and correspondingly defective attempts of experimenters with a 2-inch scantling.

Name.	Specific gravity.	Effective length.		Breadth.	Depth.	Breaking weight.	Ultimate deflexion.	Value of S from formula $S = \frac{W l}{4 a d^2}$.	Remarks on the Demerara experiments. Weight at centre.
		ft.	in.	in.	in.	lbs.	in.		
reenheart	940	10	0	2	4	2170	2·0	2034	Nos. 1 and 2, both seasoned specimens, and cut from the same plank: No. 1 was, however, scarcely of full dimensions, and was somewhat sappy. No. 2 may be taken as of very good quality. No. 1 was left with 1500 lbs. on it for three days, at the end of which, and on removal of the weight, it retained a set of $\frac{1}{3}$ inch. No. 2 broke with 2226 lbs., after hanging 3 hours. Nos. 3 and 4, both seasoned. No. 5, half seasoned. No. 3 may be considered as about the average of seasoned Greenheart, though apparently cut from a young tree: it broke after hanging 3 minutes. No. 4 was rather sappy; it broke without warning. No. 5 broke in 1 minute, with 356 lbs. Mean of 2 experiments by Mr. Barlow, (jun.). on Greenheart sent home from Berbice by Sir G. Gipps, R.E., S = 2759, sp. gr. = 1000.—*Philos. Magazine, March*, 1832.
..	1000	10	0	2	4	2226	1·5	2087	
..	931	2	6	1	1	392	1·1	2940	
..	900	2	6	1	1	350	1·3	2625	
..	1080	2	6	1	1	356	1·3	2670	
	970							2471	
Wallaba	1147	2	6	1	1	336	·8	2520	No. 6 was a faultless piece; but such as can be rarely procured when of the size used in building. No. 7 was faulty, and split early, so that the real depth was reduced to 3 inches: there are, however, but few pieces that are not defective. No. 8 is superior to the average. 7 and 8 both green.
..	1147	10	0	2	4	1020	1·8	956	
..	1147	10	0	2	4	1550	2·5	1453	
	1147							1643	
ullet Tree	1075	10	0	2	4	2250	4·0	2109	No. 9, a good average specimen, was left 4 days loaded with 1600 lbs., which gave it a set, on removal, of $\frac{1}{2}$ in. No. 11 was rather strained by the sudden breaking of the rope supporting the weight, at 336 lbs., when however it had a set of 1 inch. All these specimens were only half seasoned. Bullet Tree warps far less than Greenheart when exposed to the sun. Mean of 2 experiments by Mr. Barlow, (jun.). on Bullet Tree sent home by Sir G. Gipps, R.E., sp. gr. = 1029, S = 2651.
..	1075	2	6	1	1	420	2·4	3150	
..	1075	2	6	1	1	392	1·2	2940	
	1075							2733	
Kakarally	1223	10	0	2	4	1940	4·2	1818	No. 12, a fair specimen; it broke in $\frac{1}{2}$ hour. No. 13 gave warning at 392 lbs. The fracture is longer in this wood than in Greenheart, and more fibrous; but not so long as in the Bullet Tree, although the latter is almost flinty.
..	1223	2	6	1	1	392	2·2	2940	
	1223							2379	
Crabwood.	648	2	6	1	1	250	1·0	1875	Seasoned.
White Pine	410	10	0	2	4	1070	2·7	1003	
..	410	10	0	2	4	1020	2·0	956	
..	410	2	6	1	1	168	1·2	1260	
	410							1073	

No. of experiment.	Name.	Effective length.		Breadth.	Depth.	Breaking weight.	Ultimate deflexion.	Value of S from formula $S = \frac{W l}{4 a d^2}$.	Remarks on the Bermuda experiments.
		ft.	in.	in.	in.	lbs.	in.		
18	Bermuda Cedar	3	0	1	1·5	193	..	..	Broke at a knot.
19	..	3	0	1	1·5	339	..	1220	
20	..	2	6	1	1	295	..	2010	
21	..	2	6	1	1	236	..		
22	..	2	6	1	1	273	..		
23	..	3	6	1	3	1117	1·2	..	Broke at a knot.
24	..	3	6	1	3	1402	2·2	1636	Cracked at 1271 lbs.; from same tree as No. 23.
25	..	3	6	1	3	1387	..	1618	Recently felled; remarkably clean, and free from knots: from a large tree. Cracked at 1373 lbs.
26	..	3	6	1	3	520	..	..	Full of knots.
27	..	3	6	1	3	1328	..	..	Do. from same tree. Cracked at 1310 lbs.
								1491	Omitting Nos. 20, 21, 22.
28	Red Pine	3	0	1	1·5	476	..	1903	Good piece.
29	..	3	0	1	1·5	500	..	1800	
30	..	3	0	1	1·5	750	..	..	Ends loaded, with 150 lbs. each. Same tree as No. 28.
31	..	2	0	1	1	385	..	2330	
32	..	2	0	1	1	402	..		
33	..	2	0	1	1	378	..		
34	..	3	6	1	3	1363	1·3	1590	Broke with short fracture; the piece clean and free from knot: the tree appeared to have been bled.
35	..	3	6	1	3	1154	..		Piece doted.
36	..	3	6	1·75	1·75	974	2·4	..	
37	..	3	6	2 in. diameter		1217	2·3		Broke at a knot; a cylindrical specimen.
38	..	3	6	1	3	1632	1·4	1904	A fine piece, free from knots. At 1452 lbs. on taking off the weights there was a set of $\frac{3}{16}$ths in.
								1799	Omitting Nos. 31, 32, 33.
39	Hiccory	3	6	1·625	1·625	1000	1·9	2447	On releasing the piece from this weight it had a set of $\frac{3}{16}$ths in. On returning the weight it broke gradually at the end of ½ hour.
40	Nassau, or Horseflesh Mahogany	3	6	1	3	1632	1·4	1904	Cracked at 1500 lbs.; a clean piece, and had been in store 7 years.

No. of experiment.	Name.	Specific gravity.	Weight applied till the piece broke.	Corresponding deflexions.	Remarks on Demerara experiments. Weight at one end.
			lbs.	in.	
41	Greenheart	1040	112	1·1	Seasoned. With 200 lbs. the deflexion kept increasing, and in 3 minutes it broke; the fracture being in this, and in all the following cases, close to the support.
			150	1·75	
			190	3·25	
			200	3·7	
42	Bullet Tree	1075	112	1·42	This is the first experiment in which Bullet Tree appears in any way inferior to Greenheart. Half seasoned.
			168	2·7	
			190	. .	
43	Wallaba	1147	140	. .	Same log as No. 6.
			168	. .	
44	Kakarally	1223	112	1·1	With 200 lbs. it yielded very gradually, and broke in about 8 minutes.
			168	2·3	
			190	4·7	
			200	5·9	
45	Crabwood	648	130	2·25	Broke in 1 minute.
46	White Pine	410	112	. .	Broke short.

RICHARD YOUNG,
Captain Royal Engineers.
Died at Bermuda, 25th Dec. 1838.

REMARKS ON THE PRECEDING WOODS.

African.—Called also, but improperly, 'African Oak' and 'African Teak.' It is obtained from the natives on the African coast, near Sierra Leone, &c.; it is said to be brought from a considerable distance inland down the rivers.

It is a noble wood for all marine work, such as ships' timbers, gun carriages, large posts, &c. It can be supplied in baulks of very considerable length, *very* free from knots; and from its peculiar cross-grain serves for all three purposes of direct strength. Perhaps no timber is convertible to so many objects with less waste.

Its defects are, that in plank it is apt to warp; and as its texture allows it to absorb much moisture, it is unfit for out-door moveable fitments, as it swells with wet, and 'shakes' or splits in dry weather. Too much must not be introduced into ships, as its great weight renders them sluggish, although from its superior strength a much smaller scantling will suffice than in other woods. It works 'sandy,' (as the workmen call a peculiar grating action of some of its harder and minuter particles,) which is injurious to the tools.

Wherever small holes are observable the log should be carefully examined, if not rejected, as they are very often the external orifices of large Teredo perforations within.

"It is not known what tree produces African Oak and African Teak; at least it is not known to botanists." L.[1]

It is said that the above names of 'Oak' and 'Teak' are given to evade certain timber import duties.

See *Sneezewood.*

Ash. American or English.—For all purposes requiring strength, tolerable lightness, and a straight grain; such as handspikes, helves for hammers and axes, spokes of wheels, &c., &c., which ought to be cleft, not sawn. The American is very inferior to the English. In and near America it may be very well superseded by Hiccory, which exceeds it in all its good points, with however the disadvantage of being $\frac{1}{4}$ heavier.

Beech. American or English.—The White Beech is best; the Red Beech is only the same wood beginning to fail. It is applied to such purposes as those to which its fine grain and uniform texture render it particularly applicable, such as squares, plane stocks, bevels, stone-masons' mallets, &c., &c. It possesses great transverse strength, but is a treacherous wood where lateral cohesion is concerned, as it will crush long before it will tear asunder. Beech was used by Rennie in grooved and tongued sheeting piles at the mouths of the

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[1] L. This letter denotes a quotation from a letter from Mr. Lindley, the celebrated botanist, and vice-secretary to the Horticultural Society. Although an entire stranger to this gentleman, he has very obligingly answered certain queries that I referred to him, and which will appear in the course of this section.

docks in Woolwich and Chatham Dock-yards, where it is always under water. He formed a high opinion of the durability of this wood from having once found a blacksmith's shop, built of it, buried in a peat moss, in good preservation. It was formerly much used in dock-yards for ships' under-water planking, but was discontinued from the extent to which it was pilfered by the workmen.

If not screened from weather it is apt to 'dote,' which is, to become powdery from a sort of dry-rot.

Birch. *American.*—Black, in preference to White and Yellow. A fine wood if kept under shelter. It is used for handspikes, saw-heads, and such matters of general service. The darker coloured varieties are used by cabinet-makers to imitate Mahogany, of which it resembles the paler kinds when well oiled.

Cedar. *Bermuda.*—The sort used in pencils; it is an admirable wood for durability, where attention is paid to ventilation, and where freed from the white outside or 'sap.' Repeated instances have occurred of its lasting 100, 150, or nearly 200 years; and in one case it was taken from a house where it must have been 150 years, and then worked up as timber for a boat. In salt water, as outside planking for vessels, it may be expected to last 40 years: the objections being in this case its brittleness, and offensive smell when in confined situations. It requires the protection of sheathing, though no land animal will attack the heart or red portion. In damp cellars, covers of wells, tanks, &c., although it *may* last longer than other woods, yet it fails at last.

Its best application is in rafters, bond timbers, joists, &c.; and when well seasoned, in doors, door and window cases, and sashes. The defect of freshly hewn timber is, in this instance, not its shrinking (for it is less liable to that than perhaps any other wood), but from a resinous substance which exudes from it in that state, defeating all attempts at giving a workmanlike finish.

The stock of large timber at Bermuda was greatly exhausted during the late wars, as vessels from that colony were in great request: hence the present scantling rarely exceeds 8 inches, and this last size is not very common.

" *Guadaloupe.*—A fine wood, in great esteem in the West Indies for boats, &c.

" *Virginia.*—Much resembling that of Bermuda. There is, however, a difference in the foliage and branches: in the former they both point upward; in the latter they are either horizontal or drooping.

" *White American.*—Said to be the most durable wood for all out-door purposes, palisades, &c., as it is not apt to decay where it meets the ground. White Cedar shingles bear a high character in this respect.

Elm. *English.*—For purposes requiring great toughness, such as naves of wheels, gun and carronade carriages, caps of masts, bodies of carts and wheelbarrows, blocks of screw-jacks, paviers' rammers, beetles, &c., &c. It decays rapidly when exposed to weather or damp, although, if quite and constantly under water, it is very durable; hence its extensive application in keels of ships. When supplied in large blocks it is *very* apt to be hollow at heart; hence large allowance for 'waste' should be made in demand, or else the blocks should be cut to quarterings of given dimensions before being sent abroad.

In choosing Elm trees the 'narrow-leafed' Elm (U. stricta, or U. suberosa) should be taken in preference to the 'broad-leafed' (U. glabra, or U. campestris), as being far stronger, more durable, and not working with 'a sand': the timber of the former is, however, smaller than that of the latter, and is used where great toughness is required, as in naves of wheels, screw-jack blocks, and, where it can be had of sufficient scantling, in gun, &c. carriages, slides, and beds. The broad-leafed Elm is used in ship-keels, coffin-planks, &c., on account of its size.

Elm. *Canada.*—A very different wood from the preceding, having a remarkably clear grain, more resembling Beech in colour and texture than any other English wood. It is now much used in the dock-yards for boat-building; it, however, works with a sand, and is not very durable.

Fir. *Archangel.*—A light Deal for in-door purposes. See *Pines* also.

" *Dantzic.*—Good wood, rather knotty; for in and out-door purposes, and ship fitments. Colour, yellowish red.

" *Memel, or Prussian.*—A cleaner wood than Dantzic, but not so durable.

" *Riga.*—The best description of Fir, being very clean, and the most durable of these North Europe deals. Applicable to most dock-yard purposes, especially masts. Colour, yellowish white.

" *Spruce.*—A white wood, chiefly for in-door purposes; it is clean, but brittle; hence it has failed seriously at times in topmasts.

The names Dantzic, Memel, &c., &c., merely designate the port from whence the timber is shipped, without reference to where it was grown; it is said that some of these Firs come from a district at no great distance from the frontiers of Persia.

Hiccory. *American.*—Very strong, but generally knotty, coarse grained, and particularly liable to rend by exposure to the sun. In the dock-yards it served by contract in rough hewn straight-grained pieces for handspikes and capstan-bars. See *American Ash.*

Larch.—A tough white wood, akin to Spruce; not much known, but promising well.

Lignum-Vitæ.—Only used for block-shives. There is an inferior wood very like it called 'Greenheart,' which is liable to be served in by dishonest contractors. It is said to be a Jamaica wood, costing little more than one half the Lignum-Vitæ; it is, however, of a somewhat darker colour. Its infusion in water has a red colour, whilst that of Lignum-Vitæ is greenish.

Locust.—Only as yet used in dock-yards for treenails.

Lumber.—The American term for all Fir and Pine plank. See *Pines.*

Mahogany. *Horseflesh, or Nassau.*—The only good quality of this wood is its durability, when steadily in or out of water; but from its cross grain and brittleness, the shortness and crookedness of its logs, it is in nowise advisable for any engineer purposes. It was only used in one instance at Bermuda,—in flooring the redoubt of the land front ravelin.

" *Common, or Honduras.*—In furniture and fitments.

Mangrove. *White and Black.*—Both grow in salt water, and though a very coarse wood, is remarkably heavy and strong. The White Mangrove (or 'oyster-tree,' so called from these or any other shell-fish adhering occasionally to the peculiar pendant radicles thrown down from the boughs, as they would to any other body,) is known by these radicles, a glossy leaf, and a small yellow flower, somewhat resembling the jasmine in form and fragrance.

The Black Mangrove, so called from the colour of the wood, when old, and when it has been then fully exposed to the sun, has none of these radicles; has a dull whitish green leaf smaller than that of the above, and a little white flower with a smell like that of honey.

Both are confused together by the name of 'Hardwood,' but with about equal claims. It was at one time used at Bermuda in gun-carriages, also in stone-masons' mallets, but was given up in the latter instance as generally unsuitable. When *perfectly* well dried and seasoned it is a tough powerful wood, and has been known to last sixteen years in a pair of cart wheels. It is very apt to breed fungus, &c., when *kept damp*, though very durable when always under water.

Oak. *Adriatic.*—A bad wood; used at one time in ships' frames, but given up. It is said that we received it as part payment of a bad debt from Austria.

,, *American Basket.*—A coarse kind of wainscot, of very imposing appearance, but feeble performance. It is readily torn into strips for fishing-pots and baskets; hence its name.

,, *American Red.*—A coarse indifferent wood, so very porous that water may be sucked up through a piece 3 feet long. Its chief use is in barrel staves, especially in casks to contain molasses: it is singular that even rum-puncheons of the best oak will not hold this fluid, whilst those that answer best are made with Red Oak staves and White Pine heads.

,, *American White.*—The varieties of American Oak are so numerous, as to render it difficult to attach any precise meaning to the word. That, however, which is usually supplied as American White Oak is a respectable wood with regard to strength, but with little durability, being particularly liable to dry rot. It is now used for boats and light purposes; but much of the dry rot to which our shipping has been of late years subject is attributed to the extensive and unwise introduction of this material into the dock-yards.

,, *American Holm.*—A first-rate wood for strength and durability in ship-building; generally obtained from the southern states of America.

,, *Dantzic.*—Ships' planking to 5-inch thicknesses, under-water work, and deck-flats. In the forests that supply this wood, the best trees were marked off as 'Kron,' and the rest 'Brack.' Under these heads it was formerly served in, though of late the distinction has been disregarded.

,, *English.*—"It is doubtful which of our oaks is the Old English Heart of Oak. The common opinion is that Quercus pedunculata, the most abundant now, yielded it. But others, and I am among them, believe that it was probably both our species, and more particularly Quercus sessiliflora; at least it is remarkable that all the *very old* specimens of oak I have ever seen belong to the latter species, which is unfortunately becoming extinct. It was a mere blunder to suppose that Q. pubescens supplied it, for that species is not found in this country in a wild state, and its timber is of little value. The two British species are known from each other thus:

Q. pedunculata has	Q. sessiliflora has
Leaves, almost without stalks, a green midrib, and a margin very irregularly indented; they are also scarcely at all lucid.	*Leaves*, almost always placed on yellow stalks, and a margin tolerably regularly and shallowly indented. They are shining, like those of the chestnut, and thicker in texture.

Q. pedunculata has	Q. sessiliflora has
Acorns, on long stalks.	*Acorns*, either with no stalks at all, or very short ones.
Wood, very full of silver-grain and easy to rend.	*Wood*, with the silver-grain much less abundant, and very difficult to rend.
Carpenters call this Wood Oak.	This is always called by carpenters *Chestnut* when they find it in old buildings."—L.

Oak is a bad wood in hot climates for Royal Engineer Department purposes; it splits too much. At Bermuda it was, therefore, only used for spokes of wheels, ladder rungs, masons' squares, &c.

Oak. *Italian. Roman or Tuscan.*—A fine wood, but apt to split: much used in ships' frames. The practice now is to fill up these crevices with a mixture of lime and tallow.

,, *Lorraine.*—The same as the Dort, Dutch, and Rhenish Oaks: now discarded as not durable.

,, *Memel.*—Much the same as the Dantzic; but rather inferior in strength and durability.

Pine. *Pitch*, or *Candlewood*, so called from the singular facility with which it kindles: it is so very resinous that a stick of it will burn like a torch if once ignited, and so heavy and hard in consequence as sometimes to weigh about 60 ℔s. per cubic foot, and be troublesome to work. Much that bears the name of Pitch Pine is unworthy of it, especially that from the northern parts of America, where it is apt to be drained for turpentine; and the wood, which is thus rendered of a lighter colour, is sold under the name of Pitch Pine, or else Red or Yellow Pine, according to the remains of the resinous colouring matter. Though this is not invariably the case, it is so very generally so that preference is given to the timber from the southern United States, where it is not at present so injured.

In the selection of new ground, a settler will avoid a district wooded with resiniferous trees, such as Pines, Hemlock, Spruce, Tacmahac, &c., not only as indicating a poor soil, but on account of their great durability. After a tract of forest has been cleared to the usual extent by girdling, burning brushwood, cutting off the trees above the ground, &c., the stumps of the hard and dry woods (which also indicate good ground), such as Beech, Birch, Maple, &c., will so decay in four or five years that a plough and a good team of oxen will tear them out. It is very different with the preceding: I have seen stumps of Hemlock in the Nova Scotia woods that have survived their upper portions for forty years.

This *true Red Pine* is not only thus durable, but has great dimensions and a clean straight grain. By reference to the 'Transverse' Tables it will be found to possess considerable strength. It is delivered either in 'lumber' or baulk, and at the same price with reference to cubic content; for as such timber is now generally sawn by steam mills, the blades are set only once for lumber, but twice when the two pair of baulk sides are to be squared.

Pitch and Red Pines are used in joists and beams of permanent buildings, wheeling plank, &c., and ordinary repairs where strength is concerned. It is a good material for barrack floors, since it does not show grease marks by any means as much as the White Pine, and is far harder, stronger, and freer from knots.

Pine. *White.*—A cheap wood, and much used for such purposes as temporary establishments during the progress of works, in shops, stores, sheds, centerings, moulds, &c., &c., &c. At Bermuda it is obtained chiefly from the North American States; but in all respects, except price, is objectionable in permanent buildings, and is inferior to all the other American pines. As a general rule with regard to pines or firs (perfectly synonymous expressions) it may be stated, that the darkest colour is a sign of the greatest strength.

In contract specifications the Bermuda (Royal Engineer Department) practice was to state, that only 1 inch of sap on each side, and half the split parts at the ends, would be measured; in 1, 1½, or 2-inch plank, the loss from the latter would be considerable without such check; but by enforcing it I have seen 20 per cent. saved on a contract delivery in more instances than one.

„ *Virginia.*—A Pitch Pine, and when good, very good; but like all American pine timber, subject to the destruction of certain insects called 'Concas,' which will eat a large hole in the heart of an otherwise fine spar, with no other notice of their existence within than a few small holes externally in the first instance, and sudden and dangerous failure in the second.

Poonah.—A heavy East Indian wood used in masts.

Sneezewood. *South African.*—So called from the tendency to sneeze brought on by smelling its fresh shavings or sawdust. Could this wood be procured in large, and at the same time sound baulk, there would be but little timber like it for those architectural purposes where great strength, uniformity of texture, and durability are required: the last mentioned property it owes to the pungent resinous matter which it contains, and which is very obvious to sight and scent when burning.

Unfortunately it is difficult to procure trees that are both large and sound; hence, pieces of any size must be built by scarfing short lengths, and owing to the resistance it offers to the saw and plane, the price of labour on it will be from 1½ to twice that on yellow pine. In joists, fixed with the expensive but indifferent labour to be procured at Algoa Bay in 1837, it cost about 6*s.* 6*d.* per cubic foot; though it was delivered by the contractor in logs at 2*s.* per foot cubic.

It is by far the finest of all the woods generally used at the Cape of Good Hope, which are numerous enough; such as—

(Extracted from Corps Orders, Cape Town, by Lieut.-Colonel R. Thompson, R.E., July 20, 1833.)

	per ft. cub.		per cub. ft.
Assegai wood, at Cape Town in 1833	2*s.* 4*d.*	Curtisia faginea	61
Stinkwood „ „	2 6	Laurus bullata	55
Saffron-wood „ „	2 2	Ilex crocea	54
White Els „ „	2 0	Weinmannia trifoliata	35
Red Els „ „	2 6	Cunonia Capensis	47
Yellow-wood „ „	1 9	Taxus elongata	40
White Pear „ „	2 4	Pyrus communis	54
Iron-wood „ „	2 10	Olea varutas[2]	69

&c. &c.;

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[2] Mr. Lindley says that there is no such name; it and the preceding were obtained from a local botanist.

but which were very generally superseded at last by European or American deals, wherever framing was concerned, or even in joisting, as they could be delivered at from 3*s*. to 3*s*. 6*d*. in baulk at either Table Bay or Algoa Bay. The great defect of these South African woods is their dryness, and (in so hot a climate) consequent liability to torsion: an Iron-wood beam, of about a foot scantling, and about 20 feet in length, in part supporting a flat Dutch roof in the Castle at Cape Town, twisted at least an inch in its length. The best of the other timber is perhaps the Right Yellow-wood, which, with the Bastard Yellow-wood, is commonest by far on the frontier; but except for flooring boards it is unfit for a good building, owing to the expense in working, and its tendency to warp. Latterly, European and American deals have been introduced very generally into the Royal Engineer Department, even at Graham's Town, 100 miles from the sea-port, Algoa Bay; and at this place itself roofs of this material, framed at Cape Town, and sent round by sea, were used in our buildings in preference to availing ourselves of local woods.

Teak.—Between the Malabar Teak, weighing 52 lbs. per cubic foot, and the Rangoon Teak 26 lbs., there is every gradation; partly owing to soil, &c., and partly to the custom of draining the wood for its oil and other juices. It is a fine wood, stronger than oak, but inferior to African in nearly all points. In England it seems to be subject to dry rot, though in its own country it bears a high character for durability. It loses little in drying, and is a straight-grained wood; but, like Beech, cannot be trusted for sustaining any considerable lateral strain.

Yellow-wood. West Indian.—In those islands many woods bear this name; the subject of my experiments, they tell me, is a species of Walnut, and is in good repute as a ship timber.

" *African.*—See notice of it in *Sneezewood.*

Transverse Strengths of various Woods, ascertained by order of Sir R. SEPPINGS, *and executed by* Mr. MOORE.

TWENTY-TWO different kinds of such timber as is most used in our dock-yards were thus tried by Mr. Moore. All, except the Poonah, were determined on twelve subjects. Each specimen was 7 feet long, 2 inches square, and rested on supports 6 feet apart; ends free; weight at centre applied in the shape of water poured from a cock into an iron tank so suspended, weighing 3 cwt. 1 qr. 8 lbs., included in the breaking weight.

From the general appearance of the records, Mr. Moore seems to have taken very great pains with his experiments. It seemed to me, however, to be unnecessary to compute S for each trial, where it was assumed that all the pieces were *precisely* of the same scantling. I have therefore given it merely with reference to the average, and in this form only have noted it in my own professional common-place book; but to do every justice to Mr. Moore, and to meet the views of others, the extremes of each set have likewise been added, so that they who wish it can compute S for themselves: *e. g.* Fir, Memel, 604, 599, &c., are the average specific gravity and breaking weight, &c. of the twelve specimens; S refers to this, 599; whilst 476, 469, &c., and 684, 686, &c., are the specific gravity and breaking weights, &c. of the weakest and strongest pieces respectively.

R. J. NELSON,
Lieutenant Royal Engineers.

Name.	Specific gravity.	Breaking weight.	Ultimate deflexion.	Time taken to break each piece.		Value of S from formula $S = \frac{W l}{4 a d^2}$.	Remarks.
		lbs.	in.	min.	sec.		
African.	1006	943	4·3	7	48	2522	Well seasoned, good quality, very stiff; fracture in general long.
	916	1121	5·0	9	59		
	965	1306	6·0	10	10		
Fir. Archangel.	553	509	3·0	2	12	1370	
	531	609	3·4	3	29		
	568	754	4·3	5	21		
Fir. Dantzic.	638	539	3·5	2	36	1426	
	674	634	4·4	3	56		
	635	731	4·0	5	4		
Fir. Memel.	476	469	3·0	1	41	1348	
	642	599	4·0	3	22		
	684	686	4·8	4	29		
Fir. Prussian.	511	448	4·0	1	25	1445	
	604	642	3·8	3	58		
	674	796	3·5	5	53		
Fir. Riga.	478	519	2·8	2	20	1388	
	545	617	3·4	3	36		
	664	711	3·8	4	28		
Fir. Spruce.	530	479	3·3	1	49	1346	
	528	598	3·4	3	23		
	450	660	4·3	4	9		
Hiccory.	718	806	5·0	5	59	2192	
	758	974	6·4	8	11		
	884	1150	7·5	10	28		
Larch.	628	761	3·0	7	40	1958	
	664	870	3·5	6	52		
	684	963	4·3	8	3		
Mahogany. Honduras.	460	438	2·5	1	18	1503	
	531	668	3·3	4	16		
	584	819	4·0	6	13		
Oak. Adriatic.	700	610	5·8	3	30	1559	
	749	693	6·0	4	35		
	707	741	6·5	5	12		
Oak. American.	812	716	5·5	4	52	1699	From Canada; rather green and flexible, broke steadily, fracture long.
	815	755	6·3	5	22		
	882	891	6·3	7	33		

Name.	Specific gravity.		Breaking weight.		Ultimate deflexion.	Time taken to break each piece.		Value of S from formula $S = \frac{W l}{4 a d^2}$.	Remarks.
			lbs.		in.	min.	sec.		
OAK. Dantzig.	615 746	692	554 870	702	5·8 5·4 5·4	2 4 6	46 16 51	1579	
OAK. English.	805 823	810	771 948	853	6·3 6·3 6·3	5 6 7	35 39 52	1919	Well seasoned, and of good quality, but broke suddenly, with a fracture generally short.
OAK. Italian.	771 856	763	615 935	750	4·7 5·6 9·0	4 5 7	52 38 42	1688	
OAK. Lorraine.	854 740	794	572 756	659	3·5 6·5 5·9	3 4 5	1 9 23	1483	Well seasoned, but the fracture shorter than in American Oak.
OAK. Memel.	707 733	741	620 872	741	3·5 5·5 5·8	3 5 6	38 11 53	1665	
PINE. Red.	,, ,,	521	506 673	573	3·8 4·4 5·0	2 3 4	3 2 19	1289	
PINE. Virginia.	,, ,,	590	570 708	647	3·0 4·1 4·1	3	,, 59 ,,	1456	Time and specific gravities omitted: apparently a clerical error.
PINE. Yellow.	447 471	632	456 592	528	2·5 3·9 4·0	1 2 3	31 27 17	1188	
POONAH.	728 748	728	656 801	750	3·7 3·6 4·0	5 5 5	23 19 59	1687	5 m. 23 s. should, perhaps, have been 4 m. 23 s. Only 4 specimens of this wood given.
TEAK.	710 754	707	542 1108	873	2·4 4·4 5·3	2 6 9	38 55 33	1964	Specimns dry, comparatively light, very stiff, broke suddenly, fracture very short.

Memorandum of different Kinds of Wood of British Guiana, drawn from Reports of their Properties, &c. (supplied from the Saw-Mill at Berbice), by Sir G. GIPPS, *and from my own Notes whilst in Demerara. By Captain* JOHN SMYTH, *Royal Engineers.*

(Specimens referred to are those in a box sent by Captain SMYTH *to Lieut.* DENISON.)

Bullet Tree. *Specimen* 3.—Specific gravity, when dry, 1070; strength to resist a cross strain, 380.

This wood is very hard and durable, and fitted for all kinds of outside work, or that is exposed to weather: the principal objections to it are, that it warps a good deal, splits easily in the direction of the fibres; if used in floors becomes slippery, and for water uses is destroyed by the salt water worm, which eats it greedily.

It is principally used for sills and main uprights, for principal rafters in buildings, and for all out-of-door work.

Greenheart. *Specimens* 1 and 2.—Specific gravity, dry, 1040; relative strength, 360: or, that if a piece of Bullet Tree of any given size be capable of bearing a cross strain of 380 lbs., a piece of Greenheart of the same size will only bear 360.

This wood, in Demerara, is preferred to Bullet Tree, and perhaps not without reason, as it is more fitted for general purposes,—works up with less waste, and does not split so readily in the direction of the fibre. The heart of it, where of a dark brown colour, is superior to any other wood of Guiana.

It is used in scantling and plank generally, but particularly in floors of galleries and exterior work. In Liverpool latterly it has been, I am informed, extensively used in ship building, both for timbers and plank. Great prejudice existed against it in consequence of the difficulty of working it, but by steaming the planks much of this has been obviated.

Kakarally. *Specimen* 42.—Specific gravity, tree old and wood dry, 1100; strength, 350.

This wood is hard and heavy in an extraordinary degree; it is very difficult to work, and the circular saw (in the saw-mill) strikes fire from it as from flint.

It is used in piles, and is extremely valuable in a climate where the sea-worm is exceedingly destructive. It would be valuable for handspikes and articles of this description.

Cabacally. *Specimen* 6.—Specific gravity, when old and dry, 900; strength, 300.

This wood works with very little waste, and easier than any other that can be called hard wood; the greatest objection to it is, that it has a very strong and fetid smell, which has obtained for it the name of stinkwood, and though the smell goes off by exposure to the atmosphere, yet in close rooms, and when wet, it will always (at least for years) be perceived; for this reason it is not fit for bed-rooms, nor for the floors of galleries exposed to wet. Notwithstanding, however, these disadvantages, it is a wood highly prized, and it has almost all the good qualities of Elm.

It is used in secondary parts of frame-work, for partitions, purlins, rafters, window-sills, and door-frames, for slate-boarding, clap-boarding, and for all floors except for bed-rooms and galleries.

Locust or Hymenea. Specimen 18.—The specimens of this wood vary so much in strength and weight that they cannot be represented by any numbers with sufficient precision to be depended on.

Generally it is more hard than heavy, and more heavy than strong; perhaps as hard as Bullet Tree, as heavy as Greenheart, and as strong as Cabacally. A high price is demanded for it by the wood-cutter on account of its hardness, and as it grows singly it must be sought for in the forest. Its superiority to the other woods named consists in its neither warping nor splitting.

It is used chiefly for furniture and joiners' work.

Crabwood. Specimen 5.—Specific gravity and strength something under that of Cabacally.

This wood works with more waste than Cabacally, is very durable, and free from the disagreeable odour of the latter.

It is used for floors (in narrow breadths), and for outside boarding.

Tonquin Bean.—Specific gravity and strength like Bullet Tree, to which, however, it is superior, as it does not split so easily in the direction of the fibres.

It is not very common, and is used chiefly in furniture.

Determa. *Specimen* 30.
Red Cedar. *Specimen* 28.
Siverbally. *Specimens* 24, 25.

Are woods that work with great facility; the specific gravity in strength being considerably under that of Cabacally, but are for inside work preferable to it, from not splitting so much.

Used in floors, boarding, and furniture; the latter wood is excellent for planking for vessels, is durable in salt water, and the sea-worm does not attack it.

Wallaba. Specimen 34.—Specific gravity not accurately known, but believed to be about 950; strength, 320.

This wood works with great facility, and with little waste, but is a bad wood to resist a cross strain, and splits more than any other.

It is extensively used in the West Indies for the upright framing of inferior buildings, being abundant, cheap, and easily wrought.

Kreta. *Specimen* 17.
Semirupa. *Specimen* 27.

Are white woods, whose specific gravity would not exceed 500, and relative strength 200. They are easily wrought, and abundant.

Used in boarding and inside linings, but are so liable to be destroyed by insects as to render the use of them very little desirable.[1]

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[1] The slate-boarding of the Engineer Quarters at Demerara, and the lining of the upper rooms, partitions, boarding, &c., were of these woods, and in effecting some repairs it was found that the interior of the boards had been completely eaten away by the boring-worm and ants, leaving the

Banya, Ebony. *Specimen* 4. *Ducallaballi*. *Specimen* 7. *Letter-wood*. *Specimen* 19. *Lignum-Vitæ*. *Specimen* 12.	These woods have specific gravities and relative strength as high, probably, as Greenheart, are very compact in the fibre, and less liable to split, but they are scarce, difficult to procure in large quantities, and expensive. They are used for furniture and ornaments of various kinds.
Purple-heart,	*Specimens* 22, 23.—High specific gravity and relatively strong. It is used for mill-shafts, cogs of wheels, and mill-work generally.

Note.—The numbers set down to express the strength of the woods are relative, and mean only that, if a piece of Bullet Tree of a certain size (say 1 inch square), supported on two points at 30 inches asunder, bears a weight suspended in the middle of 380 lbs., then a similar piece of Greenheart will bear only 360, and of Cabacally only 320, and of American White Pine or Fir 150, (the specific gravity of the latter being about 410).

The necessity to an Officer of Engineers of an accurate knowledge of the resources of the country in which he may be serving, needs not, I am convinced, to be pointed out here; for it meets us in every change of station; and all officers who have been in our colonies know how much time is lost, and how much difficulty is experienced, in obtaining such information; and I would therefore very strongly urge on my younger brother officers the importance of preparing, when they have leisure and opportunity, memoranda on the nature, quality, price of materials, with Tables (on the plan of Tredgold's) and short descriptions of the timber, &c. of the places in which they may be stationed. What I have here very imperfectly contributed may serve as a commencement. Many of the observations are too general to be of much practical utility, but they may serve as a basis on which to establish more correct, detailed, and useful information. The growth of timber *in situ* should be carefully examined; the best times and seasons for felling it should also be noted. In a very able report of Colonel Sir C. Smith, on the Government Saw-Mill at Berbice, he states the extraordinary fact, from well ascertained observations, of the rise and fall of the sap in trees in Guiana (and probably in all tropical climates) in each

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surface, which was painted, looking quite sound. The wood-ants had formed their nests in the framing of the roof, and in some cases had filled in between the timber a solid compact body, from whence their operations of destruction were carried on. It is very important to avoid, in the construction of buildings in situations liable to insects of this kind, any linings or casings on the timbers. If double boarding be requisite, the two should be placed together without any interval; all external facias and boardings that leave spaces for bats to harbour are also objectionable.

lunar month, and that timber cut in the full of the moon, when the sap is in the tree, rapidly decays, and that the reverse is the case with timber cut in the new moon, or, as it is termed by the wood-cutters of Guiana, at the dark moon.

The loss which annually occurs to Government in tropical climates from the destruction of articles of British timber and manufacture by insects is incredible; and in the event of war, the necessity of retaining in storehouses in our colonies perishable stores of this description renders it a matter for very serious consideration, how far it might be desirable to modify their construction by the adoption and use of woods which are not liable to be attacked by insects, and which, at the same time, may perfectly answer the purposes to which they may be applied.

The system of supplying our foreign stations by contract with articles of the same kind and construction as are used and may be suitable for home service, is one great cause of this evil, and arises much from the wholesale way in which Government operations are carried on. There can be no knowledge, and consequently no adaptation of the article best suited to the very varying circumstances of our extensive possessions, on the part of those who enter into and make these contracts; and it would seem very desirable that information should be sought on this subject, and brought under the consideration of a competent committee, who could decide *where* it might be expedient to send articles of British manufacture, or whether to manufacture them in the colonies, or to import material or timber suitable to make and supply them. In most cases, where labour is cheap, the former plan would be most advisable (saving of transports and conveyance for embarkation and disembarkation alone considered). The officers of Artillery and Engineers and the Ordnance-Storekeepers at our foreign stations could furnish much information on this subject. I have seen large quantities of stores (to the preservation of which much care and expense has been given) rendered unserviceable in a very short time in storehouses in the West Indies. The destruction during war in crowded storehouses must have been immense, and it is well to give this subject the consideration it merits whilst leisure and opportunity are afforded for it.

In my Paper on West India Barracks, I pressed the necessity of perfect ventilation in storehouses in the dry islands, and the use of stoves, occasionally, in the humid colonies, as one means of preservation, both of the buildings and of their contents; but I would now urge, as more important, the adoption and substitution of such articles as the experience of the colonists, &c., have found the best adapted to the climates.

The articles of store for barrack purposes in which destruction goes on rapidly are—

Tables, chairs, handles of all kinds.

The articles of artillery stores are—

Powder-barrels (hooped with wood), shot-bottoms, fuzes, portfire-sticks, handles and helves for tools, carriages of all descriptions, and cases containing stores and ammunition, &c.

The articles of engineer stores are—

Handles to tools of all descriptions, especially planes, chisels, and saws.

Many, if not most of these articles, being manufactured of beech, box, plane, cherry-tree, and dry oak, are attacked by the boring-worm and wood-ant, and destroyed with great rapidity.

I would, in conclusion, suggest the necessity of stating the nature of the tools used in our different colonies in working the native woods, for though they may not in all cases present the same finished workmanship, or meet our English ideas on such points, they will be found, as in the case of the axe of the North American wood-cutter, and the tools used for the hard woods of Guiana, to have been adopted from that best of all teachers, experience.

Drawings of the tools are also wanting.

JOHN SMYTH,
Captain Royal Engineers.

Exeter, Oct. 31, 1837.

Experiments on the Strength of Timber when exposed to a Transverse Strain.

By Lieutenant DENISON, *Royal Engineers.*

THE first set of these experiments was made in America on specimens of small scantling; they were commenced with the view of ascertaining as nearly as possible the variations in weight, dimension, and strength caused by seasoning, or by difference of position in the tree. For this purpose trees were felled, and several specimens cut from each as nearly as possible of the same size, and the dimensions and weights carefully noted and marked upon each specimen. Some were then tried in their green state, while the others were left to season. Most of the specimens shown in the first Table were unseasoned, and before I could complete the experiments on the remaining specimens I was ordered home.

This series has already been published in the Transactions of the Institution of Civil Engineers, but as the results may be of service to any officer who should be desirous of following out and completing the plan which I only sketched out and commenced, I have here inserted an abstract of them. The second set of experiments were made at Chatham upon specimens of much larger scantling, most of which were furnished by order of the Lords Commissioners of the Admiralty from the dock-yard; others were sent to me by Lieut.-Col. Brown, who brought them from Ceylon. Here, again, I was interrupted before I had completed the series, and the Ceylonese woods have still their relative strengths and weights undecided.

In all these cases the experiments were similarly conducted. Two oak trestles were fixed at a given distance asunder, and the specimens being laid on these, a scale was suspended by a link from the central point between the supports; equal weights were then added at intervals of a few minutes, and the deflexion caused by each carefully noted.[1]

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[1] The deflexions were read off on a graduated circle where the actual amounts were increased in the proportion of 10 to 1.

As soon as any irregularity in the deflexions indicated that the elasticity was overpowered, which was also ascertained by removing the weight and observing whether the index returned to zero or its point of starting, the weights were added more rapidly till the piece finally gave way. In the later specimens, when from their size it became possible to ascertain the position of the neutral axis, this was observed as follows: two vertical lines, exactly parallel, were marked upon the specimen at a distance of 5 inches on each side of the central point, or 10 inches apart; divisions were then marked upon these lines at every tenth of an inch. As soon as weights sufficient to produce any amount of deflexion were placed in the scale, an accurately divided brass scale was applied to these lines; it was of course found that the upper fibres were compressed, and the lower fibres extended; the scale was then moved down from division to division on the vertical lines till it reached a point where the distance between the two (10 inches) remained unaltered, and this was considered to be the position of the neutral axis.

In the first set of experiments the weights were added by 20 ℔s. at a time, in the second set they were added by half cwts.; but I have not thought it necessary to show the effect produced by every individual weight, as in the original experiments, having merely noted these when observations on the elasticity or position of the neutral axis offered something worthy of remark.

In this Table, column 1 gives the number of the experiment; 2, the name of the wood; 3, 4, and 5, the dimensions of the specimen; 6, its specific gravity; 7, the weight which overcame the elastic force of the specimen; 8, the deflexion with that weight; 9, the breaking weight; 10, the ultimate deflexion; 11, value of S from formula $S = \frac{l\,W}{4\,a\,d^2}$.

No. of experiment.	Name of wood.	Length in inches.	Breadth.	Depth.	Specific gravity.	Weight which destroyed elasticity.	Deflexion by this weight.	Breaking weight.	Ultimate deflexion.	$S = \frac{l\,W}{4\,a\,d^2}$.	Remarks.
			in.	in.		lbs.	in.	lbs.	in.		
1	Canadian White Oak.	24	·99	·99	786·4	155	·26	295	2·437	1824	Specimen seasoned; ends loose on supports.
2	..	24	·975	·97	763·6	155	·33	365	1·85	2388	Do. do.
3	..	24	1·01	1·0	918	140	·37	260	1·75	1544	Specimen green.
4	..	24	·985	1·0	1034	100	·28	220	1·83	1340	Do., faulty specim^{n}, weakened by a knot. Heart of tree.
5	..	24	1·0	1·0	951	120	·30	250	3·83	1500	Do., heart of tree.
6	..	24	1·01	1·0	939	100	·33	200	1·05	1188	Do. do., cut from same specimen; gave way at a knot.
7	..	24	1·02	1·0	798	140	·33	300	2·72	1764	Pretty dry.
8	..	24	1·0	1·0	788·9	140	·35	280	1·32	1680	Do.
9	..	24	1·01	1·01	789·6	140	·283	280	1·50	1630	This and the former specimen broke rather across the gr^{n}.
10	..	24	1·0	1·0	790	140	·33	340	2·25	2040	
11	..	24	·99	·98	760·4	100	·255	240	1·12	1514	Broke suddenly.
12	..	24	·98	·98	738·5	100	·275	240	1·25	1530	Pretty dry.
13	..	24	·98	·98	736	120	·28	300	1·94	1912	
	Mean of all, except 3, 4, 5, & 6,				772	Mean value of S, except do.				1809	
14	Rock Elm.	24	·985	1·005	748·7	211	·37	435	2·1	2623·4	Specimen seasoned.
15	..	24	·985	·99	754	183	·37	323	2·85	2000·0	Do. do.
16	..	24	·985	1·0	740·6	120	·33	280	1·95	1705	Specimen green.
17	..	24	·985	1·02	745·5	120	·33	280	2·25	1705	Do. do.
18	..	24	·93	·97	743	140	·34	340	1·75	2331	Do., broke with a long splinter.
19	..	24	·97	·98	755	140	·30	360	2·20	2318	Do. do.
	Mean of seasoned specimens				751·8					2311·7	
	Mean of green specimens				746					2049	
20	Weep^{g} Ash.	24	1·01	1·0	761·5	120	·40	220	7·3		This is an extraordinarily tough wood; in both cases the specimen slipped thro' the supports without breaking, after bending to the amount shown.
21	..	24	1·0	1·04	763	120	·28	260	7·0		
22	White Ash.	24	1·03	1·04	781	200	·332	360	1·95	1938	Specimen green.
23	..	24	1·02	1·04	698	200	·34	360	1·95	1958	Do. do.
24	..	24	·96	·98	641·6	140	·305	320	1·75	2082	Seasoned; broke with a long splinter.
25	..	24	·96	1·0	643	140	·32	320	1·70	2000	Do., broke fairly.
	Mean of seasoned specimens				642·3					2041	
	Mean of green specimens				739·5					1948	

No. of experiment.	Name of wood.	Length in inches.	Breadth.	Depth.	Specific gravity.	Weight which destroyed elasticity.	Deflexion by this weight.	Breaking weight.	Ultimate deflexion.	$S = \frac{lW}{4 a d^2}$.	Remarks.
			in.	in.		lbs.	in.	lbs.	in.		
26	Swamp Ash.	24	·96	·98	931·7	80	·27	160	1·68	1141	Specimen green.
27	..	24	1·0	·98	919·6	80	·21	190	2·33	1189	Do.
	Mean				925·6					1165	
28	Black Ash.	24	·98	1·0	608			120		735	Gave way suddenly; specimen green.
29	..	24	·98	·98	458			155		988	Do. do.
					533					861	
30	White Hiccory.	24	·97	·97	839	120	·28	330		2170	Specimen dry; it cracked with 330 lbs., and the index was released, but it would probably have stood a good deal more.
31	..	24	·94	·94	834	120	·32	310	4·60	2240	Specimen dry.
					836·5					2205	
32	Bitt^{r} Nut Hiccory	24	1·035	1·01	926			239		1358	Green; gave way suddenly.
33		24	1·02	1·0	807			239		1406	Do. do.
34	..	24	·975	·98	880	127	·23	260	2·0	1632	Do. do.
					871					1465	
35	Bl^{ck} Birch.	24	1·02	1·0	781	120	·32	240		1387	Green; broke suddenly.
36	..	24	1·02	1·0	762·8	140	·32	240		1387	Do. do.
					772					1387	
37	Yell^{w} Birch.	24	·99	1·0	767·7	120	·20	200	1·10	1212	Green.
38	..	24	·99	·99	745·4	120	·32	240	1·20	1458	Do.
					756·5					1335	
39	Birch.	24	·94	·965	679	183	·26	365		2525	Seasoned; gave way gradua^{ly}.
40	Wh^{te} Beech.	24	·99	·99	718	140	·34	220	1·0	1360	Green.
41	..	24	·97	·99	704	120	·34	210	1·3	1400	Do., broke suddenly.
					711					1380	
42	Red Beech.	24	1·0	1·0	821	140	·26	265	2·0	1590	Green.
43	..	24	·995	·995	786·8	140	·28	285	2·3	1736	Do.
44	..	24	1·0	1·0	710	127	·25	325		1950	Seasoned; broke in 2 hours.
					772·6					1758	

No. of experiment.	Name of wood.	Length in inches.	Breadth.	Depth.	Specific gravity.	Weight which destroyed elasticity.	Deflexion by this weight.	Breaking weight.	Ultimate deflexion.	$S = \frac{l W}{4 a d^2}$	Remarks.
			in.	in.		lbs.	in.	lbs.	in.		
45	White Pine.	24	1·015	1·02	465	100	·21	220	·85	1250	Green.
46	..	24	·985	·99	397			183	1·0	1137	Seasoned; broke suddenly.
47	..	24	·965	·98	467			183	1·4	1184	Do.
	Mean of 46 & 47				432					1160	
48	Red Pine.	24	·965	·99	534	127	·37	211		1338	Seasoned; broke short in 5 minutes.
49	..	24	·976	·975	477·8			183	1·85	1184	Do.
					506					1261	
50	Tamarak or Larch	24	1·025	1·0	430·9	80	·22	160	1·2	936	Green.
51		24	1·02	1·03	435	80	·21	160	1·15	886	Do.
					433					911	
52	Canada Balsam.	24	1·01	1·0	556	100	·20	200	1·07	1188	Green.
53		24	1·02	1·0	541	100	·22	180	1·07	1058	Do.
					548					1123	
54	Hemlock.	24	1·01	1·02	876	100	·25	200	1·25	1142	Green.
55	..	24	1·01	1·02	946	100	·23	200	1·35	1142	Do.
					911					1142	
56	Black Spruce.	24	·99	1·0	670			183	1·25	1109	Green.
57	..	24	·975	·995	874			155	·85	963	Do., gave way directly.
					772					1036	
58	Iron-wood.	24	1·0	1·0	897	127	·23	316	1·75	1896	Green.
59	..	24	1·01	1·0	883	155	·28	340	2·4	2019	Do., cracked and slipped on support.
60	..	24	1·01	1·0	858	155	·45	265	2·05	1485	Do.
					879					1800	
61	White Cedar or Arbor Vitæ.	24	·99	·99	357	80	·47	120	1·20	805	Dry.
62	..	24	·99	1·0	352	80	·50	120	1·36	727	Do.
					354					766	

No. of experiment.	Name of wood.	Length in inches.	Breadth.	Depth.	Specific gravity.	Weight which destroyed elasticity.	Deflexion by this weight.	Breaking weight.	Ultimate deflexion.	$S = \frac{l W}{4 a d^2}$.	Remarks.
			in.	in.		lbs.	in.	lbs.	in.		
63	Black Oak.	24	·99	·99	956	100	·26	260	1·75	1608	Green. } This oak is principally used for staves; it is so porous longitudinally that water will find its way through a long rod.
64	..	24	·975	1·0	972	100	·25	280	1·95	1723	Do.
	Mean				964					1665	
65	Soft Maple.	24	1·01	1·02	718			267	1·65	1524	Green.
66	..	24	1·01	1·0	649	127	·22	295	1·82	1752	Do., gave way suddenly.
67	..	24	·95	1·0	659	155	·40	286	1·70	1807	Do.
					675					1694	

In all the previous experiments the ends of the pieces were allowed to rest loose on the supports; in the following 14 experiments the ends were securely clamped down.

No. of experiment.	Name of wood.	Length in inches.	Breadth.	Depth.	Specific gravity.	Breaking weight.	Ultimate deflexion.	$S = \frac{l W}{4 a d^2}$	Remarks.
			in.	in.		lbs.	in.		
1	Red Cedar.	24	·985	·96	546	357	·90	2336	Dry; gave way suddenly at a knot.
2	. .	24	1·005	·99	546	386	·90	2429	All weights taken off set ·15.
3	Black Ash.	24	·995	·985	572·8	386	2·4	2387	Green. This specimen still wet and soft, though the specific gravity was reduced from 814 to 572; the scale bruised the wood very much.
4	. .	24	·99	·975	531	337		1965	
5	Birch.	24	·98	·985	679	421		2652	Pretty dry; gave way suddenly.
6	Beech.	24	·98	·96	787	407	1·0	2684	Pretty dry; gave way suddenly.
7	Black Cherry.	24	1·0	1·0	640	520		3650	Pretty dry; began to give with 490 lbs., but the 520 lbs. remained on some hours before it broke.
8	Curly Maple.	24	·97	·97	748	477		3125	Pretty dry; gave way gradually.
9	Rock Elm.	24	·92	·94	819·5	521	1·44	3835	Pretty dry; after this weight had been on 1 hour, the deflexion was 1·53, and set ·75; the specimen was not actually fractured.
10	White Oak.	24	·975	·975	660·5	521		3362	Dry, permanent set ·5; in these cases I was unable for want of weights to break the specimens.
11	. .	24	·98	·98	685	620		3943	Green; broke.
12	Iron-wood.	24	·995	·98	768·7	521	1·20	3172	Green; after 24 hours deflexion became 1·6, and set 1·2.
13	. .	24	·985	·98	807	521	1·15	3172	Do.; in 24 hours deflexion 1·40, set ·9.
14	Bitter Nut Hiccory.	24	·985	·98	779	407	·75	2478	Green; broke in about 5 minutes.

On comparing the power of resisting cross strains, as exhibited by the latter experiments, when the ends were fixed, with that shown by the specimens lying loose on the supports, it will be seen by the Table below that the ratio varies from 2·5 : 1 to 1·66 : 1 in favour of the fixed specimens, and even this proportion is hardly sufficiently favourable to the fixed specimens, as many of them were not actually fractured.

Name of wood.	Value of S, ends fixed.	Value of S, ends loose.	Proportion.
Black Ash.	2176	861	2·5 : 1
Birch.	2652	1387	1·9 : 1
Beech.	2684	1380	2·0 : 1
Rock Elm.	3835	2311	1·66 : 1
White Oak.	3652	1809	2·0 : 1
Iron-wood.	3172	1800	1·76 : 1
Bitter Nut Hiccory.	2478	1465	1·7 : 1

Experiments on different Woods made at ***Chatham*** *in the years* **1833** *and* **1834.**

No. of experiment.	Name of wood.	Dimensions of specimen.			Specific gravity.	Weight applied.	Deflexion.	Depth of the neutral axis below upper surface.	$S = \frac{lW}{4ad^2}$.	Remarks.
		Length in inches.	Breadth in inches.	Depth in inches.						
						lbs.	in.	in.		
1	American Pitch Pine	72	2·025	3·025	826	56	·04			
						560	·405			No set.
						1120	·868	1·6		
						1400	1·124	1·6		
						1624	1·42	1·7		
						1792	1·67	1·7		
						1904	1·9	1·8	1848	Broke very short.
2	Do. Do.	72	2·025	3·025		56	·05			
						560	·486			No set.
						1064	·986	1·7		
						1288	1·25	1·7		
						1456	1·47	1·7		
						1792	2·3	1·8	1740·8	Broke very short.
3	Do. Do.	72	2·025	3·025	816	56	·036			
						560	·408			Slight set.
						840	·635	2·0		
						1288	1·046	2·0		
						1512	1·28	2·0		
						1792	1·71	2·0		
						1904	2·35	2·0		
						1960	2·75		1905	Broke.
4	Do. Do.	72	2·025	3·037	826	56	·052			
						560	·511			Slight set.
						896	·86	1·3		
						1120	1·135	1·4		
						1560	1·77	1·6		
						1792	2·33	1·6		
						1848	3·16		1794	Broke short.
5	Canada Yellow Pine	72	2·025	2·963	509	56	·056			
						392	·439			No set.
						784	·95	1·7		
						1120	1·65	1·7		
						1288	2·53		1305	Broke short and rather twisted.
6	Do. Do.	72	2·05	3·0		56	·08			
						448	·648	1·8		No set.
						728	1·12	1·8		
						896	1·5	1·8		
						1064	2·15	1·8		
						1120	2·25		1092	Broke short.

No. of experiment.	Name of wood.	Dimensions of specimen.			Specific gravity.	Weight applied.	Deflexion.	Depth of the neutral axis below upper surface.	$S = \frac{l W}{4 a d^2}$.	Remarks.
		Length in inches.	Breadth in inches.	Depth in inches.						
						lbs.	in.	in.		
7	Canada Yellow Pine	72	2·0	3·012		56	·06			
						560	·576			Hardly any set.
						784	·818	1·6		
						952	1·04	1·6		This specimen rather redder coloured than the last.
						1064	1·17	1·6		
						1176	1·35	1·6		
						1568	2·5		1452	Broke short, and near the end.
8	Do. Do.	72	2·025	3·0	403	56	·077			
						560	·77			No set.
						672	·955	1·8		
						896	1·48	1·8		
						1008	1·78	1·8		
						1232	3·28		1216	Broke short.
9	African Oak	72	2·025	3·05		56	·038			
						560	·38			
						784	·537			No set.
						1176	·848	1·9		
						2240	1·94	1·9		
						2688	3·0	1·9		
						2744	3·38		2622	Broke fairly, being strained equally throughout.
10	Do. Do.	72	2·025	3·05		56	·04			
						560	·44			
						728	·56			
						2016	1·735	1·7		
						2688			2569	Broke suddenly, with a long splinter.
11	Dantzic Pine	72	2·05	3·025	762	56	·045			
						560	·52			Hardly any set.
						1400	1·64		1348	Broke with a long splinter.
12	Do. Do.	72	2·025	3·0	794	56	·065			
						560	·665			Hardly any set.
						1512			1493	Broke short.
13	Do. Do.	72	2·025	3·025	733	56	·06			
						560	·62			No set.
						1568	2·54		1523	Broke short.
14	Do. Do.	72	3·025	2·05	508	56	·126			
						336	·798			No set.
						1008	3·5		1427	Cracked and broke soon after. This specimen was sent to me as Dantzic, but from its appearance and specific gravity I should doubt its being so.

No. of experiment.	Name of wood.	Dimensions of specimen.			Specific gravity.	Weight applied.	De-flexion.	Depth of the neutral axis below upper surface.	$S = \frac{W\,l}{4\,a\,d^2}$.	Remarks.
		Length in inches.	Breadth in inches.	Depth in inches.						
						lbs.	in.	in.		
15	American Rock Elm	72	2·025	3·025	761	56	·045			
						560	·447			
						784	·628			No set.
						2184	3·1	2·0		
						2296	3·45		2229	
16	Do. Do.	72	2·05	3·025	742	56	·043			
						560	·498			Slight set.
						1120	1·07	1·5		
						1512	1·62	1·5		
						1680	1·95	1·7		
						1848	2·53	1·7		
						2128	3·8		2032	
17	Do. Do.	72	2·025	3·05		56	·048			
						560	·506			Very slight set.
						1008	1·00	1·6		
						1344	1·55	1·6		
						1512	1·96	1·7		
						1792	3·03		1712	Cracked.
18	English Oak	72	2·0	3·025	705	56	·073			
						560	·682			No set.
						1008	1·38	1·7		
						1288	2·23	1·82		
						1736	3·9		1707	Broke fairly.
19	Do. Do.	72	2·025	3·012	761	56	·064			
						560	·65			Slight set.
						840	1·02	1·6		
						1064	1·36	1·6		
						1344	2·01	1·8		
						1568	2·66	1·9		
						1680	3·03	2·0		
						1848	3·65		1810	Broke fairly.
20	Do. Do.	72	2·025	3·0		56	·088			
						448	·695			Slight set.
						784	1·29	1·7		
						1008	1·79	1·7		
						1064	2·06	1·7		
						1232	2·51	1·7	1153	Broke very short.
21	Scotch Larch	72	2·05	3·0	470	56	·07			
						560	·686			No set.
						1288	1·85		1256	Cracked.
22	Do. Do.	72	2·012	3·0	483	56	·09			
						448	·745			No set.
						1064	2·28	1·8		
						1232	3·41		1211	Broke fairly.

No. of experiment.	Name of wood.	Dimensions of specimen.			Specific gravity.	Weight applied.	Deflexion.	Depth of the neutral axis below upper surface.	$S = \frac{l W}{4 a d^2}$.	Remarks.
		Length in inches.	Breadth in inches.	Depth in inches.						
						lbs.	in.	in.		
23	Scotch Larch	72	2·025	2·988	487	56	·095			
						560	·99			Left on 24 hours: the set was then ·07.
						1120	3·4		1113	Broke short.
24	Cedar of Lebanon	72	2·025	3·0	330	56	·058			
						560	·633			Very slight set.
						784	·91	1·6		
						1064	1·32	1·7		
						1176	1·66	1·8		
						1288	2·05	2·0		
						1512	3·25		1493	Broke short.
25	New Zealand Cowdie	72	2·025	3·05	550	56	·036			
						560	·409			Very slight set.
						1120	·86	1·5		
						1288	1·03	1·5		
						1512	1·3	1·6		
						1680	1·6	1·7		
						1792	1·85	1·8		
						1960	2·63	1·9	1873	Broke short.
26	English Elm	72	2·0	3·025	605	56	·218			
						224	·729			Slight set.
						336	1·145	1·7		
						448	1·7	1·7		
						560	2·2	1·7	551	Broke short.

The column which contains the numbers denoting the position of the neutral axis exhibits some anomalies; but from the majority of the observations I should be disposed to conclude, that while the elasticity of the timber remains unimpaired, the neutral axis occupies the centre of the depth: as the strain was increased, the position of the axis evidently changed, and approached nearer and nearer the bottom of the specimen; in some of the experiments the change seemed to be made at once, while in others no alteration was detected. It would be very desirable to institute some experiments for the purpose of deciding this very point of the position of the neutral axis while the elasticity of the material remains perfect, not only as regards wood, but also cast and wrought iron.

ABSTRACT OF RESULTS.

	Observers :												
	LT. NELSON.		CAPT. YOUNG.		MR. MOORE.		MR. BARLOW.		LT. DENISON.		Mean.		
Names of woods.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	sp. gr.	S.	
African Oak	985	2484	..	..	962	2522	982	2493	1024	2595	988	2523	Sp. gr. when dry, 777.
Ash, English	..	..	..	..	..	..	760	2026	..	..	760	2026	
„ American	611	1550	..	..	..	..	..	..	642	2041	626	1795	
„ „ Swamp .	..	..	..	..	..	..	..	..	925	1165	925	1165	
„ „ Black .	..	..	..	..	..	..	..	..	533	861	533	861	
Beech, English . . .	..	..	..	..	..	..	696	1556	..	..	696	1556	
„ American White .	..	..	..	..	..	..	..	..	711	1380	711	1380	
„ „ Red .	778	1720	..	..	..	..	..	..	772	1758	775	1739	
Birch, Common . . .	..	..	..	..	..	..	711	1928	..	..	711	1928	
„ American Black .	682	1848	..	..	..	..	649	1810	679	2525	670	2061	
„ „ Yellow .	..	..	..	..	..	..	..	..	756	1335	756	1335	
Cedar, Bermuda . . .	748	1395	..	1491	..	..	..	..	..	..	748	1443	
„ Guadaloupe . .	756	2044	..	..	..	..	..	..	..	..	756	2044	
„ American White .	..	..	..	..	..	..	..	..	354	766	354	766	
„ of Lebanon . .	..	..	..	..	..	..	..	..	330	1493	330	1493	
Elm, English	..	..	..	..	..	..	553	1013	605	551	579	782	
„ Canada Rock . .	700	1869	..	..	..	..	..	..	751	2072	725	1970	
Hiccory, American . .	871	1672	..	2447	786	2192	..	..	836	2205	831	2129	
„ „ Bitter Nut	..	..	..	..	..	..	..	..	871	1465	871	1465	
Oak, English	834	1629	..	..	816	1919	934	1672	733	1556	829	1694	
„ American White .	645	1699	..	..	836	1699	872	1766	772	1809	779	1743	
„ „ Red . .	940	1709	..	..	..	..	..	..	964	1665	952	1687	
„ „ Live . .	1160	1862	..	..	..	..	..	..	..	..	1160	1862	
„ Adriatic	..	..	..	..	718	1559	993	1383	..	..	855	1471	
„ Dantzic	..	..	..	..	684	1579	756	1457	..	..	720	1518	
„ Italian	..	..	..	..	796	1688	..	..	..	..	796	1688	
„ Lorraine	..	..	..	..	796	1483	..	..	..	..	796	1483	
„ Memel	..	..	..	..	727	1665	..	..	..	..	727	1665	
Pine, American White .	453	1456	410	1073	..	..	..	..	432	1160	432	1229	
„ „ Red . .	621	1944	..	1799	521	1289	657	1341	506	1261	576	1527	
„ „ Yellow .	..	..	..	..	516	1188	553	1102	456	1266	508	1185	
„ „ Pitch .	..	..	..	..	..	..	660	1632	820	1822	740	1727	
„ Virginia	..	..	..	..	590	1456	..	..	..	..	590	1456	
„ Archangel . . .	..	..	..	..	551	1370	..	..	..	..	551	1370	
„ Dantzic	..	..	..	..	649	1426	..	..	..	..	649	1426	
„ Memel	..	..	..	..	601	1348	..	..	..	..	601	1348	
„ Prussian	..	..	..	..	596	1445	..	..	..	..	596	1445	
„ Riga	..	..	..	..	562	1687	746	1079	..	..	654	1383	
Spruce	..	..	..	..	503	1346	..	..	..	..	503	1346	
„ American Black .	..	..	..	..	..	..	..	..	772	1036	772	1036	
Mar Forest Fir . . .	..	..	..	..	..	..	698	1232	..	..	698	1232	
Norway Spar	..	..	..	..	..	..	577	1474	..	..	577	1474	
Deal, Christiana . . .	..	..	..	..	..	..	689	1562	..	..	689	1562	
Canada Balsam . . .	..	..	..	..	..	..	..	..	548	1123	548	1123	The specimen tried by Mr. Moore probably a different kind of timber.
Hemlock	..	..	..	..	..	..	..	..	911	1142	911	1142	
Larch	..	..	..	..	658	1958	542	995	468	1052	556	1335	
„ Americ^a or Tamarak	..	..	..	..	..	..	..	..	433	911	433	911	
Lignum-Vitæ	1082	2013	..	..	..	..	..	..	..	..	1082	2013	
Mahogany, Nassau . .	812	1752	..	1904	525	1503	..	..	..	..	668	1719	
Mangrove, Bermuda Black	1188	1699	..	..	..	..	..	..	..	..	1188	1699	
„ „ White	951	1985	..	..	..	..	..	..	..	..	951	1985	
Teak	719	1898	..	..	723	1964	745	2462	..	..	729	2108	
Poon	..	..	..	..	768	1687	579	2221	..	..	673	1954	
Acacia	..	..	..	..	..	..	710	1867	..	..	710	1867	
Sneezewood	1066	3305	..	..	..	..	..	..	..	..	1066	3305	South Africa.
Yellow-wood	926	2103	..	..	..	..	..	..	..	..	926	2103	West Indies.
Greenheart	..	..	970	2471	..	..	1000	2759	..	..	985	2615	Demerara.
Wallaba	..	..	1147	1643	..	..	..	..	..	..	1147	1643	
Bullet Tree	..	..	1075	2733	..	..	1029	2651	..	..	1052	2692	
Kakarally	..	..	1223	2379	..	..	..	..	..	..	1223	2379	
Crab-wood	..	..	648	1875	..	..	..	..	..	..	648	1875	
Locust	..	..	..	..	..	..	954	3430	..	..	954	3430	
Cabacally	..	..	..	..	..	..	900	2518	..	..	900	2518	
Iron-wood	..	..	..	..	..	..	..	..	879	1800	879	1800	Canada.
Soft Maple	..	..	..	..	..	..	..	..	675	1694	675	1694	

The following Catalogue of Woods, with their specific gravities and relative strengths, has been supplied by the kindness of Mr. Fincham, the Master Shipwright at Chatham Dock-yard. The strength shown is not, as in the former Table, the value of S, but is merely the relative strength of the timber to resist a transverse strain: the resistance of Oak being assumed as 1000; if each of the number be multiplied by 1·7, it will give a close approximation to the value of S.

Name of wood.	Specific gravity.	Relative strength.	Remarks.
Rock Maple	748	384	American.
Mocro or Miro	778	740	New Zealand Timber.
Tanakaha	882	740	
Cowrie	775	730	
Totarra	709	615	
Remo	979	712	
Demo	723	692	
Kahikatoa, or Tea Tree	1213	1096	
Rewarewa	867	644	
Peppermint	1048	750	Van Dieman's Land.
Beef-wood	1146	961	
Box	923	903	
Light-wood	532	404	
Huon Pine	710	500	
Iron Bark	1426	1557	New South Wales.
Mahogany	1382	865	
Stringy Bark	1291	1000	
Blue Gum	1232	1057	
Black-butted Gum	1069	961	
Guitoe	1180	1000	Rio Janeiro.
Grabu	1226	1433	
Olio	1086	1230	
Curebarulie	1289	1365	
Amarilla	1051	1346	
Gorinda, Yellow	894	730	
Do. Brown	1059	836	

VI.—*Report on the Canal Navigation of the Canadas. By Lieut.-Colonel* PHILLPOTTS, *Royal Engineers.*

THE following Report, called for by the instructions of His Excellency the Earl of Durham, will embrace three distinct lines of communication:

I. The communication from Lake Erie to the sea by the Welland Canal, Lake Ontario, and the River St. Lawrence.

II. The communication from Lake Simcoe to Lake Ontario by the Rice Lakes and River Trent.

III. The communication from Lake Huron by the French River and Lake Nipissing, to the Ottawa River.

I. The first of these being the most important, and my attention having also been more immediately called to it, as well by my instructions as by the directions which I have subsequently received from His Excellency Lieut.-Gen. Sir John Colborne, I proceed to report upon the communication *from Lake Erie to the sea by the Welland Canal, Lake Ontario, and the River St. Lawrence.*

Assuming Port Colborne at Gravelly Bay on Lake Erie as the commencement of this very important communication, (the reasons for which will be given hereafter when I treat more particularly on the Welland Canal,) the distance from Lake Erie to Quebec may be estimated at 587 miles, as follows:

		Canal Navigation.	Lake and River.
		miles.	miles.
From Port Colborne on Lake Erie to Port Dalhousie on Lake Ontario by the Welland Canal		28	..
To Kingston by Lake Ontario		..	180
To Prescott by River St. Lawrence		..	70
To Head of Long Saut Rapid, 38 miles: in which distance the following rapids requiring canals occur, viz.			
The Galoppes Rapids	0½		
Point Cardinal	0 3/10		
Rapide Plat	3 9/10		
Farren's Point	0 8/10		
		5½	32½
To Cornwall by the St. Lawrence Canal		11¼	..
Coteau du Lac by Lake St. Francis		..	35
The Cascades, 14¾ miles: in which distance the following rapids requiring canals occur, viz.			
The Rapids at Coteau du Lac	2¾		
Ditto at the Cedars	1¾		
Ditto at the Cascades	2¼		
		6¾	8
To Lachine by the Lake St. Louis		..	21
To Montreal by Canal		9	..
To Quebec by the River St. Lawrence		..	180
		60½	526½

Making in all 587 *miles*, as above stated, in which distance it appears that the navigation is naturally good for 526½ miles, and that *only* 60½ *miles of canal are* required altogether to enable large steamers to pass from Quebec to Port Colborne, from whence the navigation is also naturally good for large steamers for a distance of 1000 miles, through Lake Erie, the River Detroit, Lakes St. Clair, Huron, and Michigan, to Chicago; so that, in the whole distance of nearly 1600 miles between Quebec and Chicago, the navigation of 1526½ miles is naturally good for large steamers, and consequently there will only be 60½ miles of canal navigation, of which the Welland Canal comprises 28 miles, and this work is absolutely required under any circumstances in order to afford a water communication between Lake Erie and Lake Ontario. Of the remaining 32½ miles, 11¼ have already been nearly completed by the Provincial Government of Upper Canada, in order to overcome the rapids at the Long Saut near Cornwall; 9 miles have been constructed for barges some years since by the Provincial Government of Lower Canada between Lachine and Montreal, which however will require to be *very much* enlarged or rather a new canal will be required for steam-boat navigation; and 12¼ miles are necessary to be made in the various short canals required to pass the other rapids of the River St. Lawrence at the Galoppes, Point Cardinal, Rapide Plat, Farren's Point, Coteau du Lac, the Cedars, and the Cascades.

In the above distance there will be 517 feet of lockage, which will require 63 locks, and the total expense of completing this long line of communication on the large scale adopted in the St. Lawrence Canal, near Cornwall, will be £2,228,700 sterling, as shown in the following Table.

	Length in miles.	No. of locks.	Feet of lockage.	Amount of estimated expense.
(Between Lake Erie and Lake Ontario.)				
The Welland Canal	28	35	328½	£1,250,000
(In the River St. Lawrence.)				
The Galoppes Rapids	0½	1	4½	29,500
Point Cardinal	0 3/10	1	2½	25,000
Rapide Plat	3 9/10	2	11½	120,000
Farren's Point	0 8/10	1	4	48,000
Long Saut Rapids	11¼	7	48	57,300
Rapids at Coteau du Lac	2¾	2	17	120,300
Ditto at the Cedars	1¾	4	30¾	125,000
Ditto at the Cascades	2¼	3	25¼	129,000
Lachine Canal	9	7	45	324,600
	60½	63	517	£2,228,700

Of the above-mentioned works, that part of the St. Lawrence Canal which has been commenced at the Long Saut Rapids near Cornwall, and the Welland Canal, which connects Lake Erie with Lake Ontario, are by far the most important, and they demand immediate attention.

The inland navigation from Quebec to Lake Michigan being alternately through the large lakes of Upper Canada and their connecting rivers, and the portion of this distance which will require canals being altogether so very short, in comparison with the length of the whole route, it is quite evident that large steamers will be much more advantageous under such circumstances than sailing vessels; and accordingly we see that, on Lake Erie and the Upper Lakes, the number of the former is increasing much faster than that of the latter: as there can be no towing on these Upper Lakes, large freight steamers, similar to those now in use on the Mississippi and its branches, will have a most decided advantage over all other modes of conveyance. This is in some measure proved by the fact that the merchants of the Upper Lakes are now in the habit of ordering their goods, which are sent from New York by the Erie Canal to Buffalo, to be forwarded upwards in steamers in preference to sailing vessels; and therefore it follows that, if we can bring these large freight steamers from these Upper Lakes down to the sea-ports of Quebec and Montreal, all the delay and expense of trans-shipment will be avoided, as well as the long and tedious navigation of the Erie Canal, and consequently one of the great advantages which may most confidently be expected to result from the opening of this communication on the large scale here proposed, will be the inducing of the greatest part of the trade from those States situated to the westward of Buffalo to pass by this route to the Atlantic; and it is believed that this will be effectually secured by affording a continuous uninterrupted steam navigation, without any trans-shipment in the whole distance of nearly 1600 miles; but if the size of the short intermediate canals on this route be reduced to the small scale required for schooner navigation, trans-shipments will be necessary, and thus one of the greatest advantages which the River St. Lawrence naturally enjoys will be thrown away, and this route will in a great measure cease to have such a decided superiority as it may be made to possess over the Erie Canal as well as that which intersects it at Syracuse from Oswego on Lake Ontario.

From a slight inspection of the map of this part of North America, it will be quite evident that the surplus produce of all that part of this continent which is situated to the westward of the Falls of Niagara, including the States of Ohio, Kentucky, Tenessee, Indiana, Michigan, Illinois, a part of Missouri, Mississippi, and Alabama, together with the territories of Wisconsin, Missouri, and Iowa, must find its way to the ports of the Atlantic by one of the following routes, viz.,

1st. By the Mississippi to New Orleans.

2nd. By the Ohio and Chesapeake Canal to Baltimore.

3rd. By the Ohio and Pennsylvania Canal to Philadelphia.

4th. By the Ohio, Kanawha, and James River, to Richmond, Virginia.

5th. By the Erie Canal from Buffalo, or by the Welland Canal and Lake Ontario *via* Oswego to New York.

6th. By the Welland Canal and River St. Lawrence to Montreal and Quebec.

while New York is open all the year round; but when we take into consideration the fact that the Erie Canal is also rendered impassable by the same cause for a longer period, this objection ceases to be of any importance, and as this route will, when completed according to the plan here proposed, be a much more convenient and cheap route to the Atlantic than any other, (and by some alterations in the Trade Act such decided advantages may easily be given to the ports of the St. Lawrence as will render these markets far preferable to New York or any others on this continent,) there can be no doubt that a very large portion of the vast trade referred to, as well as the whole of that from Upper Canada, will pass this way, and that Montreal and Quebec will become two of the greatest emporiums in North America.

From the above statement there can be no doubt that this vast and important trade may be secured to Quebec and Montreal, if the canals required to pass the rapids, &c. of the St. Lawrence be made on the enlarged scale now proposed; and therefore I proceed to report fully and in detail upon each portion, beginning with the Welland Canal.

WELLAND CANAL.

Before the last war with the United States, and indeed until the opening of the Erie Canal in 1825, the whole of the trade of the country bordering on the River St. Lawrence, Lake Ontario, and the Upper Lakes, found its way to the ocean *via* Montreal and Quebec, and it is probable that it would have continued to do so to this day, had it not been for the construction of the New York and Erie Canal, which, by affording a safe and commodious inland water communication from Buffalo, at the foot of Lake Erie, to New York, has secured to our neighbours on that side of the boundary line the transport of nearly all the products of the western country, thus depriving the inhabitants of Canada of the advantage they had previously anticipated of becoming the carriers of all produce of the extensive countries west of the Falls of Niagara, and diverting much of their own produce to the New York market.

This was soon foreseen, as the natural result of the completion of that canal, by a few enterprising individuals of Upper Canada, who, fearing the consequence to the trade of these provinces, began a survey of the country as early as 1818, between the Chippawa or Welland River, which discharges itself into the Niagara River about 2 miles above the Falls, and the Twelve-mile Creek, which discharges itself into Lake Ontario at Port Dalhousie.

In consequence of the active exertions of the individuals above alluded to, the Legislature of Upper Canada passed an Act in the year 1824, incorporating the Welland Canal Company with a capital of £40,000, which sum was considered sufficient to make a canal with locks only 7 feet wide for boat navigation, commencing at the Welland River, about 9 miles from its mouth, where the village of Port Robinson now stands, and entering Lake Ontario at the mouth of the Twelve-mile Creek where the harbour, now called Port Dalhousie, has been formed; but before any progress was made in this design, the importance of the work began to be more fully discussed, and in the following year (1825) the plan was enlarged for schooner navigation, and the capital of the Company was increased to £200,000.

It was originally intended to make the Welland River the summit level, and to pass up the River Niagara from the village of Chippawa to Lake Erie; but the high ridge of land which crosses the country between Port Robinson and Allanburgh, and rises to the height of 56½ feet above the surface of the Welland, proved a most formidable obstacle to the pursuance of this plan, to accomplish which, that part, commonly called "The Deep Cut," was undertaken, requiring an excavation of from 30 to 56½ feet in depth for a distance of nearly 2 miles.

The removal of this formidable obstacle was very nearly completed, and there was every prospect that this first and most important section of the work, commencing at Port Dalhousie and ascending from Lake Ontario through the Deep Cut to the Welland River, would soon be opened for navigation, when, in the autumn of 1828, these high banks slipped down in many places, and filled up the bottom of the canal.

This disastrous occurrence caused a very great additional expense, and it became a serious question with the Company whether it would be expedient, with their limited means, to persist in the excavation of the Deep Cut, and continue the work on the original plan, or to raise the summit level, and abandon the idea of clearing out this channel to so great a depth. It is much to be regretted that the resources of the Company were not sufficient to enable them to persist in the original plan with a reasonable probability of success; the ultimate expense of which it now became very difficult to estimate with any certainty, in consequence of the quicksand on which these high banks were found to stand; and as their prospects of obtaining funds for the final completion of the work depended upon the communication being soon opened, the Company were reluctantly obliged to embrace the latter alternative; and by throwing a dam across the Grand River at Dunville, and cutting a small canal as a feeder from thence, they have brought the water of that river over the Welland by means of an aqueduct, at a level about 15½ feet above its surface; and therefore vessels are now enabled to pass through the Deep Cut over the obstacles caused by the slides above mentioned.

Although the completion of the Deep Cut would have given a safe water communication for vessels round the Falls, by sailing up the Niagara River from the mouth of the Welland to Lake Erie, yet it would have been a very imperfect one, because there is a very strong current below Fort Erie, which can only be ascended by sailing vessels when the wind blows strongly from the eastward, and it would also have been a very circuitous one; it was therefore subsequently intended to follow the Welland to Fort Creek, which is situated about 11 miles above Port Robinson, and by a cut of about 14 miles in length through a flat swampy country to enter the Grand River, the mouth of which is capable of being made a very excellent and safe harbour for any number of vessels that may navigate Lake Erie, and this Lake would thus have been rendered the summit level and feeder of the Welland Canal throughout its whole extent.

The alterations of the plan, however, in consequence of the slides at the Deep Cut, rendered an aqueduct necessary across the Welland, and therefore the navigation of that river, which, for a distance of upwards of 40 miles resembles a canal more than a running stream, (having scarcely any perceptible current, and being sufficiently deep for any vessel that can navigate the Lake,) has been impeded.

It has also been necessary, in order to raise the water of the Grand River to the summit level required, to erect a dam where the village of Dunville is now situated, about 5 miles from its mouth, and the water is brought from thence by a feeder 20¾ miles in length; but the canal, instead of being carried to the Grand River, has been taken by a shorter cut of only 7¾ miles to Gravelly Bay on Lake Erie, where the harbour of Port Colborne has been formed; and thus the entire communication between Lakes Erie and Ontario has been completed without entering the River Niagara at all. The advantages of this alteration are very important; for besides avoiding the great impediment to the navigation caused by the strong current in that river at Fort Erie, a great reduction of the distance[1] in lake sailing has been effected, an additional harbour has been formed on Lake Erie, and the canal is now generally open for navigation much earlier than the Niagara River, which, owing to the large quantity of ice that accumulates every spring at the foot of the lake, is generally closed for three or four weeks after the ice has disappeared above.

These alterations and additions to the original plan, however, have necessarily added much to the expense of the work. In the year 1833 the Legislature of Upper Canada appointed three commissioners to superintend the expenditure of a certain sum of money on this canal, and to appoint an engineer to examine it, and make an estimate of the expense of finishing it. In consequence of which, Benjamin Wright, Esq., an experienced engineer from the United States, was employed for this purpose, who made a full Report upon the work, and suggested several improvements, some of which were adopted; and now the expenditure from first to last has been altogether not much less than £500,000, of which upwards of £200,000 have been expended on the Deep Cut alone.

Although the canal was opened for schooners in 1830, the locks were not put into an efficient state till 1835, since which time it has continued navigable with little interruption. From the return of tolls collected (see Appendix), it is evident that the traffic on it is fast increasing, and that it is already drawing a great portion of the trade of the western country by this route; and when the contemplated improvements on the River St. Lawrence are completed between Prescott and Montreal, it cannot fail to answer the expectations of its original projectors, who deserve great credit for the activity and zeal with which they have prosecuted the work, under a series of discouragements that would have induced many persons of less perseverance and energy to abandon it in despair.

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[1]

From Port Robinson to the mouth of the Welland	9¼	miles.
Thence to Fort Erie	18	,,
To Port Colborne	22	,,
Total	49¼	,,
From Port Robinson to Port Colborne, by canal	12	,,
Saving of distance	37¼	miles.

This canal, as now constructed from Port Colborne on Lake Erie to Port Dalhousie on Lake Ontario, is rather more than 28 miles in length: it may be divided into four great sections, viz., the *first*, from Port Colborne to the aqueduct, 7¾ miles in length; the *second*, from the aqueduct to Port Robinson, 4¼ miles; the *third*, from Port Robinson to Thorold, 6¼ miles; and the *fourth*, from Thorold to Port Dalhousie, nearly 10 miles.

The first section passes through a low flat country, the surface of which is about 8 feet above the level of Lake Erie. For a distance of about half a mile near the lake the excavation for the canal passes through a bed of limestone, commencing about 4 feet under the surface; the remainder, through marsh resting on clay, which can be easily removed.

The second section, after crossing the Welland River by means of a very good aqueduct, formed of wood, runs along the left bank of that river, which, being composed of good stiff clay, affords the means of forming the canal without difficulty.

The third section, soon after leaving the Welland River at Port Robinson, passes through the high ridge of land before alluded to, which crosses the country on the north side of the Welland, and through which that part of the canal called "the Deep Cut" has been excavated; it then passes by Allanburgh across the mountain ridge to Thorold.

The excavation of the Deep Cut is through stiff clay resting on quicksand, the banks of which, though far too steep, stood very well until the excavation reached the quicksand, when the slides above mentioned took place, which caused the abandonment of the original magnificent plan of carrying the water of Lake Erie through to Lake Ontario. Between the Deep Cut and Thorold the soil is generally clay, and easily excavated, excepting through "the little Deep Cut," which passes through a ridge of clay 20 feet high, resting on a bed of limestone, in which the excavation has in one part been sunk to the depth of 8 feet.

The fourth section, soon after leaving the village of Thorold, descends the mountain by a deep ravine into the bed of the Twelve-mile Creek to St. Catherine's, and terminates at the mouth of this creek at Port Dalhousie, where it enters Lake Ontario. In descending the mountain the excavation runs generally through a mixture of limestone and clay till it passes into the valley of the Twelve-mile Creek, where the soil is chiefly clay, and where, indeed, little excavation is required.

The difference of level between the two lakes is 328 feet 8 inches, to which must be added the rise of the feeder from the Grand River above the level of Lake Erie, which is 5 feet at the aqueduct.

The number of locks at present is forty, including one near Port Colborne, descending from the level of the feeder from the Grand River into Lake Erie; two at Port Robinson, descending into the Welland River; and two at Allanburgh, descending into the canal below the Deep Cut. These five extra locks have all been rendered necessary in consequence of the alteration of the summit level. The locks below St. Catherine's are 32 feet wide, and 130 feet long; the lock at Port Colborne is 24 feet wide, and 130 feet long; all the others were originally 22 feet wide, and 110 feet long; but some of them have settled inwards so much that they do not now exceed 20 feet 6 inches in width.

The canal generally, according to the original plan, was intended to be 26 feet wide on the bottom, with slopes of 2 feet base to 1 foot perpendicular; and having 8 feet water, it would consequently be 58 feet wide on the top water line.

The locks having been mostly built of wood, more than twelve years ago, are now generally in a very decayed state, and in order to keep the canal open they require frequent repairs.

By constant watching and superintendence this canal has been kept in such a state of repair that no accident of any great consequence has lately occurred, until this summer, to interrupt the navigation for any length of time; but it was necessary during the past season to close it on two occasions, for about ten days each time, while some of the locks were undergoing repair; and I feel it proper to remark, in the strongest manner, that it is quite impossible, in the present state of the work, to insure the navigation being kept open much longer unless the whole canal be immediately put into an efficient and permanent state of repair. For, besides the dilapidated state of the locks, the banks in many places require to be strengthened, and altogether the whole work is at the present moment in a most precarious state; so much so, that if permanent and efficient measures be not adopted without delay, there is great danger that this highly important communication will soon become impassable. I am therefore of opinion, and I feel that I cannot state it too strongly, that no further delay should take place in finally deciding upon the plan which is to be adopted for completing it, and carrying it into execution as soon as possible.

The Welland Canal Company have been fully aware of this for some time past, and they have used every exertion in their power to carry this desirable object into effect, in which most probably they would ere now have made much progress had not the present financial difficulties of this province rendered it impossible to procure the necessary funds for this purpose.

In the year 1837, Messrs. Baird and Killaly, two experienced civil engineers, were employed by the Company to examine the canal, and make a full Report upon it, which they have done in a very able and satisfactory manner.

In deciding upon the route which they have recommended for the canal, they appear to have been governed by the principle of availing themselves as much as possible of the outlay already incurred, and of making the most of the works as they found them; but they were particularly directed by their instructions "to interrupt the navigation as little as possible," and also to "report fully upon the propriety or necessity, as regards the public interest only, of altering the present route or any part thereof."

After thoroughly examining the subject in all its bearings, which they have fully stated in their Report, they have recommended that Port Colborne should still be retained as the point of departure from Lake Erie, and Port Dalhousie the point of entrance into Lake Ontario; but that both of these harbours should be much enlarged and improved, and that the feeder from the Grand River should be widened and deepened in several places in order to afford the additional quantity of water that will be required. They have also recommended that the old line should be adopted throughout, except in the descent of the mountain between Thorold and St. Catherine's; and they have recommended some improvements between St. Catherine's and Port Dalhousie.

In the size of the locks, which are proposed to be built of stone, they were limited by their instructions to 110 feet in length and 24 feet in width, for schooner navigation.

The canal is intended to be 36 feet broad at the bottom, which is to be 6 inches below the mitre-sills of the locks, to have 8 feet of water on the mitre-sills, and consequently 8 feet 6 inches in the other parts, with slopes generally of 2 feet base to 1 foot perpendicular. Their estimate amounts to the sum of £300,304. 2*s*. 3*d*., of which £65,189. 16*s*. 10*d*. is proposed to be expended in the improvement of the harbours of Port Colborne and Port Dalhousie, and £13,156. 11*s*. in building a junction and graving lock at Dunville.

They conclude their Report by expressing their fears that the scale above alluded to will not be found sufficient for the prospective wants of the country, even in a commercial point of view, and therefore they suggest that it should be enlarged to such dimensions as will suit the steamers navigating the lakes: with this view they propose that the locks should be made 45 feet wide and 180 feet long, which alteration may in their opinion be effected by an increased expenditure of £250,000, making in all £550,304. 2*s*. 3*d*. Halifax currency. The Welland Canal Company, however, have not felt themselves warranted, with their limited means, in adopting the suggestions of Messrs. Baird and Killaly in this respect, and therefore they are about to proceed upon the small scale for schooner navigation only.

In referring to this Report, and the plan on which it is at present proposed to proceed, I felt it my duty, as soon as I received directions to make a Report on the subject, to request that their operations might be suspended until I had an opportunity of inspecting the canal, as their work would be all thrown away if it should hereafter be determined by Her Majesty's Government to take it out of their hands, and to enlarge the plan to the scale which I am about to propose for consideration.

From every inquiry which I have been able to make on the subject, I am of opinion that it will be very inexpedient for Her Majesty's Government to follow the limited plan of the Welland Canal Company, as I feel quite satisfied that before the canal could be completed according to that plan, the necessity of making the locks large enough for steam navigation would become evident even for commercial purposes; but in the event of its being required for military operations, in which point of view it must be more especially regarded if assumed by the Government, there cannot be a question on the subject. I have, therefore, as directed by my instructions, drawn up my Report with this view, it being most important that, in the event of any misunderstanding with the United States, our vessels of war on Lake Ontario (which can be fitted out at Kingston without difficulty and to any extent) should be able to pass up to Lake Erie, where we have no naval establishment of any kind for this purpose.

Before I enter upon the plan which it is my intention to propose for the enlargement and completion of this highly important work, it may be proper for me to point out the different routes by which the communication from Lake Erie to Lake Ontario by the Welland Canal may be effected.

It would naturally have been expected that this would have been done by assuming Lake Erie as the summit level, and cutting a canal from the mouth of the Grand River, or from Gravelly Bay, to the River Welland, and thereby taking the water of the Welland down through the canal by the vale of the Twelve-mile Creek to Lake Ontario.

Although a most formidable obstacle existed to the accomplishment of this plan, which, as has been already stated, rendered an excavation from 30 to 56½ feet deep necessary for a distance of nearly 2 miles, yet this bold project was, as we have already seen, undertaken by the Welland Canal Company, who were only prevented by their limited means, and the want of adequate support and encouragement in the accomplishment of this object, from carrying it into effect.

It has been already shown that the slipping-in of the sides of the Deep Cut, when nearly completed, induced the Company to abandon this part of their plan, and to raise the summit level to the height of 8 feet above Lake Erie, by means of a dam across the Grand River, the water of which is now brought through the townships of Moulton and Wainfleet to the Welland, and carried by an aqueduct over that river 15 feet 6 inches above its level; and by this means vessels are enabled to pass over all the obstacles occasioned by the Deep Cut above alluded to.

This having been effected, it becomes a matter of comparative expense whether this important navigation shall continue to receive its supply of water from the above source,—whether the original plan of locking down from the level of Lake Erie into the Welland River shall not be resumed and carried on to completion, or whether the supply of water may not at any rate be obtained direct from Lake Erie, without obliging vessels coming up from below to rise, as they now do, 5 feet above that lake, and then descend into it at Port Colborne.

I. If this canal continue to receive its supply from the Grand River, and the summit level be kept, as at present, 5 feet above Lake Erie, four modes present themselves for our consideration.

1st. By following the present route from Allanburgh to Port Colborne, and receiving the water by the feeder from the Grand River, according to the plan now adopted by the Welland Canal Company.

2nd. By following the present route to Port Robinson, and then locking down into the Welland, and following that river 4 miles to Hellem's Creek, immediately below the aqueduct; then rising by a single lock of 10½ feet to the level of Lake Erie, and passing on straight to Port Colborne, or rising by a double lock of 15½ feet at Hellem's Creek to the level of the feeder, and descending by a single lock of 5 feet into Lake Erie at Port Colborne.

3rd. By following the present route to the aqueduct, and then descending by a double lock of 15½ feet into the Welland River, and proceeding up that river 6½ miles to Fork Creek; then by a double lock of 15½ feet ascending to the present level, and entering the feeder at Marshville, 4 miles distant from the Welland, and following the feeder 9 miles to Broad Creek, which may be entered by a single lock of 7 feet fall about 1¼ mile from the Grand River, which it joins 2 miles from its mouth on the level of Lake Erie.

4th. By supplying the Deep Cut from the Grand River by means of a tunnel or inverted syphon under the Welland, instead of an aqueduct over it, and locking down into the Welland by a double lock of 15½ feet at Port Robinson, following the Welland 10½ miles to Fork Creek, and proceeding from thence, as described above (No. 3), by Marshville and the feeder into Broad Creek, and thence to Port Maitland at the mouth of the Grand River.

II. If the original plan of conveying the water of the Welland River through the Deep Cut be resumed and carried on to completion, only two modes present themselves; to accomplish either of which it will be necessary to sink the Deep Cut 15½ feet more than will be required by the present plan of feeding it from the Grand River, and 10½ feet more than would be required if it were supplied with water from Lake Erie. The average depth of water now in the Deep Cut is about 8 feet, and therefore an increased depth of only 2 feet will be sufficient, on the present plan, to give 10 feet of water; and if Lake Erie be made the summit level, an increased depth of 7 feet will be sufficient for this purpose; but if it be supplied with water from the Welland, it will be necessary to sink it 17½ feet lower than it is at present.

Having sunk the Deep Cut to the level of the Welland, the only remaining point to determine would be whether the canal should enter Lake Erie at Port Colborne in Gravelly Bay, or Port Maitland at the mouth of the Grand River.

1st. In the former case a lock of 10½ feet lift will bring a vessel to Lake Erie level at Hellem's Creek, near the aqueduct, and a canal of less than 8 miles will bring it from thence to Port Colborne, where a regulating lock will be required.

2nd. In the latter case a lock of 10½ feet lift will also be sufficient to bring a vessel to the level of Lake Erie, between Marshville and Fork Creek, which, for a distance of 1½ mile, may easily be made navigable; and by cutting half a mile across a point to Misener's Saw Mill, 1½ mile of easy excavation will bring it to Marshville, from whence the present feeder, being enlarged for a distance of 9 miles, will bring it to Broad Creek, within 1¼ mile of the Grand River, which it will enter about 2 miles above its mouth.

By the former route a canal of less than 8 miles in length will take a vessel from the Welland into Lake Erie at Port Colborne, where it will be 18 miles distant from Port Maitland, at the mouth of the Grand River, which is the only naval depôt on Lake Erie.

By the latter a canal of 14 miles will be necessary, but though so much longer than the former, the excavation on this route will be comparatively easy, and therefore this part will not be very much more expensive; and this route has the decided advantage of being 6 miles shorter to the naval establishment on the Grand River than the other, and also of communicating with that important station without any exposure whatever to the lake; and in addition to its being 18 miles higher up the lake, the mouth of the Grand River is always free from ice in the spring before Port Colborne, and it is altogether a more commodious situation for military purposes.

III. If the canal receive its supply of water from Lake Erie, two modes present themselves for consideration.

1st. By bringing the Lake Erie level from Port Colborne to the Welland, and building a large aqueduct across that river, then proceeding by the present line, 5 feet below the present level, through the Deep Cut to Allanburgh.

2nd. By erecting a dam across the Welland, near Port Robinson, and thus raising that river 10½ feet to the level of Lake Erie, and proceeding from Hellem's Creek, near the aqueduct, to Port Colborne, as before described (I. 2); or passing up the Welland to Fork Creek, and proceeding from thence by Marshville and Broad Creek to the Grand River, as described (I. 3). This plan will also lower the surface through the Deep Cut 5 feet, and of course increase the excavation to that extent.

Taking all the circumstances into consideration, I believe that the first mentioned plan will be the cheapest; but as there is reason to doubt whether the supply of water from the Grand River will always be found sufficient when the locks are enlarged, and as the last mentioned plan will be in every respect by far the most commodious and secure when complete, I am induced to recommend its adoption, and I believe that the difference of expense will not exceed £50,000 sterling, the rough estimate for the former being about £1,200,000, and that for the latter £1,250,000 sterling, if the canal be taken from Hellem's Creek to Port Colborne; but if it be taken from Fork Creek to the Grand River the expense will exceed this sum, and therefore I have for the present estimated for the route to Port Colborne only, the detailed expense of which will be given in a future Report, accompanied by an estimate showing the extra expense to the Grand River, which will certainly be at all times the more commodious of the two for naval and military purposes. From the Deep Cut the old line may be enlarged to Thorold, from whence it will be desirable to deviate from the present course, and to follow a deep ravine or branch of the Ten-mile Creek for some distance; it may then cross over to a branch of the Twelve-mile Creek which joins the old line a little more than a mile above the village of St. Catherine.

From Port Dalhousie to Kingston, a distance of about 180 miles, the navigation by Lake Ontario is very good for steamers of any size, and so indeed is that of the River St. Lawrence, as far as the town of Prescott; but between Prescott and Montreal there are numerous rapids, in consequence of which, and particularly of that of the Long Saut, near Cornwall, the difficulty and danger of conveying heavy stores and merchandize is very great. This was found such a serious inconvenience during the last war with the United States, that a short time after the peace of 1815, Major-Gen. Nicolls, then Commanding Royal Engineer in the Canadas, was directed to send an officer to explore the country between Kingston and the Ottawa River, in order to ascertain whether it would not be practicable to form a secure and commodious water communication by an inland route, which being remote from the frontier, and therefore beyond the reach of an enemy, would be at all times available for military purposes.

Captain Jebb, Royal Engineers, who was employed on this duty, reported in favour of the practicability of forming this communication; but nothing was done respecting it for many years afterwards.

In 1821 the Legislature of Upper Canada passed an Act "to make provision for the improvement of the internal navigation of the province," and appointed commissioners to report on the subject; and in 1824 they sent in estimates for connecting Lake Ontario with the Ottawa River by the Rideau.

They also sent in an estimate for the improvement of the St. Lawrence, particularly at the Long Saut, which was considered more immediately necessary in consequence of the recent cession by the British Government of Barnhart's Island to the Government of the United States.

Nothing further appears to have been done on this subject, however, until 1826, when the British Government, seeing the absolute necessity of opening a secure water communication between the lakes and Lower Canada, in the event of another war with the United States, determined on forming the communication by the Rideau, and sent out Lieut.-Col. By, Royal Engineers, for this purpose. Under his superintendence this canal was formed, at the sole expense of the Home Government, and opened for public use in 1832.

About the same time canals were also formed by the Royal Staff Corps at Grenville, at the Chute à Blondeau, and at Carrillon on the Ottawa River, which, in connexion with the canal about to be formed next year by the Provincial Government at St. Ann's, and the Lachine Canal, which has long been open to the public, will complete the line of water communication between Montreal and the lakes.

Although this is a very tedious and circuitous route, the question will at first sight naturally be asked by all persons not well acquainted with the subject, why the above mentioned canals, which now afford a safe communication to Kingston, and to which the British Government have already so largely contributed, will not answer every purpose? and why therefore they should be called upon to assist in completing the works on the St. Lawrence?

To which it may be answered, that although the Ottawa and Rideau Canals are most useful in a military point of view, and in the event of a war with the United States they would be invaluable, yet they are so circuitous, and so much impeded by lockage,[3] that they will not answer for commercial purposes; at least they never can compete with the American canals for the trade of the Western States. Some of the locks on the Ottawa Canals are at present too small for steamers; and even if they were enlarged to the size of the Rideau locks, they would be altogether too small for the steamers which

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[3] Vessels passing from Lake Ontario by this route rise 165 feet 4 inches to the summit level at the Rideau Lake, and then descend 292 feet 3 inches to the Ottawa, from whence the lockage to Lachine is 82 feet: making altogether 539½ feet of lockage. By the St. Lawrence it is only 209 feet from Kingston to Lachine. The distance by the latter route also is only 190 miles: by the former it is 237 miles.

navigate Lake Ontario and the Upper Lakes, and therefore a trans-shipment at Kingston would be necessary: consequently a canal on that scale, even if it were made along the line of the St. Lawrence, would never draw off the trade of the Western States to the sea-ports of Lower Canada to the extent that it may be made to do if completed on the scale here proposed. For unless we open an uninterrupted navigation for *large freight steamers*, capable of conveying a cargo of at least 300 tons, *without any trans-shipment* before they arrive at Montreal or Quebec, we have no chance whatever of securing any great portion of that vast and important trade which must ere long be carried on between the Western States and the Atlantic Ocean, a very large proportion of which may, if properly encouraged, be most undoubtedly induced to come by this route, and thus confer incalculable advantages on the inhabitants both of Upper and Lower Canada; for besides the benefits which will ultimately result to these provinces from these works, when completed, they will derive the greatest possible advantage from them during their progress in many ways, and particularly in the very favourable opportunity they will afford of encouraging emigration from Great Britain to almost any extent, and on such a plan as will soon insure to these provinces a large numerical majority of good and loyal subjects. And I fully believe that nothing would tend so much to quiet the different parties in both provinces, and to produce contentment in the minds of all the well affected portion of the population, as the speedy completion of this very important communication, of which I now proceed to enter upon the details.

THE RIVER ST. LAWRENCE.

The River St. Lawrence, which conveys the waters of Lake Ontario to the Atlantic, has always been navigable for the largest steamers without interruption from Kingston to Prescott, a distance of about 70 miles, and this latter port was for some time considered the termination of steam navigation; but of late years steamers of great power and small draught of water, carrying passengers and light freight, have passed daily to Dickenson's Landing, which is situated at the head of the Long Saut Rapid, and about 38 miles below Prescott: from Dickenson's Landing to Cornwall, a distance of about 12 miles, this river is only navigable for boats and large barges.

At Chimney Island, about 4 miles below Prescott, there is a shoal which makes the channel very narrow, and the navigation rather intricate; but in ordinary seasons, when the river is not unusually low, vessels not drawing more than 9 feet of water may pass through it, and in all other parts of the river above the Long Saut there is a sufficient depth of water.[3]

In the year 1833 the Legislature of Upper Canada passed an Act "for the improvement of the navigation of the River St. Lawrence," and appointed commissioners to make the necessary arrangement for this purpose. They employed Mr. Wright and Mr. Mills, two civil engineers from the United States, who made a report and estimate of the expense required for improving this part of the river between Prescott and Cornwall, and who subsequently laid out the canal at the Long Saut, which was required by the Act to be commenced and finished before any other part was undertaken.

It appears by their Report, that between Prescott and Dickenson's Landing there are four rapids, which will require improvement before this part of the river can be made navigable for steamers carrying merchandize and heavy freight, &c., viz.

The Galoppes Rapids, the Rapid at *Point Cardinal*, *the Rapide Plat*, and *Farren's Point*. The plan they have suggested of passing these by short canals is a very good one, but I am of opinion that it will cost much more than the sum they have mentioned in their estimate.

The Galoppes Rapids are situated about 7½ miles below Prescott; here a lock of 4½ feet lift will be necessary, and a canal about 2400 feet in length, which, as descending vessels will pass down by the river, need not be more than 50 feet broad at the bottom. The expense of this point is estimated by Mr. Wright at £15,848. 10*s*. 6*d*. Halifax currency; but I am of opinion that it will amount to £29,500 sterling.

The rapid at *Point Cardinal* is situated about 1½ mile below the Galoppes Rapids, and here a lock of 2½ feet lift will be required, with a canal about 1500 feet in length; the expense of which has been estimated by Mr. Wright

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[3] In the chart published at the Hydrographical Office of the Admiralty in 1828, from the survey made by Captain W. F. W. Owen, R. N., in 1826, the soundings here are marked 12 to 15 feet, and I found about the same depth when I sounded here in July last; but I had not the means of ascertaining the exact nature and position of the shoal above alluded to, as the current is very strong in this part of the river: it is therefore very desirable that the officer commanding on the lakes should be requested to have it properly examined as soon as possible.

at £13,484. 18*s*. 6*d*. Halifax currency; but I am of opinion that it will amount to £25,000 sterling.

From Point Cardinal to the head of the Rapide Plat the distance is about 10 miles, in which there is a good channel for vessels drawing 9 feet of water; there are, however, three rapids in this part of the river, which it may be proper to notice, though they may be passed by steamers without much difficulty.

Opposite Presqu'île, for about 1500 feet, the current runs at the rate of nearly 5 miles an hour. At Point Iroquois, for a distance of about 2710 feet, it runs at the rate of $5\frac{1}{2}$ miles an hour; and at Pine Tree Point at the rate of 6 miles an hour. At the two latter points the St. Lawrence is very narrow, not exceeding 430 yards in breadth at the former, and 390 yards at the latter.

At the *Rapide Plat* three different routes have been suggested, by Mr. Clowes in 1826, Mr. Barrett in 1830, and Messrs. Wright and Mills in 1833. The first passes up Sawyer's Creek for about half a mile, then runs along a little in rear of Maria Town, and enters the river again near the mouth of Campbell's Creek. The second passes up Sawyer's Creek for about a mile, and running much more inland than the former, comes out at the bay near Broffle's Storehouse. The third runs along the side of the river from the mouth of Sawyer's Creek to the bay near Broffle's Storehouse.

I agree in opinion with the latter gentlemen, that the third is by far the cheapest route, and therefore to be preferred. The fall here being $11\frac{1}{2}$ feet, two locks will be necessary, with a canal $3\frac{9}{10}$ miles in length; the expense of which, for one lock only, is estimated by Mr. Wright at £51,451. 8*s*. 9*d*. Halifax currency; but I think it will amount to £120,000 sterling.

Farren's Point is situated about $10\frac{3}{4}$ miles below the foot of the Rapide Plat, and here a lock of 4 feet lift will be necessary, with a canal about 4000 feet in length; the expense of which is estimated by Mr. Wright at £26,485. 3*s*. Halifax currency; but I think it will amount to £48,000 sterling.

The *Long Saut Rapid* begins a little below Dickenson's Landing, and about 5 miles below Farren's Point, where the river ceases to be navigable for any thing but boats and large barges as far as Cornwall, and consequently a continuous canal of $11\frac{1}{4}$ miles in length was commenced here in 1834 by Messrs. Wright and Mills, whose estimate for this work was £216,342. 1*s*. 2*d*. Halifax currency; but owing to the sudden and very unprecedented rise in the price of provisions and labour in 1835 and 1836, the contractors were quite unable to procure workmen, at any wages which they could afford to pay, under the contracts made by them in 1834. The commissioners therefore felt it necessary to make an advance on those prices of 10 per cent. in 1835, and 30 per cent. in 1836; in consequence of which, and of some alterations in the plan, the expense has far exceeded the above estimate; but notwithstanding these difficulties, this magnificent and important work would probably have been completed in the year 1838, and now in full operation, if the necessary funds which have already been voted for it by the Provincial Legislature could have been procured.

About £362,134. 11*s.* 10½*d.* Halifax currency have been expended on this canal altogether, including the sums paid for land and claims for damages; and if it be now carried on to completion without further delay, it will only require the comparatively small sum of £51,500 Halifax currency to make it navigable; but if it be left in its present state, every year will add very materially to the injury which a large unfinished work of this kind must necessarily receive from being so exposed to the effects of the trying climate of this country.

Owing to some difficulty which has occurred in raising money for the debentures that have been voted for this purpose by the Provincial Legislature of Upper Canada, in consequence of the present political and financial difficulties of the province, this work is now suspended for want of the comparatively small sum above mentioned, the expenditure of which will, it is believed, make it navigable, and thus give a steam-boat navigation from the head of Lake Ontario to Coteau du Lac, at the lower end of Lake St. Francis, about 36 miles below Cornwall.

There are some unsettled claims for damages to property of no great amount, which must eventually be provided for, as well as the sum of £5,215. 15*s.* 6½*d.* Halifax currency, for which the commissioners have given notes bearing interest to some of the contractors and other persons for work, &c. performed since the money which they have received from the Government was expended; and it is true that a further outlay of £10,000 or £12,000 will eventually be necessary at some future period, in order to give the work a finished appearance; but this is not at all essential to its utility, and therefore it may be delayed until the canal is completed and in operation, when there can be no doubt that the tolls will soon raise that sum, and thus the whole amount eventually required for this canal will be about £57,300 sterling.

In this canal the fall is 48 feet, which is overcome by 6 locks of 8 feet lift each, besides the regulating or guard-lock at the upper end. These locks (which are all built of cut stone of the best description) were required by the Provincial Act to be made 55 feet broad, and not less than 150 feet long; but Mr. Wright, considering that vessels of such a breadth would require a much greater length in order to give them a due proportion, very properly increased the length of the locks to 200 feet between the gates, so that they will now pass steamers from 175 feet to 180 feet long, and upwards of 52 feet broad. The depth of water over the lower mitre-sill of the locks was required by the Provincial Act to be 9 feet, and therefore the other parts of the canal have been made 10 feet deep; and as descending vessels will not be able to pass down this part of the river with safety, the width of the canal at the bottom has here been made 100 feet. There is a surf berm 2 feet below the water surface on each side of the canal of 5 feet in breadth; all the slopes, both inside and outside, have 2 feet base to 1 foot perpendicular, and therefore the breadth of the canal at the surface of the water is 150 feet; the banks are made 4 feet above the water surface, and 12 feet broad at the top.

In order to avoid bridges, road culverts have been built where bridges would otherwise have been indispensable. They have been constructed of good coursed rubble masonry, giving a passage of 12 feet broad, (of which 2½ feet are taken off for foot passengers,) and 10 feet high to the crown of the arch, which, rising 3½ feet, is built of cut stone 1 foot 6 inches thick, laid in cement: the top or outside of the arch is covered with flat stones, laid in cement, which are afterwards covered with 2 feet of puddle.

The expenditure of the money required for this work, as well as the general management of every thing connected with it, has been entirely under the control of the commissioners appointed by the Provincial Act above alluded to, who have annually rendered a full report of their proceedings, as well as a detailed statement of the expenditure, to the Legislature. The work, after a fair competition by public advertisement, has been performed by contract, and in general the contractors have been a most respectable body of men.

The stone used for the locks is a compact limestone,[4] being a species of

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[4] Its specific gravity is 2666⅔.

black marble found a few miles from the canal, easily worked, and easily procured in large masses, so that many of the courses are 2 feet thick: the specification for the masonry required that none of the courses should be less than 12 inches, but generally from 16 to 24 inches; the stretchers not less than 3 feet long, and the headers not less than 2 feet in the length of the course. The whole of the masonry of the locks is laid in mortar, composed of hydraulic lime or cement from Messina, (a village situated in the State of New York, about 9 miles from the canal,) and a due proportion[5] of sand.

The lock-pits have in all cases been excavated in clay or gravel, so that there are no rock foundations. The canal generally has been excavated through hard clay or gravel, which changes in some places to light loam and sand. At the Long Saut, where the excavation has been from 40 to 50 feet in depth, the first 10 feet of it have been generally through stiff clay, below which it is mixed with gravel and some hard-pan, with occasional veins of sand and a quantity of large boulders, which are principally of limestone. There is no rock excavation in any part of the canal as now executed between Cornwall and the Long Saut, but in some sections there is a large quantity of loose stone and large boulders.

A full and minute description of the masonry, &c. of the locks, as well as of the construction of the lock-gates, the improvements invented by one of the contractors, Mr. Wilkinson, in the capstan and shaft, in the mode of adjusting the friction-rollers, and in constructing the valve-gates, will be found detailed at length at the end of this Report.

The works above mentioned comprise all the improvements required in Upper Canada. In the Lower Province there are three rapids between Lake St. Francis and Lake St. Louis, which will require to be overcome; and the canal between Lachine and Montreal will require to be very much enlarged, or probably it will be better to make a new canal altogether between these two places.

No vessels of any size have ever attempted to pass that part of the St. Lawrence which runs between Lake St. Francis and Lake St. Louis, large barges alone having hitherto been employed here on account of the *rapids at Coteau du Lac, the Cedars, and the Cascades,* which, like the rapids of the Long

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[5] The proportion was from 2 to 3 parts of the cement to 1 of sand, the smaller quantity being allowed when St. Regis or river sand was used.

Saut, cannot be navigated safely by descending vessels of a large size if heavily laden. The Legislature of Lower Canada, therefore, in the year 1833, authorized the appointment of commissioners for the improvement of this part of the navigation, who employed Mr. Wright and Mr. Mills to make a Report on this part of the river, in doing which they suggested the three following plans.

1st. By forming a canal from M^cDonald's Point at the lower end of Lake St. Francis to the foot of the rapids at Coteau du Lac, then entering the river, and making use of it in those parts which can be navigated without much difficulty, and connecting them by intermediate canals at the rapids of the Cedars and Cascades, which form a serious obstacle to the navigation.

According to this plan, it is proposed to make use of about 8 miles of the river, and to form about 6¾ miles of canal in the whole distance, which is altogether about 14¾ miles. In doing this, 9 locks will be required, and the expense is estimated by Mr. Mills at £235,782. 3*s*. 2*d*. Halifax currency.

2nd. By commencing a canal from M^cDonald's Point, above mentioned, and following the general direction of the river, but going rather more inland, and thus forming one continuous canal of about 14¾ miles in length to the foot of the rapids of the Cascades. This plan will require 10 locks, and the expense is estimated by Mr. Mills at £324,943. 11*s*. 5*d*. Halifax currency.

3rd. By commencing a canal also at M^cDonald's Point, but running across by a route still further inland 13½ miles to the Lake of the Two Mountains, which it enters a little below the church at Vaudreuil. This plan will require 10 locks, and the expense is estimated by Mr. Mills at £402,164. 4*s*., but it would require a further expense of £40,598. 15*s*. 11½*d*., making altogether £442,762. 19*s*. 11½*d*., to extend this communication through to Lake St. Louis, as an additional lock would be necessary in order to pass the rapids at St. Ann's. This plan, therefore, appears to be decidedly objectionable, because it is far more expensive than either of the others, and because the Lake of the Two Mountains is always closed by ice for a longer period every year than Lake St. Louis and the River St. Lawrence; and another very decided objection to this route is, that there appears to be no good channel of sufficient depth between Lake St. Louis and Vaudreuil.

I have not yet had time to devote so much attention as is necessary for a proper examination of either of these plans on the ground; but I am disposed to agree in the opinion expressed by Mr. Mills in his Report, that the first plan is preferable to either of the others, inasmuch as it appears to be the cheapest; but I am of opinion that his estimate is far too low, and that it will cost £374,300 sterling. I proceed, therefore, to enter a little into the details of that plan, as follows.

In order to pass the rapids at *Coteau du Lac*, Mr. Mills proposes that a canal should commence at M^cDonald's Point, and pass down along the north bank of the river as far as Fer à Cheval, a little below the fort: the length of this canal will be a little more than $2\frac{3}{4}$ miles, its breadth at the bottom 100 feet; and as the river falls 17 feet in this distance, two locks will be required here, besides guard-gates at the upper end; the expense of which will be about £117,050 sterling.

With reference to this part of his plan, Mr. Mills remarks in his Report, that "it interferes with and will destroy all the improvements which have been effected by the British Government" (at Coteau du Lac); and he adds, "I have laid my plans disregarding them altogether, presuming that every privilege and facility would be given to the province, without the least hesitation, in view of the improvement proposed."

On this I would remark, that his plan does here interfere very materially with the fort and barracks at Coteau du Lac, the latter of which must necessarily be removed, as well as the powder magazine, if it be adopted; but good permanent buildings might be constructed of equal extent, and affording better accommodation, and a suitable alteration in the fort might also be effected, for the sum of £3,250 sterling, which will increase this part of the estimate altogether to £120,300 sterling.

From Point Fer à Cheval to the village of the Cedars, a distance of 6 miles, there is a good and direct channel, having from 12 to 35 feet of water; and therefore the river may here be said to be navigable for this distance by large steam-boats, although there are three points which present some difficulty to sailing vessels, viz., Point au Diable, Point à Wattier, and Point à Biron.

At the first of these points the current runs at the rate of about 5 miles an hour for about 452 feet; at the second it runs about 4 miles an hour for only a short distance; and at the last it runs about 5 miles an hour for nearly a quarter of a mile. In this whole distance of 6 miles the river falls $7\frac{1}{2}$ feet; the bank here is from 20 to 30 feet high, and composed of clay, with some veins of sand, which, as they cause frequent slides into the water, would present a very serious obstacle to the construction and maintenance of a canal along this part of the bank, either on the top near its brow, or along the bottom;

and it is rather a singular circumstance that, though this difficulty occurs again below the rapids at the Cedars, where the river is also navigable for steamers without a canal for some distance, it does not occur at any of the rapids or intermediate points where a canal is indispensable.

At the rapids of *the Cedars* the river falls 30 feet 9 inches in a distance of nearly 1¾ miles; a canal of this length, therefore, must be constructed here, which may be carried across Point aux Cèdres, and formed from thence along the river to Point à Moulin, through which it may be cut to the navigable part of the river below. It will require three locks of 8 feet 9 inches lift, and a single lock of 10 feet lift, making four in all, besides guard-gates at the upper end. The whole expense will be about £125,000 sterling.

From Point à Moulin the river is again navigable for steamers for a distance of a little more than 1¾ miles to Point à Coulonge, there being a channel from 10 to 35 feet deep, which, however, is not so direct as that above the Cedars. Between these two points the current runs about 2½ miles an hour, and the river falls 1 foot 9 inches. The bank of this part of the river, like that above the Cedars, is also subject to slide off into the water, thus presenting a very serious obstacle to the construction of a canal, and therefore it is fortunate that one is not required here.

From Point à Coulonge to Lake St. Louis, a distance of a little more than 2¼ miles, the navigation of the river is obstructed by the rapids at Split-Rock Point and the Cascades, the latter of which present one of the most formidable obstacles of the whole.

In this distance the river falls 25 feet 3 inches, and therefore three locks will be necessary, besides guard-gates at the upper end, viz., one at Split-Rock Point of 7 feet lift, two at the entrance from Lake St. Louis of 8 feet 9 inches and 10 feet lift respectively: the canal will be cut through Split-Rock Point, and also through the point at the Cascades, which being composed of rock, the excavation here will be very expensive. In the other parts Mr. Mills proposes to form the canal by constructing a bank along the river to retain the water to its proper level. The expense of this section will probably amount to £129,000 sterling.

From hence it appears that the whole distance from Lake St. Francis to Lake St. Louis is a little more than 14½ miles, which may be divided into five sections, as follows: the *first* section from McDonald's Point, near the steamboat landing, to Point Fer à Cheval; the *second* from Point Fer à Cheval to the village of the Cedars; the *third* from the Cedars to Point à Moulin; the *fourth* from Point à Moulin to Point à Coulonge; the *fifth* from Point à Coulonge to the entrance of Lake St. Louis at the foot of the rapids of the Cascades.

The *second* and *fourth* of these sections, comprising a distance of nearly 8 miles, are already navigable for steamers, and therefore nothing is required to be done to them, although the river falls 9½ feet in this distance; in the other three sections, comprising a distance of about 6¾ miles, the river falls 73 feet, in which 9 locks will be required of various lifts; so that the whole descent from the foot of Lake St. Francis to the head of Lake St. Louis is about 82½ feet, and the estimated expense required to render this part of the St. Lawrence navigable for large steamers is £374,300 sterling.

In the latter part of this Report, Mr. Mills states, that he visited the south side of the river, and passed over the country from Lake St. Francis to Beauharnois on Lake St. Louis, but not with instruments, and therefore he does not speak positively on the subject; he says, however, that "he believes it will require a longer canal, and although very feasible, yet possessing no advantages and no extraordinary facilities for construction."

In the year 1835, Mr. Baird was employed, in conjunction with Mr. Stevenson, a civil engineer residing in Lower Canada, by the agent of the 'Seigniory' of Beauharnois, in order to prove that the south side of the river does possess advantages over the north side, and that a continuous canal may be made more easily, and at a smaller expense, on the former than on the latter.

According to the Report made by Mr. Baird, it appears that a cheaper canal may be constructed by following the River St. Louis for some distance, the expense of which he estimates at only £194,800. 7*s.* 10*d.*; and, according to the Report made by Mr. Stevenson, a canal may be made by a route running nearer to the St. Lawrence, the expense of which he estimates at only £224,444. 5*s.* Halifax currency. Both of these estimates are lower than Mr. Mills's first and cheapest plan; but I am of opinion that they are too low, as well as those made by Mr. Mills, and that this work cannot be executed properly for the sum mentioned; but before I can venture to give a decided opinion upon either of these routes, it will be necessary to examine each of them far more minutely than I have yet had leisure to do. I have no doubt, however, that the communication between Lake St. Francis and

Lake St. Louis can be completed for the sum I have put down for this purpose.

It is proper that I should here notice a remark, very justly made by Mr. Mills on this subject. In reference to the south side of the river, he says that, "Purely geographically, this would seem the most natural and direct route for a canal between these waters;" but he adds, that "there is a political objection to its being constructed on the south side of the St. Lawrence, which I will barely name. The work in contemplation must be considered national in its character, and therefore ought to be so located as to be least in danger in case of foreign invasion."

If this was considered an objection in 1833, when Mr. Mills made this Report, how much more ought it to be so considered after the events of 1837 and 1838; for it is quite certain that if this canal had been constructed and in operation on the south side in 1838, the communication would have been interrupted by those persons who rendered necessary the march of the Highlanders from Glengarry to Beauharnois, as well as the expedition to Napierville, Château-guay, &c. And this certainly may be considered a strong objection to placing the canal on the south side of the St. Lawrence, because it would be so much exposed in the event of a war with the United States. To this it may be answered that the communication now under consideration is chiefly, if not altogether, intended for commercial purposes, and that the whole line of the St. Lawrence would be so much exposed in the event of a war as to preclude its use to any great extent. This important question, however, requires full consideration, and it will of course be decided by higher authority than the Report of any individual. I have here provided for placing the canal on the north side of the St. Lawrence, according to Mr. Mills's plan; and if Mr. Baird and Mr. Stevenson are correct, the sum I have mentioned will be more than sufficient for placing it on the south side, if that route shall be finally decided on.

I think it probable that by putting one or two dams across from the north shore to Grande Isle, the river itself may be made navigable nearly all the way to St. Timothy; but I have not yet had an opportunity of examining the ground sufficiently to enable me to speak positively on the subject: I am, however, induced to believe that in any case it may be found possible to construct a canal on the south shore cheaper than on the north.

From the foot of the rapids of the Cascades large steamers may pass through

Lake St. Louis to Lachine, a distance of about 21 miles, without meeting with any serious obstruction. As far down as the middle of St. Bernard's Island, which is situated at the mouth of the River Château-guay, the navigation of this lake has always been found good; but it has been very generally understood that large vessels could not pass the shoals or banks of sand and stones which occur opposite the mouth of that river. I have, however, ascertained from actual observation, as well as from the information I have obtained from the most experienced pilots on this lake, that there is a good navigable channel by which vessels drawing not more than 9 or 10 feet of water may pass down to Lachine without difficulty.

THE LACHINE CANAL.

The rapids between Lachine and Montreal render it necessary to form a continuous canal of about 9 miles in length between these two places.

A joint-stock Company, which was incorporated by an Act of the Provincial Legislature about twenty years ago, caused the preliminary surveys to be made for this purpose in 1819; in the following year the Provincial Government purchased the rights of this Company, and commissioners were appointed to superintend the work, which was fully opened for the use of the public in 1825, since which time it has been in constant use, and it is now generally in good order.

The present canal is about 8½ miles in length; its width at bottom is 28 feet; at the top water line, where the excavation is in rock, it is 36 feet, and where it is in earth, 48 feet, with 5 feet depth of water.

The locks, which are built of cut stone, are 100 feet long and 20 feet broad; they are seven in number, including the guard-lock, and of various lifts, from 6 to 9 feet; the whole descent from Lachine to Montreal being about 45 feet.

The total cost of this work was £109,601. *0s.* *9d.* Halifax currency. The tolls, which in 1825 were only £1280. 12*s.* 4*d.*, have very much increased during the last ten years, and they amounted this year to £6638. 10*s.* 4*d.*, as will be seen by the statement given in the Appendix.

At the upper end, near Lachine, the excavation has been carried through solid limestone rock for upwards of 2 miles, where the cutting has been rather deep; but from thence to Montreal it runs chiefly through clay and gravel.

and the ground is generally very favourable for the purpose, excepting near the fourth mile stone, where a species of hard-pan occurs for about half a mile.

The stone for the upper locks was obtained from Caughnawaga, and that for the lower locks from the quarries near Montreal.

The present entrance at Lachine is very inconveniently situated, even for the small vessels which now pass through it, on account of the shoals and rocks in the neighbourhood; it will therefore be necessary, in forming a canal for large vessels, to make the entrance at Leichman's Point, nearly half a mile higher up the river, where the water is deep very near the shore, and the entrance will be very commodious.

Considering the great expense that would be required to alter the present canal, and enlarge it to the dimensions now proposed, and also the very serious inconvenience to which the public would be exposed if they were deprived of its use for two or three years, which they necessarily must be if any attempt be made to enlarge the present work, I have projected a new canal altogether, which, beginning at Leichman's Point and running in rear of the village of Lachine, will cross the road leading to Montreal a short distance from the foot of the hill, and meet the present canal about 4 miles from Lachine, by which means some deep cutting in rock excavation will be avoided, and altogether this part of the line will be more commodious than the present one, and more easily executed.

After meeting the present canal, it may be carried along the north side of that work until it comes near Montreal, where it will be necessary, in order to avoid the expense of purchasing the numerous valuable buildings which have been erected near the lower locks, to carry it into the old canal, which may for this short distance be enlarged without much inconvenience to the public, as the forwarders may very easily for one season cart their goods, &c. to the point of junction.

Some alteration may probably be made with advantage in the disposition of the locks. No. 1, or the regulating lock, will be near the entrance. At the Côte St. Paul, locks Nos. 2 and 3, which now fall 12 feet by two combined locks, I propose to place one of 9 or 10 feet lift; and by making No. 4 or the St. Gabriel lock to fall 10 or 11 feet, instead of 8, we shall obtain the same level as at present in the reach below that lock, from whence the remaining descent of 25 feet into the St. Lawrence may be overcome by three locks, thus reducing the number of locks to six instead of seven.

Three small culverts will be required as at present, besides an additional one between the entrance of the new canal at Lachine and its meeting the old one at the point above mentioned; one swing or drawbridge at each end, and three intermediate ones: viz., at the crossing of the main road near the foot of the hill; at the crossing of the road between the Tanneries and the Côte St. Paul; and at the crossing of the Lower Lachine Road above Montreal; besides which, from six to eight accommodation bridges are said to be necessary; but I think that some of these at least ought, if possible, to be dispensed with, or probably large scows may be substituted for them.

It will be desirable to straighten the course and deepen the bed of the little River St. Pierre, without which large claims for damages resulting from the backing of the water in wet seasons may be anticipated.

The expense of this canal, according to this plan, will be about £324,600 sterling.

From Montreal any vessels which can pass through the canals above described will be able to proceed to Quebec without difficulty, and thus the whole expense of improving the communication by the Welland Canal and the River St. Lawrence for large freight steamers from Lake Erie to Quebec, and of thus opening a continuous inland navigation from tide-water at the latter port of 1600 *miles in extent*, may be estimated at £2,228,700 sterling. It will be desirable to undertake the St. Lawrence Canal from the Long Saut to the Cascades and the Welland Canal in the first instance; both of which may be completed in three or four years from the time of their being properly commenced, provided a sufficient number of workmen are procured for the purpose, by encouraging a large emigration. The other works mentioned in this Report may also be completed in the same time from the period of their being commenced.

Between Montreal and Quebec the shoals on Lake St. Peter's offer a very serious impediment to large vessels heavily laden from the sea; but as such vessels cannot possibly proceed beyond Montreal, this difficulty, though a very serious inconvenience to that city, does not materially affect the trade of the Upper Province and of the Western States, and therefore I do not feel it necessary to take any further notice of it in this Report, which is respectfully submitted for your Excellency's consideration.

George Phillpotts.

Detailed Estimate of the Masons' Work, Carpenters' Work, Timber and Iron-Work, &c., required for the construction of one of the Locks on the St. Lawrence Canal, with Gates complete.

Masons' Work in the Lock.

			£.	s.	d.
Main body of lock	3925 yards.				
Main breast	147 "				
Upper breast	117 "				
Extension of wings	506 "				
Anchor stones	32 "				
	4727 yards of masonry at 40*s.*,		9,454	0	0
Excavation of lock-pit, foundation, &c., 11,500 yards, at 1*s.* 3*d.*			718	15	0
Labour in puddling and filling in rear of walls, &c., 4800 days, at 3*s.* 9*d.*			900	0	0
28,500 feet superficial 2-inch pine plank laid double on the floor of the lock chamber, and under the walls, £17. 10*s.*			498	15	0
7250 superficial feet of ditto laid in sheet piling, £8.			58	0	0
4100 superficial feet of 5-inch hard-wood plank laid in the recess floor, £32. 10*s.*			133	5	0
12,000 feet of timber laid in the foundation, at £43.			516	0	0
Twenty-seven trusses framed and laid for recess floors, each £11.			297	0	0
Iron-work for ditto, 10,544 lbs., at 9*d.* per lb.			390	8	0
1067 of 4-inch spikes for recess floors, weighing		1717 lbs.			
Thirty-three of 1⅜-inch iron bolts for main breast, 3½ feet long, weighing		1036			
Sixty-six of 1-inch fox-wedged iron bolts, 1½ feet long		703			
		3456 at 9*d.*	129	12	0
Total of masons' work, &c., in body of lock			13,095	15	0

Carpenters' Work, and Timber in the Gates.

	White Oak.	Pine.
One pair of upper gates.		
Twelve bars 28 × 13 inches, 32 feet long each (oak)	970⅔	
Two quoin-posts 18 × 20 inches, 16 feet long (ditto)	80	
Two mitre-posts 18 × 16 inches, 16 feet long (ditto)	64	
Eighty planks 2½ inches thick and 12 feet long, and 10 inches broad (Norway pine)		800
One pair lower gates.		
Eighteen bars 28 × 13 inches, 32 feet long (oak)	1456	
Two quoin-posts 18 × 20 inches, 22 feet long (ditto)	110	
Two mitre-posts 18 × 16 inches, 21 feet long (ditto)	84	
Eighty planks 2⅓ inches thick, 16 feet long, and 10 inches broad (Norway pine)		1066⅔
	2764⅔	1866⅔

	White Oak.	Pine.
Brought forward	$2764\frac{2}{3}$	$1866\frac{2}{3}$
Two mitre-sills (oak).		
Four pieces 22 × 12 inches, and 33 feet long	242	
One piece 25 × 9 inches, and 12 feet long	21	
The 4-inch studs between the bars of the gates will come off the other sticks.		
	$3027\frac{2}{3}$	$1866\frac{2}{3}$

	£.	s.	d.
That is, $3027\frac{2}{3}$ of oak timber at 2*s*. 6*d*. per foot	378	9	2
2000 feet of $2\frac{1}{2}$-inch Norway pine, at £7. 10*s*.	15	0	0
Carpenters' work, framing gates, and fixing iron-work, &c.	400	0	0
Laying mitre-sills	47	0	0
Fitting anchor stones, boring for bolts, &c.	35	0	0
Total for timber and carpenters' work, in gates, &c.	875	9	2

Iron-work in the Gates.

	Upper Gate.			Lower Gate.		
	Wrought Iron.	Cast Iron.	Brass.	Wrought Iron.	Cast Iron.	Brass.
Sixteen ╥ plates, weighing . . . lbs.	1312	..	..	1312	..	..
Sixteen T plates	752	..	..	..	..	..
Forty do.	..	..	..	1880	..	..
136 screw bolts and nuts for do.	680	..	..	..	..	..
208 do. do. do.	..	..	..	1040	..	..
Four valve-gates, with rods and fixtures . .	2564	..	122	2748	..	122
Four valve-gate screws, with fixtures . . .	1521	328	168	1521	328	168
Two friction-rollers, with bars, &c. . . .	1122	340	128	1274	340	128
Two do. screws and brass boxes	96	..	78	96	..	78
Twelve pieces of segment	..	4317	..	..	4317	..
Six plates for do., with spikes	600	..	..	600	..	..
Eighty-four bolts for segments	336	..	..	336	..	..
Twenty-two screw bolts for mitre-sills, nuts and washers	319	..	..	319	..	..
Sixteen rag bolts for blocks for mitre-sills . .	224	..	..	224	..	..
One plate and spikes for do.	113	..	..	113	..	..
Two bars for edge of do.	424	..	..	424	..	..
Fifty-two spikes for do.	19	..	..	19	..	..
Twelve bridge knees	336	..	..	336	..	..
108 bolts for do.	54	..	..	54	..	..
Twelve hand-rail supports and two hand-rails . .	717	..	..	717	..	..
Four caps for quoins and mitre-posts, with hoops and nails	184	..	..	184	..	..
Two anchors, with hoops and wedges, &c. . .	900	..	120	900	..	120
Sixteen bolts for do.	134	..	..	134	..	..
Four capstans and drums	68	3248	59	68	3248	59
Four capstan shafts	1488	..	..	2032	..	..
Four do. with well covers and brass boxes . .	4	1160	81	4	1160	81
Twenty-four bolts for do.	12	..	..	12	..	..
Carried forward	13979	9393	756	16347	9393	756

	Upper Gate.			Lower Gate.		
	Wrought Iron.	Cast Iron.	Brass.	Wrought Iron.	Cast Iron.	Brass.
Brought forward . . . . lbs.	13979	9393	756	16347	9393	756
Four capstan T plates, with brass boxes	156	..	81	156	..	81
Twelve bolts for do.	48	..	..	48	..	..
Four capstan steps, with plates, boxes, and bolts	222	..	35	222	..	35
Eight capstan handspikes	444	..	..	444	..	..
Two chains 43 feet long	408	..	..	408	..	..
Two do. 81 feet long	770	..	..	770	..	..
Two fixtures for do. on gates	233	..	..	233	..	..
Four riders for capstan	272	..	98	272	..	98
Four iron braces for gates, 17½ feet × 4 inches × ⅝ inches	576	..	..	..	..	..
Four do. do. 21½ feet × 4 inches × ⅝ inches	..	..	..	732	..	..
Two connecting do., 2 feet long	32	..	..	32	..	..
Twenty bolts for do., with nuts	160	..	..	..	..	..
Twenty-eight do. do.	..	..	..	224	..	..
Two quoin-post steps, hoops, &c.	74	186	8	74	186	8
Two snubbing posts	38	66	..	38	66	..
Twenty bolts, with nuts and washers for connecting the bars of the gates together	411	..	..	..	..	..
Twenty-six do.	..	..	..	533	..	..
720 7-inch spikes for planking	735	..	..	..	..	..
1300 do.	..	..	..	975	..	..
Total	18558	9645	978	21508 18558	9645 9645	978 978
Total quantities in both gates				40066	19290	1956

	£.	s.	d.			
Therefore 40,066 lbs. of wrought-iron at 9*d.* per lb.	1502	9	6			
19,290 lbs. of cast-iron at 3¾*d.* per lb.	281	6	3			
1956 lbs. of brass at 2*s.* 6*d.* per lb.	244	10	0			
Frame-work, &c., of gates				2028	5	9
Timber, and carpenters' work				875	9	2
Masons' work, &c., in the lock				13,095	15	0
Total for lock				15,999	9	11
Add 15 per cent. for contingencies				2400	0	0
5 per cent. superintendence				800	0	0
				£19,199	9	11

A single lock may therefore be estimated at £19,200.

THE LOCKS.

The walls of the locks are built upon floors laid longitudinally on sleepers of pine or hemlock 12 inches square, which cross the lock at 8 inches distance from each other. The floors of the chambers of the locks are 2 feet 6 inches lower in the middle than at the sides, so that the sleepers meet there at an angle of nearly 167°, like an inverted roof, which prevents their rising; under the walls they are laid horizontally. These sleepers are supported by seven rows of range timbers laid longitudinally under the front and rear of the walls, under the middle of the chamber, and half-way between the front of the walls and the middle of the chamber; and they are well secured to these longitudinal timbers by oak treenails. The spaces between the joists being well filled in with gravel, the horizontal part under the walls is covered with 4-inch plank, the remainder with a course of 3-inch plank, and the joints of the latter are afterwards covered by a course of 2-inch plank; the whole being well secured with oak treenails and ragged iron bolts when necessary. The floors within the recesses for the gates are of 5-inch plank, either of oak or rock elm, laid on twelve rows of timbers 12 inches square, which are placed 2 feet apart, and framed upon the heads of piles driven at a distance of 2½ feet apart under the walls, and 4 feet apart between the walls. Wherever the nature of the soil in the lock-pit prevented the driving of piles, inverted trusses made of timber 12 inches square have been used as a substitute for them; these are placed about 18 inches apart, excepting at the angle of the mitre-sills, where an additional truss has been put in: additional piles have also been placed at this angle where piles have been used. The flooring between the wing-walls outside the recesses is laid level on timbers 12 inches square, placed 8 inches apart, and it is carried down about 4½ feet below the masonry of the lower wings; that part which is under the walls is supported by cross timbers laid longitudinally as in the chambers, but only 2 feet apart; the remainder is kept from rising in the middle by means of anchor stones, about 3 feet square and 2½ feet thick, to which they are secured by fox-wedged iron bolts 1 inch thick.

Plates VIII. and IX.

The walls of the chambers are 20 feet high and 13 feet broad at the bottom;

they rise with a slope of 8 inches to the foot in front for the first 10 feet,[6] and afterwards with a slope of 1 inch to the foot; and by means of offsets at the back, their breadth is reduced to 5 feet under the coping, which is 16 inches thick, and 4 feet broad.

The walls of the recesses are perpendicular in front, but as they curve horizontally to receive the gates, they are 10 feet 5 inches broad in the middle, and 11 feet 6 inches at each end; their breadth is reduced by offsets at the back to 9 feet 2 inches at the height of 10 feet from the foundation, and to 5 feet under the coping, as in the chambers. At the hollow quoin piers, which are perpendicular, the locks are 55 feet broad, and at the end of the gates 55½ feet. The centre of the lower chain hole is 16 feet below the end of the recess, and from this centre the outer edge of the coping, for the circular part of the wings, is described by a radius of 8 feet.

In order to keep the valve-gates or sluices (which are placed in the lock-gates) below the water surface, and also to preserve the wooden floors of the recesses, the breast of the locks only rises in the first instance 6 feet above the bottom of the chamber walls, at which level the recess floors are placed; a second or upper breast is consequently required at the upper part of the recess, which is 3 feet high and 8 feet thick, and the top of which will support the stop logs[7] when necessary: the circular part of the upper wings is described from a centre taken in the line of the back of this upper breast, with a radius of 8 feet.

The walls of the lower wings are finished like those of the chambers. Those of the upper wings have a slope in front of 3 inches to the foot as far up as the water level, and from thence to the coping they have only a slope of 1½ inch to the foot.[8] They are 9 feet thick at the bottom, and they are reduced by offsets in the back to 5 feet thick below the coping.

The man-holes are 2 feet square; but they are enlarged to 3 feet for a distance of about 4 feet, where the T plates are built into the wall to support the capstan shaft.

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[6] These walls would have been better if the lower part had been built like the upper part, with a slope of 1 inch to the foot. Anchor stones might have been placed to keep the timbers from rising, if necessary.

[7] A caisson may probably be adopted here with advantage, instead of the logs.

[8] These walls would have been better if built with the same slope as the upper part of the chamber walls.

The timber and plank used for the foundations are pine or hemlock. The trusses and planking of the upper recesses are of rock elm.

Several rows of sheet piling, made of 3-inch pine plank, tongued and grooved, are placed across the locks under the planking, being well secured to the timbers, and carried to the outside of the masonry. They are placed at the head and foot of each recess across the lower end of the locks below the wing-walls, and in some cases across the upper end also.

LOCK-GATES.

Plate X. The lock-gates are 32 feet 6 inches long each, the cross bars being 29 feet 4 inches in length, the mitre-posts 18 inches × 16 inches, the quoin-posts 20×18 inches. The two lower bars are 12 inches thick; the upper bar is only 10 inches thick: these being the principal bars, all of them are 27 inches broad in the middle, 16 inches at the end next the mitre-post, and 18 inches at the quoin-post, having a convex curve towards the head of the canal of 10 inches, and a tenon into each post of 9 inches.

The intermediate bars vary in thickness from 12 to 9 inches, according to their position; they likewise have a convex curve on the upper side, and a concave curve on the lower side, of 7 inches;[9] and as 2½ inches are taken off for the thickness of the planking on the upper side, they are only 17½ inches broad in the middle, 13½ inches broad at the end next the mitre-post, and 15½ at the quoin-post. They are placed at different distances, according to their heights from the bottom, varying from 9 to 16 inches, except the two lower bars, which are 18 inches apart, in order to give room for the valve-gates.

Plate XI. These valve-gates, which are affixed to the second bar, are on quite a new construction, the invention of David Wilkinson, Esq., of the Cohoes Falls, State of New York, one of the contractors for the lock-gates. The peculiar novelty in their construction consists in their being so made as to open by the pressure of water from above, and they are closed by means of a screw against the head of water, the weight of the paddle-gate being made to assist in closing them.

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[9] This curve has been cut out of the lower side of these bars, in order to make them lighter; it may be doubtful, however, whether it is not as well to leave it in.

The openings for these valves, of which there are two in each gate, are 5 feet long, so that the column of water which passes through them when opened is 20 feet by 15 inches, and it is computed that they will fill the locks in about 5 minutes.

These valve-gates open on horizontal hinges attached to the second bar, which is so placed that these hinges are 1 foot below the water line of the lower level; their under surface being curved, gives the water a downward course when passing through them, and thus prevents its injuring the vessels in the locks. The hinges are let into the under part of the second bar, between two studs of 9 inches thick, the lower bar being bevelled to conform to the downward course of the water; the screws which close the valve-gates are 3 inches in diameter, and they are worked on the bridge of the lock-gate by a frame, as shown in the plan.

Plate XII. The lock-gates move on a friction roller which runs on a segment of cast-iron. This roller is 16 inches in diameter, and it is let into the lower bar about 3 feet from the end of the gate.

It is held in its place by means of two stirrups of iron, to which is attached an iron rod 2½ inches in diameter, the upper end of which works in a screw box let into the under side of the top bar of the gate, by means of which this end of the gate is supported, and it may be raised or lowered when necessary. With a view of giving strength to the outer end of the lower bar, where it is cut to receive the friction-roller, a piece of oak is added on the top 6 inches thick and 6 feet long, which is secured above and below by means of wrought-iron plates $\frac{5}{16}$ths of an inch thick, connected by six bolts 1⅛ inch in diameter.

In order to prevent the gates from settling at all in the middle, on account of their great length, two braces of 4-inch bar-iron ⅝ths of an inch thick, are carried down from the head of each post to the second bar, on which they nearly meet at the middle, where they are connected together by a piece of bar-iron of similar dimensions; they are let into all the bars of the gates immediately under the planking, and they are secured to the post and to each bar by iron bolts 1 inch in diameter.

The bars of the gates are further kept in their places by means of small studs 4 inches thick and the full width of the bars; on the sides of these studs screw bolts with nuts are placed, connecting each bar to the one above and below it, and thus the whole is kept firm together.

The bars are connected to the posts by means of single tenons, each of which is 9 inches long, and ⅓rd the thickness of the bar in width, that is, 5½ inches at the mitre, and 6 inches at the quoin-post, and they are boxed into the post with a shoulder of ½ an inch. They are all held to their places in the posts by means of T and ╥ plates, made of 4-inch bar-iron ⅝ths of an inch thick, extending upwards along the posts on both sides of the gates, from the middle of the lower to the middle of the upper bar, that part of the plates which runs along each bar being 3 feet 7 inches long. These plates are all attached to the gates by means of screw bolts with square nuts running through from the upper side, and connecting them with the corresponding plates on the lower side.

The upper side of the gates is covered with 2½-inch plank of Norway pine, grooved and tongued together, and let into the bars, which, as well as all the rest of the wood-work of the gates, are of the best white oak.

The bridges of the gates are of 3-inch oak plank 27 inches wide; they are supported by iron knees 3¼ inches by ⅝ths of an inch, and by pillars or posts of iron 1½ inch diameter, which run through the knees, and extend upwards 3 feet, in order to support the hand-railing, which is of rod-iron 1⅜ths of an inch in diameter.

The mitre-sills are 22×12 inches, and they are so placed as to form a salient angle of 130°; they are secured to the recess floors by means of screw bolts 1½ inch in diameter and 29 inches long, four of which pass through the planking to the middle of each truss or cross timber below; the thread of the screw is 12 inches in length, to correspond with the thickness of these timbers: the whole is well bedded in cement. On the lower side they are further supported by three blocks of wood, which are likewise secured in the same manner as the mitre-sills by four screw bolts through each. The block at the centre or point of the sills is covered by a wrought-iron plate to prevent the chain of the gates from wearing the mitre-sills; it is 6 feet by 22 inches; those on the sides are 5 feet by 18 inches. A bar of 4-inch wrought-iron ½ an inch thick is placed along the top of the mitre-sill, projecting about ½ an inch on the upper side, so that the pressure of water against the gate may make a close joint. This bar is let into the mitre-sill and secured to it by spikes.

The lock-gates are opened by means of close-linked chains 2 inches in diameter, made of wrought-iron ⁹⁄₁₆ths of an inch thick, which are attached to the gates near the friction rollers by strong hooks, so constructed that the chains can be taken off and replaced if required without drawing off the water from the canal. These chains are worked by a capstan placed on the walls of the locks, turning a perpendicular wrought-iron shaft 3 inches in diameter, having a cast-iron drum round the lower end of 5 inches in diameter, to the bottom of which the chain is attached; and as it rises by the turning of the capstan, it is kept in its place, and prevented from becoming entangled in any way, by means of a rider (also the invention of Mr. Wilkinson) placed at the bottom of the capstan, which is constructed by having a thimble to pass around the drum, the under edge of which is made in a spiral form with a tube attached to the same, through which the chain passes.

Plate XIII.

A wrought-iron step 3 inches in diameter is inserted in the masonry at the bottom of the man-holes to receive the drum, and it is kept in its place by a wrought-iron plate 15 inches square. A brass box is inserted in the bottom of the drum about 1 inch thick, which covers this step. The capstan shaft is supported and kept in its place by means of a T plate of 4-inch bar-iron $\frac{5}{8}$ths of an inch thick, built into the masonry about $5\frac{1}{2}$ feet from the bottom, having a brass box for a bearing to prevent friction, and brass boxes are also placed in the iron stirrups, which hold the friction-rollers, for the same purpose.

The man-holes are covered by circular cast-iron plates about an inch thick, one half of which is made to open, in order to enable a person to descend in case any thing requires repair; and in the centre of these plates a brass box also is placed, which forms a third bearing for the shaft.

The capstan head is made in two parts, in the lower of which two palls are placed to prevent its being turned the wrong way.

The quoin-post is supported by a cast-iron step let into the recess floor, which runs into a socket in the bottom of the post, having a small brass plate 1 inch thick placed on this step to prevent friction. The diameter of hole which is made in the floor to receive this step is 1 inch more than that of the step itself, in order to allow the screw attached to the friction-roller to raise the gates if necessary.

The quoin or heel-post is kept in its place by a collar fastened to the anchors which are let into the coping. This collar is wrought-iron $2\frac{1}{4}$ inches square, and within it are placed two half hoops of 6-inch bar-iron $\frac{1}{4}$ of an inch thick, connected together by the collar which passes through them. A small lip 1¾ inch broad projects over the coping from that part of the hoop which is between the anchors, in order to prevent any thing falling down behind the quoin-post; and small plates of brass ½ an inch thick are let into that part of the quoin-post which is in contact with this hoop. The anchors are of wrought-iron 6 inches wide and 1¾ inch thick, gradually tapering to 4 inches in width at the ends. They are let into the coping, and secured to the masonry by 1½-inch iron bolts 3 feet long, having round nuts at the top, counter-sunk into the anchors, so that no part projects above the surface. These bolts are secured in the masonry by means of a composition of sulphur and iron ore, of nearly equal weights, which expands and fills the holes better than lead, and which is in every respect equally good and much cheaper.

APPENDIX.

A.

Abstract of the Tolls collected on the present Canals between Lake Erie and Montreal during the year 1839, as shown in the following statement.

	£.	s.	d.
Welland Canal	12,700	0	0
Rideau ,, ...	7,000	0	0
Ottawa ,, ...	2,000	0	0
Lachine ,, ...	6,638	10	4
Total in 1839,	£28,338	10	4

Statement of the Tolls collected on the Welland Canal from 1833 to 1839.

Year.	Amount of tolls collected.			Remarks.
	£.	s.	d.	
1833	3618	1	6¾	
1834	4300	8	5¾	
1835	5807	5	11¼	
1836	5754	12	3½	
1837	5516	4	4	
1838	6740	13	10	
1839	12700	0	0	This is given as an approximation, the return not yet having been received.

Statement of the Tolls collected on the Rideau and Ottawa Canals during the years 1837, 1838, and 1839.

Year.	Rideau Canal.			Ottawa Canals.			Total.		
	£.	s.	d.	£.	s.	d.	£.	s.	d.
1837	4189	16	0	No returns yet received.					
1838	5297	8	8	1754	1	6½	7051	10	2½
1839[1]	7000	0	0	2000	0	0	9000	0	0

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[1] The accounts for the present year are not yet made up, but these amounts have been given as near approximations.

Statement of Tolls collected on the Lachine Canal from 1825 to 1839, both years inclusive. Montreal, 24th December, 1839.

Year.	Downward.			Upward.			On boats, &c. wintering, and on boats, &c. built and repaired, and wharfage dues, &c.			Total.		
	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
1825	1089	14	8	190	15	8	..			1280	10	4
1826	1571	2	1½	458	16	4½	..			2029	18	6
1827	2433	19	7	818	16	7	..			3252	16	2
1828[2]	321	11	10	54	8	6	..			376	0	4
1829	1884	15	3	1040	15	4½	..			2925	10	7½
1830	3708	3	3	1604	17	11½	..			5313	1	2½
1831	4461	12	10	2171	5	6½	..			6632	18	4½
1832	3802	7	9½	2107	12	0½	..			5909	19	10
1833	4844	0	3½	2310	3	9	..			7154	4	0½
1834	4308	6	11½	2222	15	11	..			6531	2	10½
1835[2]	39	12	7½	41	3	1	..			80	15	8½
1836	3869	16	8	2409	19	4½	97	4	0½	6377	0	1
1837	2438	17	9½	2158	9	8	65	17	5	4633	4	10½
1838	2982	14	5½	1705	16	9	63	3	9	4761	14	11½
1839	4180	2	3½	2369	3	6	89	4	6½	6638	10	4

B.

The Erie Canal, which connects the tide-water of the Hudson River with Lake Erie, was commenced in 1817, and completed in 1825. It is 363 miles long, and its original cost was $7,143,789, equal to £1,785,697. 5*s*. Halifax currency; the canal being only 40 feet wide on the surface, and 4 feet deep.

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[2] Mem.—No tolls were collected after 1st May in the years 1828 and 1835 respectively, the Provincial Acts authorizing their collection having been suffered to expire. If this had not been the case, it is estimated that the tolls for those years would have been as follows:

	Downward.	Upward.	Total.
In 1828 . .	£2496 19 9	£1014 1 11	£3511 1 8
In 1835 . .	3234 11 7½	2264 5 5½	5498 17 1

(Signed) F. Griffin,
Secretary, Treasurer, and Toll Collector.

The following is a statement of the Tolls received on it since its completion:

Year.	Dollars.	Halifax currency.			Remarks.
		£.	s.	d.	
1824	340,000	85,000	0	0	
1825	566,000	141,500	0	0	
1826	762,167	190,541	15	0	
1827					
1828					
1829					
1830	795,054	198,763	10	0	
1831	1,194,610	298,652	10	0	
1832	1,195,804	298,951	0	0	
1833	1,422,695	355,673	15	0	Reduced 20 per cent.
1834	1,294,956	323,739	0	0	Reduced 15 per cent. since.
1835	1,491,952	372,988	0	0	
1836	1,440,539	360,134	15	0	
1837	1,144,170	286,042	10	0	
1838	1,414,174	353,543	10	0	

D.

Extract of a Letter from C. J. Burckle, Esq., one of the most respectable Merchants at Oswego, in the State of New York, to Lieut.-Col. Phillpotts, Royal Engineers, dated Oswego, 2nd June, 1839.

"The enclosed papers will put you in possession of some authentic information as to the views entertained by our States' Government and people of the importance of the Western trade: they furnish statistical statements of the amount of its tonnage, value, increase, &c., and will convince you that it is considered of the utmost importance by the States of New York, Pennsylvania, Maryland, Virginia, and latterly of South Carolina, to draw as much of it as possible to their sea-ports; that very large sums are now being laid out, and have already been laid out, and that still larger ones are contemplated to be laid out, upon improvements tending to obtain this great, this all-desirable object.

"I myself am of opinion with the old experienced engineer, Benjamin Wright, that *none of the intended and already established routes can compete, in cheapness of transportation, with that via the Welland Canal and St. Lawrence River, whenever an uninterrupted steam-boat and ship navigation from the Upper Lakes has been opened to Montreal and the Ocean*; particularly if the dangers of the Gulf of St. Lawrence in spring could be remedied by a connexion with the Bay of Fundy; and should, in aid of this cheapness of transportation, judicious and liberal regulations respecting the importation of wheat, flour, cotton, tobacco, ashes, lumber staves, &c. into England via the St. Lawrence be adopted, the current of trade will soon be forced from its accustomed into the new channel: the commercial as well as political effects this diversion of trade would produce in the United States may well be pronounced as prodigious; for rest assured, that if once the West exports via Montreal, *it will and must soon import the same way*, particularly bulky and low-priced articles: for instance, crockery-ware; the transportation of that low-priced article from New York to Chicago is generally $25, and often $30 per ton of 2000 lbs. Now let us suppose a vessel laden with 300 or 400 tons should sail from Liverpool to Chicago via the St. Lawrence and Welland Canal, (which on an average would not require more than eight or ten weeks to perform the voyage,) it would earn from $9000 to $10,000 in that time,—an enormous freight: this would, of course, create competition, the price would be greatly reduced, and the consequence would be, that earthenware would be delivered in the West at so low a rate that more, much more would be consumed, and thereby the British manufacturer, ship-owner, &c., greatly benefited. This would be the case with other low-priced and bulky articles, such as iron, iron castings, hardware, glassware, paints, &c., sugar, rum, and molasses from your colonies, &c.; but, Sir, may we not reasonably suppose that the finer articles of manufacture, &c., would soon follow, and be added to the coarser merchandize, particularly if, as may reasonably be supposed, the city of Montreal should, like New Orleans, be amply supplied with what would be wanted? The people of the West would demand from the United States' Government that their ports should be made ports of entry for foreign merchandize, and they being entirely unaccustomed to the very rigorous and highly vexatious revenue laws of the United States, and by no means as tame and submissive as the people on the Atlantic shores, they would revolt at them, the tariff or protective system would soon become entirely obnoxious and hateful to them, the commercial relations with Atlantic states and cities would be greatly weakened, and, in fact, entire new interests created throughout the Great West, all tending to benefit England and the Canadas. At present all the vessels navigating the lakes are laid up during at least five months of the year: make your Welland Canal equal to your improvements on the St. Lawrence (at Cornwall), so that steamers and sailing vessels of a large size can navigate the lakes from the ocean, most of the small vessels now in use would soon prove unprofitable, and large vessels be preferred, who may proceed to sea with their cargoes of wheat, &c., previous to the closing of the navigation in the fall, and return with cargoes of merchandize, sugar, rum, molasses, &c., in spring.

"I might extend my speculations on the consequences *ad infinitum;* the mind gets lost in the contemplation; and I think that the subject well deserves the most serious consideration of your statesmen. It would completely silence faction and discontent in the Canadas, and give an impulse of life and activity to Old England itself.

"Permit me to observe further, that I have consulted the most eminent ship-builders of New York on the feasibility and practicability of constructing vessels of from 300 to 400 tons burthen, fit to navigate the ocean to any part of the world, and pass through your locks on the St. Lawrence of 200 feet length, 50 feet breadth, and 9 feet depth; they tell me *that it can be done easily.*

"If these hasty remarks should prove of any use to you, by suggesting new ideas or otherwise, it will afford me great gratification.

"I remain with great respect, Sir,
"Your most obedient servant,
(Signed) "C. J. Burckle."

Extract from a Letter from **Benjamin Wright**, Esq., Civil Engineer, to Lieut.-Col. **Phillpotts**, Royal Engineers, dated Scott's Ferry, Albermarle County, Virginia, July 2nd, 1839.

"I set down as true that for all that part of the year when the lakes, and rivers falling into the lakes, can be navigated free from ice, and the proper connexion now in progress of execution between Lake Michigan and Illinois Rivers, between Wabash and Lake Erie, between Wisconsin and the Green Bay, (together with some railroads now making,) shall be completed, that the trade of all the country now forming the States of Ohio, Indiana, Illinois, Missouri, Michigan, and the territories of Wisconsin and Iowa, which will soon become States, will all find it for their interest to export eastward, and receive their merchandize from the ports north of the State of Virginia on the Atlantic.

"Now with all the competition which is arising between Baltimore, Philadelphia, and New York, for the trade of this great country, it is impossible to see where or how the division of the products of the soil, and the merchandize to supply the inhabitants, will be made as to these cities. And here I may digress a little by saying, that Montreal may have a share of this trade if she pleases to do so, as long as she is connected with England, whose Government can by proper laws induce the exports of the soil to pass that way whenever they choose to do so, after the proper facilities by way of improvement of the St. Lawrence and the Welland Canal are made.

"The territory lying north of the Ohio, and north of the Missouri River, and east of the Rocky Mountains, will in twenty years contain from twelve to twenty millions of souls, who are working, energetic, industrious people: this population must export and import a very large amount of value. I have no tables to show the value of exports and imports per head as applied to other countries, neither do I think that any such tables would apply to the population of this country. We are a different people from any other; we can effect more with the same number of men than any other people; we have more energy of character, more resources within ourselves, than other nations, and we cannot therefore be estimated as others. But as we have no other data to take, I do not see but you must assume—say, dollars and cents per head for exports, and dollars and cents for imports, and then assume that the population will increase in a certain ratio. Next year the census of the United States will be taken, and you will see that the increase in the part of country I have assumed as trading eastward will be very great.

"Now the question is, what portion of this trade will concentrate upon Lake Erie? I say, one half; because all the rivers, Ohio, Wabash, &c., are hardly navigable for boats for four months on an average, and the last year, for more than five months no navigation was carried on upon the Ohio because of low water. I was near the Ohio in September last, at a point 300 miles below Pittsburgh, and there was then only 18 inches water in the channel. The merchants of Cincinnati and other towns did not receive their foreign merchandize bought in August until December or January.

"*Now*, of the trade which falls upon the lakes, what portion can be induced to go to Montreal? This is a question of very difficult solution, as much depends upon the acts of the Government in its municipal regulations; much depends upon the safety and rapidity with which property is or may be converted into money.

"If this trade was put upon such a footing as to induce the flour to go to Montreal, and be thence shipped to England, you would soon see (after the improvements are made) millions of barrels of flour sent from the great wheat-growing country in Ohio, Indiana, Illinois, Michigan, and Wisconsin (the finest wheat-growing country in the world) to Montreal. With your increasing manufacturing population in England you could from this source be certain of a resource of bread stuffs;—if Poland and the Baltic failed you, here is a certainty, which Great Britain can find nowhere else to look for supplies of a bad harvest. Think of this as a matter of great moment, and it will justify the mother country in making the St. Lawrence a good and perfect navigation; and I may ask, why may not this course be the strongest tie to the people of Canada to remain connected with the mother country? or will there for ever be demagogues and restless spirits to make the people uneasy?

"I have endeavoured to answer your circular as well as I could, although you are very sensible that from the rapid changes going on in these States, more particularly in the new States, on the Ohio and Mississippi, all statistical tables of exports and imports are no data at all for the statesman to found his calculations upon: he must anticipate and assume data from the rapid improvements, the increased population, and wealth of those States, regularly progressing as they are; and that before the improvements of the St. Lawrence and Niagara Rivers could be completed, there will be a surplus of the products of the earth, to be sent to foreign countries, of many millions value. Look at the new State of Michigan, and see that, notwithstanding the emigration to that country, there is supposed a surplus of flour and grain to the amount of a million of dollars in value."

H.

Extract from a Report of the Select Committee of the Legislature of New York, on the petition of the Inhabitants of the County of Oswego. In Assembly, 14th April, 1834.

"The subject referred to the Committee, in whatever light it may be viewed, may justly be considered of the first importance, both to the enterprise and interests of the State of New York. The citizens of this State have witnessed with high satisfaction the commencement, completion, and successful operation of the Erie Canal, which has more than answered the expectations of its ardent and patriotic projectors. The value of property has been multiplied manifold; the arm of industry has converted the almost interminable regions of the forest in the western part of the State into fertile fields, enriching alike the hardy cultivator and the great commercial emporium of the State; cities and villages have arisen, as if by enchantment, where, but for the Erie Canal, would now have been a wilderness. Great and important have been the results of these works of internal improvement, not only to this State, but to a portion of the territory bordering upon the basin of the great western lakes."

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"Three great objects were primarily contemplated in constructing the Erie Canal:—first, to furnish the citizens of this State with an easy and cheap conveyance of their surplus produce to market; second, to secure and preserve the trade of the West; third, revenue.

"The first of these objects has been attained, and the attention of your Committee has been principally directed to a consideration of the second. That to secure and preserve the trade of the West is an object worthy the continued exertions and resources of the 'Empire State,' cannot and will not be denied; that it is so secured may well be doubted. The importance of the western trade will be seen by a view of the vast extent of country bordering upon and surrounding the western lakes,—a region of country more fertile and productive the sun in his course through heaven does not shine upon. If we glance an eye over the immense regions connected by the western lakes and their tributary streams,—if we regard the fertility of soil, the multiplicity of product which characterize those regions, and if we combine these advantages afforded by nature with the moral energy of the free and active people who are spreading their increasing millions over its surface,—what a vista through the darkness of time opens upon us! We see arts, science, industry, and social happiness already increasing in those countries beyond what the most inflated fancy would have dared to hope thirty or forty years ago.

"As yet the commercial and agricultural resources of the West are not developed.

These twin sisters of the wealth of nations are yet in their infancy. Owing to the rapid increase of population in Ohio, and the wild and uncultivated state of a portion of her territory, the surplus productions of her farmers have until recently been consumed within her own territory. Michigan[2] and Illinois, comparatively speaking, have furnished nothing for transportation; but when their exhaustless soil shall be cultivated and improved by the hardy and industrious yeomanry of the north and east, who are emigrating thither to a degree unprecedented in the annals of our country, their rich productions will be put afloat, and will find a market upon the shores of the Atlantic, *through such channel as presents safety, cheapness, and speed to the most advantageous market*. The citizens of the West have witnessed the commencement, progress, completion, and effect of the splendid system of internal improvements in this State, and are nobly imitating the example with an enterprise and zeal worthy their character. Already are the head-waters of the Mississippi connected at different places with the great chain of western lakes, by means of canals and railroads. The channels of communication now opened, and which will hereafter be opened, between the lakes and the interior, will be thronged with vehicles of transportation, conveying the rich fruits of the labours of millions of free and happy people to flourishing cities and villages upon the shores of the lakes, whose population, wealth, and enterprise will be equalled only by those upon the shores of the Atlantic.

"The surplus productions of this extensive region will find their way to the Atlantic. *Natural communications possess facilities and advantages which artificial never will and never can.* Lake and river navigation is being understood. *Steam power has changed every thing.* Twenty-three by-gone years have witnessed improvements in commercial facilities in our own State which have claimed the admiration and imitation of the world.

"The lethargy under which the people of Canada have slumbered for the last century has been thrown off, and they are now fully awake to the importance of internal improvements. They are beginning to appreciate the *natural water communications with which nature has so bountifully supplied them.* They have entered the lists, and are nobly contending for a participation in, *if not a monopoly of*, the rich dowry of the western trade. Their enterprise has caused a communication to be opened around the Falls of Niagara, a distance of forty-one miles, by which vessels carrying 1000 barrels of flour can go through, without being lightened, at an expense of one cent per barrel, exclusive of tolls. The amount of business done upon this canal will be seen by a reference to the fact, that 50,000 barrels of salt passed through it during the last season; and had the requisite repairs been made so as to have opened the canal with the commencement of lake navigation, the revenue would have amounted to more than $ 50,000.

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[2] It will be seen that this was written in 1834. During the late season, 1839, Michigan is said to have exported one million bushels of wheat.

"The evil which the Canal Commissioners *feared in* 1812 *now really exists.* The produce designed for transportation upon the Upper Lakes is now let down to Lake Ontario by means of this canal with facility and for a trifling expense. The prediction of the Canal Commissioners, '*that articles for exportation when once afloat on Lake Ontario would, generally speaking, go to Montreal, unless our British neighbours were blind to their own interests,' is now fully verified.* By a reference to the parliamentary proceedings of the Canadas during the last winter, it will appear obvious that they are not thus blind; that, on the contrary, they duly appreciate the importance of this trade, and that the greatest industry, activity, and talent are employed in the attainment of further improvements on the most magnificent scale. Appropriations have already been made for the improvement of the St. Lawrence, by which it is intended to connect the Atlantic with the lakes by ship and steam-boat navigation. Let them make the Welland Canal and the St. Lawrence navigable as they purpose to do, and which they will do, for steam-boats, *and Cleveland will be within sixty hours' ride of Montreal.* When these improvements are completed, *vessels of* 300 *tons can load at Chicago, at Cleveland, at Detroit, at Oswego, and other ports on the lakes, and deliver their cargoes at foreign ports.* When direct exportation has once succeeded, *direct importation will follow as a matter of course.* When the Welland Canal shall be completed, *and the St. Lawrence improved, as designed, goods may be delivered at Cleveland, from London, for less than one half of what it now costs by the way of New York and the Erie Canal.* Make the Erie Canal a public highway, *and the Canadian route will be preferable by one quarter in point of expense.* The vast superiority in the great point of economy in transportation effected upon *natural water communication, admitting of navigation by large vessels or steam-boats, above transportation upon canals and railroads, has been satisfactorily proved by experience on the Hudson, the lakes, and the great rivers of the West.* Even at the present reduced rates of toll upon the Erie Canal, river transportation has the advantage by more than 300 per cent. The charge upon the transportation of wheat, per bushel, from Troy to New York, *is three cents,* while the *same transportation for a like distance upon the canal cannot be effected for less than ten cents.*

"The importance of the western trade has aroused a spirit of enterprise and competition in sister States. To participate in this trade, rival canals and railroads have been constructed in Pennsylvania, Maryland, and Virginia; and it cannot be denied that these are already diverting a part of that trade from its natural current towards the lakes and Erie Canal, and will no doubt continue to produce such diversion in a ratio regularly augmented in their progress to completion. It cannot be questioned that a great portion of the produce and merchandize going to and coming from the fertile countries, at some distance south of the great chain of the lakes, and east and north of the tributary streams of the Mississippi, must find their way into Virginia, Maryland, and Pennsylvania. To prevent this diversion, the tolls upon the Erie and Ohio Canals have been very judiciously reduced during the present winter."

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"That the trade of the West is of vast importance, and is becoming yearly more and more important to the commercial interests of this State, cannot admit of doubt; and that there is danger of its being diverted, or a portion of it at least, through other channels than the Erie Canal to the Atlantic, your Committee think is equally apparent.

"In the spirit of enterprise and rivalry with which our southern and northern neighbours are actuated, your Committee see no cause for serious apprehension, jealousy, or alarm, because they believe it is within the power of this State to secure the trade of the West beyond the reach of competition or rivalry.

"The remedy, and only remedy, which can be applied to secure to ourselves and posterity this rich inheritance of national wealth, is by opening a communication between the Hudson and Lakes Ontario, Seneca, Cayuga, and Oneida, of sufficient magnitude to admit the passage of the smaller[3] class of steam-boats, and of the ordinary vessels which navigate those waters. The advantage to be derived from such a communication must be apparent to all. It will combine safety, cheapness, and expedition, the three great considerations in commercial enterprise, and save the loss and expense attendant upon numerous trans-shipments." * * * * *

"The amount of revenue to be derived from transportation is difficult to be imagined, and much more difficult to be ascertained. Judging, however, of the future from the past and the present, we may safely come to the conclusion that ten years will not elapse, after the completion of the proposed project, before we witness the same busy scenes upon its waters that we do now upon the Erie Canal. Calculation, like our advance in numbers, outruns fancy. *Things, which twenty years ago a man would have been laughed at for believing, we now see.* At that time, the most ardent mind proceeding on established facts by the unerring rules of arithmetic, was obliged to drop the pen at results which imagination could not embrace."

Extract of a Letter from BENJAMIN WRIGHT, Esq., Civil Engineer, to JOSEPH E. BLOOMFIELD, Esq., dated New York, 1st April, 1834.

"The project which the Canadians have in hand to make a steam-boat canal of ten feet water, to pass all the rapids between Montreal and Ogdensburgh, on Lake Ontario, is one which has a very important bearing in its consequences upon the people of the State of New York and the Erie Canal tolls. It is certain to my mind, that with such a canal as I have projected along the St. Lawrence and Welland Canal, in good order, that all the products of the soil, from all the Upper Lakes, can be carried

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[3] It is now generally admitted that *small steam-boats*, as here described, cannot compete with large ones; and therefore this communication, if completed, could not compete with the route proposed by the St. Lawrence.

to tide-water *a great deal cheaper by this route than they can ever be done by the Erie Canal or any other work.*

"The plan of the improvements as projected along the St. Lawrence is, to make short canals and locks around the rapids, leaving the steam-boat to navigate the river and lakes in all the intermediate spaces. The whole length of all the canals (although in seven or eight different pieces) does not exceed 31 miles, and about 175 feet of lockage. This can be executed for about three millions of dollars, and completed in three years from the time of its commencement, if they choose to do so.

"That the Welland Canal can and will be put in good order there is no doubt, as it appears by the measures adopted at the last session of their parliament, that they intend to make it a Government work, and will, no doubt, do so next winter.

"I have not said any thing about the competition which is to be looked for from Pennsylvania, if she goes on to form a connexion between her canal at Pittsburgh with the Ohio Canal at Akron. This latter place is about forty miles from Cleveland, on Lake Erie, and we see already that Pennsylvania has been this year navigating her canals since about the 10th of March. The truth is, and we ought not to disguise it, that Pennsylvania can navigate three or four weeks earlier than we can, and even Canada can open her Welland Canal nearly one month earlier than we can our Erie Canal; and the St. Lawrence Canal can be navigated earlier than our canals, if they pay a little attention to management to clear the ice."

Extract of a Letter from General DUNCAN, of Illinois, to the Hon. CHARLES F. MERCER, Chairman of the Committee on Roads and Canals, dated December 30th, 1833.

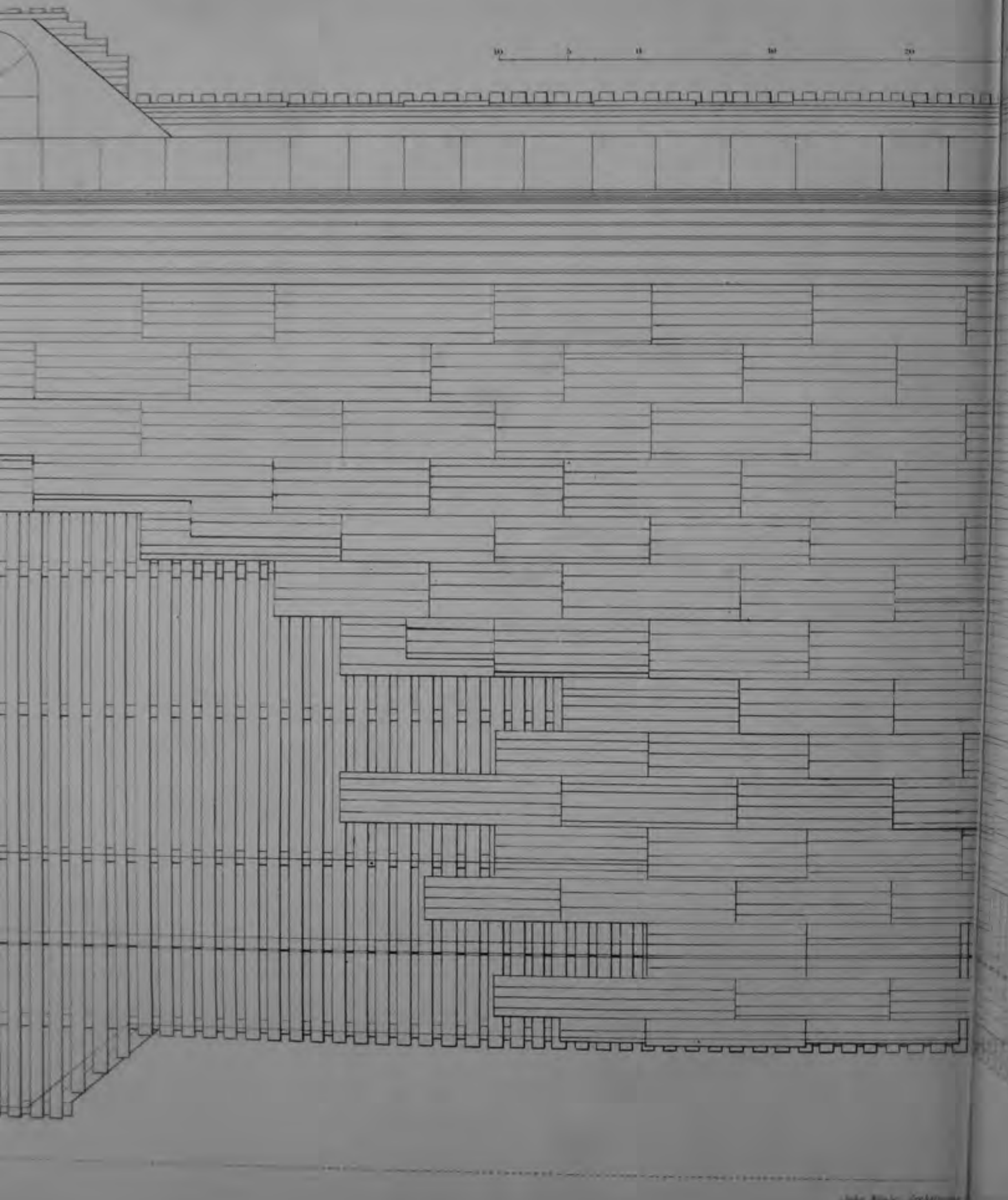
"Sir,—Allow me most respectfully to call your attention, and that of the Committee of which you are chairman, to the proposition submitted by me on the 17th day of December, 1833, authorizing an inquiry into the expediency of a grant by Congress of efficient aid to the State of Illinois to enable her to construct a steam-boat channel from Lake Michigan to the Mississippi River.

"It can scarcely be necessary for me to urge the importance of an early completion of this great work to every portion of this Union, connecting, as it would, more than twenty States.

"By this small improvement we should secure the most extensive internal steam-boat navigation that now is, or perhaps ever will be, known, penetrating for more than twenty-five hundred miles the most fertile regions of country on the globe; capable of supplying every part of Christendom with every thing necessary to make man independent and happy, and on whose lakes and rivers are seen in increasing numbers the whitening sail and torrent-stemming boat.

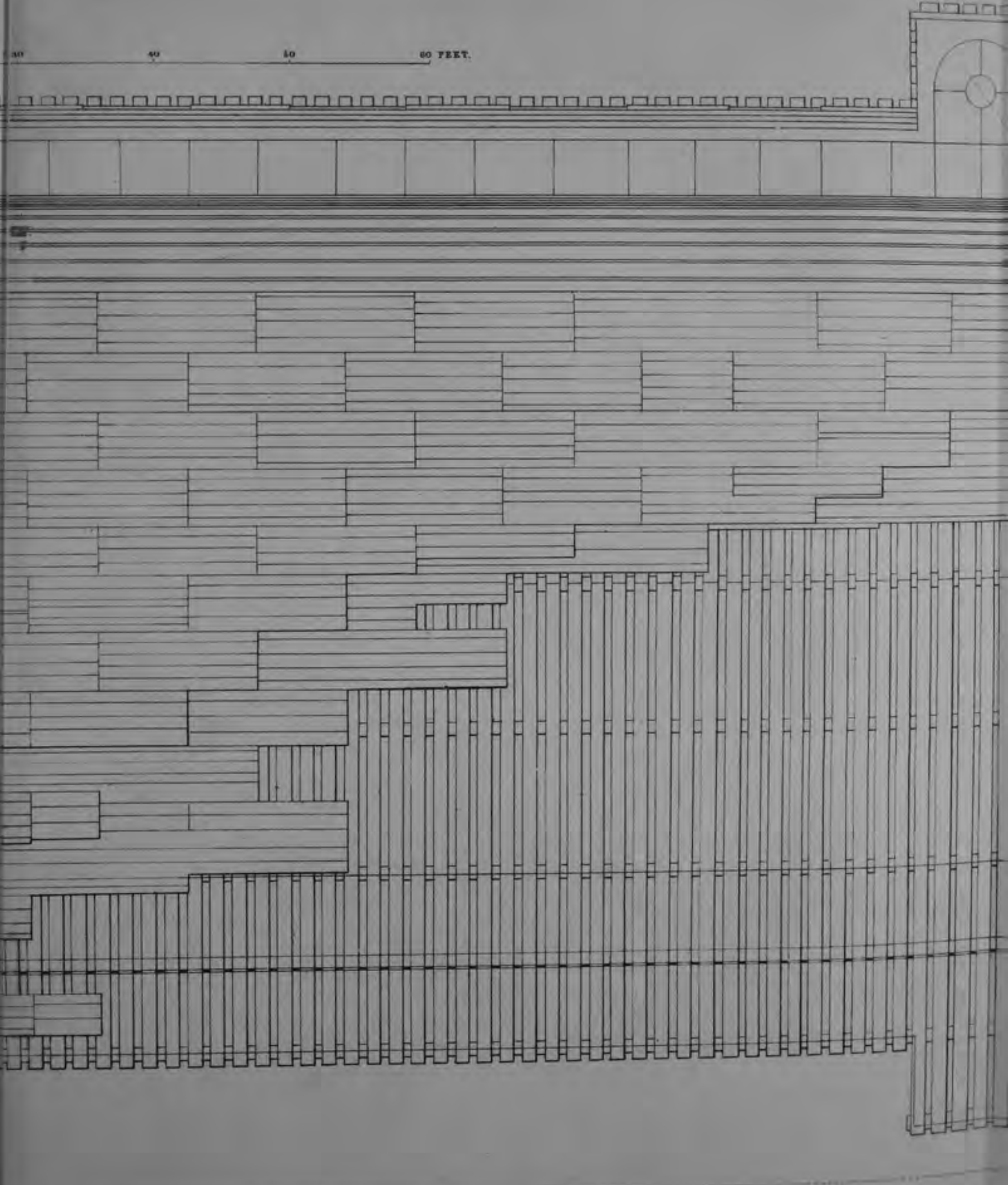
"Through this channel the sugar, cotton, rice, and tobacco of the south, the lead,

PLAN OF ONE OF THE LOCKS ON



John Rennie Architect

HE ST LAWRENCE CANAL.



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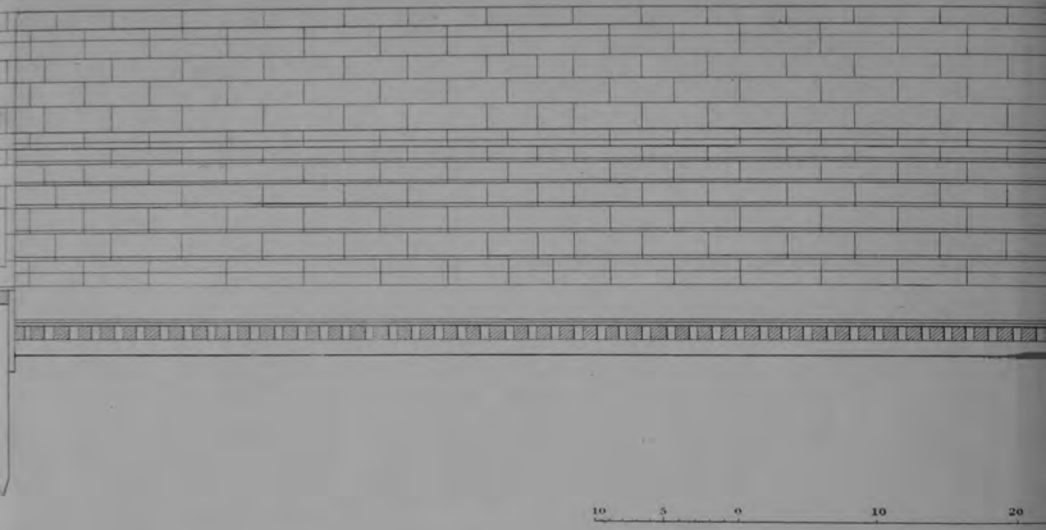
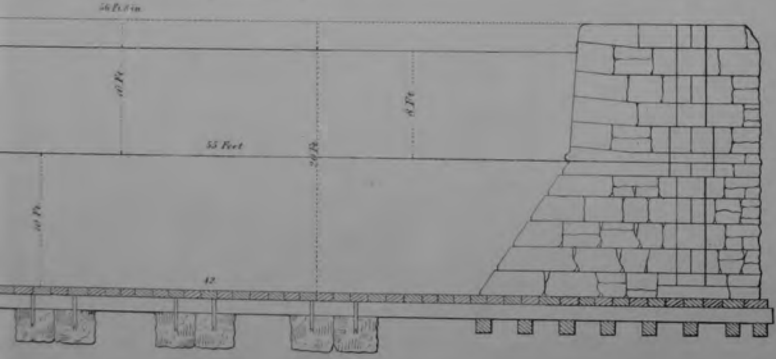
ELEVATION OF ONE

LONGITUDINAL SECTION THROUGH

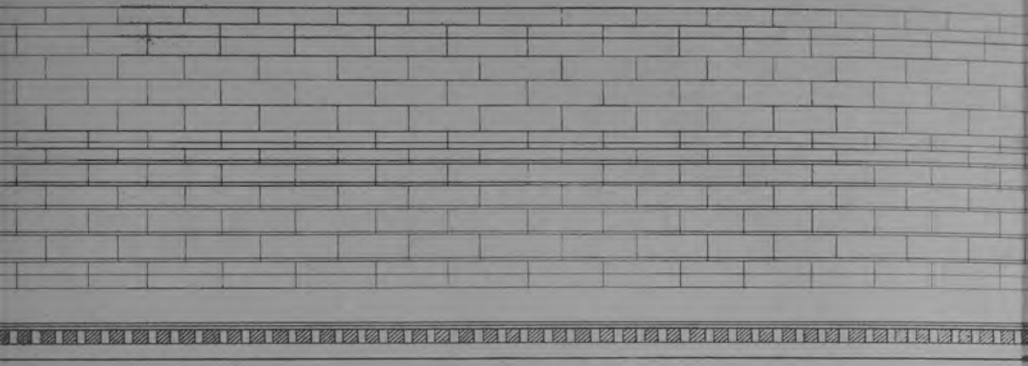


SECTION THROUGH CC.

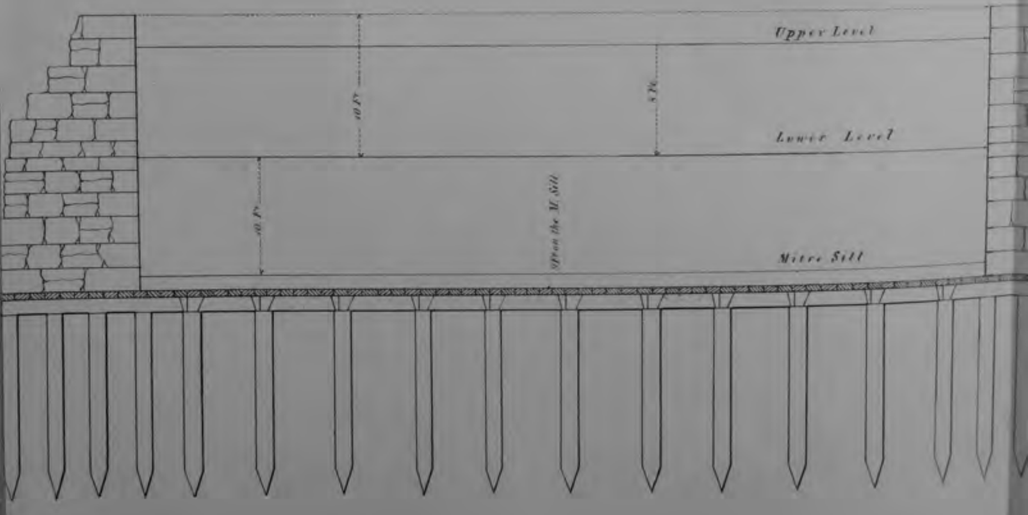


John Weale, Architectur

IDE OF A LOCK AND
E CENTRE OF THE FOUNDATION.



SECTION THROUGH BB WHERE PILES ARE USED.



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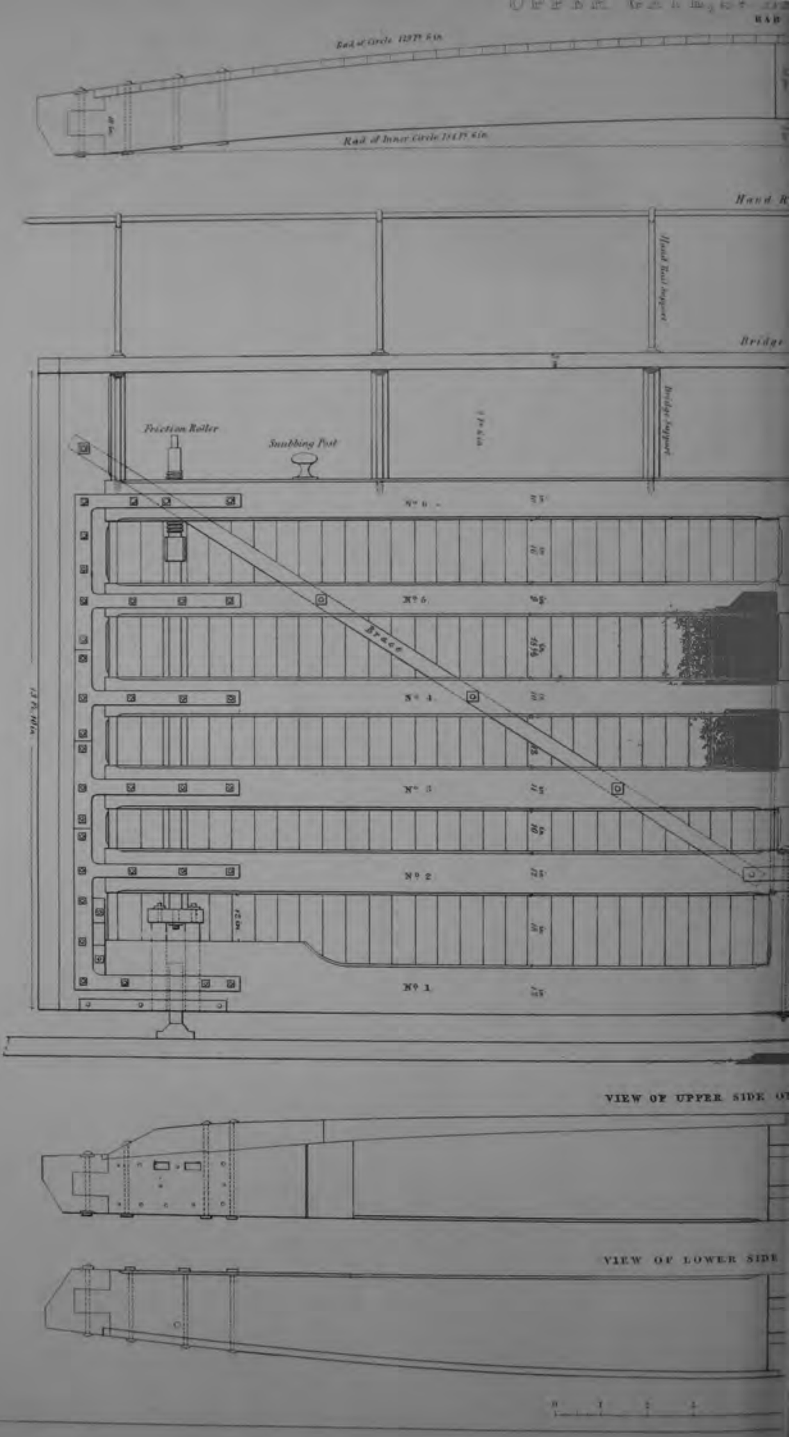
UPPER GATE
Rad. of Circle 129 Ft 6 in.
Rad. of Inner Circle 124 Ft 6 in.
Hand R
Hand Rail Support
Bridge
Bridge Support
Friction Roller
Snubbing Post
Brace
Nº 6
Nº 5
Nº 4
Nº 3
Nº 2
Nº 1
VIEW OF UPPER SIDE OF
VIEW OF LOWER SIDE
0
1
2
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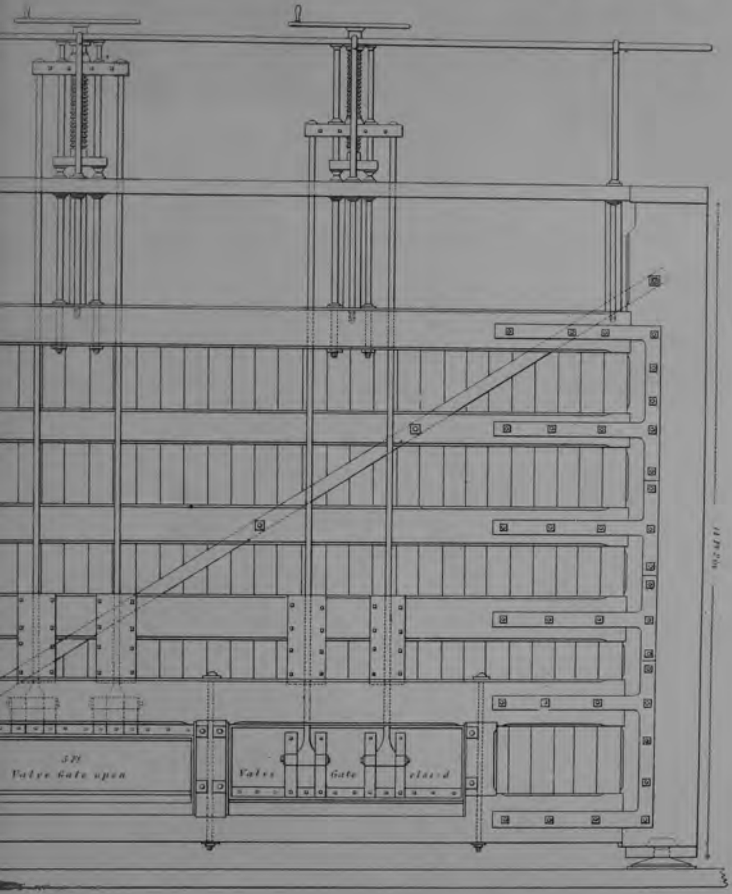
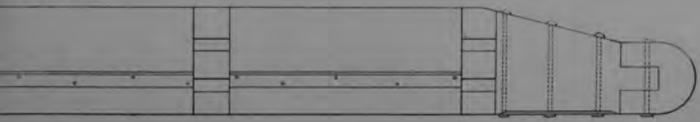


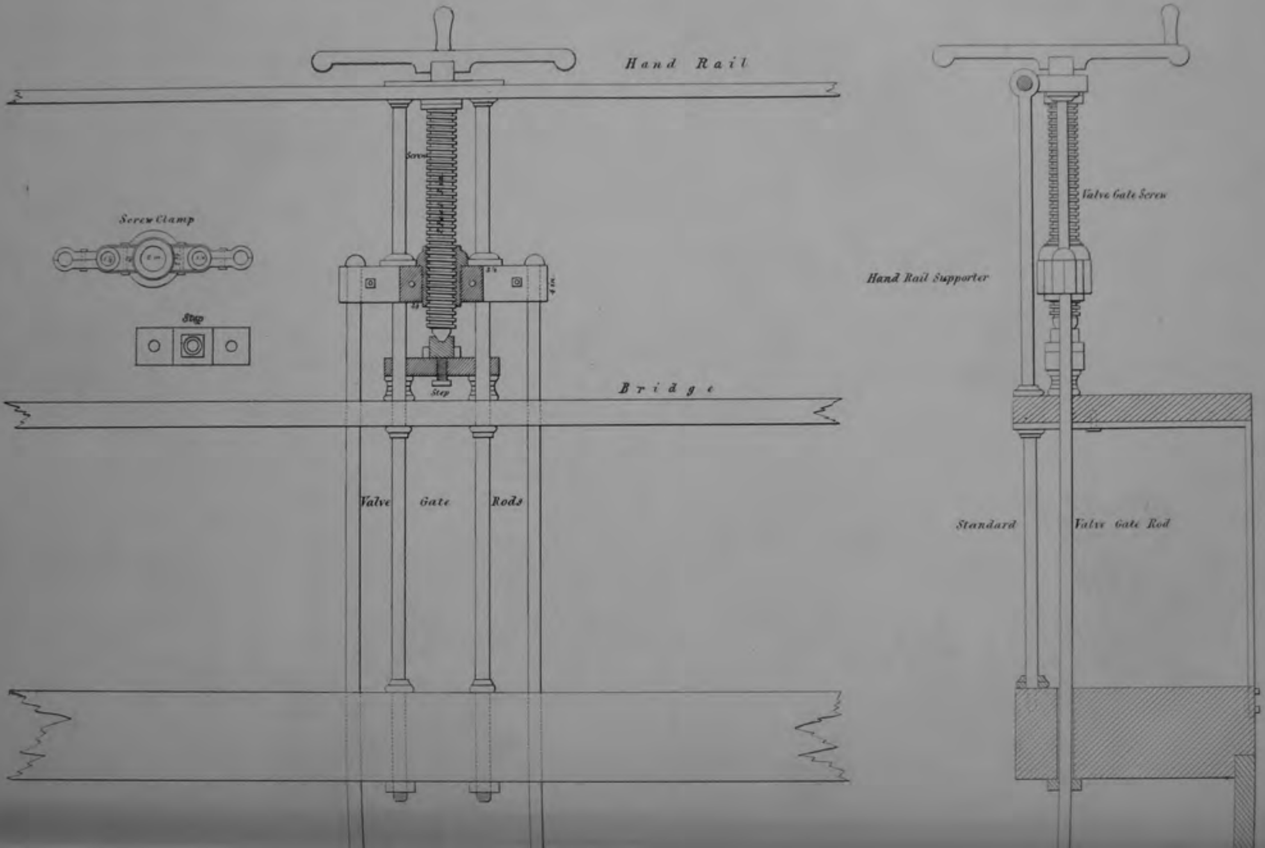
R BAR N° 1.

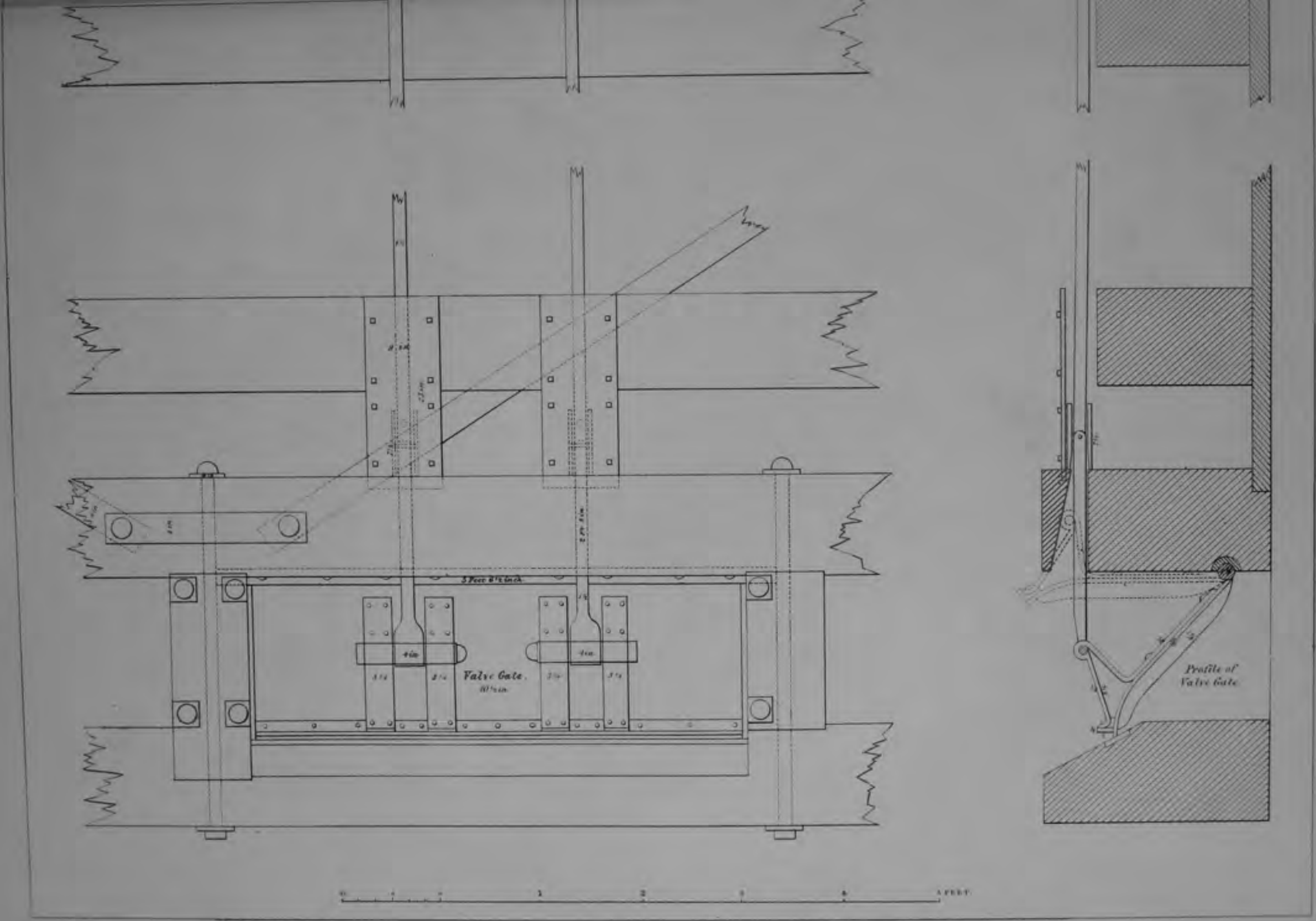


OND BAR N° 2

PLAN OF THE IRON WORK *used for opening & shutting the* VALVE GATES *on the* ST LAWRENCE CANAL.

To accompany Lt Colonel Phillpotts Report on the Inland Navigation of the Canadas

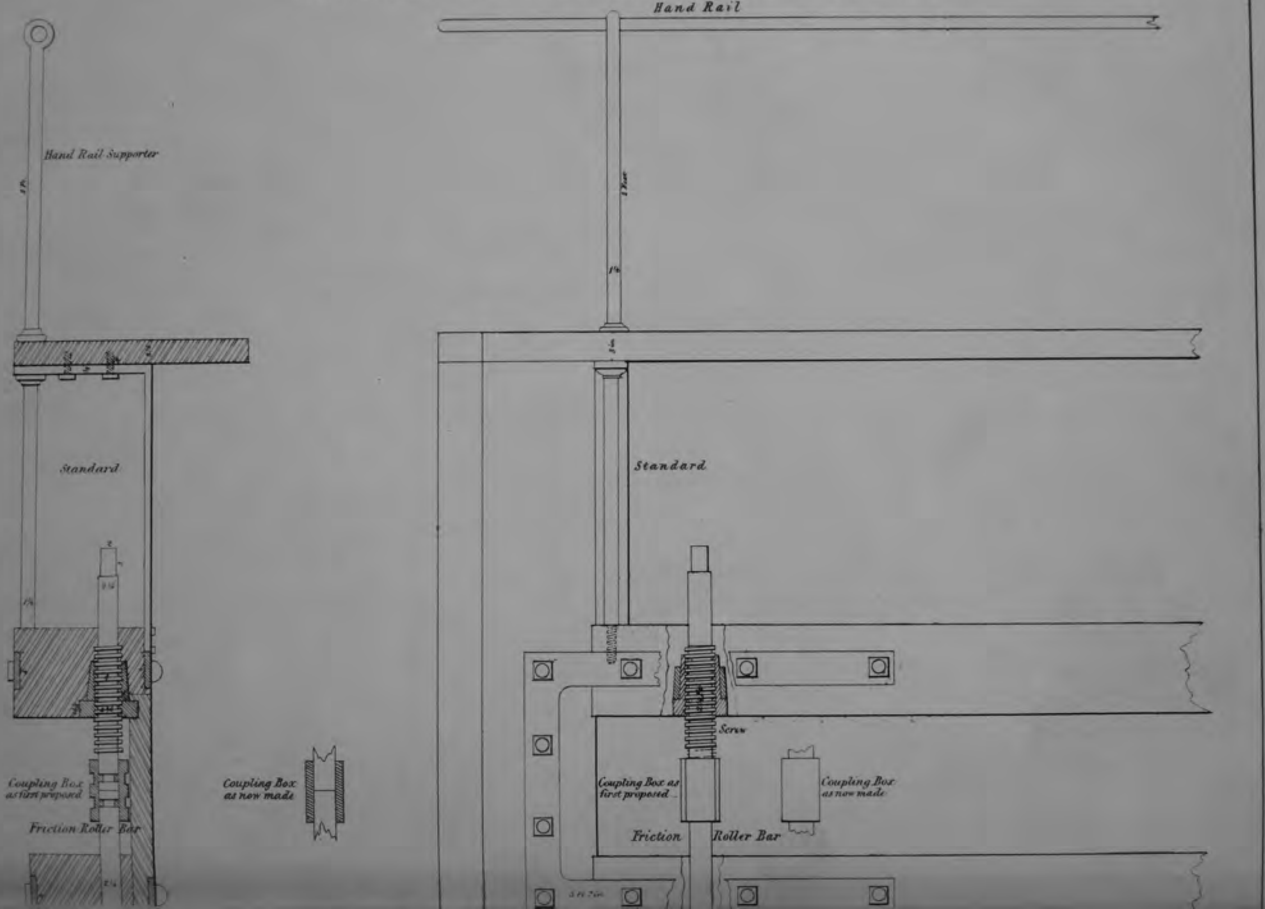


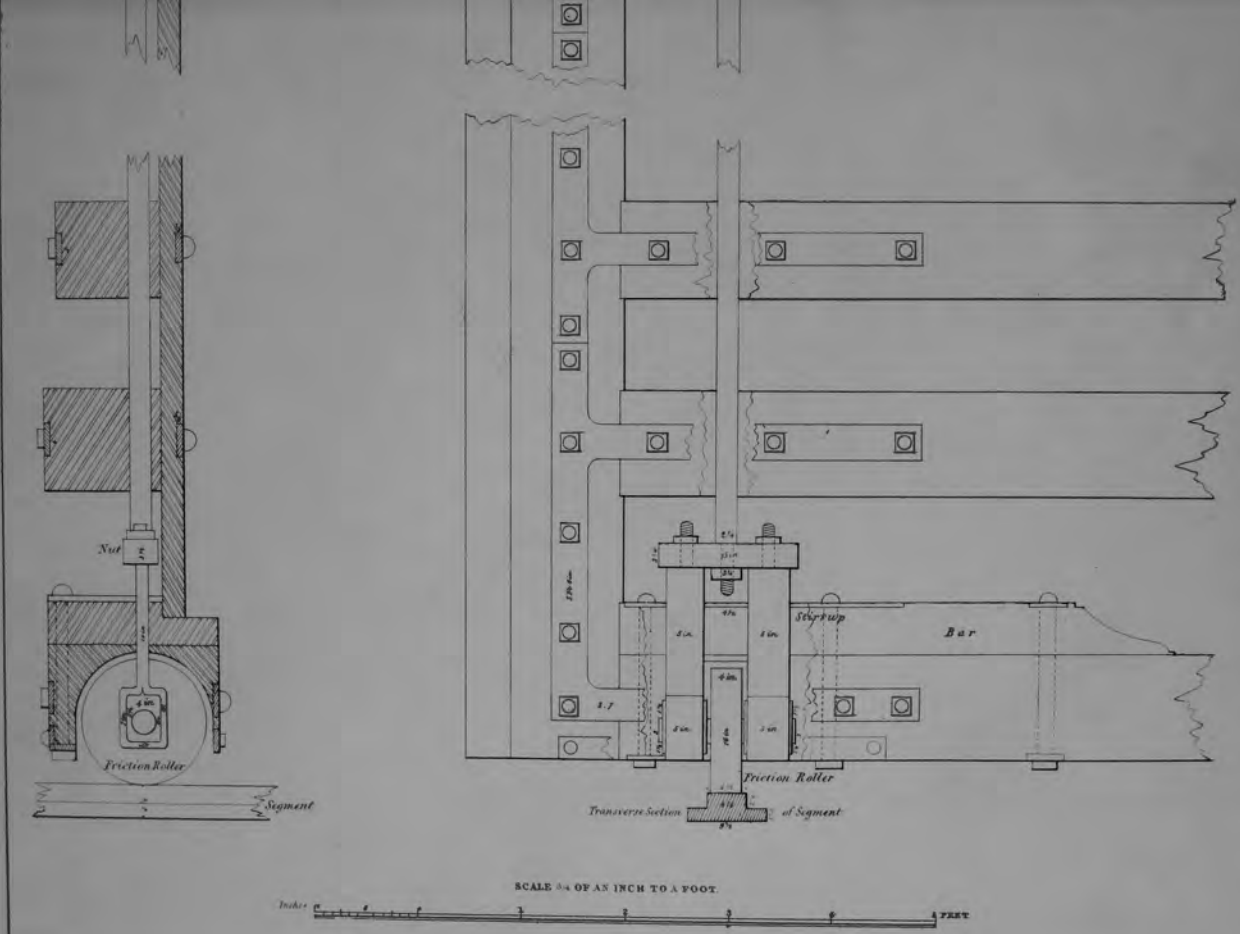


John Weale, Architectural Library, 59, High Holborn.

PLAN OF THE IRON WORK & SCREW *used for adjusting* THE FRICTION ROLLER ON THE LOCK GATES OF THE ST LAWRENCE CANAL,

To accompany Lieut. Colonel ***Phillpotts*** *Report on the* ***Inland Navigation of the*** *Canadas.*





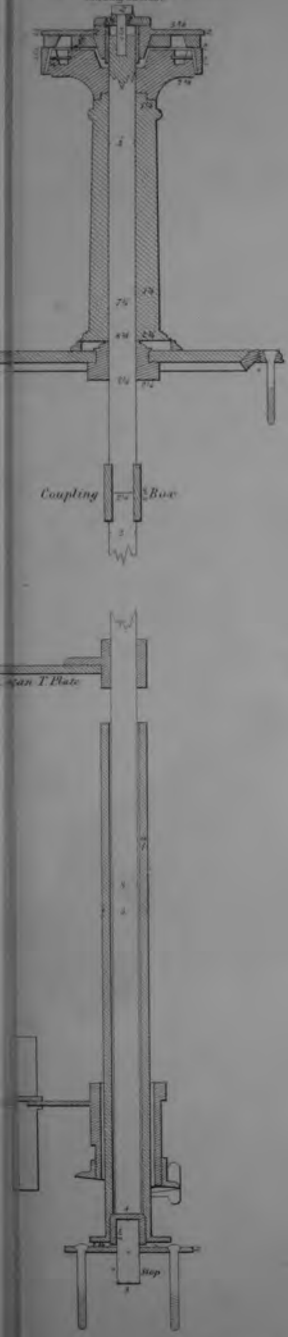
SCALE 3/4 OF AN INCH TO A FOOT.

J.R. Jobbins Lith.

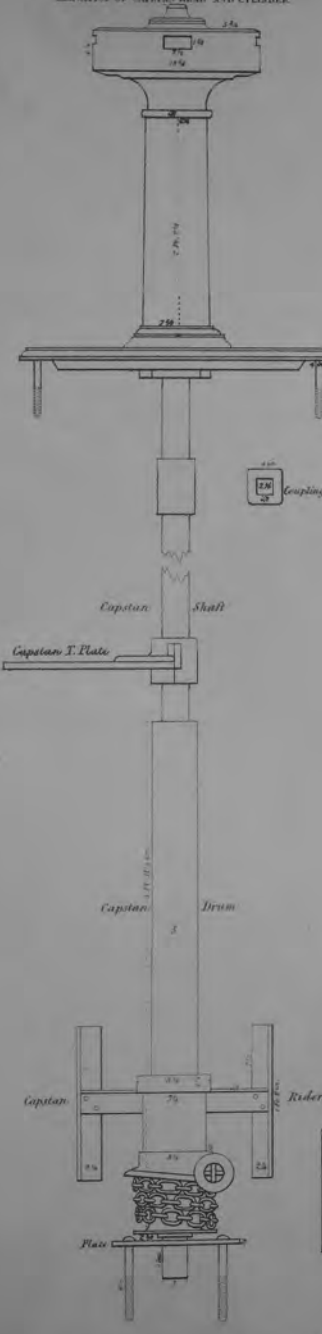
John Weale, Architectural Library, 59, High Holborn.

ON THE ST LAWRENCE CANAL.

CTION OF CAPSTAN HEAD AND CYLINDER.
Showing the Shaft.



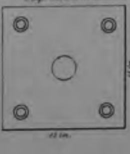
ELEVATION OF CAPSTAN HEAD AND CYLINDER.

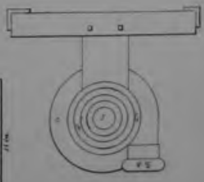


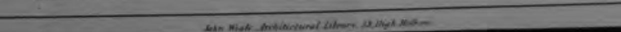
PLAN OF LOWER PART OF CAPSTAN HEAD.


WELL COVER

Capstan Plate







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coal, bread-stuffs, pork, beef, and other products of the West, would pass to the North, exchanged for their salt and timber, manufactures and merchandize.

"It is now estimated that there are about 315 steam-boats on the western waters, and about 350 schooners, smaller vessels and steam-boats, on the lakes; the increase of which can scarcely be anticipated, when we see that the steam-boats have increased from 1 in 1814, to 315 in 1833, less than twenty years, and the vessels, &c., on the lakes have increased almost as fast.

"The commerce carried on on the western waters was estimated this year at one million seven hundred thousand tons, which is said to have been worth about one hundred and seventy millions of dollars; freights have been reduced from five dollars to thirty-seven and a half cents per hundred from New Orleans to Louisville; passage and other charges have fallen in the same ratio: the amount and value of the commerce on the lakes can scarcely be estimated except by the number of vessels engaged in carrying it on, and the unequalled growth and improvement of the whole lake country. It seems to me that national pride, as well as national interest, should press on the accomplishment of this great work.

"Of its practicability there can be no doubt, unless the observations of more than one skilful engineer have been deceptive; and it is the shortest and best, if not the only route for the union, by such a channel, of these vast national waters.

"There is a reason for the immediate action of Congress on this interesting subject, which I will respectfully suggest. A portion of the country on the contemplated route of this canal, and on both sides of the Illinois River, is rapidly settling; an extensive commerce is now carried on with New York, Philadelphia, and Canada, from Chicago, on Lake Michigan, and through the Illinois River to New Orleans, and all the West, which is pressing the State for an immediate construction of this work; and I am confident that the next Legislature of Illinois will commence a work of some kind to connect these waters."

VII.—*Description of a Traversing Crane used by the Butterley Company in erecting Cast-iron Bridges and other Public Works. Communicated by* JOSEPH GLYNN, F.R.S.

THE Traversing Crane shown in the annexed Plates, XIV. and XV., is one of those used by the Butterley Company in the construction and erection of cast-iron bridges and other large objects intended for public works, and also for fitting together the heavy parts of steam engines, cast-iron water-wheels, and other powerful machinery.

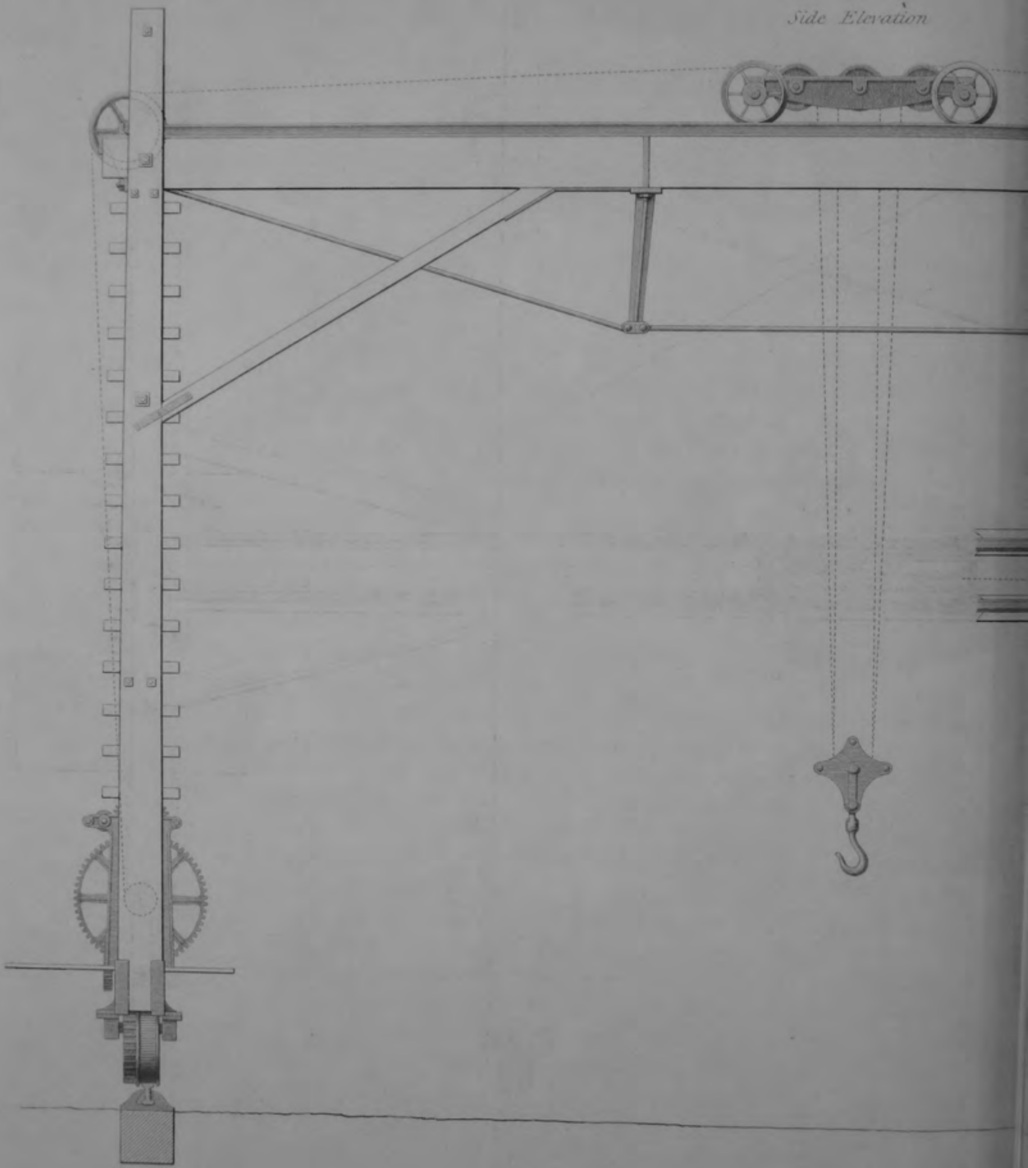
This Crane was employed at the Butterley Iron Works in fitting together the large cast-iron draw-bridge over the River Ouse at Selby. It is now returned to its former position at Butterley, where the view with the camera-lucida has been taken. Similar cranes were used in erecting the bridge over the River Trent, which has been described in the last volume of the Professional Papers of the Royal Engineers.

There are few machines more useful than the Traversing Crane, and it only requires to be better known to be more generally introduced.

By referring to the engravings, which consist of a side elevation and half plan, Plate XIV., an end elevation and perspective view, Plate XV., it will be seen that it is composed of two triangular frames of timber, based on cast-iron plates set edgewise, and mounted on wheels similar to those of railway waggons. These frames support two parallel beams of timber, trussed underneath by wrought-iron tie-bars an inch and a quarter in diameter, and cast-iron struts. On these beams is laid a railway, upon which travels a carriage containing the pulleys for the chain, and constituting a fourfold purchase-block, the chain passing between the two beams to the lower blocks. The ends of the chain pass along and above the beams to the fixed pulleys at each end, and thence down to the winches, which are secured upon the cast-iron bases of the two triangles.

TRAVERS

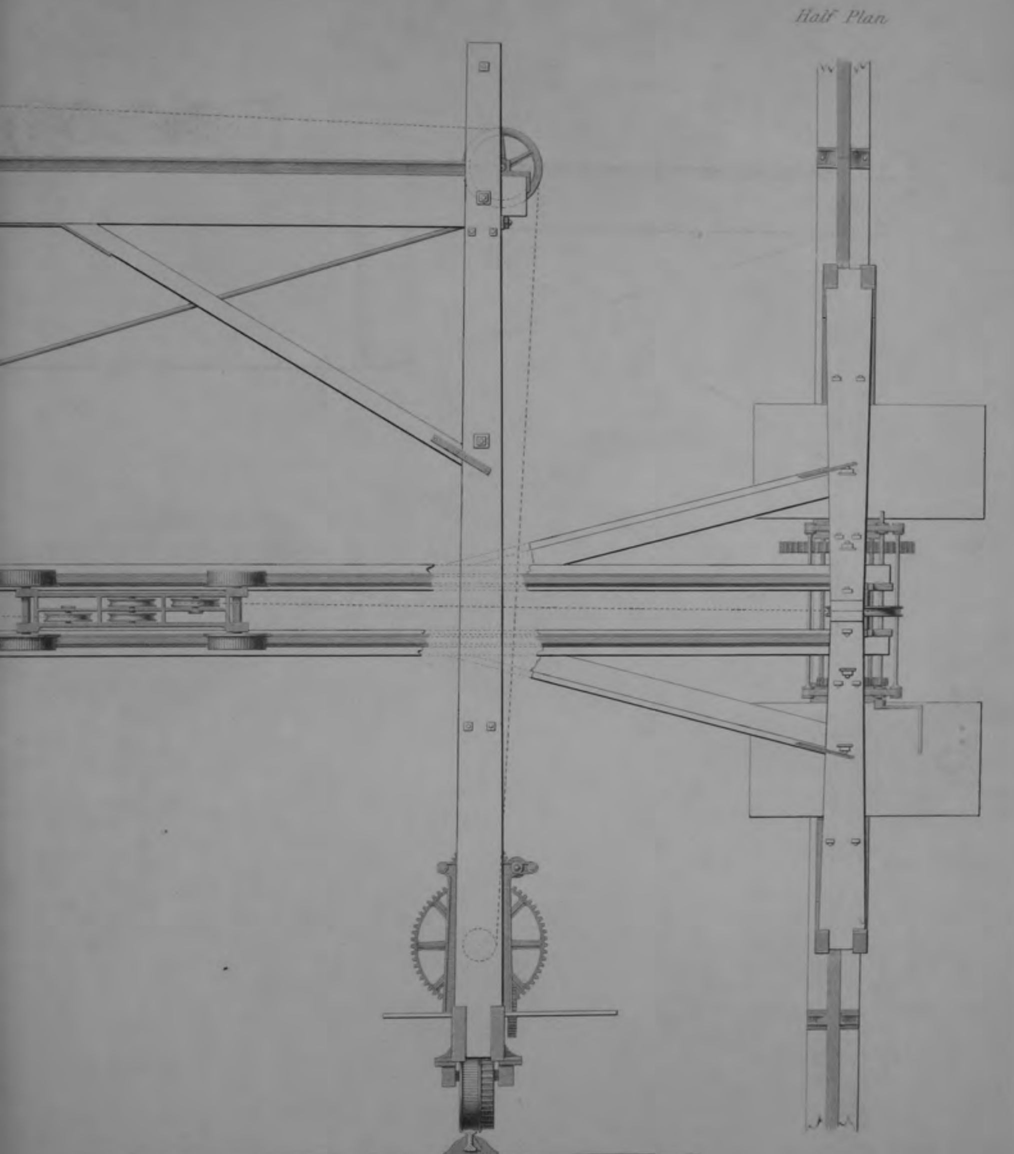
Side Elevation



Geo. Glynn F.R.S. del.

John Weale, Architectu

CRANE. Plate XIV.



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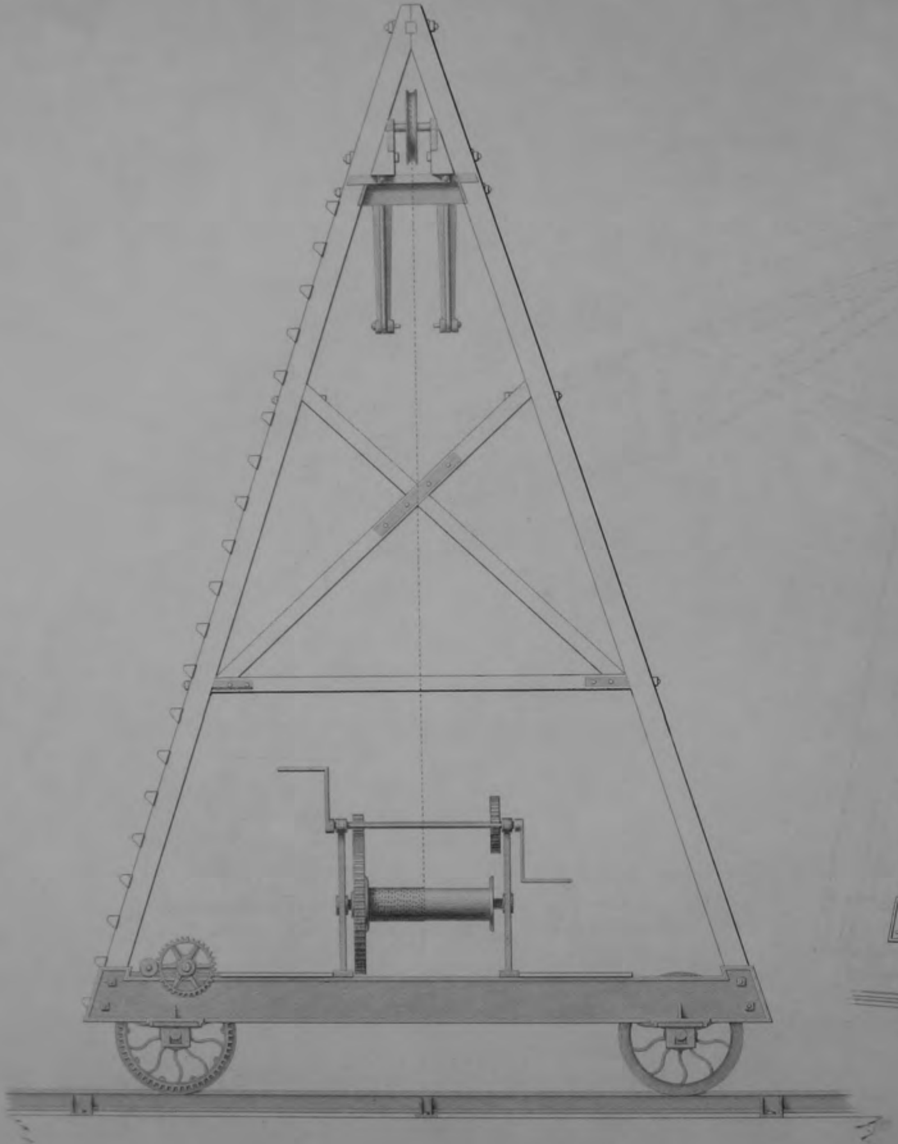
TRAVERS

End Elevation

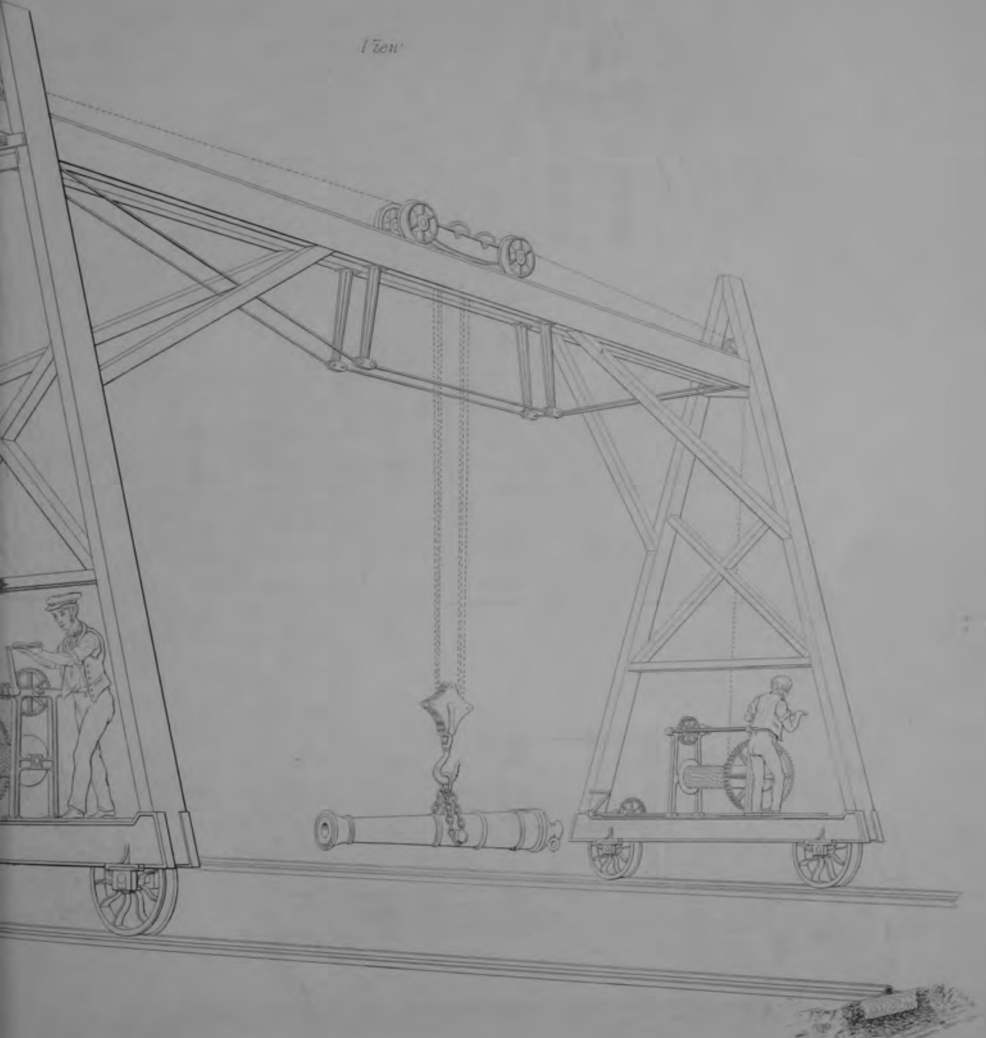


Jos. Glynn F.R.S. del.

John Weale, Architectu

G CRANE.

View



ibrary. 59, High Holborn.

G. Gladwin

By winding one of these winches, and unwinding the other at the same time, the carriage and the load suspended from it travel from one end of the beams to the other, and by winding or unwinding one of the winches only, the load is raised or lowered. The waggon-wheels, on which the triangular end frames are mounted, have toothed wheels and pinions attached to them; by turning the pinion-handles the waggon-wheels are made to revolve, and the whole fabric with its load travels like a locomotive engine along the two parallel lines of railway on which it is placed. These rails are of the strong kind used on the London and Birmingham Railway, and are laid 30 feet apart; this transverse distance may be called the span of the Crane.

The longitudinal distance is of course limited only by the length of the line of railway.

By the combination of these movements every point within the area comprised between the rails may be commanded with the greatest exactness and facility. Hence the utility of this Crane for the purpose of fitting together the heavy portions of large work which cannot be done by a Crane moving round a fixed centre. It may also be made very useful in stacking or storing heavy materials, as timber, anchors, or cannon.

The Crane here represented will lift a weight of 8 tons. The geometrical drawings are made to a scale of $\frac{3}{8}$ths of an inch to a foot, and the sketch taken with the camera-lucida shows their combination. It is readily taken to pieces for removal. The cost of it, including the chain and blocks, was £150. The rails cost at the time they were laid £12 per ton; they weigh 65 ℔s. to the single yard; and the cast-iron pedestals, which are 3 feet apart, and weigh about 24 ℔s. each, cost £10 per ton.

VIII.—*Memoranda and Details of the Mode of Building Houses, &c. in the Island of Malta. By Major* HARRY D. JONES, *R.E.*

THE Island of Malta is formed of a calcareous rock more or less indurated, affording an excellent building material, but varying very much in quality. The nature of the rock, being in general very compact, permits of its being quarried in large blocks, which, being easily worked, affords great facilities for employing it in every description of building, from the most ornamental to the plainest and most simple in its construction. No particular style of architecture is observable: in the different cities may be seen almost every variety of building, from the large and magnificent hotels of the Knights to the small and simple house of the tradesman, all presenting an appearance of great beauty and neatness, arising from the whiteness of the stone. The Malta stone, as a building material, varies very much in quality; some of it stands exposure to the atmosphere remarkably well;[1] the other and softer quality decomposes very rapidly, but this is of little consequence, as houses and walls are so easily new faced with stone of a better quality,[2] and which has been more generally employed since the English have been in possession of the island. Both the hard and soft qualities are easily worked, and after being dressed by the mason present a beautiful appearance.

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[1] The arms of the Grand Master, "*L'Isle Adam*," which were sculptured in Malta stone nearly three hundred years ago, are as perfect as when cut, and may be seen at the present moment in the south front of the building, formerly the Grand Master's residence, in Fort St. Angelo.

[2] The quality of the stone with which the colleges at Oxford are built greatly resembles the Caen and Malta stone. It is much to be regretted that the heads of colleges do not pursue the same plan, and occasionally expend small sums on repairs to the external walls, which would cost little, and would tend not only to the preservation of the buildings, but would give them a much more creditable appearance than the half worn-away walls and quoins which now present themselves on either side of the High Street.

Foundations,—in every case the rock.

Walls—are of two descriptions, single and double.

A single wall is formed of one stone, varying in thickness from 8 to 12 inches. Plate XVI. fig. 1.

A double wall is 3 feet thick, composed of two single walls with the core filled in with rubble stone; the single walls in this case vary from 8 to 14 inches in thickness; the height of the courses is usually 11 inches. Fig. 2. When buildings are three or four stories high, the external walls (which are double walls) are increased in thickness by 6 inches for every story more than two above the ground floor.

Figs. 3 and 4, 3*a* and 4*a*. Masonry ribs for supporting floors or terraces are arches turned from the double walls, either segments of a circle or elliptical. The spandrels are filled up with squared stone to the level of the upper part of the key-stone, so as to form a horizontal bed for the ceiling stones to rest upon. The ribs are generally 4 feet distant from centre to centre; sometimes it is usual to cut away part of the upper course and key-stones to form a bed for the ceiling stones to rest upon: this plan takes away from the heavy appearance the full depth of the arch-stones would otherwise give to a room. By this method not more than 5 or 6 inches of the key-stone appear under the ceiling.

a. Flooring stone, 3 inches thick. Figs. 3 and 4.

b. Stone chippings, 2 inches thick.

c. Roofing or ceiling stones, 3 inches thick.

d. Arched rib of masonry.

e. Double wall with thorough courses of squared Ashlar.

Cellars.—Cellars are generally excavations in the rock, the stone from which is employed in raising the fabric above them.

The floor is sometimes paved, a small quantity of earth or rubbish being laid upon the rock to form a bed for the paving stones.

a. Paving stone, 6 inches thick. Fig. 5.

b. Rubbish.

c. Rock.

d. Double wall.

Cellars and tanks are covered by the floor of the story above them, supported on arched ribs of masonry. Under the *Great Hospital* in Valetta are some very fine groined arched cellars of considerable span.

Floors.—The method of forming the floor is as follows:

Plate XVI. figs. 6 and 7. When rib arches are not adopted, beams of red pine timber from the Adriatic are placed across the room from one principal wall to the other, 4 feet distant from centre to centre. On these are laid the ceiling stones (*c*), 3 inches in thickness and 10 or 12 inches in breadth; these are placed as close as possible to each other without mortar; on them are spread stone chippings, 2 inches in thickness (*b*): this makes a good bed for the paving stones, and prevents the passage of the sound between one room and another. On this bed the paving or flooring stones, 3 inches thick (*a*), are laid, which are from 18 to 24 inches square. These stones are jointed with fine mortar; when dry, the upper surface is scraped and covered with a thin coat of warm oil; this hardens the stone, gives it a polish, and prevents the floor losing its beautiful appearance by stains, &c. Without being oiled, it cost about 3*d*. per square foot, materials and labour included.

Figs. 8 and 9. This is the operation for all ceilings and floors except that which forms the roofs, which in Malta are flat, and called terraced roofs.

Ceiling and common roof.—The ceiling stones (*c*) are placed on arched ribs or beams (*d*) 10 inches × 11 inches scantling, as before described; upon them is laid 4 or 5 inches of *forba*[3] (*b*) soaked with water, arranged in such a manner that one part shall be rather higher than the other to give a fall for the rain water to run off. The forba is beaten with rammers, occasionally being sprinkled with water until it becomes nearly dry and formed into a compact body: over the forba thus prepared, a cement, made by a mixture of lime and Figs. 8 and 9a. puzzolana, or lime and *diffone*[4] in a liquid state, about $\frac{1}{4}$ of an inch in thickness, is floated, and likewise beaten with rammers until it also becomes nearly dry; the surface is then well worked with a trowel: occasionally water is sprinkled over it during the operation. When the coating of cement is laid on, as many women and children are employed with wooden hand-beaters as can conveniently be placed in a single row extending across the roof of the building; very often as many as thirty may be seen at one time at work. After this operation is performed, and in order to prevent the heat of the sun from cracking the cement before it is thoroughly dry, a thin coat of sand or stone chippings is spread over it; after a few days it is swept clean, leaving a

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[3] Forba consists of small stones, mixed with red argillaceous earth excavated from fissures in the rocks, which are generally found to be filled with it.

[4] Diffone is composed of broken earthen pots and pans.

beautiful, even, and polished surface, perfectly impervious to water and of great durability: a square foot weighs about 80 lbs.

Stone roof.—In some cases a roof is formed by paving stones instead of using *forba*; in this case the joints are left open about one inch; these are filled with small stones (*a*) (acting as wedges) and with puzzolana cement well Plate XVI. fig. 9a. driven down, the whole of them plastered over with cement and well worked with a trowel. This forms an excellent roof, but the weight has a tendency to cause a deflexion of the beams which opens the joints, and it is consequently a leaky roof for the first wet season after the erection of a building, or when a new roof has been laid down.

Fig. 10. *Roof over farm houses.*—In farm houses where the breadth of the room does not exceed 9 feet, flat roofs are constructed by single stones 6 inches thick and 7 feet 6 inches long, supported on corbels (*f*); upon these stones 3 inches of forba (*b*) is laid, and this is covered in the usual manner with $\frac{1}{4}$ of an inch of cement of *diffone* and lime (*a*). The walls (*d*) are double, filled in with rubble stone. Passages not exceeding 8 feet 6 inches in width are covered by Figs. 11, 12. a single stone (*a*), 6 inches thick, supported by brackets.

Tanks.—Tanks are generally excavations in the rock under the body of a house, and except in the city of Valetta (in which only can they be filled with spring water), contain the sole supply for the family. All the rain which falls upon the roof of a house is conveyed into the tank by baked earthen pipes; the water thus obtained remains in an excellent state for years, if not exposed to the light of the day. In the course of years a great quantity of sediment accumulates in the tank; it then becomes necessary at the end of the summer to draw off all the water and cleanse it,—a disagreeable operation, and, if performed long before the autumnal rains commence, attended with great inconvenience and often distress to the occupants, from the want of that necessary element, which in a warm climate is above all essential.

The method of forming a tank is as follows:

After the excavation in the rock has been made, the walls or sides and bottom are rough picked, and their surfaces covered with a coat of cement $\frac{1}{4}$ of an inch thick, well worked with a trowel until dry, water occasionally being sprinkled upon it while working it. The extent and capacity of some of the principal tanks is very considerable. At the barracks at Rabbato in the Island of Gozo, a few years since, a soldier's wife was washing linen near the entrance of the tank: one of her children fell into it; and immediately upon hearing the splash and missing one of them, attempts were made by herself and some soldiers with poles and drags to get the child out, but without success. A boat was then brought up from the Marina and launched into the tank; three days elapsed before the body was found. This length of time may in some degree be accounted for by eddies having been formed by the agitation of the water, but still it may serve to give an idea of the size of the tank.

The water conveyed into these tanks does not undergo any system of filtration. For a few days after a fall of rain the water will be slightly turbid, but soon becomes clear and fit for use, and without any disagreeable flavour.

Plate XVII. fig. 13. *Stairs.*—The stairs in every house are stone, one end resting upon and let into the principal or division wall; the other rests upon a wall built for that purpose, supported on an irregular arch (c) turned from stone columns erected at the bottom and angles of the staircase.

Fig. 14. *Balconies.*—To the windows of the principal floor of almost every house there are balconies, either open or covered; in both cases surrounded by a balustrade 3 feet high, and in the latter covered in with wood and Jalousie blinds.

Balconies are generally supported upon corbels (*a*) formed of large stones, which are very ornamental: an agreeable shade from the heat and strong glare of the sun, reflected from the white walls and ground around the house, is thus obtained.

Revêtements.—Although the fortifications in Malta are very extensive, there being upwards of 20 running miles of parapet, nothing can be learned from them as to the proper section for retaining walls. In general the revêtement is merely a facing to the rock of a less perishable material than the rock itself, and intended to protect it from the destructive effects of the atmosphere, being made more or less thick according to the decomposed state of the rock: if it has been much worn away, the wall is generally backed in with rubble stone and mortar, in some parts being three or four times thicker than is absolutely necessary. Fig. 15. In the Cottonera and Santa Marguerita Lines, the revêtements vary from 30 to 70 feet in height, and are built "en décharge." The arches might be converted to many useful purposes, if required, by the military. A few years since they were occupied by the poorest of the inhabitants, and were then the abodes of poverty, wretchedness, and misery.

Mortar.—Some of the Malta stone, when burnt, makes excellent lime: for common buildings and backing of revêtement walls, the mortar used is merely earth and water mixed, the external joints being afterwards pointed with good lime and sand mortar.

In other buildings the mortar is a mixture of chippings produced in dressing the stones; the chippings are sifted and mixed with lime in the proportion of one part lime and one part of sifted chippings.

In superior buildings the mortar is composed of two parts lime and one part sand.

Cement.—The cement used for lining tanks and for covering roofs is made of puzzolana and lime, in the proportion of four parts lime and three parts puzzolana.

When *diffone* is used (which is broken earthern pots and pans) and mixed with lime, the proportions are five parts lime and three parts diffone.

Names and dimensions of the different descriptions of building stone, and to what purposes applied.

Name.	Length.	Breadth.	Thickness.	To what purposes applied.
Vasi	1 foot	1 foot	11 inches	For building external and division walls.
Double Cantoni	..	10 inches	..	
Single Cantoni	..	8 inches	..	
Ciangatura . .	1 foot 8 in.	to 2 feet	Squared and 3 in. thick	Common paving stone.
Balate forma .	1 foot	1 foot	6 in. to 1 foot	Paving do. (thick).
Capitelli	3 to 6 feet	1 foot 3 in.	6 to 8 inches	Ceiling and roofing.
Balate di tetto	3 to 6 feet	11 inches	3½ inches	Roofing.
Scalini	3 to 6 feet	1 foot 4 in.	6 to 8 inches	Steps and stairs.
Scarpa	1 foot	1 foot 6 in.	1 foot 6 in.	Revêtements, scarps, parapets, and gun platforms.
Hard	..	..	..	

Hard stone, when dry, weighs per cubic foot (Malta) .	146 ℔s.
Do. Do. Do. (Gozo) .	145 ℔s.
Soft stone (Malta)	122 to 144 ℔s.
A flooring stone 18 inches square	65℔s.

Beams for roofs and floors.—The scantling of beams for supporting floors and roofs, as measured in a large building, were found to be as follows:

Between the points of support.	Scantling. in. in.	Distance apart.
22 feet	14 × 9	2 feet 3 inches.
13 feet	9 × 8	feet 9 inches.
11½ feet	11 × 10	3 feet 5 inches.

The greatest distance between the points of support for a beam is 30 feet, and the scantling 13 × 11 inches. Instead of using these large beams, which are difficult to handle, I caused an experiment to be made with two 3-inch planks, bolted through an intermediate block at each end to preserve the same (Plate XVII. fig. 16.) breadth as when the beam was used: by this mode there was a considerable saving in expense and labour. Often it was found difficult to procure large quantities of perfectly sound and straight-grained balks: by using 3-inch plank these difficulties were obviated.

When looking down upon the city of Valetta and the four cities on the opposite side of the Great Harbour, the buildings erected when the Order of St. John was first established in Malta are easily to be distinguished: they have all a pitched roof, and were either the hotels of the Knights, or buildings used for military purposes, such as the Great Hospital of St. John, in which the sick were attended by the Knights, (the principal ward is 600 feet long,) St. John's Church, Artillery Arsenal, and the Bakery. All other buildings have invariably the flat terrace roof.

Fig. 17. Section of part of the roof over the *Auberge de Provence.*

The beams were 3 feet 4 inches distant from each other, and 35 feet the space between the walls.

Scantling.	inches.	
a. Tie-beam	12½ × 10	
b. Rafter, length 21½ feet.		
Scantling top	7 × 4	
Butt	8½ × 5	
c. Collar beam, length 16 feet.		
Scantling	6 × 5	
d. Ceiling joist	3 × 3	1 foot 4 inches asunder.
e. Purlins	3 × 3	1 foot 3 inches asunder.
f. Struts	6 × 4	
g. Bracket	11 × 10	Projects 4 feet.

Fig. 17a. Is a section of the granary attached to the great military bakery in Valetta.

The beams and ceiling joists in most buildings of a superior order are covered with thin boards neatly moulded round the edges, forming ornamental panels, which greatly improve the appearance of a room. In many of the auberges the ceilings of the principal rooms were coved and lined with canvas, on which allegorical subjects were painted. The timber having perished with age, the canvas was taken down when the roofs were repaired, and a coved ceiling is now rarely to be seen. The effect was extremely good, and gave the apartments an appearance of finish and comfort, which is seldom the case in the private Maltese houses. The interior of a Malta house presents nothing but the bare walls and a polished floor; the former either whitewashed or covered with a plain wash of a salmon or buff colour. Since the English have been established in Malta a great improvement has taken place; the walls have been stencilled, and many present an appearance difficult to be distinguished from beautiful paper with a rich border. Fire-places have been constructed generally in houses occupied by the English.

Timber.—Timber is purchased by the tratto.

1 tratto = 7¾ cubic feet English.

There is a public officer whose duty is to measure all timber upon being discharged from the vessels. After measuring it, he stamps each log with a mark, which indicates the number of tratti for which the purchaser is obliged to pay. It very often happened that timber, when delivered at the engineers' workshops, did not contain, when measured, the cubical contents which it ought to have done according to the mark upon it.

Deals are sold by the bollo, and paid for according to their breadth, which is also fixed by the Government measurer.

1 Bollo	11½	inches in breadth.
2 do.	12⅝	,,
3 do.	13¾	,,
4 do.	14⅞	,,
5 do.	16	,,
6 do.	17⅛	,,

Payment is made agreeable to this arrangement, and as all the deals from Venice are cut to the same thickness, *breadth* only is attended to in the purchase.

Sand is sold by the boat load of 6 salms, Malta measure: 1 salm is equal to about 8 English bushels.

Lime is sold by the salm.

Measures.—1 Palm = 10¼ inches English.
7 Palms = 6 feet English.
8 Palms = 1 canna, Malta measure, 6 feet 10 inches English.
Weights.—1 Cantar = 175 lbs. English.
1 Tumulo = 94 lbs. English.

The houses, as may easily be conceived, are very substantial; cold in winter, and warm in summer: in this season, when once the walls become heated, they never cool until the rainy season sets in. The thermometer during the summer months seldom falls at midnight more than 2° or 3° lower than what it registered at mid-day; the reverse takes place in winter. Wood is a bad material to use in situations exposed to the influence of the sun, the heat of which absorbs all the juices of the timber, warps and splits it. Common colours in oil are not preservatives in that climate. Where metal can be used, it is preferable to wood.

It is only necessary to state that the metal sashes which were manufactured in England expressly for the windows of the Grand Armory in the Palace answered remarkably well. It may excite some surprise when it is stated that in every powder magazine, except those which have been built or repaired by the English, all the doors and shutters are covered with sheet iron, and the locks and hinges are made of the same material! though scarcely a winter passed in Malta during the period I was quartered there without some church or elevated building being struck or much injured by lightning. An accident to a magazine from lightning was never known.

Cones.—Cones for holding corn are simple excavations in the rock, of a pear shape, and about 30 feet in depth. Corn is poured into them, and the mouth or man-hole covered with a large stone (*b*) cemented upon the collar (*c*); this prevents the entrance of damp or moisture from the atmosphere, and in this manner corn is preserved in an excellent state for many years. It may be interesting to mention a circumstance which took place shortly after the English obtained possession of the island. In all excavations in the rock there is a greater or less degree of moisture; this was considered by the English as likely to be extremely prejudicial to wheat, and, with a view to remedy it, a lining of good dry masonry was built, as represented in fig. 18*a*: this excluded the moisture, but destroyed the corn; and, in consequence, the cone so altered is never used except from absolute necessity, and then is always the first to be opened for issues. The moisture from the rock is considered extremely beneficial, even if not necessary, to the long preservation of wheat when closed up, as in the cones.

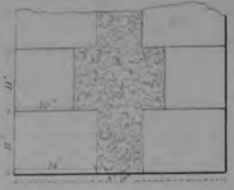
Plate XVII. fig. 18.

Every body who witnesses the Maltese stone carriers when employed in moving a large stone, cannot fail to admire the ready manner in which they adjust the poles and ropes by which it is suspended, and carried to the spot where it is to be used by the masons, without the *arises* being in the slightest

DETAILS OF THE MODE OF BUILDING HOUSES IN THE ISLAND OF MALTA.

Section of a Double Wall.

Fig. 2.

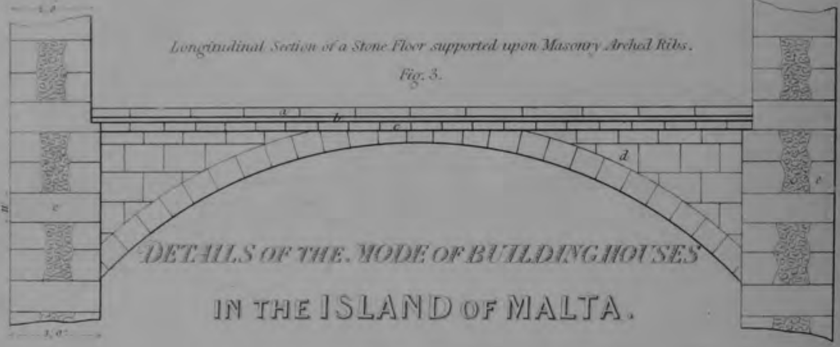


Section of a Single Wall.

Fig. 1.

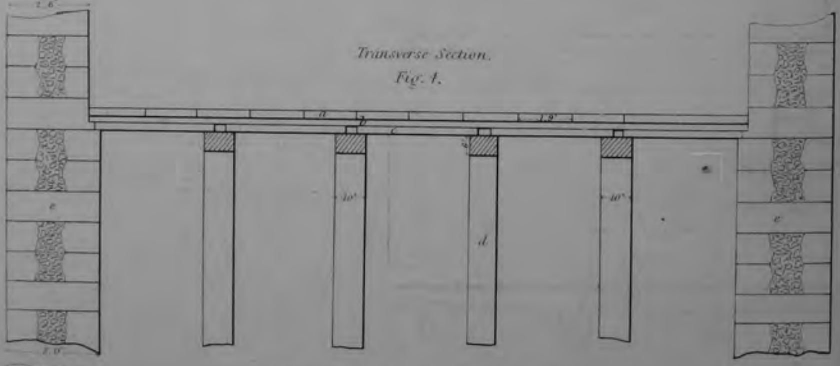
Longitudinal Section of a Stone Floor supported upon Masonry Arched Ribs.

Fig. 3.



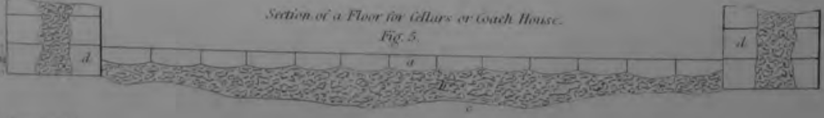
Transverse Section.

Fig. 4.



Section of a Floor for Cellars or Coach House.

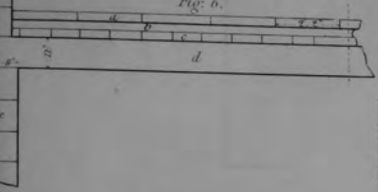
Fig. 5.



E. A. Bernays del.

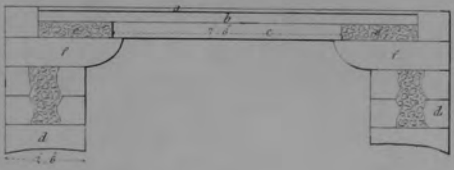
Longitudinal Section of a Stone Floor supported on Beams.

Fig: 6.



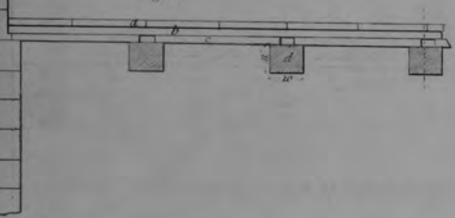
Section of a flat Roof used for Farm Houses.

Fig. 10.



Transverse Section.

Fig. 7.

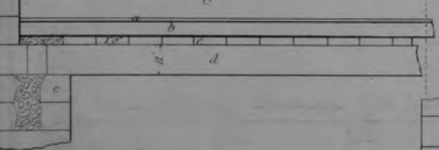


Transverse Section of a Floor supported on Corbels for Paſsages not exceeding 8ft. 6in. in breadth

Fig. 11.

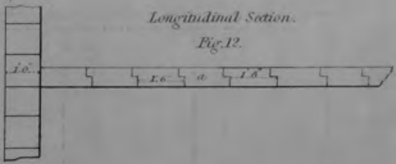
Longitudinal Section of a Roof supported by Beams.

Fig. 8.



Longitudinal Section.

Fig. 12.



Transverse Section.

Fig. 9.

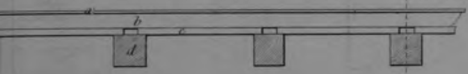
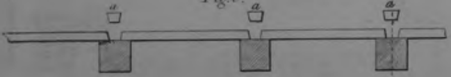


Fig. 9.a



B.R. Davies sculpt.

ary, 59 High Holborn, 1841

Sketch shewing the Style of building "Revetments on Decharge".

Fig. 15.

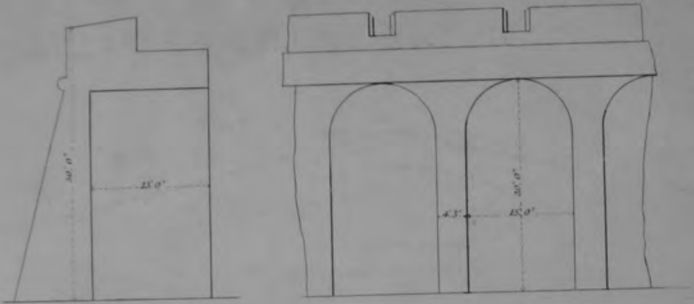
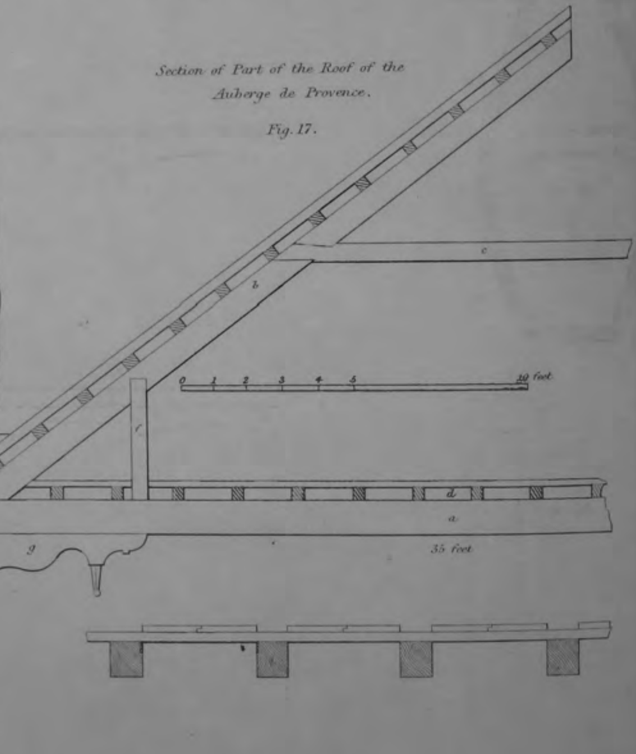


Fig. 13.

Section of Part of the Roof of the Auberge de Provence.

Fig. 17.

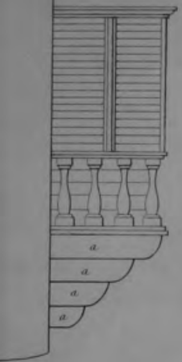


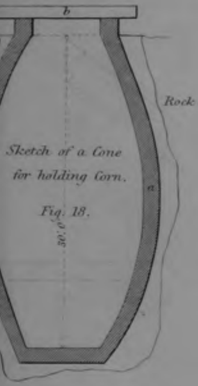
E.A. Bernays del.

London, Published by John Weale

DETAILS OF THE MODE OF BUILDING HOUSES
IN THE ISLAND OF MALTA.

Fig. 14.





Sketch of a Cone
for holding Corn.
Fig. 18.

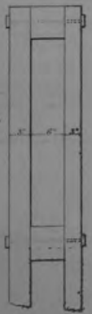
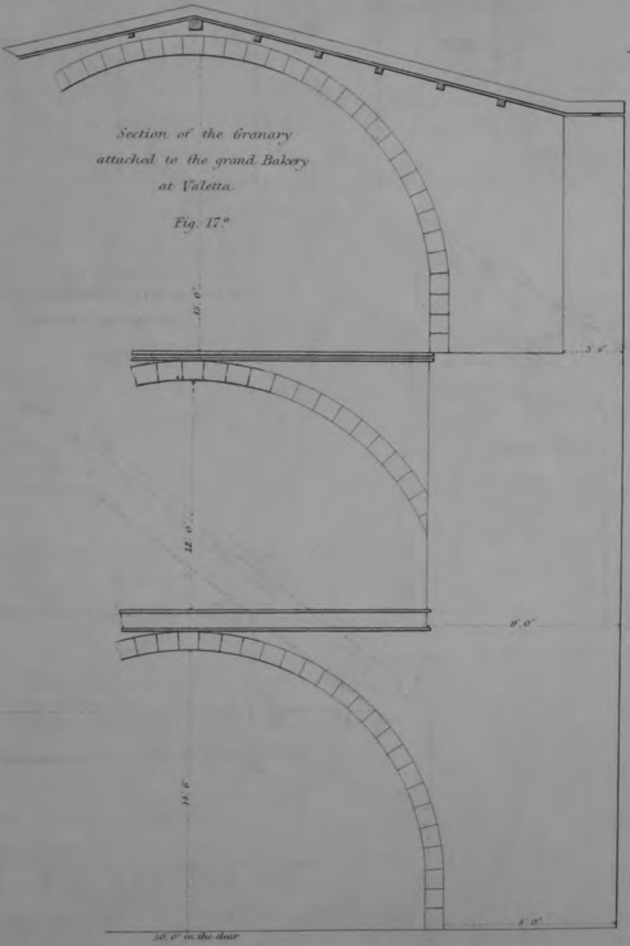


Fig. 16.



Section of the Granary
attached to the grand Bakery
at Valetta.
Fig. 17.a

B.R. Davies sculp.

rary, 59 High Holborn, 1841

degree injured. The stones are suspended and carried in the same manner as pipes of wine and oil by the *gallegos* at Lisbon and Cadiz, and the *hamals* at Constantinople; that is, by poles resting upon their shoulders: as many as sixteen men may often be seen employed in carrying one stone. The Maltese masons are very expert in turning arches of considerable span without the expensive centering to which we are accustomed: in breaking doorways or windows through walls they also show great skill.

In closing these Memoranda, I cannot omit to express my obligations to Mr. Calcedonio Bonavia, the talented and intelligent clerk of works, and also to Mr. Beck, the zealous overseer of works, in the Royal Engineer Department, for the information they so willingly communicated to me on my first arrival in Malta. Any officer who feels interested in his professional duties must, on joining at Malta, apply for information to either of those individuals: the system differs so essentially from what he has been accustomed to at other stations, and the language of the lower classes of Maltese, being nearly pure Arabic, prevents him from interrogating the foreman or workmen, and acquiring information through those channels.

HARRY D. JONES.

Dublin, 15th April, 1840.

IX.—*On Drawbridges, chiefly from the French of* M. DE PONCELET. *By* DOUGLAS GALTON, *Lieutenant Royal Engineers.*

ALL drawbridges are composed of two distinct parts, viz., the platform, which revolves on a horizontal axis, acting as a barrier or gate when in a vertical position, and becoming a bridge when in a horizontal position; and the contrivance necessary to balance the platform in every position. The equilibrium should be such that friction is the only force to be overcome in raising or lowering the platform.

The chief difference between drawbridges lies in the arrangement of this latter contrivance, for the platforms only differ in small details of construction, which have very little influence on the qualities which are essential to the arrangement of the balancing apparatus. These qualities remain the same whether the drawbridges are used for closing communications in fortified works, or merely for forming passages across navigable canals. They are principally as follows:

1st. The whole system should possess sufficient strength to be perfectly free from danger in all positions and at all times, and should therefore be constructed of solid and lasting materials.

2nd. A small number of men should be able to raise or lower the bridge in a short space of time. This quality requires all the parts to be in equilibrium when friction is not considered.

3rd. The machinery for raising and lowering the bridge should not obstruct the communications either in front or in rear of the buttresses of the gateway where it is placed; and also the space formed by raising the bridge should be as wide as possible, for this space constitutes the chief use of the bridge.

4th. The counterpoise and the machinery attached to it should be raised as little as possible above the platform when vertical; in order that it may not be much exposed to the enemy's fire, and that it may be easily covered by the advanced works; besides that, by raising it, the expense of constructing and the inconvenience of working the machine is increased, and the strength of the gateway or postern is sometimes diminished.

5th. The counterpoise and its machinery should not be much below the level of the ground, and particularly very little below the level of the surface of the water in wet ditches. At all events the descending parts should be enclosed in narrow shafts of masonry secure from damp. In order not to weaken the postern walls, they should be at least 3 feet in rear of them.

We find, on examining the different ancient or modern drawbridges, that by far the greatest number do not fulfil advantageously all the above-mentioned conditions; but they should not be too readily condemned on that account; for however objectionable a bridge may be in some respects, it may possess qualities which render it suitable under certain circumstances or in some positions.

Thus, for instance, the Gothic drawbridge, on account of the simplicity of its construction, can be placed wherever there are men and materials, at a very small cost. Plate XVIII. fig. 1.

But it does not follow that because it has retained its ancient form until the present time, on account of these advantages and from habit, it should be preferred to other systems which have their machinery more under control, and attain their object better both in an architectural and in a military point of view.

It is not to be supposed that one particular sort of drawbridge should always be preferred to all the others, for there are few that do not possess some essential qualifications under certain circumstances.

I shall confine myself in this short account to a description of those which are most remarkable for their construction, or for their having been successfully employed in forming communications in fortified works.

As the chief mechanical principle to be adhered to in the construction of drawbridges is, that equilibrium should subsist between the counterpoise and platform in all positions, if there were no friction, it is evident that the force necessary to move the platform in this case is absolutely nothing. This will be true for every position of the platform; therefore the centre of gravity must always remain in the same horizontal plane, or, in other words, "the algebraic sum of the momenta of the different weights should be constant, and it should be constantly equal to O when these momenta are considered with respect to a horizontal plane passing through the point which is the centre of gravity of the system, which will be the same for all the positions of the system."

THE GOTHIC DRAWBRIDGE.

Plate LVIII. Fig. 1.

In this system the platform is raised by means of a counterpoise, consisting of two beams, one over each side; B′C is one of them seen in elevation; they are joined together by cross-bars. Two chains, one from each side of the front of the platform, are fixed to the ends of the beams above; the other ends of the beams are loaded with weights which balance the platform.

As there is some advantage in having the plane of the counterpoise parallel to that of the platform in all its positions, the quadrilateral figure A B B′ A′ is made a parallelogram.

If we suppose half the weight of the chain B′B to be collected at each of the points B and B′, and G and G′ to be the centres of gravity of the platform and counterpoise, it is evident from the principles of the lever, that if P and P′ are the weights of the platform and counterpoise respectively collected at their centres of gravity,

$$P . AG = P' . A'G',$$

from which equation the weight of the counterpoise is determined; for in all cases the platform is constructed first, and the counterpoise made to suit it. Usually, when a bridge of this description has been laid down, the weight of the platform acting at the ends of the beams of the counterpoise causes them to become curved to such a degree that sometimes the platform can no longer fit the sides of the gateway. This defect can only be remedied by increasing the weight of the counterpoise, which will then only be in equilibrium in certain positions.

The following are also defects to which this bridge is liable, viz.:

The counterpoise is exposed to the view of an enemy at some distance.

Accidents often occur from having the counterpoise placed above the roadway.

These counterpoises diminish the strength of covered communications, and are prejudicial to the architectural beauty of the gateway.

THE LEVER DRAWBRIDGE, WITH THE COUNTERPOISE UNDER THE ROAD-WAY.

The most simple method of obviating the defect of having the counterpoise Plate XVIII. fig. 2. above the road-way is to place the counterpoise in the prolongation of the platform. In this case the side beams of the platform are produced, and are not connected by cross-braces. If the bridge is intended to be immediately in front of an escarp wall, their upper surfaces must be below the level of the road. Pits or grooves, lined with masonry and secure against damp, must be constructed, in which the counterpoise is worked. The front of these pits should be at least 3 feet in rear of the escarp wall, not to weaken it too much; this reduces by 3 feet the space formed by raising the platform.

The principles of equilibrium in this bridge are as simple as possible, being merely those of a common lever.

This bridge is more expensive than the former one.

The space left by raising the bridge is less than the real width of the platform.

The escarp wall immediately beneath the platform is weakened.

The counterpoise may be worked by men placed under it, or they may stand above and force it down by poles, as is the case at Metz; or else a Fig. 3 rack wheel may be used. This is an usual method in Holland.

Several other drawbridges of the same nature have been proposed, but as they have more defects than these two, I shall not describe them.

BELIDOR'S DRAWBRIDGE.

Belidor was the first who proposed a counterpoise not consisting of a wooden Fig. 4. frame-work. Instead of it he employed two cast-iron rollers, moving round their axes, placed one on each side of the passage in rear of the gateway, and attached to the platform by means of chains passing over pulleys in the piers of the gateway. The rollers move on a curve of such a form that the platform is in equilibrium in every position. Belidor called this curve a *sinusoïde*, on account of its property of having its ordinates proportional to the sines of the arcs of the abcisses. This curve may be easily traced.

When the position and weight of the roller is found with reference to the horizontal position of the platform, the common centre of gravity O of the system will be established, as well as the horizontal line K L in which this centre moves.

Let the platform be in any position A B, let P be its weight, G g the distance of its centre of gravity from K L, W the weight of the roller, G′ g' the distance of its axis from K L. To ascertain the length of G′ g' we have

$$W \cdot G' g' = P \cdot G g, \text{ or } G' g' = \frac{P \cdot G \cdot g}{W}.$$

The total length of the chain B M M′ G′ is constant, as also the portion M M′; the portion B M may be ascertained for every position of the platform, which will determine the length M′ G′. The pulley M may be supposed to be reduced to a point. Therefore an arc described with a radius = M′ G′, intersecting the horizontal line C D in the point G′, will determine the position of the axis of the roller. The line C D is parallel to K L at a distance = G′ g'.

This operation being repeated in several positions of the platform will form a curve with tolerable accuracy.

To prevent either of the rollers running off the curve in case a chain should break, the curve is carried up to the rear sufficiently high to check the roller in its course.

The weight of the chains is not considered in this method; it would alter the amount of power to be applied to the different positions of the platform.

Plate XVIII. fig. 5.

Captain Délile, of the Corps du Génie, proposed to join the rollers by a bar across the road-way, and to work them by never-ending chains.

This method is, however, more inconvenient than the former one; for, in raising the platform, when it approaches the vertical position, the men who are working it must leave the chains, and apply themselves to the bar joining the rollers.

And if the chains connecting the rollers with the platform should break, the rollers would roll to the bottom of the curve, and the bar of iron would completely block up the road-way.

DOBENHEIM'S DRAWBRIDGE.

Fig. 6.

This bridge is raised by loaded bars acting on the chains connecting the platform with them, like levers; the chains passed, as before, over a pulley M; but instead of being fixed to a roller, it was attached to a bar C′ D′, loaded with weight sufficient to balance the platform in a horizontal position: this bar should be at right angles to the chain in that position. A second bar C D comes into operation when the platform has reached an angle of 45°; it is loaded so as to balance the platform in that position, and it will raise it to a vertical position.

In this method the platform is only in equilibrium in three positions; and to raise it through the intermediate ones the force necessary for a platform of 36 cwts. would be 3 cwts. or $\frac{1}{12}$th.

DÉLILE'S DRAWBRIDGE.

Captain Délile proposed, as an alteration in Belidor's drawbridge, to use bars of iron instead of chains, one end of the bar being fixed to the platform, and the other to the roller; it passes through a vertical groove cut in the piers of the gateway. Plate XVIII. fig. 7.

The simplest method of constructing this bridge is to place B, the point where the bar is attached to the platform, in the prolongation of the line A G, by which means the centre of gravity O of the system will occupy a constant position at the axis of the bars. This will determine the position of the axis with reference to every position of the platform; for the weight P of the platform may be divided into two, one of which acts at the point A, and has no influence on the equilibrium of the platform; the other, which is equal to $P.\frac{AG}{AB}$, which acts continually at the point B. Similarly the weight of the rollers may be considered to be collected at the point C.

These weights may be supposed to be collected at a point O in the bar, which divides its length into two parts reciprocally proportional to the vertical forces applied at B and C.

This curve may be traced by placing a lath K L, with a straight edge, horizontally, and fixing another lath A B, equal in length to the distance, from the axis of the platform to the point where the bar is fixed, to a pivot which is placed where the axis of the platform is to be, and fixing to a pivot at B the lath B C equal in length to the bar. On this the position of the point O is marked by a nail running through the lath. If a nail is fixed to the end C of the lath, and the point B raised, at the same time keeping the point O touching the horizontal line K L, the nail at C will trace the required curve. Fig. 8.

The roller is worked by means of an endless chain acting on a grooved wheel.

The chief disadvantages of this bridge are, that it weakens the piers of the gateway in front of which it is placed, and that in many places it cannot be used on account of the distance to which the curves for the rollers must be carried to the rear.

COLONEL BERGÈRE'S DRAWBRIDGE.

This method is founded on the principle that the point O in Délile's drawbridge has of remaining continually in a horizontal line.

Plate XVIII. fig. 9. The platform is raised by means of a straight bar of iron, fixed to it at one end, having at its centre a roller O, which, when the platform is horizontal, will be at the point M on the horizontal bar M N.

When the platform is raised or the point C lowered, the roller O will move towards the point N, causing the point C to describe a curve similar to the one in Délile's drawbridge.

Plate XIX. fig. 10. This method may easily be made available for drawbridges over the ditches of field-works, by using carriage or limber-wheels for the roller O, and a strong beam or a mass of masonry covered with a plate of iron, for the horizontal rail M N.

This drawbridge has the same disadvantages as Délile's.

DERCHÉ'S DRAWBRIDGE, WITH A SPIRAL COUNTERPOISE.

This bridge was first constructed by Captain Derché, of the Corps du Génie, at Osopo, in 1810.

Fig. 11. The platform is raised by means of a constant weight Q fixed by a chain to a curve *a b c d*, which revolves on a horizontal axis. This counterpoise is attached to the bridge by means of a chain passing round a large wheel or pulley, which revolves on the same axis as the spiral curve *a b c d*.

The whole is set in motion by means of an endless chain passing round a grooved wheel having the same axis.

Fig. 12. The following is the method of obtaining the curve. Let P be the weight of the platform, which is supposed to be collected at the centre of gravity G; let the platform be raised to any position A B; from G let fall the vertical line G P

to meet the horizontal line A B′. Draw A K from the point A perpendicular to the chain B C. Let t represent the tension of the chain B C, which, by means of the counterpoise Q, keeps the platform P in equilibrium.

We may consider K A P as a bent lever acted on by the forces t and P at right angles to it; hence

$$t \times \mathrm{A\,K} = \mathrm{P} \times \mathrm{A\,P}, \text{ or } t = \frac{\mathrm{A\,P}}{\mathrm{A\,K}} \cdot \mathrm{P}.$$

As the lengths of A K and A P will vary for each position of the platform, the value of t will vary, and must be calculated for several positions.

Plate XIX. fig. 13. Let R denote the radius of the wheel round which the chain B C D passes, and r that of the curve $a\,b\,c\,d$, for the assumed position of the platform; since t balances Q we have

$$t \,.\, \mathrm{R} = \mathrm{Q} \,.\, r, \text{ or}$$

$$r = \frac{\mathrm{R}}{\mathrm{Q}} \cdot t = \frac{\mathrm{A\,P}}{\mathrm{A\,K}} \cdot \frac{\mathrm{P}}{\mathrm{Q}} \cdot \mathrm{R}.$$

In order to construct the curve from this, the length of chain that would be folded round the wheel M D L in raising the platform from the horizontal to the vertical position, must be divided into a sufficient number of equal parts, and the value of r calculated for the positions of the platform corresponding to each of those parts. Then let any point a_1 be taken in the circle D L M, as the point corresponding to the horizontal position of the platform; from that point set off the above-mentioned divisions along the circle a_1, a_2, a_3, a_4 . . . . and draw the radii $\mathrm{E}\,a_1$, $\mathrm{E}\,a_2$, $\mathrm{E}\,a_3$, $\mathrm{E}\,a_4$ . . . . and make $\mathrm{E}\,r_1$, $\mathrm{E}\,r_2$, $\mathrm{E}\,r_3$, $\mathrm{E}\,r_4$ . . . . equal to the values of r corresponding to the different positions of the platform; the curve is then obtained by joining the points r_1, r_2, r_3, r_4.

Fig. 14. The calculation for r would be simplified by placing A G B in a straight line, and considering the pulley (I) reduced to a point. In this case the platform A B is kept in equilibrium by its own weight at G = P, and the tension of the chain I B at B = t. If I H be let fall from the point I perpendicularly, to meet A B produced, the forces will be represented by the three sides of the triangle I B H; therefore

$$\mathrm{I\,B} : \mathrm{I\,H} :: t : \mathrm{P} \,.\, \text{ or } t = \frac{\mathrm{I\,B}}{\mathrm{I\,H}} \cdot \mathrm{P},$$

$$\text{but } r = \frac{\mathrm{R}}{\mathrm{Q}}\, t = \frac{\mathrm{P}}{\mathrm{Q}} \cdot \frac{\mathrm{I\,B}}{\mathrm{I\,H}} \cdot \mathrm{R}.$$

In this drawbridge the weight of the chains is not considered.

Captain Creuilly, of the Corps du Génie, proposed a method for considering their weight in this system, but it is too complicated to be ever put in practice.

Plate XIX. Fig. 15. A more simple method than the above would be to fix the curve *a b c* to the platform, and have a constant weight Q acting on a common pulley.

The curve could be easily traced according to the condition that A G . P = A K . Q, which would give the length of C D for every position of the platform.

This method is very simple, and would probably answer well under certain circumstances.

BUREL'S DRAWBRIDGE.

Fig. 16. In this method the platform A B is raised by means of a chain C E passing over a curve E *d* F, fixed vertically at the side of the platform, and through a groove in the pier of the gateway to the rear, where it is fixed to the lowest point C of a similar curve, suspended vertically at the side of the passage; the curve is a quadrant of a circle. In order to allow the platform when raised to rest close to the piers of the gateway, the curve E *d* F passes through the groove before mentioned.

The counterpoise M is placed on a beam M D N, which is a prolonged radius of the curve. This beam is placed so as to be parallel to the bridge in its horizontal and vertical positions, but in the other positions it forms an angle with it.

It may be seen by the principles of the lever, that when the counterpoise and platform are in equilibrium in one position, they will balance in all equally well. Equilibrium may be established by placing the counterpoise M nearer to, or further from, the point N on the beam N M, as may be required.

The distance between the platform and counterpoise may be very great, provided the chain connecting them is properly supported by pulleys *z z*.

If this chain varies in length from change of temperature or other causes, it may be accurately rectified by means of the wedge V.

A bridge of this description could be easily constructed, and, if necessary, easily repaired.

It could be raised and lowered without much inconvenience.

Variations occasioned by a change of temperature could be easily remedied by altering the position of the weight M.

PONCELET'S DRAWBRIDGE, WITH A VARYING COUNTERPOISE.

Colonel Bergère, of the Corps du Génie, was the first person who proposed constructing a drawbridge with a varying counterpoise.

The method he suggested was to have two weights, which were to be immersed by degrees in water. It would, however, be inconvenient to employ this in the ordinary communications of a fortress.

Poncelet proposed that the chain B I D attached to the platform A B should pass over a pulley C, and a wheel D F on a horizontal axis, and be fixed to other chains composed of links of a weight sufficient to balance the platform. These chains have the other end made fast to fixed points K, so that, as the platform is raised from the horizontal to the vertical position, the weight acting on it gradually diminishes. Plate XIX. fig. 17.

The wheel D F is made to revolve by means of an endless chain acting on a grooved wheel E′ E, having the same axis.

The chains forming the counterpoise may be of any form; but in order to combine solidity and weight in the smallest compass, it is better to use thick oblong plates of cast-iron, having semicircular ends. They are connected by means of bolts passing through the chain.

The size of the plates depends entirely on the weight of the platform.

The following is the method of calculating the weight of the counterpoise for every position of the platform. Let P be the weight of the platform, acting at the point B; let f be the weight of one foot of the small chain B I M Q; and l be the length B I. Fig. 18.

The weight of $BI = f \,.\, l$, which we may suppose concentrated at the point O, and may be decomposed into two weights, each equal to $\frac{l}{2} \cdot f$, one of which acts at the point I, the other at the point B. The latter will only add to the weight of the platform, which is equal to $P + \frac{1}{2} l \,.\, f$.

The tension t of the small chain will be obtained from the proportion

$$t : P + \tfrac{1}{2} l \,.\, f :: HI : BI, \text{ or}$$

$$t = (P + \frac{f}{2} \cdot l)\, \frac{HI}{l}.$$

A portion of the length IB of the small chain will assist in balancing the platform.

This is determined by drawing O O′ horizontally through O, the centre of gravity of the length of chain B I; for the weight $= f \cdot \frac{l}{2}$ acting at the point I, may be divided into two, one acting against the pulley C, the other in the direction I B, which latter is equal to two forces, one acting horizontally, the other vertically; the vertical force will be represented by the line I N = M O′, therefore the portion of M F which will assist in balancing the platform is equal to O′ F.

Hence the total weight of the counterpoise Q required to balance the platform is

$$Q = (P + \frac{f}{2} l) \frac{HI}{l} - f \cdot O'F,$$

from which formula the different values of Q for every position of the platform may be easily computed.

This bridge is found to answer very well in practice. It would, however, be perhaps more expensive than some others.

A great impediment to the facility of *manœuvre* in drawbridges is the necessity of their having a hand-rail, which must either be removed every time the platform is raised, and replaced when it is lowered, which always occupies some time, or else it must be constructed so as to act with the bridge.

The following method, which is very simple, and could be easily applied to any bridge, is, on that account, I think, preferable to many others.

One similar to this is in use at the Château de Belfort. It was executed under the direction of Captain D'Estoile, of the Corps du Génie. On each side of the gateway, in the horizontal space between the platform and the chains by which it is raised, an iron bracket A *a* is fixed into the masonry; at the extremity *a* an iron bar *a b* is fixed to a hinge, which acts vertically; the end *b* of this bar has a pin on its lower side, which, when the platform is horizontal, fits into an eye in the rail which is on the side of the road-way in front of the bridge.

Plate XIX. fig. 19.

A little in rear of the pin at the point *c* the rail is supported by two parallel bars *c d*, joined at both ends; this support is fixed to the platform by a bolt *d*, on which it revolves; the other end is fixed similarly to a bolt *c* on the rail.

By referring to the figure, the position of the rail, &c., when the platform is partly raised, may be seen in dotted lines. When the platform is vertical, the rail rests against the piers of the gateway.

The following remarks will show how a drawbridge may be made available for both ends of a communication.

In order to effect this with a bridge having a lever counterpoise acting in Plate XX. fig. 20. the prolongation of the platform, a counterpoise K T must be placed at each end of the platform; these are worked by means of the beams L, which are lowered by the chains attached to them. The platform is quite separate from these counterpoises, but may be connected with either in the following manner.

On each side of the platform, and firmly attached to it, is a strong iron bar D D, with bolts E at each end; this bar can be moved by the lever B backwards and forwards in the direction of the length of the bridge; when moved towards either end, it causes the strong bolt at that end to slip into an eye fixed to one of the transverse sleepers of the counterpoise, where it is secured. When the counterpoise is in this manner connected with the platform, the bridge may be raised and lowered with the usual facility.

If the bridge is raised by a counterpoise rolling on a curve, like Belidor's, Fig. 21. the platform is connected by the former arrangement I K L to beams E, which are at right angles to the platform, and revolve on pivots D. To the upper part of these beams iron bars F are attached; these pass down to the platform to a point F′, whose distance from the foot of the beam E is equal to one-third of the whole length of the platform. At the lower end of this bar there is a hook F′, which rests under the platform, and a projection M, which catches the iron bar L L, when this latter is moved so as to connect the platform to the beam E, and is freed from the bar L L, when it is moved in the opposite direction; it is intended to keep the platform firm whilst being raised, and to prevent it from falling backwards whilst in a vertical position.

The bar L L, when moved so as to connect the platform with either side, acts on a small bolt N on that side, and causes it to raise a bar O, which passes up the lever E, and supports at its top a short beam P, one end of which abuts against the lever E, when it is vertical, and the other is fixed by a hinge to the masonry supporting the curve on which the counterpoise moves. The use of the beam P is to prevent the lever E from having any tendency to fall backwards when not connected with the platform. The bar L L, by raising the bar O, causes it to displace the beam P, thus allowing the lever E to be acted on by the counterpoise G.

The curve supporting the counterpoise of this bridge is not the same as that for Belidor's, because the levers E and bars F must be considered.

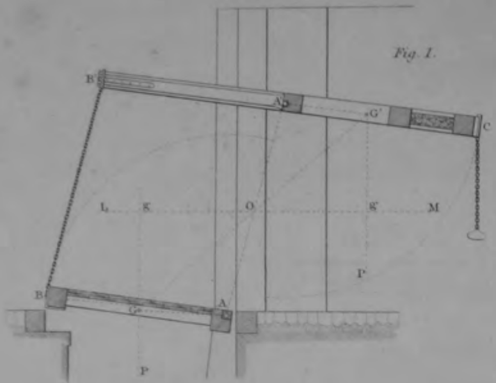
Plate XX. fig. 22.

The centre of gravity of a common drawbridge having a counterpoise on curves would be at the point C. In this case it will be at the point H. Join D H, and produce it to I, which is in the circumference of the curve described by the platform.

The vertical force required to balance the platform at this point may be supposed to be acting at K or N. Let G N represent the force required at G to balance the platform, &c. Let N O represent the weight of the counterpoise; then G O will be the direction in which G will act on the curve. Therefore a line P Q drawn perpendicular to G O will be a tangent to the curve at the point G. Any other point R in the curve may be found by taking a point S in the circumference I K U, as that at which K has arrived, and making S R equal to K G, and proceeding as before.

The required curve will be obtained by joining several such points made to correspond to the different positions of the platform.

These methods would be cheaper than employing two drawbridges; and in some cases, where there is very little space, they would be the only ones that could be used.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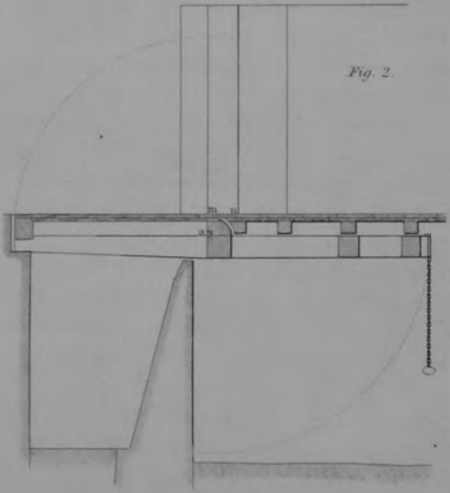
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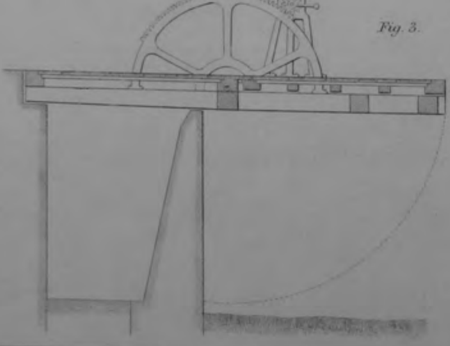
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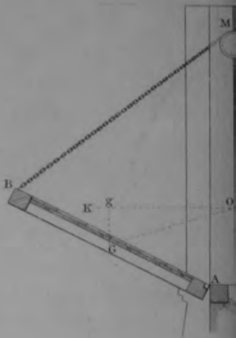

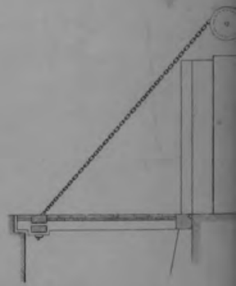

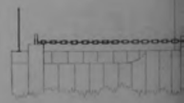

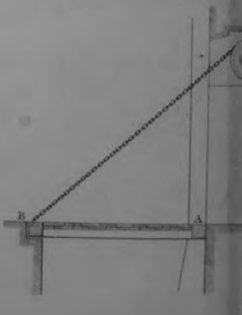

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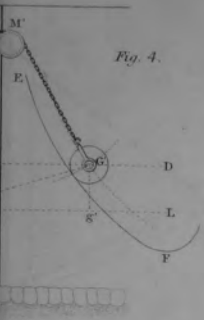
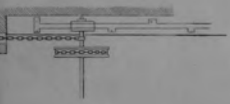


Fig. 4.

Fig. 5.



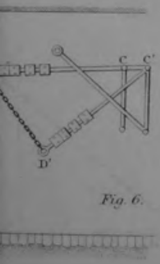
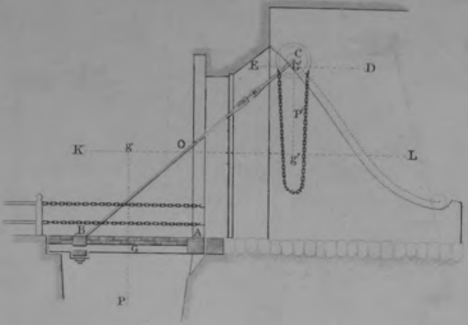


Fig. 6.

Fig. 7.



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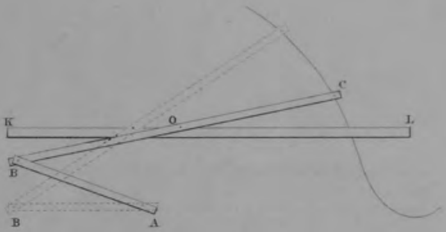

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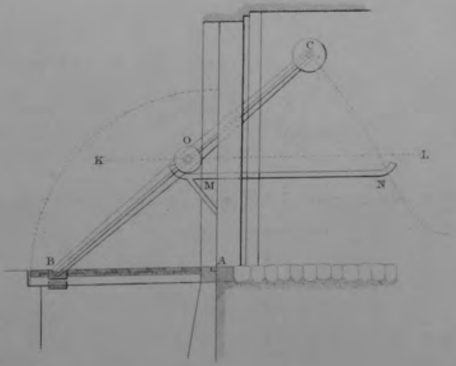


B.R. Davies sculp.

y, 59 High Holborn: 1841.

Fig. 10.

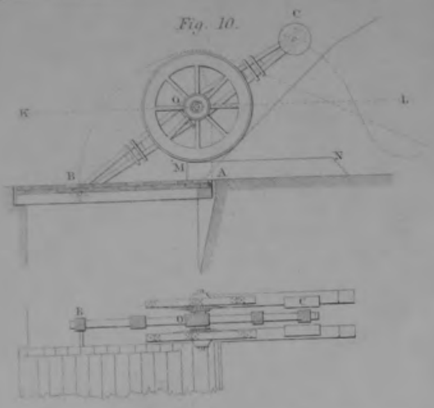
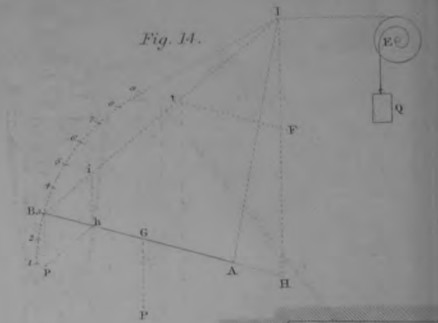


Fig. 14.



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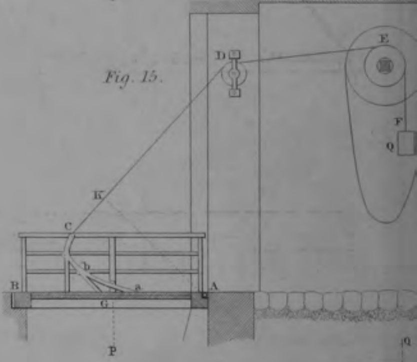

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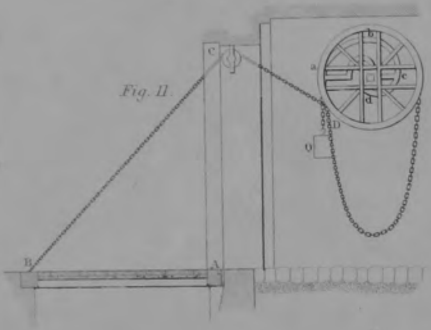

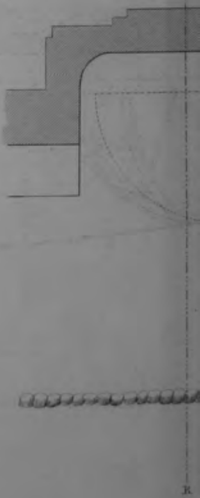

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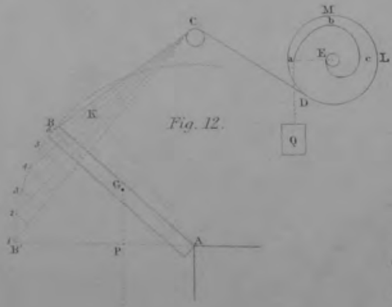

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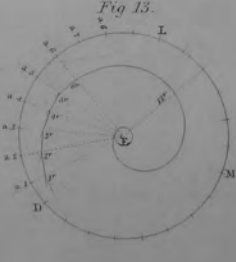

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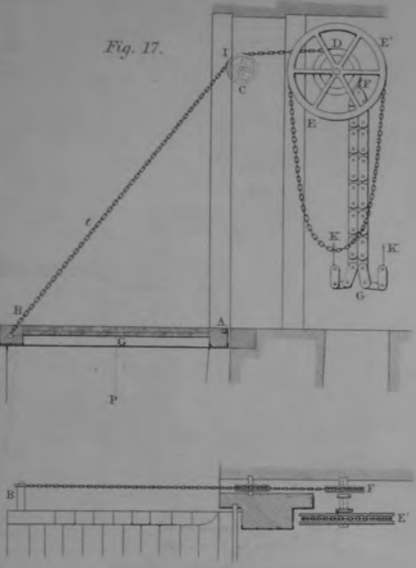
Fig. 17.



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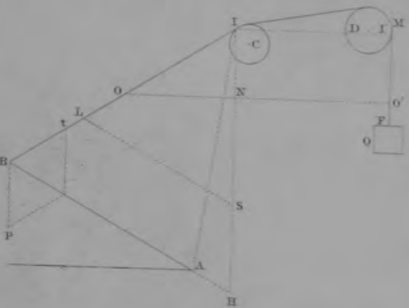

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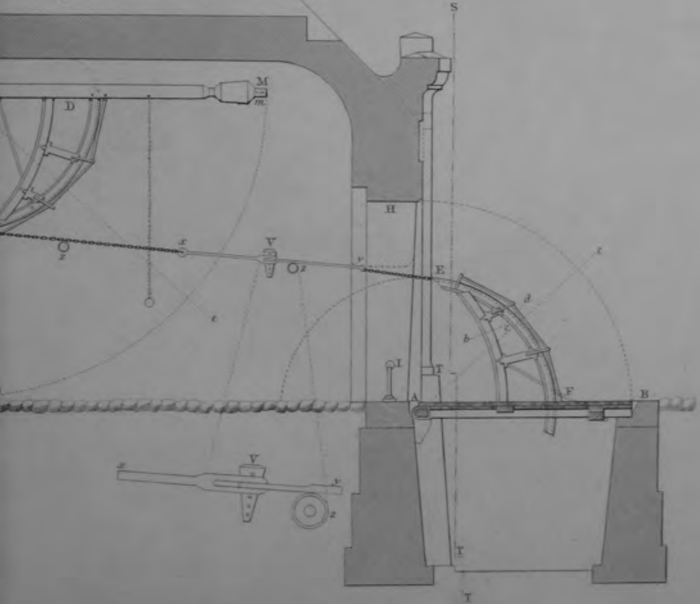
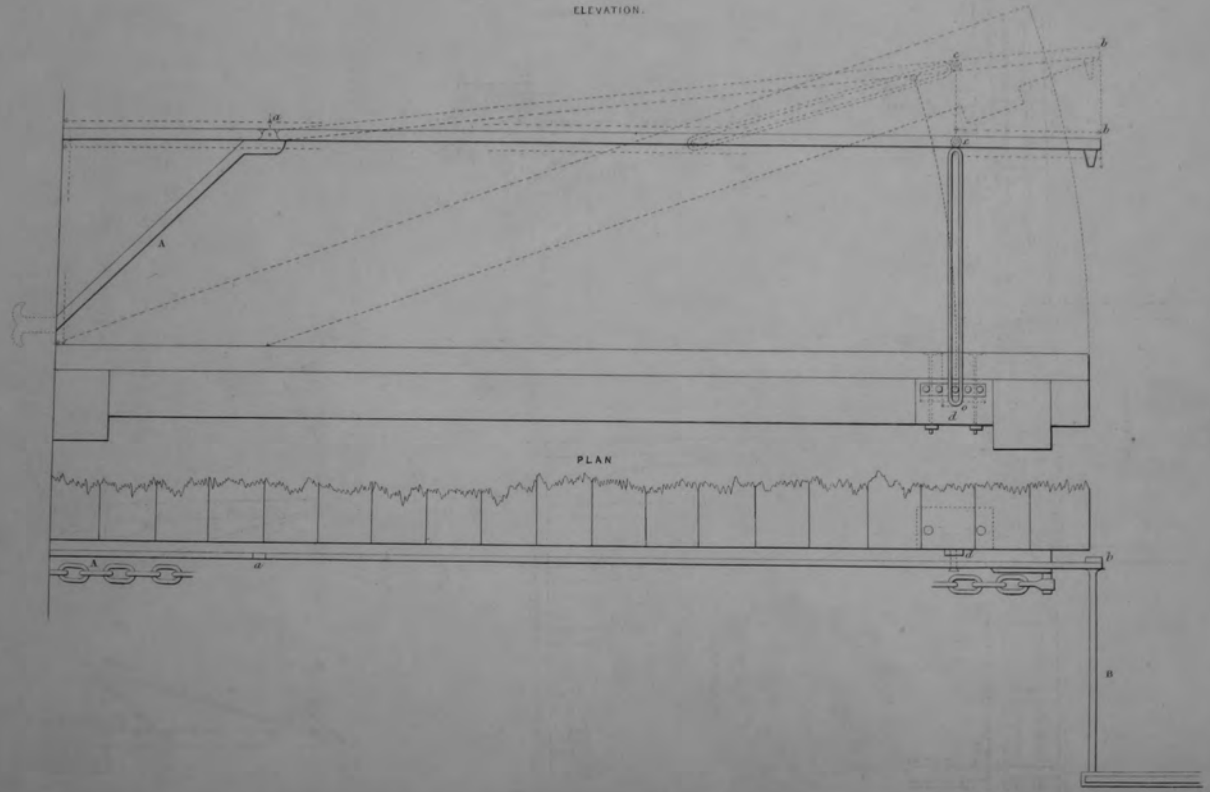


B.R. Davies sculpt

Fig. 19.


ELEVATION.

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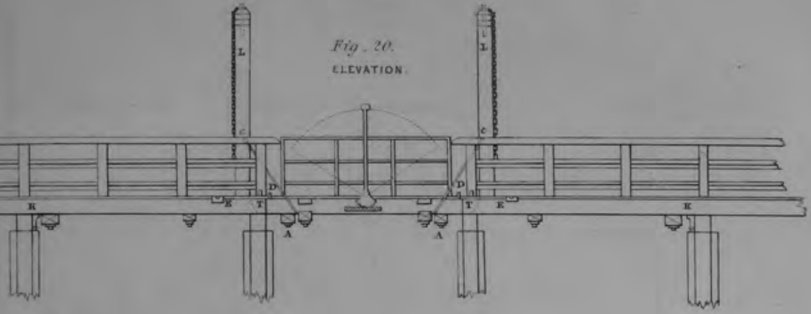

Fig. 20.
ELEVATION.

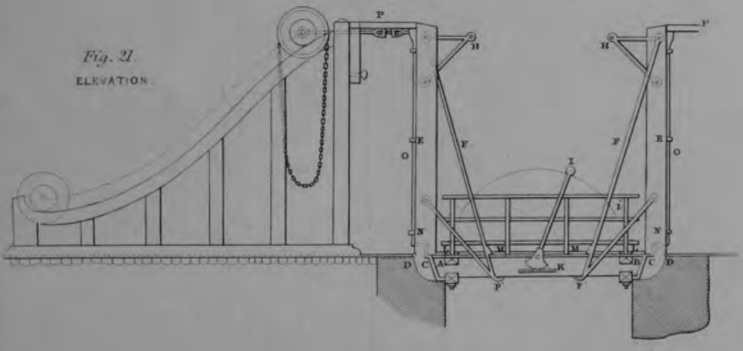

Fig. 21.
ELEVATION.

Fig. 22.

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X.—*Description of the Machinery in operation at the Royal Arsenal for the Manufacture of Leaden Bullets by Compression. By Captain* DENISON, *Royal Engineers.*

IT has long been known that a small air-bubble exists within the common cast bullet, notwithstanding its apparent solidity, diminishing in a trifling degree its weight, and consequently its range, and affecting, though but slightly, the accuracy of direction of a shot discharged from a barrel with a smooth bore. The practical inconveniences, however, arising from this cause were not, for a long time, looked upon as of sufficient importance to call forth any earnest attempts for their removal; and it was not until the year 1838, when a new kind of rifle, with only two grooves in the bore, was imported from Germany, the ball for which had a rim or belt[1] prepared to fit the grooves, and which ball was said to be manufactured by compression, that the attention of machinists was called to the subject.

The rifle above mentioned having been adopted into the service, it was desirable to have machinery prepared to manufacture the bullets, and Mr. Napier, of York Road, Lambeth, being applied to, has invented the machines described in this Paper, and for which he has taken out a patent. The machinery is adapted at present to the manufacture of musket-bullets, and those for the two-grooved rifle; but, by altering the dies, it is capable of making balls of any figure. I shall proceed first to describe the various processes through which the lead passes before it is turned out as a perfect solid bullet.

The first operation is to cast the lead into cylindrical ingots 3 feet long, and ⅞ths of an inch in diameter. This is done by pouring the lead into a metal frame containing twelve moulds, and thus twelve ingots are turned out at once.[2]

These, when cool, are taken to the machine shown in Plate XXI. figs. 1 and 2,

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[1] The term (belted) has been adopted for this ball.

[2] The musket-ball and the belted rifle-ball are both pressed from the same ingot.

and are first passed between the pair of rollers marked *d*, which are slightly grooved in their periphery, and are notched for the purpose of holding and drawing forward the ingot. By passing through these two rollers the ingot is, from a cylinder, reduced to a sort of flattened oval, one diameter being reduced from $\frac{5}{8}$ to $\frac{1}{2}$ an inch, while the other is increased from $\frac{3}{4}$ to $\frac{13}{16}$. It is then passed through the second pair of rollers marked *g g*, which are of rather larger diameter, are slightly grooved on their circumferences, and have semi-elliptical holes cut on their edge, which, from the rollers being exactly of the same size, fall opposite each other constantly, when once properly adjusted. The ingot now receives a pressure in the direction of its longest diameter, or at right angles, to what it did before; and after leaving these rollers the bullet assumes the form of an irregular spheroid, connected with its neighbours by a flat piece of metal about $\frac{1}{4}$ of an inch thick. The roller *g* has a cutter left upon it at one point of its circumference, as shown in the enlarged section: by this cutter the ingot is so nearly divided as to allow the boy who superintends this part of the work to separate the parts by a slight twist, and as the ingot is in length equal to about thrice the circumference of the roller, it is by this divided into three nearly equal parts. In this state it is taken to the compressing machine, shown in Plate XXII. figs. 1 and 2. Here the projection left upon the ingot by one of the semi-elliptical holes in the edge of the second pair of rollers is received into the fixed die marked *b*, while the moveable die *b′* is forced against the other projection, leaving the bullet completely formed, but connected in the ingot by a film of metal equal in thickness to the distance between the two dies when closed, or about that of a wafer. The only thing that now remains to be done is to free the bullet from this surrounding metal. Fig. 4 is a sketch of the most important part of the machine for this purpose. The lower half of the ball is inserted into a hollow cylinder of steel, the upper edge of which is left sharp, and the diameter of which is nicely adjusted to the size of the ball, so as just to allow of its being forced through it by the action of a punch worked by a simple treddle. The ball falls through the cylinder into a box prepared to receive it, and is then perfect and fit for use.

I shall now proceed to describe the machinery by which these results are produced.

Figs. 1 and 2, Plate XXI., show the front and end elevation of the rolling machine. This consists, 1st, of a cast-iron frame *a a*, strengthened by diagonal braces below, and connected above by the bolts *p p*; 2nd, of a frame *n n*, which carries the end of the fly-wheel shaft. To the first frame are fixed two wheels *l l*, of the same diameter, which receive motion simultaneously from a pinion in the fly-wheel shaft; on the axis of the upper of these two wheels is fixed a pinion *r*, and also the lowermost of the first pair of compressing rollers; another pinion of exactly the same dimensions, and which works with the former, is fixed on the axis of the upper roller, and serves to communicate the same rate of motion to it as is given to the lower roller. The same description applies to the lower wheel and compressing rollers *g g*.

Another set of shafts and pinions is shown in the drawings. These are for the purpose of working a pair of compressing rollers whose periphery is formed into a shape to suit the belted ball for the two-grooved rifle. In fig. 2 the pinions are shown out of gear, and the rollers not in their place, as they would interfere with the rollers *g g*; but at *f*, fig. 1, is shown the necessary machinery for adjusting them.

The axis of the fly-wheel which carries the driving pinion also carries the lower roller of this pair, and in consequence this pair of rollers revolves at a much greater speed than either of the other pairs; indeed, in the proportion of the diameter of the driving wheel to that of the pinion.

Figs. 1 and 2, Plate XXII., show the side and end elevation of the compressing machine: it is composed of a strong frame of cast-iron *a a*, which carries all the machinery of the compressing apparatus, and of a separate frame, which carries the end of the fly-wheel shaft and winch, &c.

The fly-wheel shaft at its other end is fixed in Plummer blocks upon the frame *a*, and carries a small crank, to which is fixed a connecting rod *e*, which works the bent lever *c c*. In fig. 1 the crank is shown nearly at its lowest point, and consequently the arms *c c* of the lever form nearly their smallest angle. When the crank is at its highest point, the arms are nearly in one straight line; and one end of the lever being fixed, the other, which carries the piston *l*, and the moveable die *b′*, is pushed forward till the face of the moveable die is nearly in contact with that of the fixed one. There are means of adjustment by a screw on the fixed end of the bent lever, as also by a screw on the piston carrying the fixed die, so that the two dies may be brought as nearly as possible into contact.

The arms *c c* of the lever are not, as they would appear on the drawing, in any way connected with the centres *d d*, on which they move; their ends are formed as shown in fig. 3, on a large scale, and therefore, although they can perform the office of pushing the die forward, they cannot withdraw it again. This is done by the springs *g g*, which are compressed when the die is moved forward, and, by their effort to resume their original position, withdraw the die, and keep the centre *d* on the moveable piston in contact with the end of the arm of the bent lever.

It was found by experience that lead compressed into an iron or steel die adhered so forcibly to the surface as to make it a work of difficulty to withdraw it. The dies, therefore, in this machine are not simple hemispheres; they have each a small piston about $\frac{3}{16}$ths of an inch in diameter, which, passing along the axis of the large piston by which the dies are carried, acts at its other extremity against a spring *m*, the tension of which is regulated by screws in such a manner as to enable the re-action to force the piston forward and free the ball from the die.

Fig. 4 is the machine for freeing the ball from the slight film of lead which connects it with the others in the same ingot. The connecting rod *c* is worked up and down by a treddle; the arm of the lever *b*, to which it is attached, is rather longer than the arm to which is attached, by a short connecting link, the punch *d*. This leverage, with the weight of the rod, is sufficient to keep the punch in the position shown in the drawing; *e e* is a brass guide for the punch, bolted to the frame *a*; *f* is a steel cylinder worked to an edge on the upper circumference. The ball is placed in this, and the action of the foot on the treddle forces up the connecting rod *c*, and the arm *b′* of the lever, and of course the arm *b* and the punch descend, and force the ball through the cylinder.

The whole of the machinery is admirably constructed, and does great credit to the ingenious inventor, Mr. Napier.

To keep the whole in constant work, twelve men and five boys are required; three men work at the winch of the rolling machine, while a boy passes the ingot through the rollers. The men work about a quarter of an hour, and are then replaced by three others.

One man, relieved in the same manner as those at the rolling machine, works the winch of the compressing machine, while a boy places the balls

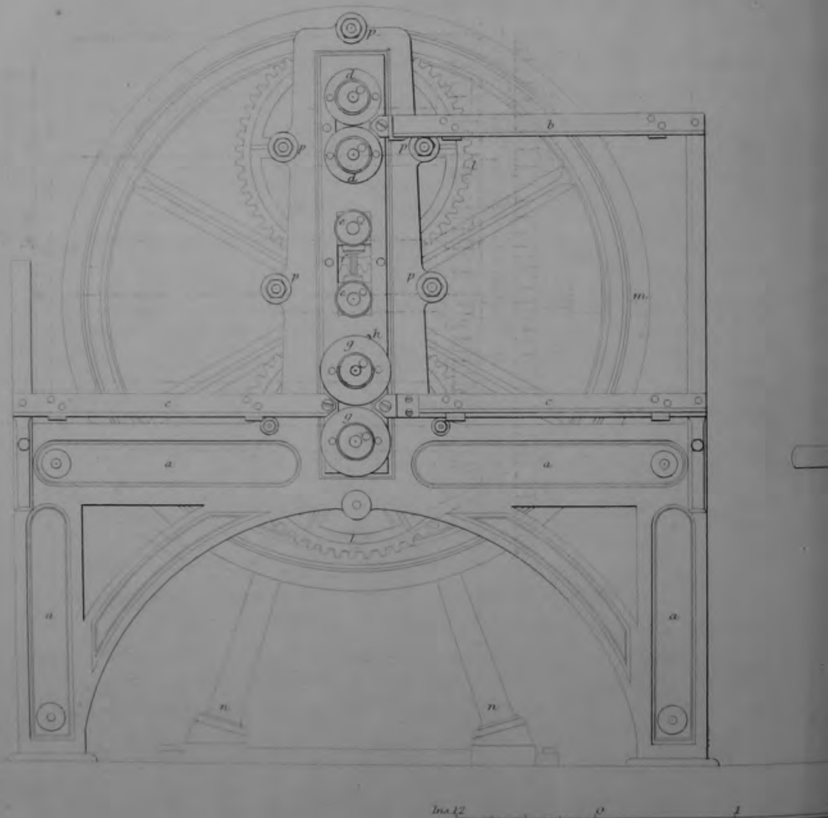
ROLLING MACHINE

a Frame
b Ledge to support the roll of lead through d.d
c D.° D.° g.g
d.d First pair of rollers
e.e Shafts & bearing &c for rollers not in use
f Screw for lightening D.°
g.g Second pair of rollers

h Cutter for periphery of g to divide lead
i.i Wheels for d.d
j.j D.° D.° e.e
k.k D.° D.° g.g
l.l Intermediate gear
m Fly
n Frame for D.°

o Wooden table covering the lower frame

Fig. 1. Front Elevation.



G.D.Dempsey del.

London, Published by John We

COMPRESSING BULLETS.

Fig. 3.

Section of first rollers, d.d.

Fig. 4.

Section of Second rollers, g.g.

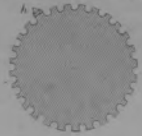
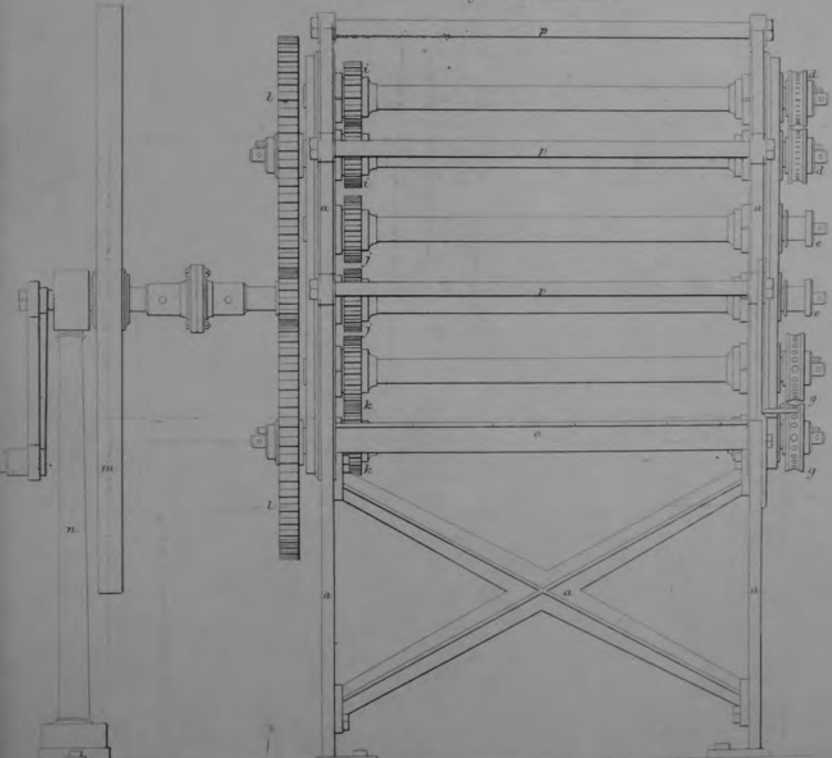


Fig. 2. End Elevation.



B.R. Davies sculp.

Library, 59 High Holborn, 1841.

MACHINE FOR CON

a. Framing.
b. Dies or Punches.
c. Arms for moving
d. Joints of d°.
e. Crank Arm.
f. Crank
g. Springs for reco

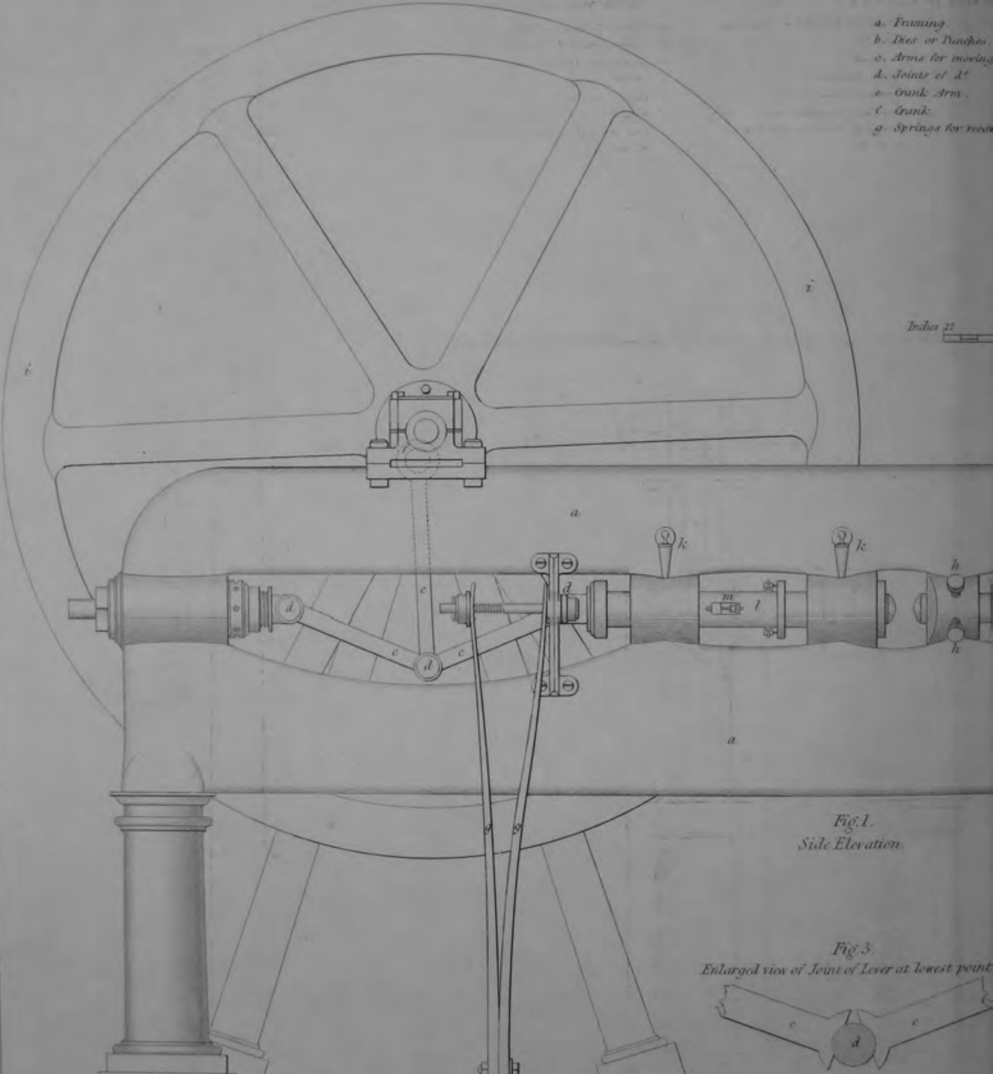


Fig. 1.
Side Elevation.

Fig. 3.
Enlarged view of Joint of Lever at lowest point

G. D. Dempsey del.t

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SSING BULLETS.

S TO FIGS. 1. 2. & 3.

es.

- h. Screws for holding & adjusting fixed Die.
- i. Fly wheel.
- j. Winch (broken off)
- k. Openings to oil Shaft.
- l. Shaft for moveable Die.
- m. Springs for working the Pistons in the Dies.

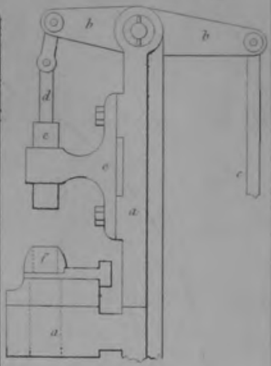
REFERENCES TO FIG. 4.

- a. Frame bolted to Table.
- b. Lever worked by rod c.
- c. Rod from Treddle.
- d. Punch.
- e. Guide for Punch.
- f. Mould in which Ball is placed and through which it is driven by the Punch d.

Side Elevation of Machine for clearing the Bullets from the Ingot.

Fig. 4.

Scale double that of Figs. 1 & 2.



Scale

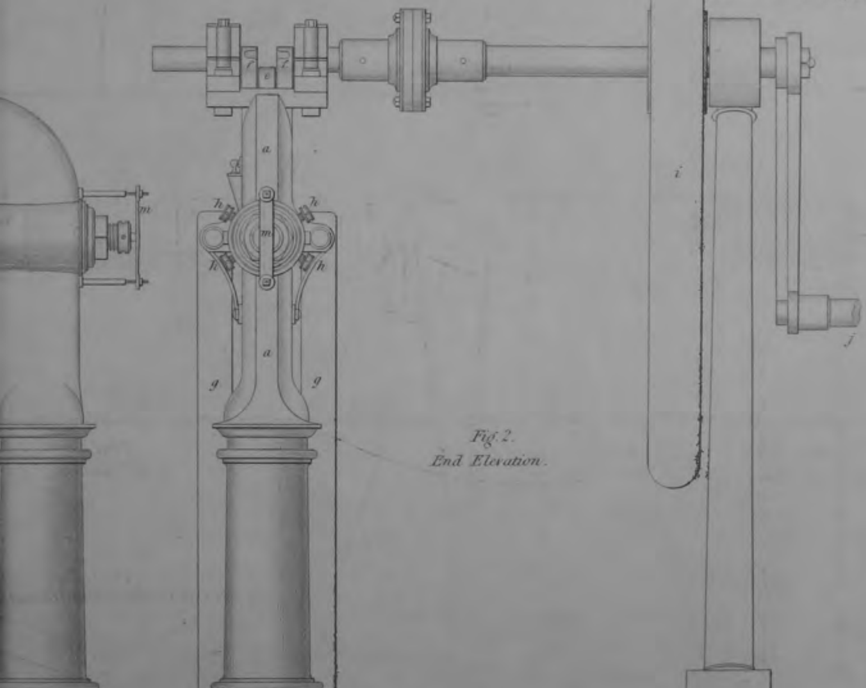


Fig. 2.
End Elevation.

B.R. Davies sculpt.

Library. 59 High Holborn, 1841.

in the die. Another boy works the machine for freeing the balls from the ingot.

One of the rolling machines will supply two of the compressing machines, and, kept thus constantly going, 25,000 bullets will be produced in a day. The difference of weight between the compressed ball and the cast ball does not exceed four drachms in the pound, or about $\frac{1}{64}$th.

XI.—*Description of a Dock lately constructed in Woolwich Yard.* *By Captain* DENISON, *Royal Engineers.*

THE state of the Docks in Her Majesty's Yard at Woolwich had been a subject of serious consideration for some years; they were constructed of wood, and although the timbers and planking of the bottom were pretty sound, yet the side timbers composing the altars, and the land ties and other framing of the upper portion, which were more particularly exposed to the alternate action of water and the atmosphere, were in a state of complete decay. One of these (a double dock) was so completely rendered useless, that the upper end of it was filled up, and the tide, being allowed to flow in and out of the lower part, had deposited in it at this period (1837) 8 or 10 feet of mud.

As, however, a plan for straightening the river front of the Yard, and at the same time adding a valuable space to its interior, had been in operation since 1835, in which plan the construction of two new docks on the site of the old wooden docks was a prominent feature, it was not considered advisable to commence to work upon them before the wall had been brought up to the point where the wing-walls of the dock entrance would connect with it.

The wall itself was in some measure an experiment; it was first commenced by M. Ranger upon a plan of his own, which may be briefly described as follows:

Two rows of sheet piling, 15 feet long and 4 inches thick, were driven at a distance of 10 feet apart, one row forming the foot of the front of the wall, the other that of the rear. A waling of half timber was bolted along the outer face of each of these rows, and at every 15 feet an iron tie-bolt connected the two rows together. The walings were fixed about 2 feet above low-water mark of spring tides, or 22 feet below the top of the wall. The ground between the rows of piling was then cleared out to the depth of 4 feet below the waling, and concrete, composed of one part of ground Dorking lime and seven parts of Thames ballast, mixed up with hot water, was then thrown in from a height of upwards of 20 feet: when above the level of the waling, the face of the wall was built up with blocks of concrete made in moulds of the proper size and form, and bedded in cement; while the backing was formed of rough concrete, as before described, and the space between the back of the new wall and the face of the old one was filled in with ballast from the river. All this was done by tide work, the unfinished wall being overflowed every tide. A distance of about 300 feet was constructed in the manner here described, and as shown in section fig. 1; but some doubts having been started Plate XXIII. as to the stability of a wall on such a plan, and on such a foundation, Mr. J. Walker was called in, and by his advice the modification shown in section fig. 2 was adopted. Here the wall is supported on bearing-piles; a row of sheet-piling in front, of half timber, still defined the outer foot of the wall, but in this case that piling was driven down to the chalk, as well as the bearing-piles; the section of the wall was altered and increased, and counterforts added from distance to distance; chain ties were likewise introduced, as also a chain bond or continuous bar of iron 4 inches broad and half an inch thick, into which the bolts connecting the fender-piles to the wall were fixed, and to which also the chain ties were fastened. In the rear of the wall too, instead of allowing the gravel to press at once on the back of the concrete, a mass of gravel and lime 12 feet thick was carried up in courses with the wall itself, and in front the mud was taken out to the depth of 7 feet and the width of 30, and the space filled in with gravel. In other respects the wall was similar to the former one; it was built of concrete faced with concrete blocks, as before. A distance of upwards of 700 feet was built in this manner. The ice, however, in the hard winter of 1837, having acted injuriously on the face of the concrete, breaking away a good deal of the smooth surface of each block, and exposing the rough mass beneath, it was determined to substitute granite blocks for the concrete facing, and as at the same time various cracks were exhibited along the face of the wall, showing evidence of partial settlements, it was decided to add two rows of diagonal piling to the foundation, as shown in section fig. 2, and this was accordingly done. Upon further settlements, however, taking place, it was discovered that they were caused by the weight of the chain ties, and the load of earth upon them, pulling back the wall at points where it was not supported by the masses of the crane pits which formed heavy counterforts; and piles were therefore driven at about 30 feet apart to prevent the sagging of the chains. So much of the wall as was founded upon piles was constructed as above described. A portion at the eastern end was founded upon chalk, and here of course it was unnecessary to make a fore-shore, but the chain ties were continued.

According to the original plan proposed by Mr. Taylor, the Civil Architect of the Admiralty, it was intended to carry the foundation of the wall across the proposed dock entrance to the depth of 30 feet instead of 26, and to carry up the wall, using it as a coffer-dam to keep out the water while the dock was constructed; this wall was afterwards to be cut away, and the wing-walls of the docks connected with it to the right and left. This idea, however, was given up, and the wall having been carried on piles as far as the western pier of the westernmost of the two docks, two piers and the apron of the dock entrance were built by tide work, the foundations being carried down to the depth of 30 feet below the coping in the chalk, which was found to be but a few feet below low water mark. The piers were built with brick in cement, faced with granite, as high as the top of the culverts; above that, concrete was used for the mass of the wall, all the exposed parts in the man-holes, shafts, &c., being faced with granite. The apron was made of granite set upon brick in cement, in one course 4 feet thick laid as a flat invert, the joints of the stones being drawn to a centre 75 feet distant. These two piers and apron being finished, or so much of them as was necessary to support the weight of the coffer-dam, a single dam (as described in Vol. IV.) was erected. At the same time, to prevent the water making its way round the eastern pier, where the river-wall was purposely left unfinished, and to avoid the necessity of a coffer-dam about 150 feet long, it was decided to build by tide work Plate XXIII. a wall of brick in cement, as shown in fig. 5, which should at once form part of the backing of the dock, and at the same time keep the work clear of water. This wall was carried down in the chalk to the same depth as the apron, or 30 feet below the coping; it was backed with concrete as an additional security against the pressure of the water, and counterforts were carried up from distance to distance both on the inside and the out, those on the out having the additional object of serving as foundations for the bollards. When this wall was finished, and its junction with the ground of the dock-yard made secure by puddle, &c., it was found perfectly water-tight. The whole of the piers, apron, and coffer-dam walls were executed by tide work as follows: a small space being surrounded by sheet-piling carried up about 6 or 8 feet above low water mark, a pipe from two 18-inch pumps worked by a steam engine was led into this enclosure; as soon as the tide fell below the sheet-piling, these pumps began to work, and the space was pumped dry in a short time, allowing the men to work till the rising tide flowed over the sheet-piling. This, though liable to inconvenience arising from the large quantity of mud deposited every tide, yet was far cheaper than enclosing the work with a coffer-dam, and by taking care to clear away the mud from the surface of the work every tide, and, in case of concrete, by clearing away also any portion of the surface that might be affected by the water, a sufficiently solid mass of masonry was put together to resist both infiltration and the direct pressure of the water.

As soon as these works were finished, and the water completely kept clear of the work, the excavation for the dock itself was commenced. The chalk in the previous excavation had been found so solid and dry, that it was not thought worth while to construct the floor of the dock on the principle of an inverted arch, as had been done at the apron, and it was therefore decided to pave the bottom with blocks of granite 2 feet thick, except the centre, or keel course, which was made 3 feet thick. Plate XXIII., fig. 3, shows the general plan of the dock as finished; fig. 4, a section of the steps at the head of the dock, and an elevation of the side altars, &c.; fig. 5, a cross section, shows the coffer-dam wall on one side, and the mass of concrete on the other. On one side the section shows the altars as they are called, on the other the steps by the side of the timber slides. As will be seen on the plan, the first four altars are narrow, having 11 inches tread and 13 inches rise; then comes a broad altar 22 inches tread by 26 rise; then four more narrow altars, and above these six broad altars, the whole being kept to the same size, so as to give a uniform slope from top to bottom. The advantage of the narrow altars is shown in shoring a vessel, while the broad allow of a ready communication all round the dock. The timber slides were made 2 feet 6 inches wide, so as to allow persons to step easily across them. The steps by the timber slides, following the line of the altars, were all 11 inches tread and 13 inches rise; but as this is rather steep, it was decided to make those at the head of the dock more easy, and this was done by increasing the width of the broad altars in the curved part of the dock, describing the front from one centre, and the back and the intermediate small altars from another: the rise of the steps was so managed as to bring a tread on the level of each broad altar. In clearing away the ground for the dock, it was of course necessary to remove the timber of the old wooden dock; this was found in many instances perfectly sound, but the oak of which it was principally constructed was turned completely black, like the bog oak in Ireland.

When the excavation was got out to the proper depth, a few small springs were discovered at different points, having no connexion with the water in the river; these it was decided to lead away in earthenware pipes to the engine-well, and accordingly under the centre of the keel course a drain was dug, falling gently towards the steam engine, which stood at the head of the dock. In this drain, upon a bed of brick in cement, a course of 4-inch cylindrical drain-tiles was placed, and all the small springs were led into the main drain by small ranges of pipes. Brick in cement was afterwards carefully built over the drain, and the foundation carried up as solid as possible. The cross section of the floor shows a fall from the upper surface of the keel course to the drains at the sides, of 3 inches in about 16 feet; and the longitudinal section shows a fall from the head of the dock to the gutter in rear of the apron, of 1 foot 6 inches. All the water, therefore, falling upon the altars or bottom will be discharged into the gutter, which has also a fall from west to east towards the spot where the engine-well is intended to be placed, and which, if made large enough, will be sufficient to contain all rain water, leakage from caisson, &c., if not excessive, until it may be advisable to use the pumps.

The backing of the dock being formed of concrete, it was not thought advisable to cut away solid chalk to substitute concrete in its place, and therefore, as is shown in the cross section, only so much was cut away as to admit the stone-work and a backing of brick in cement about 1 foot 2 inches, or 1 foot 6 inches thick. It would have been wiser, however, to have taken out 4 or 5 feet more of the chalk, as the rain water and springs filtering through crevices in the strata made their way through the brick-work in places, and showed themselves at some of the horizontal joints of the altars, causing an unsightly appearance. No harm, however, could happen from this, for owing to the mode in which the stones were notched one upon the other, as shown in fig. 6, it was impossible that one could move either backwards or forwards without carrying with it its neighbour in the upper or lower courses.

Plate XXIII.

No difficulties were experienced during the construction of the dock; the only doubt that occurred to me as to the propriety of the plan adopted turned upon the omission of the inverted arch to the bottom of the dock. Had I to construct another under similar circumstances, I should most certainly adopt the invert; as it was, each stone of the floor was joggled to its neighbours by dovetail joggles of Valentia slate bedded in cement, so as to make it next to impossible that any stone or course of stone should move without carrying its neighbours with it; and as the gutter stones are bedded under the side altars, the whole must move together. The utmost pressure arising from land-water cannot amount to more than a head of 11 feet, the land springs standing 18 feet below the line of the coping: to counterbalance this there are 2 feet of granite and 1 foot of brick in cement, which altogether is equivalent to about 450 ℔s., while the water is equivalent to 688 ℔s., leaving thereby a surplus of power acting upon each square foot of about 238 ℔s.; against this, however, must be placed the tenacity of the cement, and the power necessary to crush at least 3 joggles about 4 inches square, which will be far more than an equivalent to this power, supposing that the water can be considered as acting under the whole surface of the floor at once, which, however, can hardly happen.

The river water is admitted into the dock through a culvert 5 feet high and 3 feet wide, passing through each pier; each of these is shut at pleasure by a cast-iron sluice, the plan and section of which, and the machinery by which it is worked, are shown in Plate XXIV.

Fig. 1 is an elevation showing the sluice-gate and frame, the rack by which it is lifted or lowered, and the screw, which, working upon the teeth of the wheel shown in elevation in fig. 2, turns a pinion carried on the same axis as the wheel, the teeth of which act on the rack, and so raise or lower the sluice. The screw itself has a spindle, which passes through a brass collar fixed to the iron plate covering the man-hole; this spindle has a square head, on which a key is fitted, and worked by a handspike. The power of one man by this means is amply sufficient to work the sluice, but of course the motion is slow. Fig. 3 shows the plan of the cast-iron frame, which, bolted to the sides of the man-hole, as shown in fig. 2, serves to carry the heel of the screw and the centres upon which the wheels and pinions turn; it shows also a section of the rack, the back of which has a flange, which works in a groove in a small roller, which serves to keep it in contact with the pinion, and at the same time to prevent any lateral movement which might cause the sluice to jam in the groove of the frame. Fig. 4 shows a plan of the sluice in its frame. The frame is a heavy casting, which is set into the stone-work of the shaft and culvert, and solidly bedded therein. The groove in which the sluice moves up and down, as will be seen in fig. 2, gets narrower towards the bottom, the width of the casting remaining the same, so that there is a large mass of metal at the bottom to resist the pressure of the water acting on the back of the sluice, and at the same time the wedge shape of the sluice serves to bring its face, which has a brass on it, quite tight against the face of the frame, which has also a brass, against which the other works. The whole cost of one sluice, exclusive of the labour of fixing, was £159.

As a dock, at all events where there is much rise and fall of the tide, is generally allowed to empty itself as far as possible by leaving the sluices open during the ebb, after which recourse is had, if necessary, to pumps to clear away what water will not run off by the sluices, the size of these openings or the mode of opening them is a matter of very little importance; a few minutes more or less in the opening or closing the sluice does not make the same difference as is the case in the sluices for filling and emptying the locks on a canal, where the amount of traffic is dependent upon the time a boat takes to pass through a lock.

The kind of sluice above described is one commonly used in large docks, and from the slowness of the motion it has the advantage, before stated, of requiring but one man to work it.

Plate XXV. Figs. 1 to 11 show drawings in detail of a new cast-iron capstan, which has been adopted for the new dock. Hitherto most of the capstans in the yard have been made of wood, and were of course very subject to decay, being from their position exposed to all the vicissitudes of the weather. These wooden capstans, like those on board ship, were framed on a heavy wrought-iron spindle, which was stepped into a brass box fixed either in a stone or wooden framing at the bottom of a pit about 6 feet deep. The principal alteration in the present capstan, independent of the material of which it is made, is the substitution for the wrought spindle of a cast-iron one, fixed into, or forming part of the bed-plate, which is firmly fitted into and bolted by a mass of stone-work. This spindle is turned true at top to receive a brass collar, and also a brass cap, and at the bottom are fixed eight friction-rollers; the body of the capstan, or drum on which the rope is wound, being well connected to the head where the levers work, the whole is suspended upon the top of the spindle, upon the brass cap before mentioned, while the brass collar and the friction-rollers keep the motion smooth and true without any shake.

The barrel of the capstan is shown in the drawing without any whelps; had it been intended to work with chain cables, iron whelps would have been adopted, and cast with the barrel; but as common hawsers are generally used in docking vessels, wooden whelps will be used, and bolted into the spaces between the flanges of the barrel, where room is left for five of them. It is intended to adopt Gryll's patent whelps in one or more of the capstans, for the sake of comparison. The difference between this and the common whelp is shown in fig. 9; the essential difference being in the side angle of the patent whelp, or while one has the two sides parallel, the other is wide at top and bottom, and narrow in the centre. The advantage claimed by the patentee is, that the rope or chain has always a tendency to the centre, and never surges on the barrel.

The cost of a common wooden capstan with an iron spindle is about £51; the cost of the present one is £39; the expense of the foundation for both would be about the same. The fittings, perhaps, of the cast-iron one would be rather more expensive than those of the wooden, but not to any great amount.

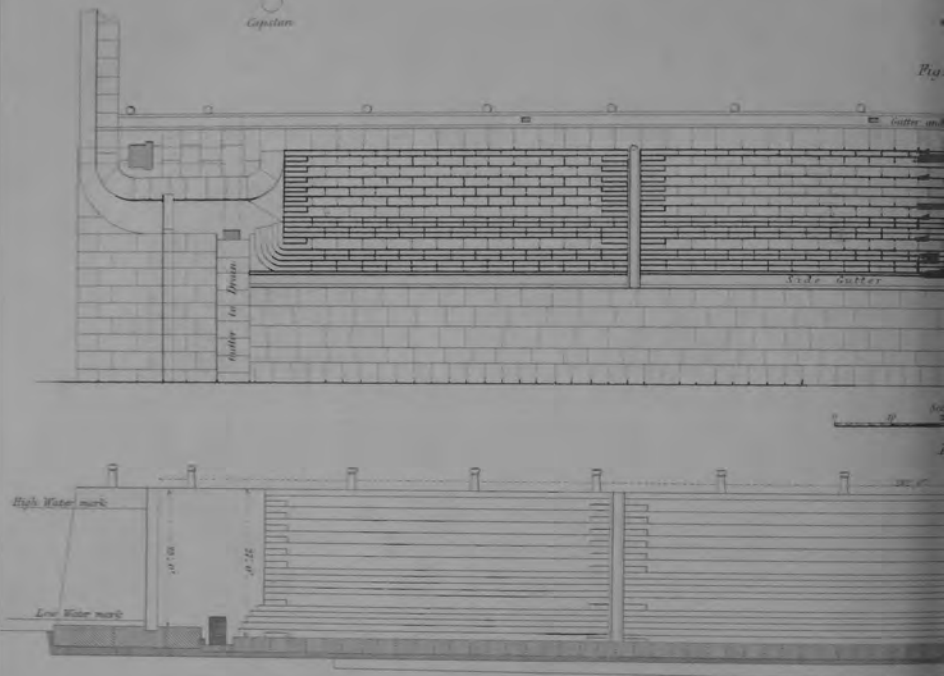
It will be seen, on reference to the plan of the dock, that the entrance is closed by a caisson: much discussion took place on the subject before the question between gates and a caisson was finally settled. There can be no question but that in a general way gates are much the most handy, giving less trouble in opening and closing, and being managed by much fewer men; but in situations where the mud is liable to accumulate upon the apron in front of the gates to a great amount, the advantage arising from these facilities is neutralized. The gate when opened moves the mud before it, and a bank is created against the piers, which in a short time, if steps be not taken to clear it away either with rakes or by other means, prevents the full opening of the gate.[1] On the other hand, a caisson is independent of the quantity of mud outside upon the apron, and, indeed, has the power of clearing away any quantity that may have collected by means of a simple arrangement of sluices in its interior. A caisson can hold up the water in the dock, and allow it to

---

[1] Some idea may be formed of the quantity held in deposit by the river water by the amount deposited in the dock during about four months between the time of taking down the coffer-dam and fixing the caisson; a small dam about 6 feet high had been erected within the gutter to allow the masons to work at the caisson-groove, and the space from this dam to the head of the dock was filled with mud to the average depth of 8 feet.

rush out at low water, thus forming a scour, which cannot be done with gates. Now, the accumulation in front of the dock-yard at Woolwich is very great; at present the general level of the mud at the foot of the river wall is about 18 feet below the coping, or 7 feet above the apron of the dock; and the low water mark, which is 1 foot above the level of the apron, is about 100 feet from the wall. It would manifestly be impossible to open gates against such a collection as this; and although, were it once cleared away, it could never have time to collect to the same extent again, yet the deposit is so rapid, that if a vessel were detained, for heavy repairs, some weeks in dock, I believe it would be found very difficult, if not impossible, to open the gates after that to their full extent, and much labour would be required to clear the apron several times in the course of the year. All these considerations decided the adoption of a caisson instead of gates. The next question to determine was the construction of this caisson for an opening of 65 feet; there is a wooden caisson for the opening into the basin, which is 57 feet wide, but this is so heavy and draws so much water, as to prevent its being floated out at neap tides, which is a great inconvenience, and the additional 8 feet of width of opening would not be likely to diminish the draft of water. It was therefore decided to try an iron caisson, and Messrs. Ditchburn and Mares, of Blackwall, sent in a drawing and tender for one, which was approved. The specification stated that the caisson was to be capable of withstanding the utmost pressure which could be brought against it, which amounts, in case of a high spring tide and a northwesterly wind, to 24 feet, and at the same time it was to draw, when light, not more than 10 feet water. Various circumstances caused such a delay in the delivery of this caisson, that I have not been able to get the drawings ready in time for this Volume, but they will be given, with a full report of its performance, in Volume VI.

THE EASTERN DOCK



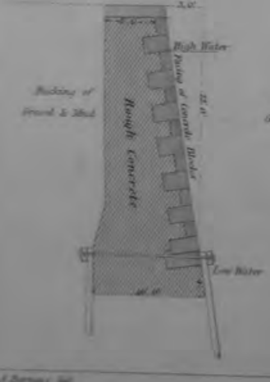


Fig. 1.
1st Plan of River Wall

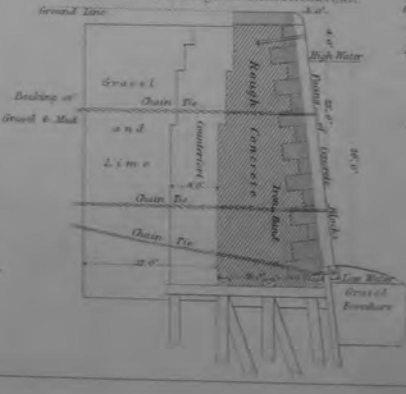


Fig. 2.
2nd Plan of River Wall
with additions as Diagonal Piles, Foreshore, &c.

Section through the Steps

E. A. Burney del.

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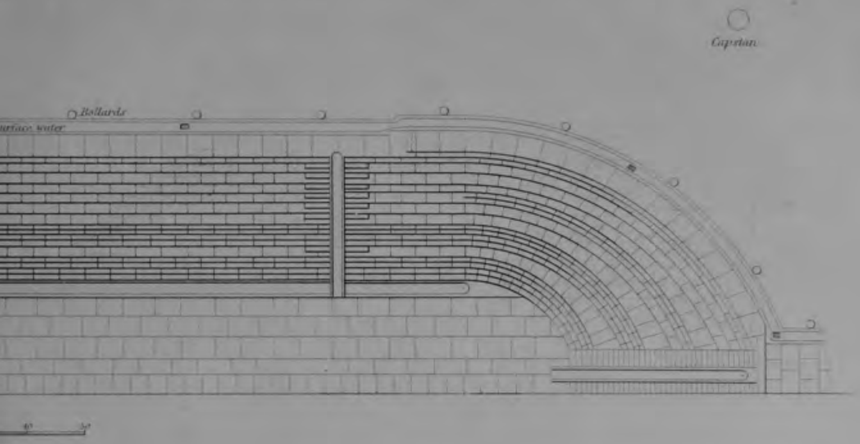
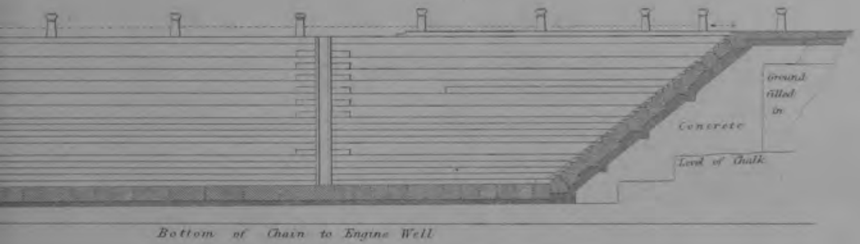
OCK YARD, WOOLWICH.





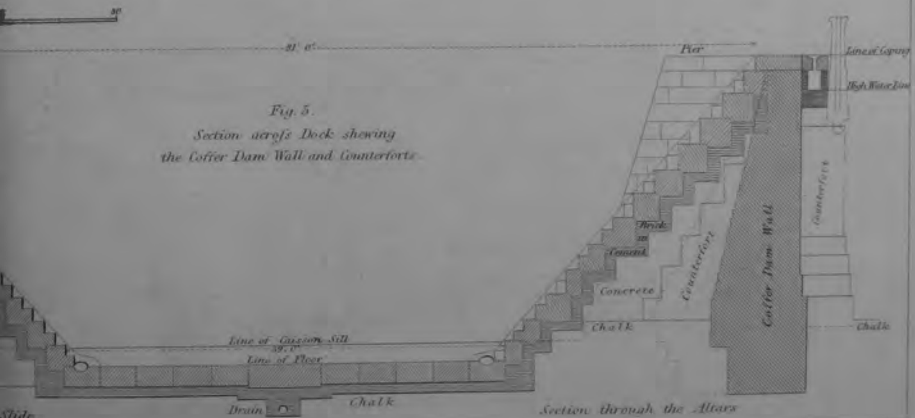


Fig. 5.
Section across Dock shewing
the Coffer Dam Wall and Counterforts.

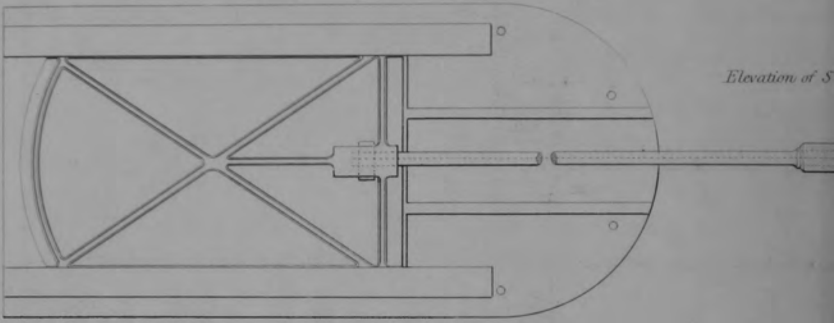
Section through the Altars

B.R. Davies Sculpt

v. 59 High Holborn 1841.

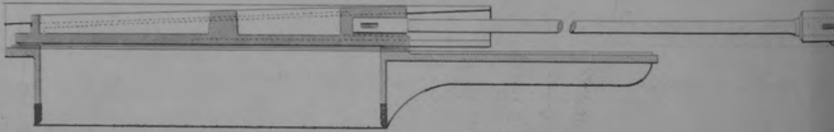
LARGE SLUICE H.

Elevation of S



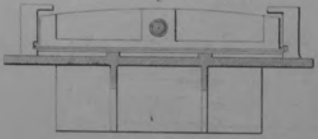
Vertical Section of Sluice and Machin

Fig. 2.



Transverse Section of Sluice

Fig.4.

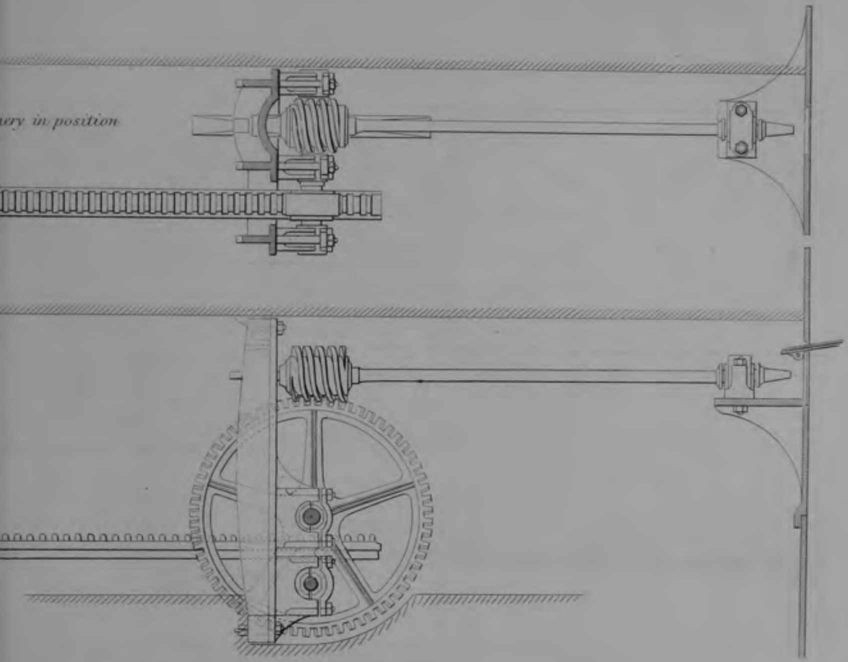


E.A Bernays del.

London, Published by John Weale

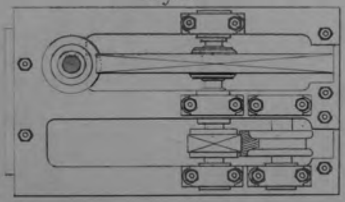
Plate 34.

CK YARD WOOLWICH.



Plan of Machinery for raising & lowering Sluice.

Fig. 3.



e.

6 7 8 9 10 Feet

B.R. Davies sculp.

ibrary, 59 High Holborn, 1841.

CAST IRON CAPSTAN
H. M. Dockyard,
WOOLWICH.

Fig. 8.

Fig. 10.

Fig. 2. *Fig. 7.*

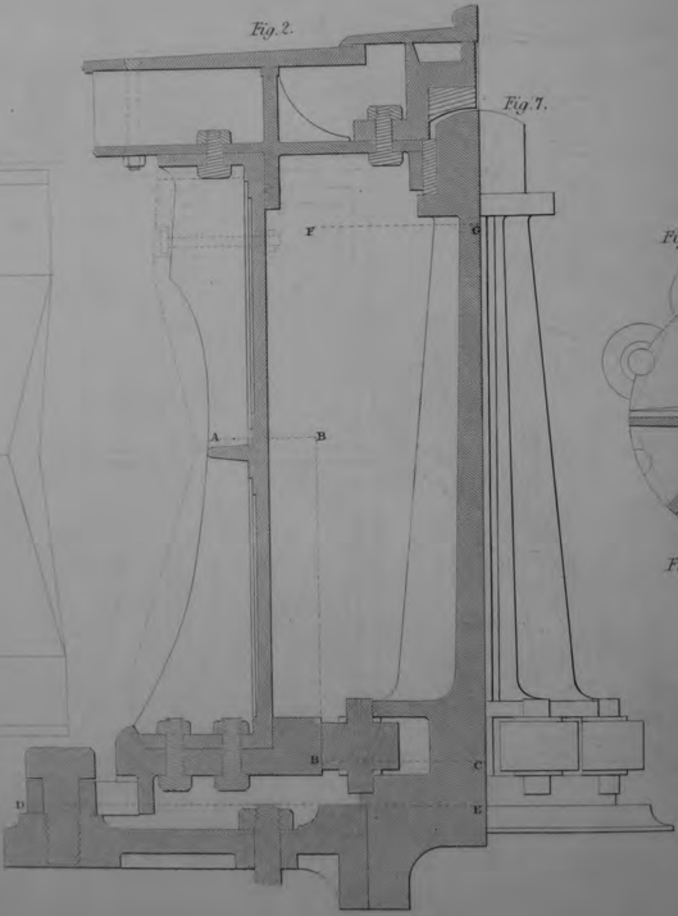


Fig. 5.

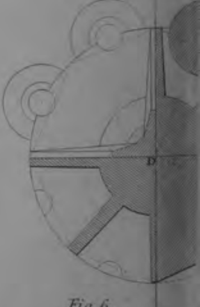


Fig. 6.

E. A. Borriggs del.

London, Published by John

1. *Half elevation of Capstan without wooden whelps.*
2. *Shewing a Section of the covering plate & upper plate on Line* A B C. *Fig. 8. Also a Section of the cylindrical barrel lower plate and central Shaft &c. upon Line* A B C D. *Fig. 3. Also a Section of the Bed plate and Palls Line* D E F. *Fig. 4.*
3. *Horizontal Section and Plan on Line* A B C. *Fig. 2.*
4. *Horizontal Section and Plan on Line* D E. *Fig. 2.*
5. *Horizontal Section and Plan on Line* E G. *Fig. 2.*
6. *Horizontal Section and Plan on Line* B C. *Fig. 2 omitting the Friction Rollers.*
7. *Elevation of Central Shaft Friction Rollers &c.*
8. *Plan of Upper Plate and Cast Iron Cap containing the Braſs Cap upon which the Capstan hangs.*
9. *Plan of the underside of the upper plate shewing a Section of the upper part of the Shaft & the brass Collar.*
10. *Elevation of Gryll's Patent Whelp as applied to the Capstan and as shown in Section by the dotted Lines or Fig. 2.*

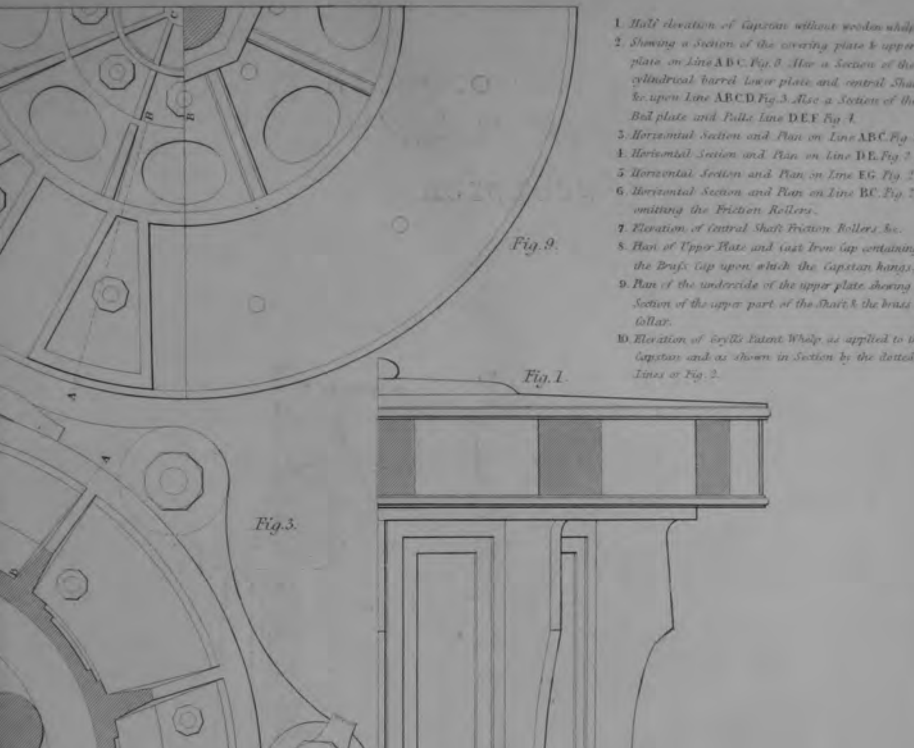


Fig. 9.

Fig. 1.

Fig. 3.

Fig. 4.

B. R. Davies sculpt.

ibrary, 59 High Holborn 1842.

XII.—*Description of the Machinery employed in Deptford Dock-yard for Spinning Hemp and Manufacturing Ropes and Cables. By Mr.* JOHN MIERS, F.L.S.

BEFORE attempting to point out the many advantages offered by the very simple and beautiful contrivances now employed in the Royal Dock-yard at Deptford, which have there superseded the old methods still practised in the other Dock-yards, for the spinning of hemp into yarns, and the final preparation of the same into ropes and cables, for the service of the Navy, it will be better to proceed, in the first place, to the simple description of the machinery, in order to facilitate a more ready comprehension of the subject. The different ingenious operations here combined may be classed under two heads: first, the spinning of hemp into yarns; and secondly, the manufacture of the yarns into ropes and cables.

FIRST.—THE SPINNING MACHINERY.

The processes here employed consist, first, in separating the fibres of the hemp, and disposing them as nearly as possible into parallel juxtaposition; secondly, the conversion of these bundles of parallel fibres into a flattened riband-like form called a sliver; and thirdly, the spinning of this sliver into a yarn, or simple twist. Plate XXVI. figs. 1 and 2, exhibit a side and front elevation of

The first Preparing or Gilling Machine, the same letters referring in each separate view to the same details. The essential parts of this machine consist of a number of pointed wires called gills or heckle teeth, fixed in an erect position on different transverse bars, attached to a series of links connected together as an endless chain, and moving onwards with one uniform velocity, the main purpose of which contrivance is to straighten and separate the filaments of the hemp; connected with which is a combination of rollers, serving at the same time to draw out the fibres lengthwise without disturbing their parallelism, and to compress them into a riband or sliver, in readiness to be spun into yarn. *a* shows the general framework of the machine; *r* is part of the feeding trough (of which a transverse section is shown in fig. 3), the rough hemp in small bundles being spread out upon it into a loose bed by the boy whose duty it is to attend to this operation, as well as to see that the material enters regularly between the revolving fluted iron rollers *i i*, he arranging it with his hands as it enters the rollers, so that the hempen bed may advance in an uniform broad sheet, which is then combed into parallel fibres by the advancing heckle pins, which in their forward motion perform the duty of teeth in disentangling the fibres, and preserving their parallel juxtaposition. The hempen stream being gradually drawn forward by the means about to be described, is at length quitted by the heckles, and received between the drawing rollers *h h′*, which, revolving at a much quicker speed than the rollers *i i*, draw out the fibres into a thinner but more equal degree of consistence, and the hemp is here compressed into a broad thin riband of lax filaments, whence by a guide it is gathered into a narrower space, and compressed between other small rollers *h h*, which deliver the sliver thus far prepared into a can, in readiness for a further process in the next machine.

The mode of action of the heckling process being very ingenious, is worthy of a more minute description, and enlarged details of the several parts are given in figs. 3, 4, and 5 of Plate XXVIII., which refer equally to the parts of the first and second preparing machines, in order to render this still more intelligible. The heckle teeth or combs stand erect upon several transverse bars *s*, sliding vertically in as many pairs of open links, which are combined together in two endless chains, in such manner that they all move in one uniform direction by means of the projecting ends of these bars working into grooved guide frames provided for this purpose. The two endless chains are urged forwards each by two toothed cams or wipers, fixed upon two transverse spindles *b b′*, which propel the links in succession by reason of their teeth filling the spaces between the joint pins, as seen in fig. 5.

It has already been shown that the ends of the transverse bars *s* work into grooved channels of the guide frames; but these channels are so arranged, that as each link in succession is pushed upwards and forwards by the teeth of the first wiper, each respective transverse bar rises towards the end of the slit in that link, in such manner that the heckle pins now project beyond these links, as shown in figs. 4 and 5, a position they retain (in order to perform the duty already described) until they arrive at the opposite wiper, when, owing to a change in the direction of the grooved channels of the guide frames, the transverse bars are now drawn in towards the bottom of the links, so that the heckle pins in their retrograde movement are concealed within the space of these links, and are thus prevented from catching hold of any intervening substance; and as they descend into this position on quitting the stream of hemp, they are not allowed to draw down any portion of fibres that may have adhered to them, by reason of an interposing plate of metal called the guard, which is fixed edgewise near the summit of each link, and which serves to clear away any of the filaments that may have become entangled in the heckle pins. The ends of the spindles $b\,b$, projecting outside the framework a, are provided with toothed wheels $c\,c'$, of equal diameters, which are made to revolve with equal velocities by means of the three intermediate wheels $d\,d'\,d''$: the toothed wheel c' is driven by a pinion upon the same spindle that carries the toothed wheel e, by means of which its velocity is reduced; and this in its turn is urged by the pinion f fixed upon a shaft, at the opposite end of which are seen the live and dead riggers $g\,g'$, put in motion by a strap, worked off the main power derived from the steam engine. The lower roller h is of iron fluted, and is driven by a pinion f, working in the cog-wheel e: the due amount of pressure upon it, by its corresponding upper wooden roller h', as also that of the roller i' upon i, (through both pairs of which the hemp passes before and after being combed by the heckle pins,) is regulated by two levers moved by the springs $j\,j$, which can be set to any degree of tension required. Attached to the spindle of the fluted roller i is an endless screw n, which, working in a pinion m, moves the bevel wheels $l\,l$ attached to the index wheels and register dial k, all which parts are shown separately on a larger scale in fig. 4, Plate XXVI.; the object of this being to inform the attendant of the exact interval in which he ought to feed the machine with a fresh supply of hemp, as the progress of the index hand upon the dial is always in a constant ratio to the motion of the feeding rollers $i\,i$.

The second Preparing Machine is exhibited in a side elevation in Plate XXVII. fig. 1; an end elevation in fig. 2; a plan in Plate XXVIII. fig. 1, and the opposite end elevation in fig. 2, parts of which machine in detail are shown in figs. 3, 4, and 5: *a* is the general framework, *b* the driving riggers communicating the motion from the steam engine to the machinery, *c* the guide frames in which the ends of the heckle bars slide, as shown at *e* in fig. 3; *d d* the heckle links, also seen more detailed in fig. 5. As the mode of action of the heckle frame, as well as of the drawing rollers, is similar to that of the machine before described, it will not be necessary to repeat the description of the same, or of the gear work by which their motions are regulated; but it will be seen that the heckle pins differ from those of the former machine, by being in two distinct sets, and adapted for operating upon six of the slivers prepared in the first machine, which are placed before it in as many cans *h*. The ends of the slivers are first introduced through the guides *e e*, passing over the grooved roller *g*, and pressed upon by the wooden rollers *ff*, by which three slivers, combined into one, have their fibres again separated and combed into a more parallel direction by the heckle pins, at the same time that the whole is urged forward and drawn out by the action of the rollers *f f*, between which the hempen riband passes after leaving the heckles, and which rollers, moving with a far greater velocity than the rollers *g g*, cause the bundle of fibres to be regularly drawn out into a thinner and more regular stream; and by its subsequent compression between the rollers, to attain the degree of cohesion that enables it to undergo the next process. The machine, therefore, delivers through the guides *e e* two equal slivers at the same uniform velocity into one can *i*, an operation called *the doubling*: *j* is a spring whose power is regulated by a screw, by means of which the requisite degree of pressure may be given to the rollers *f f*. It is to be observed that any greater number than three of the slivers prepared in the first machine are passed through each set of heckle teeth on this occasion accordingly as a thinner or thicker yarn may be required for different purposes. The doubled sliver thus made is then removed to a third preparing machine exactly similar to the one last described, where it is still further drawn out into a single and more uniform sliver, and received into a delivering can, in which state it is now passed to another machine called

The Compressor, which is exhibited in Plate XXIX. In fig. 1 is shown the plan, and in fig. 2 the elevation: *a* represents two triangular frames, on the top of which, in fixed bearings, the square horizontal bar *d* is made to revolve quickly, by means of a live and dead rigger *g*, worked by a strap from the steam engine, which strap is turned upon either rigger by means of the fork *h*, moved by its rod *m*, which sets the machinery in motion, or stops it at pleasure. There is also a self-acting contrivance by which the machine ceases to move on arriving at the end of the operation, as will shortly be described. The sliver prepared by the former machine is placed in the delivering can *e*; the end, passing thence over a roller, is received into a trumpet-shaped cone *f*, which has a vibratory action given to it by means of a short lever impelled by the small crank-wheel *i*, which, being cogged on its exterior edge, is made to revolve by the working of its teeth into an endless screw, attached to the end of the square bar *d*, and through which this is made to slide when it is drawn out for the purpose of removing the can *b*. On this bar, between two fixed ends or caps, is placed the filling can *b*, being secured to them firmly between four long bolts, and which thus acquires the quick rotary action of the bar *d*. The cap *e* next the vibrating trumpet is of a conical form; and within the can *b*, upon the square bar *d*, a solid metallic piston *k* is made to slide with some considerable resistance, caused by a spring *l*; one end of this piston being also conical, corresponding to the inner surface of the cap *e*, against which it is at first adjusted before the machine is put into action, when the end of the sliver is first passed through a slit in the cap *e*, and then tied to the piston: by the revolution of the bar and can, the sliver is then made to wind itself upon the bar *d*, and to be compressed at the same time between the cone *e* and the piston, while the small delivering end of the trumpet *f*, by its vibratory action, passes the sliver alternately up and down the conical surfaces, so that it is wound tightly upon the bar *d* in a series of conically spiral coils. The process of winding the sliver continues, and the piston is pushed before it until the can is filled with the sliver thus compressed, when the piston arriving at the spring *l*, acts upon the rod *m*, which throws the forked lever aside, and shifts the driving strap on the loose rigger *g′*, when the machine stops of itself. The boy in attendance then draws out the bar *d* by its handle, and releases the can *b* filled with its coil, which is removed and replaced by another empty can to have the same operation repeated.

The Spinning Machinery is exhibited in Plates XXX., XXXI., XXXII, and

XXXIII.; the plan being seen in fig. 1, Plate XXX., the front elevation in Plate XXXI., and the side elevations in Plate XXXII. It comprises twelve spinning tubes, and three winding drums: *a* represents the general framework, *l* the main driving shaft urged by the power of the steam engine by means of a strap, which is turned either upon the live or dead rigger *d d*, by the forked lever *g*, which is so arranged that the machine may be put in motion, or stopped at pleasure, by merely shifting the rod *h*, fixed above the revolving cans. Upon this main shaft *l* are twelve pulleys fixed at equal distances, in which endless cords work, that pass also in corresponding pulleys attached near the base of twelve vertical spindles provided with flaunches, which carry an equal number of cans *b*, previously filled with compressed sliver from the last described machine, and which are thus made to revolve with the speed required, in order to give a preparatory degree of torsion to the slivers. Upon the upper part of the frame as seen in the front elevation, exactly over the cans *b*, are twelve spring tubes or hollow spindles *e*, worked by small pulleys, by means of other endless cords that pass over corresponding pulleys fixed upon the shaft *o*, which shaft is driven by a strap upon a rigger *d′* from the before-mentioned rigger *d*. The sliver, already somewhat twisted by the motion of the cans *b*, receives a further degree of torsion by passing through the revolving hollow spring tube *e*, furnished at its apex with clipping jaws which grasp the thread, thus made to twist with great velocity, at the same time that the yarn so formed is subjected to a considerable degree of tension and compression by the following contrivance. Upon the opposite end of the shaft *l* is fixed another rigger *d′*, from which its motion is communicated by a strap to another corresponding rigger on the upper part of the frame, attached to which rigger is a pinion that works into a spur-wheel *p*, thus causing the revolution of the horizontal shaft *q*, furnished with twelve small double pulleys *q′*; nearly over this shaft are two other similar shafts *r* and *s*, each furnished with an equal number of single pulleys *r′* and *s′*, so that the newly spun yarn coming from the tubes *e* and the compressing jaws *f*, is made to pass over the pulley *r′*, under one of the grooves in the pulley *q′*, over the pulley *s′*, and again under the other groove in the pulley *q′*, which pulleys being made to revolve at equal speeds by the cog-wheels and pinions already described, thus cause a certain strain upon the yarns while they undergo the operation of twisting and compression.

The details of these contrivances are fully shown in figs. 1 and 2, Plate XXXIII., where fig. 1 exhibits an end elevation, as seen from the opposite side to that represented in Plate XXXII., in which all the several riggers and pinions are shown which drive the shafts *q*, *r*, and *s*. Fig. 2 shows a section of this portion of the machine through the revolving sliver can *b*, the spring tube *e*, the compressing jaws *f*, and the relative positions and action of the three sets of pulleys q', r', and s'. Fig. 3 represents on a larger scale the construction of the revolving tube *e*, with one of the clips thrown back to show the use of the springs, the same being seen closed in fig. 4, and the plan of the link in fig. 5, which is sometimes used in lieu of the springs, the plan of which is represented in fig. 6. Fig. 7 exhibits a plan of the compressing jaws *f*, and the mode in which these are tightened by a lever acted on by a weight.

The yarns being now completely prepared, remain to be wound upon the drums intended to receive them, which operation is simultaneously accomplished by the same machine. The mode in which this is effected is shown in Plates XXX. and XXXII., where are seen the three winding reels *c j*, each receiving at one time four yarns from as many spinning tubes *e* already described, and which are prevented from becoming entangled with each other by passing separately through corresponding holes in the register plate of the regulating bar *i*, (as shown on a larger scale in Plate XXX. fig. 3). The winding drums *c*, (shown also in section in Plate XXX. fig. 2,) though contrived so as to be easily removed, are carried upon a horizontal shaft, which is supported on short carriages, and worked by a rigger *k*, from a strap upon a smaller corresponding rigger fixed on the shaft *l*. In order that the yarns, as they are delivered from the spinning apparatus, may be equally wound upon all parts of the drum, a combination is ingeniously planned for giving the threads a successive motion to the right or left, when they are wound from one end of the drum to the other, and back again. The regulating bar *i*, moving in corresponding grooves of the carriages, has a right and left horizontal motion given to it, amounting to the length of each winding drum, for which purpose one end is made to project, where it is furnished with a toothed rack, that works in a small horizontal spur-wheel, whose cogs are impelled by a short endless screw working on the extremity of the drum-shaft. Attached to the lower part of the spur-wheel is a lever whose motion is regulated by proper guides, and which, when the rack has arrived at the termination of its action, causes a catch to act upon a tumbler which throws the weighted lever *p* on the opposite side, an action that at the same moment shifts the clutch *m*, which works on a feather upon the shaft, and being thrown either to the right or left, catches into and impels the small wheels upon that respective side, and thus reverses the motion of the endless screw, so that the horizontal wheel is made to turn alternately in opposite directions, communicating this reciprocating action laterally to the regulating bar *i*, which causes the yarns to wind upon the drum from left to right, and then from right to left, in succession.

The Winding Machine is very simple in its construction, and has a twofold object; 1st, to separate the four yarns previously coiled together upon each drum, as just described, and then wind them a second time upon distinct bobbins or reels; and 2ndly, by the same operation to reverse the lay of the yarns, so that in going through the subsequent process each may follow the same course in which it was spun, otherwise the ends of the fibres would be drawn out, and the strands would present a rough and unsightly appearance.

Fig. 1, Plate XXXIV., represents the plan of this machine; fig. 2 its front elevation; and fig. 3 its side elevation: *a* is the general framework; *b* a live and dead pulley, driven by the power of the steam engine, is fixed on the spindle of the drum *d*, which traverses the machine: over this drum are four endless straps *e*, passing also round four small riggers *f*, fixed upon the vertical spindles upon which the reels or bobbins *c* are secured. One of the drums filled with yarn is brought from the spinning machine just described, and fixed upon a temporary horizontal spindle running loose upon its own bearings, when the ends of the four yarns *k* are brought over a bar *p* belonging to the sliding frame *h*, and attached to the reels *e*. The spindles being now caused to revolve by the arrangements just mentioned, the yarn is made to wind itself upon each reel, and in order that all parts may be filled equally, the yarn is made progressively to rise and fall alternately by a motion for this purpose. Upon the opposite end of the drum-shaft *d*, from which the power is derived, is a bevel-wheel *l*, working into a similar one fixed upon an inclined spindle *m*, having at its lower end an endless screw which impels a toothed wheel *n*, and upon the spindle of this is fixed a heart-shaped cam *g*, upon whose periphery rests the end of a bent lever *i*, affixed to the spindle *k*, that traverses the machine: upon this spindle are two horizontal arms having their extremities jointed to two upright bars *h*, that slide in the guides *o*, and carry the transverse bar *p*, over which the yarns pass on their way to the reels: it is therefore evident that the rotation of the cam *g* acting simultaneously with the action of the bobbins, must communicate to the bar *p* a vertically reciprocating motion, by which the yarns become uniformly wound upon the reels.

SECOND.—THE ROPE MAKING MACHINERY.

This may be comprehended under two sections: 1st, the tarring and registering of the yarns into strands; and 2ndly, the laying of these strands, first into rope, and next into cables.

The machinery for registering is exhibited in Plates XXXVI., XXXVII., and XXXVIII., while the preparatory operation of tarring the yarns is explained in Plate XXXV.

The Tarring Process.—It is shown that the tarring house is separated from the adjoining room where the registering process is effected, by a secure partition, in order to guard against any accident from fire. A fire-place is constructed in the centre of the apartment, which is wholly protected by an arched enclosure of brickwork, the details of which are sufficiently given in the Plate. For the same reason, the manner in which the tar kettle is fixed in the brickwork, and is heated by the fire, needs no further elucidation.

In like manner may be seen the way in which the tar kettle is covered by a casing or funnel, which carries off the fumes of the heated tar through the roof into the atmosphere. Having ascertained the number of yarns required for the strand, according to the purpose for which it is destined, the same requisite number of reels filled by the machinery last described are arranged in several series upon a vertical square frame of wood, constructed for that purpose; a section of one of these series, and of the frame, being represented in Plate XXXV. at *a*, *a*.

The ends of all the yarns from these several reels are brought in a converging direction across the apartment to a square iron plate *b*, perforated with a number of round holes, and each yarn is made to pass through a separate hole: the ends are then brought in a parallel direction obliquely downwards to another similar plate *b′*, fixed in the middle of the tar kettle.

and are then directed horizontally towards and through another plate *b*″, perforated in like manner; then upwards obliquely through a fourth similar plate *b*‴, and afterwards they pass horizontally to a convex circular plate *c*, which is pierced in like manner with round perforations concentrically disposed, and through which the yarns are severally introduced, all converging thence into one common point through the register plate *d*, in which is a cylindrical tube of metal, fixed by its collar to a framework made for this purpose. All the yarns, thus brought together in many regular concentric series within this tube, here undergo a preparatory amount of torsion and pressure, and the strand thus formed is then conveyed straight to the register machine in the adjoining apartment, in order to undergo a further operation of twisting and compression. The object of heating the tar is twofold: 1st, to render it more fluid, and thus better able to penetrate thoroughly between the fibres of each yarn; and 2ndly, to communicate to the hemp such a degree of heat as will dispel both air and moisture, for which purpose the temperature is not suffered to descend below 212° Fahrenheit, a thermometer being placed in the heated tar to regulate the fire accordingly. The surplus amount of tar adhering to the threads is first scraped off in passing over the margin of the holes in the plates *b*‴ and *c*, and is further squeezed out by the compression of the united yarns in the register tube *d*. The strand thus impregnated with a full proportion of tar now passes on to the next operation.

The process just described is called the warm register, in which it is evident that the tar is made to fill all the interstices between the yarns, which become thus agglutinated into an elastic substance almost impenetrable to water or damp: this is especially well adapted for hawsers, standing rigging, and other kinds of cordage most exposed to the weather, and tends greatly to their durability; but it is found that in proportion to its impenetrability to the weather, it becomes more rigid, and therefore less applicable to running rigging, for which latter purpose what is called the cold register is much used. In this latter process the yarns are previously tarred, and then wound upon reels, which are fixed in a framework similar to that already described: the tar kettle and the four perforated plates *b* are altogether dispensed with, the tarred yarns being passed only through the circular convex plate *c*, with perforations concentrically disposed, and the register tube *d*, when the united yarns are forced into a strand, and subjected to the same operation of torsion as that of the warm register before explained.

The Registering Process. Plate XXXVI. represents the apparatus attached to the register machine, which, at the same time that it compresses the strand into a firm body, removes whatever superfluous quantity of tar may have remained from the previous operation. Fig. 1 offers a side elevation; fig. 2 a front elevation of the same; and fig. 3 the compressing parts in detail on a more enlarged scale: *a a* are two upright posts or jambs of wood, in which the apparatus is fixed; *b* is a rod with a pointed end pressing on the compressing dies, (which rod may be lengthened or shortened, if necessary, by a screw, as seen in fig. 3); *c* is the lower compressing plate or die, which is fixed to the framework, and *c′* is the upper plate or die, working vertically in a grooved guide; *d* is a horizontal lever acted on by a weight *e*, affixed at one extremity, while its other end resting in its fulcrum *f*, situated near the rod *b*, causes a considerable pressure upon that rod, and consequently on the die *c′*, between which and the die *c* the strand proceeding from the tarring house is made to pass; and while undergoing considerable pressure between these dies, all the superfluous quantity of tar, as before mentioned, is forced out, and allowed to fall into the can *g*: a cord *h* is attached to the lever *d*, near *e*, in order to relieve the pressure from the dies when required: *i* is the part of the machinery marked *a* in Plate XXXVII.

The registering machine is shown in plan in Plate XXXVII., while Plate XXXVIII. exhibits in fig. 1 a side view, and in fig. 2 another side view on the opposite side, after completing half a revolution upon its centres *b b′*. The purpose of this mechanism is to give the requisite degree of torsion to the united fascicle of yarns, simultaneously with the compression effected by the last described operation, and to wind the strand thus formed upon a drum in proportion as it is delivered from the register plate. *a* is a square frame of wood, supported horizontally upon two fixed gudgeons *b b′*, upon which the whole apparatus is made to revolve with some rapidity; the gudgeons working in Plummer blocks or bearings fixed on the framework. To the gudgeon *b′* is attached a shifting friction clutch *d*, which by means of the lever *f* is made to connect or detach at pleasure, so that the action of the machine may be stopped in the latter case, or put to work whenever it is coupled with the shaft *c*, which is impelled by the toothed wheel *i*, that in its turn is acted on by corresponding gear work moved by the power of the steam engine. It is therefore evident that by shifting the handle into the position represented in the Plate the entire apparatus attached to the frame *a* will acquire the same revolving action as the rigger *i*.

To the Plummer block in which the gudgeon *b* revolves is a fixed pinion *j*, into which works a toothed wheel *k*, fixed on a short spindle *l*, that is supported on competent bearings upon the revolving frame *a*: the action of *k* upon *j* therefore produces a sort of sun and planet motion, by which a rotary action is given to the spindle *l* proportionate to the velocity with which *a* revolves: upon *l* is fixed a bevel pinion l', which works another bevelled wheel m', attached to a spindle *m* that traverses the framework, and turns in its respective bearings. Upon this spindle is affixed a toothed wheel m'', acting upon a similar wheel n', which has its spindle *n* parallel to *m*; and in the middle of these two spindles are fixed two pulleys *o* and o', which thus acquire a simultaneous rotation proportioned to the speed of the framework *a*. The strand, therefore, entering through the gudgeon *b*, which is made hollow for this purpose, passes under and over the pulley *o*, and then again under and over the pulley o', so as to preserve an uniform tension when it passes over a guide frame *x* to the drum *s*, upon which it is wound by an action about to be described.

Upon the projecting end of the spindle *m* is a small mitre pinion, working into a similar pinion p', attached to a spindle *p*, which is fixed in a somewhat oblique position on the outer side of the frame *a*: this spindle *p* impels another spindle *q* continuous with it, to the end of which is attached a bevelled pinion q', that works into a bevelled wheel r', fixed upon the end of the spindle of the winding drum *s*. It is therefore manifest that, simultaneously with the revolution of the frame *a*, both the tightening pulleys *o* and o', as well as the winding drum *s*, have each their own distinct rotations. The bevel-wheel r' is of somewhat larger diameter than q', in the proportion that the diameter of the drum *s* bears to that of the pulleys *o* and o'; but it will be seen, that as the coiling advances, the diameter of the winding surface goes on enlarging, which would give an increased amount of tension to the strand, and subject it to an unfair strain, if a contrivance were not made to prevent such an occurrence: with this view the clutch *t*, which unites the spindles *p* and *q*, has two frictional surfaces, by which one part is allowed to slip upon the other, and overcome the resistance opposed to it, whenever the drum *s* has acquired a tendency to overwind the pulleys *o* and o'.

There now remains to be described the mode in which the strand, in being wound upon the drum, is made to pass gradually from one end to the other, and *vice versâ*, so as to produce a regular series of uninterrupted coils. On the opposite end of this drum to that already mentioned is a mitre pinion, impelled by another similar one attached to a short spindle *u*, which is furnished at its extremity with an universal joint, acting upon the forked end of an oblique spindle *u′*, which latter bears an endless screw working into a toothed wheel *v*; this wheel is fixed upon the end of a spindle placed across the frame *a*, which spindle carries a wooden roller *w*, that by such means is made to acquire a rotary motion, in a determined ratio to the revolution of the frame *a*. Upon this roller is a long oblique endless groove, in which a stud is made to act, that projects from beneath the under face of the reciprocating guide frame *x*, to which it is attached, and whose centre of vibration is at *x′*: it is therefore clear, that in proportion as the revolution of the drum *s* advances, the roller *w* receives from it a very slow rotary motion, while this in its turn communicates to the guide frame *x* a corresponding reciprocating action alternately from side to side.

Now it is manifest, that in proportion to the diameters of different kinds of strands, the time of this reciprocating motion must be varied, in order to produce a regular coil upon the drum, and very simple means are provided for effecting this by merely substituting for *v* another toothed wheel of a different diameter; and in order that the spindle *u*, with its spiral screw, may conform itself to any sized wheel *v*, the bearing or stud in which its end revolves is made to shift its position to any part of the segment *z*, in which it has a sliding motion, and where it is firmly secured by a screw, so that, however the spindle *u′* may change the obliquity of its position, it constantly receives an uniform impulsion from the spindle *u*, and readily adapts itself to such motion by means of the universal joint already described. At the extremity of the reciprocating guide frame *x* are two vertical rollers *y*, and another horizontal one *y′*, the use of which is to confine the strand, so that, whatever may be the angle in which it is conveyed from the pulley *o′*, it is always maintained in a position at right angles to the direction in which it is coiled upon the drum.

There is, besides, a very ingenious contrivance for measuring the length of the strand as it comes into the registering apartment, by passing over a pulley of a certain diameter, which sets in motion a series of wheels forming a kind of counter that expresses upon a dial the number of fathoms that have passed over the pulley: an index being set to the number required, an apparatus sets a bell ringing when the number of fathoms have been prepared, which enables the attendant to know when to stop the machine. The strand now prepared is wound off the drum *s* upon a loose reel, so that when transferred to the drum of the spole-frame it may become reversed, end for end, in which state it is ready to undergo the operation of being formed into rope.

The Rope laying Machine is shown in Plates XXXIX., XL., XLI., and XLII. Plate XXXIX. exhibits the general elevation; Plate XLI. in fig. 1 a section in plan through the upper portion, and in fig. 2 a section in plan through the lower portion of the machine. It is essential in the formation of a good rope, that each strand of which it is constituted should receive an equal degree of torsion and tension, and this is effected by means of a separate apparatus for each strand, while the results of these distinct actions are at the same time united by a general combination of these motions into one centre. This partial apparatus is called a spole-frame, and as it is usual to form a rope of three strands, three spole-frames are combined together in this machine. An elevation of one of these spole-frames is shown in fig. 1, Plate XL., where also are given details of some other parts of the machinery.

The solid foundation of stone and brickwork is shown in section in Plate XXXIX., in which the foot of the central fixed pillar *a* is firmly secured: this pillar, just above the masonry, has a circular bearing turned upon it, and is provided also with a strong flaunch on which the lower portion of the revolving framework rests. The summit of the pillar has another circular bearing on which the upper portion of the framework revolves. The lower part of this framework consists of a large iron bevel-wheel *d*, having a series of wooden cogs with their faces downward upon its outer rim, which is strengthened within by a broad expansion that serves to carry three vertical iron columns *b*, while its arms converge into a strong central bush or nave, by which the whole framework turns steadily round the central pillar. The three columns *b* support a horizontal iron frame above, which consists of six converging arms united by cross stays, and a central bush, by which it works steadily on the upright pillar *a*. The rotation of this open cage or framework, which is intended to carry the spole-frames, is effected by the working into the cogged rim *d* of a toothed bevel pinion *e*, which is impelled by the power of the steam engine.

The spole-frames are of cast iron, in form of a parallelogram, having, in the centre of their transverse top and bottom plates, firm gudgeons; the lower gudgeons work in three steps, formed on the internal rim of the wheel *d*, in intermediate spaces between the vertical columns *b*, while the upper gudgeons, which are hollow, work in Plummer blocks fixed to the arms of the upper framing, so that each spole-frame is thus allowed to maintain a gyratory motion of its own, which it acquires by means of a series of cog-wheels, both in the upper and lower parts of the general framework. *h* is a cog-wheel fixed upon the lower gudgeon of each spole-frame; an intermediate toothed wheel *g* is fixed upon one of the arms of the frame *d*, and works into *h*, as well as into the fixed central cog-wheel *f*. By an inspection of the plan it will be seen that the great frame is urged round by its cogged rim *d*, so that each intermediate wheel *g*, being made to revolve about *f*, acquires thus not only a general revolution around the central pillar, but a distinct rotary action about its own centre, which gyratory motion it communicates in an opposite direction to the wheel *h*, and consequently to the spole-frame *c*.

In the lower compartment of each spole-frame, in fixed bearings, is a drum *i*, upon which is previously wound a sufficient length of registered strand, prepared in the manner just described; and, in order to preserve a due strain upon the strand, so as to prevent its overwinding, friction bands *j* are adapted on one side of each drum, so that any degree of retarding force can be applied by merely tightening a screw; which parts are shown in detail on a more enlarged scale in figs. 2 and 3, Plate XL.

During the action of the machine each strand is wound off its drum by a set of two pulleys *k*, the position and action of which are seen very distinctly in fig. 1, Plate XL., an equal amount of motion being given to them by means of two cog-wheels *k′*, which are made to turn by the bevel-wheel *n* working into the bevel pinion *n′*, while this is impelled by a toothed wheel *o*, and this again is acted upon by a cog-wheel *p*, fixed on the upper gudgeon of the spole-frame, and *p* is set in motion by another system of gyratory wheels, similar to that already described as existing in the lower part of the framework. It is necessary to explain why (as seen both in Plate XXXIX., and in fig. 1, Plate XL.) there are two toothed wheels of equal diameter, *p* and *p′*.

upon the upper gudgeon of the spole-frame: the latter is destined to communicate the impulse from the gyratory system of wheels, while the former permits the action of *o* around *p* during the revolution of the spole-frame, which would otherwise be impeded by the intervention of the intermediate wheel that forms part of the sun and planet motion about the central pillar.

The three strands, by the contrivance already described, being thus gradually and equally drawn over by the pulleys *k*, now pass upwards through the upper gudgeon of the spole-frame, which is made hollow for this purpose, and then curving over a series of rollers *l*, which are fixed inclined in the varying manner shown in the drawing, in order to prevent the slipping off of the strands, now all unite into one common centre, and each by the peculiar revolution of its own spole-frame having received its proper amount of torsion, they are at this point, by the general rotation of the entire frame, all twisted together into a rope, which is carried upward to the apparatus shown in Plate XLII., there to undergo an equal strain upon all parts collectively, a principle essential to this system of rope making, that is applied in every stage of the process from the first spinning of the yarns.

In all the cordage made for the service of the British Navy, there is not only a coloured worsted thread introduced into the centre of each strand, but there is also a peculiar simple yarn laid in the centre of every rope, between the three strands, which affords a mark to distinguish it at all times from every other kind of rope: for the purpose of introducing this, a reel *m* of the intended yarn is fixed upon the end of the vertical central pillar *a*, immediately under the newly forming rope, which, as it proceeds, carries within it the distinguishing yarn from the reel just mentioned.

The details of the rollers *l* before described for guiding the strands, and preventing their slipping, are represented on a larger scale in fig. 4, Plate XL., which shows the form of the ball and socket ends, the mode of their support, and the gradual change of their inclination. In the same Plate, fig. 5, is seen the pulley for giving a certain amount of pressure upon the strand in the pulley *k*, as it comes from the drum of the spole-frame; and in figs. 2 and 3 are also shown the details of the clutch band *j*, fixed on one end of the same drum, the purport of which is already mentioned.

Plate XLII. represents the apparatus just alluded to for giving a proper degree of tension to the rope *j*, as it proceeds from the laying machine. A strong frame of cast-iron serves to support the gear work: *a* is the driving pinion, impelled by intervening gear urged by the steam engine: this works into a spur-wheel *b*, upon the shaft of which (*b′*) is a tension pulley *c*, and a toothed wheel *d*, into which work two other toothed wheels of equal size, *d′* and *d″*, and upon the spindles of these are two other tension pulleys *c′* and *c″*, similar to the former. Beneath *c″* is a roller *o*, fixed on a transverse spindle, whose bearings are made to shift upon the framework, so as to advance or throw back the roller, which must be so adjusted that the rope *j* in its ascent from the laying machine may bear on its periphery, and thus check any vibration it may have acquired at the point of union below. The rope *j* now passes over the pulley *c″*, under *c*, and then over *c′*, against the outer periphery of which it is subjected to the action of a compressing pulley *e*, this being fixed upon the end of an upright lever that forces it against the rope upon the rigger *c′*, by means of a strong spring, that by a screw may be tightened to any degree required. The end *k* of the rope is now finally coiled away to the storehouse adjoining.

To this apparatus is attached a barrel *g*, intended to afford the preparatory amount of tension before a sufficient length of rope is made to reach the end *k*. Upon the spindle of *g* is a rigger *g′*, round which is coiled a rope, proceeding from another rigger *g″*, upon the spindle of which at the opposite end is a ratchet-wheel *k*, into which the ratchet pall *l* catches, (it is represented in the figure as thrown back and out of use,) and which is moved by the lever *m*. On the spindle of the ratchet-wheel is a toothed wheel acted on by the pinion *h*, which may be worked by the handle *i* when it is required.

The Establishment of Deptford Dock-yard has three laying machines of this description, all similar in construction, but varying in size; the smaller one being used for cordage of ordinary size, the intermediate one for larger rope and hawsers, the more powerful one being chiefly employed in manufacturing cables and hawsers of large size. It is calculated that the latter will make about 2000 tons of cordage per annum, of 313 working days, taking the mean average of cables at from 14 to 24 inches, and hawsers at from 7½ to 12 inches; that the second machine will make about 700 tons of cordage per annum, taking the mean average of cable-laid rope at from 8 to 16 inches, and hawser-laid from 5½ to 7½; and that the smaller machine will prepare about 300 tons of cordage in the same time, taking the mean average of cablets at from 5½ to 7½ inches, and shroud-laid from 3½ to 5. The average cost of laying the rope, including all charges for officers, workmen, labourers, engine power, repairs of machinery, &c., which at present amounts to £1. 4*s*. per ton, would not exceed 17*s*. 4*d*. per ton, were the whole machinery employed to the fullest extent of its capability.

Although these three machines are able to provide with regularity the large amount of cordage above mentioned, which is sufficient to answer the demands of the whole British Navy, the spinning department has not yet been placed upon the same footing of capability, so as to supply them with the requisite amount of yarns, or furnish the quantity of strands necessary to keep all the laying machines in full work.

Some considerable difficulty was at first experienced with the spinning machinery, as it was found that the yarn produced by it was not of such regular texture, or equal in appearance to that spun by hand; such difference, however, exists no longer, for the yarn now formed at Deptford is said to equal the best handspun yarn made at Chatham and the other Government Yards; and there is no doubt but that as improvements are constantly in progress, it will soon altogether supersede the old method. At present there is only one set of spinning tubes, which make about 90 tons per annum, and as the expenses of this branch of the rope department at present amount to £340 per annum, it follows that the actual cost of spinning yarn is about £3. 15*s*. 9*d*. per ton: it is, however, calculated that if ten sets of spinning tubes were provided, the cost of labour, engine power, and repairs, would be about £2735, and the quantity of yarn produced would amount to 1000 tons per annum, giving a cost of £2. 14*s*. 8*d*. per ton, while, if as many as twenty sets were erected, these would afford an ample supply of yarn to keep all the laying machines in constant use, as there would be spun about 2000 tons of yarn per annum: in such case it is calculated that the expense of this branch of the establishment, including every charge, would amount to about £4650 per annum, so that the cost of the spun yarn would not exceed £2. 6*s*. 6*d*. per ton.

Upon the calculation of spinning and making 1600 tons of cordage per annum, we may safely estimate that the total cost of manufacturing rough hemp into different kinds of cordage would not exceed £4 per ton, exclusive of the value of the hemp and tar, while the cost of the same manufacture, in a merchant's yard, is ascertained to amount to £6. 10*s*. per ton, that is, £4 per ton for spinning and preparing the yarns, and £2. 10*s*. per ton for making the same into cordage. In Her Majesty's dock-yards it is estimated that the cost of converting the yarn into rope and cables amounts to £4. 7*s*. 3*d*. per ton, viz.,

Reeling	£1 0 0
Tarring the yarn	0 8 3
Warping	0 5 0
Registering and making strands	0 4 0
Laying the rope	2 10 0
	£4 7 3

The quantity of cordage expended per annum in all Her Majesty's dock-yards, on an average of three years, amounts to about 1800 tons, of which about 200 tons are below the size of 2¾ inches in circumference; the remaining quantity, 1600 tons,[1] may be arranged as follows:

Shroud-laid from 2¾ inches to 8½. Cable-laid 5½ inches to 16 = 1464 tons.
" " 9 " 12 " 17 " 26 = 136 "

Total demand . . . . 1600 tons.

Now the quantity of these descriptions of cordage that the second and third laying machines are computed to make, amounts to . . . . . 1151 tons.

The first being able to make . . . . . 2018 "

Capability of production . . . . . 3169 tons.

It will, however, be seen that the capability of the large machine affords the means of making nearly 15 times the quantity demanded for consumption of the size above quoted, while that of the two smaller machines falls somewhat short of the demand; but as it is at all times possible to change some of the wheels, so as to cause the large machine to manufacture a large proportion of the sizes of cablets and hawsers now apportioned to the second sized machine, the total quantity that all the three machines can be made to produce will not only answer the entire demand for the consumption of the naval service of Great Britain, but considerably exceed it, so as to be able to

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[1] Quantity of cordage consumed in one year, on an average of three years, in Her Majesty's dock-yards.

	CHATHAM.				PLYMOUTH.				PORTSMOUTH.				TOTAL.			
	tons.	cwt.	q.	lbs.	tons.	cwt.	q.	lbs.	tons.	cwt.	q.	lbs.	tons.	cwt.	q.	lbs.
Cable-laid 26 in. to 17 in. Shroud-laid 19 in. to 12 in.	19	1	1	14	23	0	0	0	93	18	2	12=	135	19	3	26
" 16 " 8 " 8½ " 6	135	10	3	4	184	0	0	0	163	12	0	13=	483	2	3	17
" 7 " 5½ " 6½ " 2¾	251	3	1	8	437	0	0	0	298	4	1	13=	987	7	2	21
Total	405	15	1	26	644	0	0	0	555	15	0	10=	1605	10	2	8

answer any extraordinary demands that may arise during sudden exigencies in time of war.

The comparative cost of making the total amount of cordage consumed in the service of the Royal Navy, when manufactured by the old methods practised in the other Royal dock-yards, and when made by the machinery now in use at Deptford Yard, may be estimated as follows:

Cost of reeling, 20*s*. Tarring, 8*s*. 3*d*. Warping, 5*s*.; and making strands, 4*s*. Total, £1. 17*s*. 3*d*.

For 1600 tons of cordage and shrouds, between 26 inches and 2¾ inches	£2980	0	0
Cost of laying ditto, at £2. 10*s*. per ton	4000	0	0
	£6980	0	0

Cost of the laying department in the rope making establishment in Deptford Yard.

Master rope-maker	£250	0	0
Foreman	200	0	0
Assistant foreman and kettleman	130	0	0
Leading man, 4*s*. per diem	62	12	0
Two men, first class, 3*s*. 6*d*. per diem	109	11	0
Two men, second class, 3*s*. 4*d*. per diem	104	6	9
Five labourers, 2*s*. 9*d*. per diem	215	3	9
Five boys, 1*s*. 6*d*. per diem	117	7	6
Engineer	77	15	0
Stoker	41	1	0
Coals for engine, 300 tons, at 18*s*., £270 0 0 Coals for tarring, 94 tons ,, 84 12 0	354	12	0
Oil for machinery	10	8	0
Repairs of machinery, &c.	240	0	0
Total cost of registering and laying 1600 tons of cordage by machinery, exclusive of cost of hemp and tar, nearly £1. 4*s*. per ton	1912	17	0
Difference in favour of new machinery	£5067	3	0

The relative cost of the two methods being in the ratio nearly of 7 to 2.

The machinery described in the foregoing pages embraces a regular and perfect system of rope making, from the beginning to the end: in the first place it cleans and combs the hemp, divests it of its loose splinters, disposes the fibres in a parallel and uniform direction, and spins them into yarn, with an equal degree of twist and tension; while the method of registering and tarring the yarns, and twisting them into one uniform strand, and the manufacture of such strands into ropes and cables by contrivances that maintain in every stage one continued strain, combined with an uniform amount of torsion, all contribute to the end desired in such manner that the elasticity of the fibres is preserved, and the whole strength of the hemp is maintained unimpaired in the cordage so formed. All these beautiful and happy combinations present altogether a perfection of system that is truly admirable, since the whole is founded upon scientific principles.

Having stated some of the advantages in regard to the economy of time and cost, which the machinery above described offers in the fabrication of cordage for the use of the Royal Navy, it now remains to examine the relative merit, in point of strength and durability, which rope so made possesses in comparison with that manufactured under the old system. In order to render this comparison the more manifest, it will be necessary to say something in respect to the principle upon which this new system is founded.

The invention was originally that of Captain Joseph Huddart, whose patent is now expired: the patent cordage has been severely tested, both in the Royal Navy and in the Merchants' Service, so that sufficient evidence upon which we may rely, both in favour and against the machine-laid rope, has been adduced, by which we are enabled to form a tolerably correct opinion on the subject.

One of the principal and earliest features in Captain Huddart's invention was that of the register, which was adopted with the view of keeping all the yarns separate from each other, for which purpose they were wound upon reels that remained at liberty to turn upon their own spindles, in such manner that each was allowed to contribute its exact length, and no more than was requisite, in the formation of an uniform twist, during the operation of making a strand. After the yarns were so arranged, the end of each was passed through the register plate of a somewhat hemispherical form, pierced with as many holes as there were yarns, which holes were made in several concentric circles, care being taken so to apportion the number of yarns in each circle, that they disposed themselves in as compact a form, and with as few vacancies as possible, round one common central yarn. The distance or diameter of each concentric circle around the adjoining one in the register plate was such as to allow the several series of yarns to arrange themselves at a determined angle, in order to give them a proper position to enter into the general twist now about to be given to the strand: this done, the body of yarns united for this purpose was received into a cylindrical tube, wherein they were made to undergo a certain degree of torsion, by which at the same time the whole was compressed into a compact body; and this gave to the strand so formed a truly cylindrical figure. Finally, a certain amount of *hard*, or greater degree of twist, was given to the strand, thereby increasing the angle of the outside series, with the view of compensating for the stretching of the yarns, and the compression of the strand.

For the purpose of ascertaining the number and position of the holes in the register plate, by means of which, in the formation of a strand, the yarns take their due position, and lay up at the exact angle necessary to secure an equality of strain, Captain Huddart adopted the following formula. Basing his system upon the rule established by long experience in common cordage, that in order to make rope compact and durable, the yarns composing a strand must be twisted until the proper amount of *hard* is given, that is to say, until they become shortened about $\frac{1}{5}$th of their length, prior to their being laid up,—hence he deduced as $5 : 4 :: \text{radius} : \text{cosine of } 36° \, 52'$, which he established as the proper angle for the lay of the outside series of yarns. Then making $a = 36° \, 30'$; $b =$ the number of yarns in that series; $c = 6{\cdot}3$, being nearly the proportion of the circumference of a circle to its radius; $x =$ the circumference of the strand; $y =$ the length of one turn of the strand. Then as cosine $a : \text{radius} :: b : \frac{\text{rad.} \times b}{\cos. a} = x$; and as $\text{tang.}\, a : \text{rad.} :: x : \frac{\text{rad.} \times x}{\text{tang.}\, a} = y$, the length of one turn, and as all the yarns have one turn in the same length, we have only to reduce the circumference of the strand x to that of any other series, as $x - c$; $x - 2\,c$; $x - 3\,c$, &c.; supposing the circle to be in the centre of the yarns of each series. Therefore as $y : x - c :: \text{rad.} : \text{tang.}\, a'$ the angle of the 2nd series, and as $\text{rad.} : \cos.\, a' :: x - c :$ the number of yarns in the 2nd series, and so on for the remainder.

Thus, let $a = 36° \, 30'$, and $b = 40$ yarns; hence
$\frac{\text{rad.} \times 40}{\cos.\, 36° \, 30'} = x = 49{\cdot}7$ and $\frac{\text{rad.} \times 49{\cdot}7}{\text{tang.}\, 36° \, 30'} = y = 67{\cdot}25$. Therefore

$x \quad = 49{\cdot}7$ and $\dfrac{x\,R}{y} = \text{tang.}\ a$ $36^\circ\ 30'$. $\text{cos.}\ a \times 49{\cdot}7 = 40$ or 40 yarns in the 8th series.

$x - \ c = 43{\cdot}4$ and $\dfrac{x - c\,R}{y} = \text{tang.}\ a'$ $32^\circ\ 50'$. $\text{cos.}\ a' \times 43{\cdot}4 = 36{\cdot}47$ or 36 " " 7th "

$x - 2\,c = 37{\cdot}1$ and $\dfrac{x - 2\,c\,R}{y} = \text{tang.}\ a''$ $28^\circ\ 52'$. $\text{cos.}\ a'' \times 37{\cdot}1 = 32{\cdot}485$ or 32 " " 6th "

$x - 3\,c = 30{\cdot}8$ and $\dfrac{x - 3\,c\,R}{y} = \text{tang.}\ a'''$ $24^\circ\ 36'$. $\text{cos.}\ a''' \times 30{\cdot}8 = 28{\cdot}005$ or 28 " " 5th "

$x - 4\,c = 24{\cdot}5$ and $\dfrac{x - 4\,c\,R}{y} = \text{tang.}\ a''''$ $20^\circ\ 1'$. $\text{cos.}\ a'''' \times 24{\cdot}5 = 23{\cdot}02$ or 23 " " 4th "

$x - 5\,c = 18{\cdot}2$ and $\dfrac{x - 5\,c\,R}{y} = \text{tang.}\ a'''''$ $15^\circ\ 9'$. $\text{cos.}\ a''''' \times 18{\cdot}2 = 17{\cdot}57$ or 18 " " 3rd "

$x - 6\,c = 11{\cdot}9$ and $\dfrac{x - 6\,c\,R}{y} = \text{tang.}\ a''''''$ $10^\circ\ 2'$. $\text{cos.}\ a'''''' \times 11{\cdot}9 = 11{\cdot}72$ or 12 " " 2nd "

$x - 6\tfrac{1}{2}\,c = 8{\cdot}752 \times 0{\cdot}7958 =$ area of unity . . . . $= 6{\cdot}085$ or $\left\{\begin{array}{l}\text{5 " " 1st "}\\ \text{1 central yarn.}\end{array}\right.$

Comprising a strand of 8 series of yarns around a central one, or in the whole . . . . . . } 195 yarns.

Where the angle of a series comes out less than 12°, it is only necessary to find the area of that vacancy by deducting $\frac{1}{2}\,c$, and thus the number of yarns to fill it, which may be disposed around one as a central axis. It will be evident that the length of the yarns, though equal in each circle, will vary in the eight different series, increasing gradually outwards; the exterior ones being generally about $\frac{1}{5}$th longer than the central yarn, which remains pretty nearly equal to the length of the strand, at least never varying beyond a difference of 1 foot in the length of 85 fathoms, or 1 in 510, a difference of trifling amount, arising probably from some small irregularity in the diameters of the several surrounding strands, by which the central yarn may be thrown out of its true centre by an almost imperceptible quantity, but the sum of which several minute deviations may amount to the insignificant diminution of length stated.

His next step toward improvement was the adaptation of the registering apparatus at a short distance from the tube, and the winding of the strand so formed upon a drum, subjecting it in the interim to a considerable tension, a contrivance that ensured one common uniformity of twist and diameter from one end of the strand to the other, which could never be attained to the same extent while the strands were made on the ordinary rope grounds, where they remained extended a length of nearly 1000 feet, offering, from several causes, a variable degree of elasticity, and an uncertain amount of tension in different parts of the strand.

This was combined with his invention of the warm register already described, which occurred to him upon considering that the body of yarns of which a rope is constituted can never be brought together in a cold state without leaving considerable vacancies, into which water must enter while the rope is exposed to the weather, and engender decay from fermentation, caused by the included moisture: he therefore conceived that by the immersion of the yarns in heated tar, and subjecting them to the requisite amount of torsion while still warm, giving them at the same time a sufficient amount of compression, and winding the strand so formed as above alluded to, the strands would by such means retain not only the proper degree of elasticity, but all parts of the combined fascicle would be brought to support an equal strain throughout when in use. The consolidated body of yarns so prepared was proved upon trial to be much stronger than when made by the cold method, and was more especially adapted to standing rigging, shrouds, &c.; a fact soon acknowledged by all, it being found that the durability of cordage so exposed was greatly increased, and that it did not stretch by exposure to the weather or the continued action of tension, like all other rope,—a circumstance of the utmost importance in a nautical point of view.

The success obtained by Captain Huddart in the application of this mode of registering induced him to apply the same principle to the laying of rope, and he accordingly invented the laying machine before described, which originated in deep reflection, and profound investigation into the circumstances essential to the formation of sound and efficient cordage, and brought the art of rope making to a high degree of perfection. This machine, by the action of the spole-frames, provides that an exactly equal degree of *hard*, or twist, shall be given to each strand, which is so disposed that it shall contribute, in proportion as it is required, just the proper amount of its length, and which is always placed at the precise angle that enables it to enter into its true position in the act of laying the rope, which takes place in a contrary direction by the general revolution of the entire machine; arrangements being provided that at the same time the rope is made, it shall be subjected to the action of such an amount of tension upon drawing pulleys, as will enable it to exert and retain its elasticity in all the positions to which in use it is likely to be exposed. The system, although founded upon such manifestly scientific principles, for some time encountered considerable opposition, owing to long existing prejudices; but its merits were at length appreciated, and it has finally established a lasting monument to the fame of its ingenious inventor.

Cordage may be classed under two kinds: cable-laid, and shroud or hawser-laid; the former being composed of 3 primary strands that are each formed of three simple strands, of a certain thickness: a shroud-laid rope consists of 3 simple strands, composed of as many yarns as may be necessary to constitute the diameter required: 30 fathoms of yarn are calculated to form 18 fathoms of cable-laid rope, or 20 fathoms of shroud-laid. Cable-laid ropes, measuring between 1 and 10 inches, are generally termed cablets, those from 10 inches upwards being called cables; shroud or hawser-laid rope seldom exceeds 10 inches in girth. The rule for finding the number of yarns for each strand of different sized 3-strand shroud-laid cordage is as follows, the diameter of the yarns being designated by a certain numbered thread:

Thus, for 20-thread yarn as $10^2 : 216$ threads $:: 6^2 : 77$ threads in each strand,
,, 25 ,, $10^2 : 272$,, $:: 8^2 : 174$,, ,,
,, 30 ,, $10^2 : 334$,, $:: 9^2 : 270$,, ,,
,, 40 ,, $10^2 :$ $:: 4^2 :$

and the following is the weight of the various sized threads of 170 fathoms in length:

20-thread yarn = 3·5 lbs. not tarred, or 4·2 lbs. tarred.
25 ,, = 2·77 ,, — 3·33 ,,
30 ,, = 2·33 ,, — 2·8 ,,
40 ,, = 1·75 ,, — 2·1 ,,

In order to find the length of strand required for any 3-strand hawser-laid cordage, it is the practice in the Government yards to estimate, as 152 is to 113, so is the length of strand to the length of rope desired: thus for a rope 80 fathoms long, as 113 : 152 : : 80 : 107·6 fathoms of strand. In private establishments the rule is to multiply the length of rope required by 7, and divide by 5, for the necessary length of strand. The rule for cable-laid cordage in the public service is as 152 to 101, for the length of the strands, to that of the cable: thus for 90 fathoms of cable, as 101 : 152 : : 90 : 135 fathoms, which is the length that the strands require to be made. The rule in private establishments is to multiply the length of cable required by 3, and divide by 2, for the length of the strands.

In all the methods of rope making previously in operation, it was necessary to have an uninterrupted range of buildings upwards of 1000 feet in length, it being essential that all the yarns of which cordage is composed should be stretched out their entire length of 180 fathoms. A number of yarns with their ends upon a hook were made to receive a certain degree of torsion, in a direction contrary to the twist of the yarns; and as under this operation they necessarily became shorter, the general supports upon which the ends remained secured were attached to sledges that moved with considerable resistance, so that they could approach each other in proportion as the threads by twisting became shorter: hence, as all the yarns in the beginning were carefully adjusted to an equal length, it followed, that from the very commencement of the operation of laying a strand, the outermost series of yarns necessarily coiled round a larger diameter than the more internal ones, and consequently became much tighter, while the inner yarns were rendered more slack. To remedy this inconvenience, it was customary to reduce the slack of each loose yarn by making a hitch in it, the loop of which was held by the loop of another slack yarn, hitched up for the same purpose, and so on in succession during the process, an operation called *lacing;* but still there remained always a number of yarns tighter than others, which increased as the formation of the strand neared its completion. When, therefore, such strands were subsequently combined into rope, it always happened that the whole resistance fell upon the outer series, while the more central yarns bore no part of the strain: those yarns, therefore, subjected to so unfair a pressure, necessarily gave way in succession, and the rope soon became worn out. Many contrivances were brought forward with the view of remedying this great defect. Among others, the principle of subdividing the number of yarns composing a strand into smaller fascicles of from 5 to 10 each, which received individually in succession a small amount of twist; and all these were again collected into one common bundle, when the remaining amount of twist was given to the whole combined into a common strand. This method, called the *selvagee* system, equalized more than formerly the length of the yarns, but though the old defects were in some degree remedied, they were not entirely removed. Similar inconveniences arose in the formation of rope, from causes of much the same origin; for some of the strands, in undergoing the operation of twisting, became shorter than others, so that it became necessary either to untwist the shorter ones, or to give more torsion to the slacker strands, which, becoming harder twisted than the others, took a more central position in laying up, while those least twisted fell into a more external position than they should have done, so that the rope, instead of presenting regular spires, became indented in some parts, and assumed the distorted appearance called *cockling*: such rope, when put to use, soon wore out, in consequence of all the strain being thrown upon the tighter strands. In making cable-laid rope, it was usual in the old system to twist the 3 strands at both ends, in contrary directions, until what was called the *hard*, or preparatory amount of twist, was obtained by each separately, which generally took place when they became shortened about $\frac{1}{10}$th part of their length. Then the ends attached to the sledge were combined, and hooked upon a single revolving centre, while the other ends of the strands remained distinct upon their respective hooks, by means of which the additional degree of torsion was yet to be given. When the *hard* had been attained, it was customary to put in what was called the *top*, which was a cone of hard wood with 3 longitudinal grooves, which was thrust between the strands close to their point of junction: the other ends of the strands, by means of their several hooks, were twisted by winch handles, another workman grasping all the while the *top* firmly in both hands, and advancing it gradually as the 3 strands behind the top twisted of themselves in an opposite direction, and formed the rope; and as there was always a certain degree of friction both at the top and against the revolving collar, it was always assisted by a winch, turned by hand, to maintain the natural degree of twist as it was produced.

With the view of correcting the defects before spoken of, a contrivance called the *aftertwist* was tried in addition to the remedies already mentioned, and this met with some success. This designation was given in contradistinction to the *foretwist*, which was the appellation of the turn which the 3 strands severally received in the process of laying rope. The aftertwist was effected by giving a more rapid motion to the handle of the collar bearing the united strands as soon as the laying of the rope commenced: this was in fact anticipating a portion of the twist which the strands had to receive by means of the foretwist; and it was given with the view of easing the foretwist, and rendering the strands more pliable, so as to enable them the better to take up their position in the lay.

Although ameliorated by such means, the same defect of principle still remained; indeed, it was impossible to foresee how much one strand would shorten more than another, and it is manifest, that whenever the tension of one strand varies in respect to that of another, however small in degree, the result must be a distortion in the rope, and a consequent inability to bear the strain equally upon all its parts alike. Indeed, it cannot be denied that the soundness of cordage made upon the old system depends wholly upon the art of the rope-maker, and the degree of vigilance exerted upon the occasion; for so many partial corrections and compensations require to be made, and varied at every stage, that it is essential that the eye of the master rope-maker be directed constantly to every part in succession, when he must give instructions to his different workmen when, and to what extent, such partial corrections are necessary.

Since the art of rope making upon the old plan depends upon so many contingencies, it is manifest that cordage so prepared can never be depended on to the extent, and with the same degree of confidence, as the rope manufactured by the unerring regularity of machinery.

In order to maintain the utmost possible uniformity in the elasticity of all the yarns combined, it is customary to cause not only the sledge to which the separate ends of the yarns are attached, but that also carrying the top, which regulates the lay of the strands, to travel on a kind of tramway, and in order to give these a sufficient degree of adhesion to the trams, or floor, so as to provide a due maintenance in the uniformity of the tension, weights are placed upon them, until they acquire the exact amount of resistance; but it is found necessary to alter this pressure in different parts of the process, as well as to vary the angle at which the yarns take their position in the strands, which is regulated by the amount of torsion given to the yarns; and the same caution is necessary in regard to the angle which the strands assume in forming a cable; the whole of which compensations, in addition to those already described, must be regulated by the skill of the master rope-maker, all tending to increase the difficulties and nicety of this art.

In order to afford an idea of some of these various accessory compensations, we derive from a statement made by an officer of Portsmouth Dock-yard, the following precautions there adopted in the formation of a cable 100 fathoms long. The length of the lessoms for this purpose should be 152 fathoms, which are laid at an angle of 27°; what is technically called *hard* (an increased amount of torsion) is given until each strand is shortened the length of 10 fathoms, when the angle must be 37°: in making the strands, the sledge travels 24 fathoms, and the angle when made should be 32°: in laying the cable, the length of the strands thus formed amounts to 118 fathoms, and the angle, when hard, should be 40°: the length of the cable, when finished, turns out generally 101 fathoms, the strands entering with an angle of 35°, while laying, and finishing at one of 38°.

Now it is to be observed, that the *press* (or weight placed upon the sledge) for the strands of a 12-inch cable commences at 60 cwt., which, at 5 fathoms length, is reduced 10 cwt., and at 7½ fathoms another 10 cwt., so that the press, when the strand is *hard*, is 40 cwt., which, when it "lays well," is reduced another 10 cwt., leaving 30 cwt. for the press for the remaining distance: in laying the cable, the press begins at 160 cwt., is reduced at 1½ fathom 10 cwt., taking off another equal weight at 2 fathoms; and when the cable is observed to "lay well," another reduction of 10 cwt. takes place, leaving a press of 130 cwt. for the remaining length of cable.

These remarks are offered to show how much depends upon the skill and attention of the master rope-maker, who, in regulating the fabrication of cordage, can establish no fixed rules; indeed, in the practice of his art every thing depends on his tact and judgment.

The comparative advantage of the improved system will therefore be the more apparent, when it is seen to be free from all such embarrassing contingencies, and to be in no way encumbered by rules so fallible and uncertain in their nature. It has, however, been objected by the advocates of the old system, that in Captain Huddart's method there exists no means of compensating for the twist, should the strands not prove exactly of equal diameter, while the ropes made by hand can have any irregularity in that respect easily removed; but to this objection it has been answered, "that the strands receive that degree of twist which is necessary, are laid at any angle with the greatest regularity, the pressure is regulated to give the required degree of elasticity, and all parts of the rope are made to bear equally; in no instance has a rope or cable thus formed been found defective in the lay, or stiff, or difficult to coil." By the supporters of the old system it is again urged, "that all the 4-strand hawser-laid rope is laid at an angle of 41°; after it is thus laid up, we apply the aftertwist, until the angle in the lay is brought to 45°; the reason of bringing in the lay of 45° is to ease the foretwist, which has the effect of preventing the rope from snapping off short, also the external yarn from breaking when belayed round a cleat or bit-head, and also causing the rope to work with greater pliability. The 3-strand rope is laid up at

to temper this with an admixture of Stockholm tar, especially every time it is again heated, in order to retain its preserving qualities. When so managed, cordage thus prepared is found equal in strength and durability, for a similar period, to any rope made in the most careful manner by the cold register.

There is a considerable difference in the weight of common cordage and that prepared by the register, of equal girth, containing the same number and quality of yarns: thus from experiment it has been ascertained that 5 fathoms of

3-inch	common cordage	weigh	11¾ lbs.,	while registered cordage	weighs	11¼ lbs.
3½ ,,	,,	,,	16 ,,	,,	,,	15¼ ,,
4 ,,	,,	,,	20½ ,,	,,	,,	19½ ,,
4½ ,,	,,	,,	26 ,,	,,	,,	25 ,,
5 ,,	,,	,,	32½ ,,	,,	,,	31 ,,
6 ,,	,,	,,	46½ ,,	,,	,,	44 ,,
6½ ,,	,,	,,	54 ,,	,,	,,	50½ ,,
7 ,,	,,	,,	62½ ,,	,,	,,	58½ ,,
8 ,,	,,	,,	82 ,,	,,	,,	77 ,,

This difference in weight arises from the common rope having, as before shown, a greater length in the central yarns, which increases the weight of large rope about 7½ per cent., and which adds also not only to the expense, but to a loss of strength, as it has been demonstrated that the central yarns bear no part of the strain, which is thrown entirely upon the outer series. Large ropes of registered cordage are, on the contrary, not only lighter, but will certainly bear a far greater strain, because from the very principle upon which the cordage is manufactured, every yarn individually and collectively throughout the rope is made to support an equal strain, a fact that is proved by numerous experiments.

In proof of this assertion the following tabular view is offered, showing the comparative strength of cordage made by the old method, and by the registering process and laying machine of Captain Huddart's invention, from trials made in the presence of many competent judges, and offering the mean results of 300 experiments; and as these statements have never been controverted, we may assume them to be established facts.

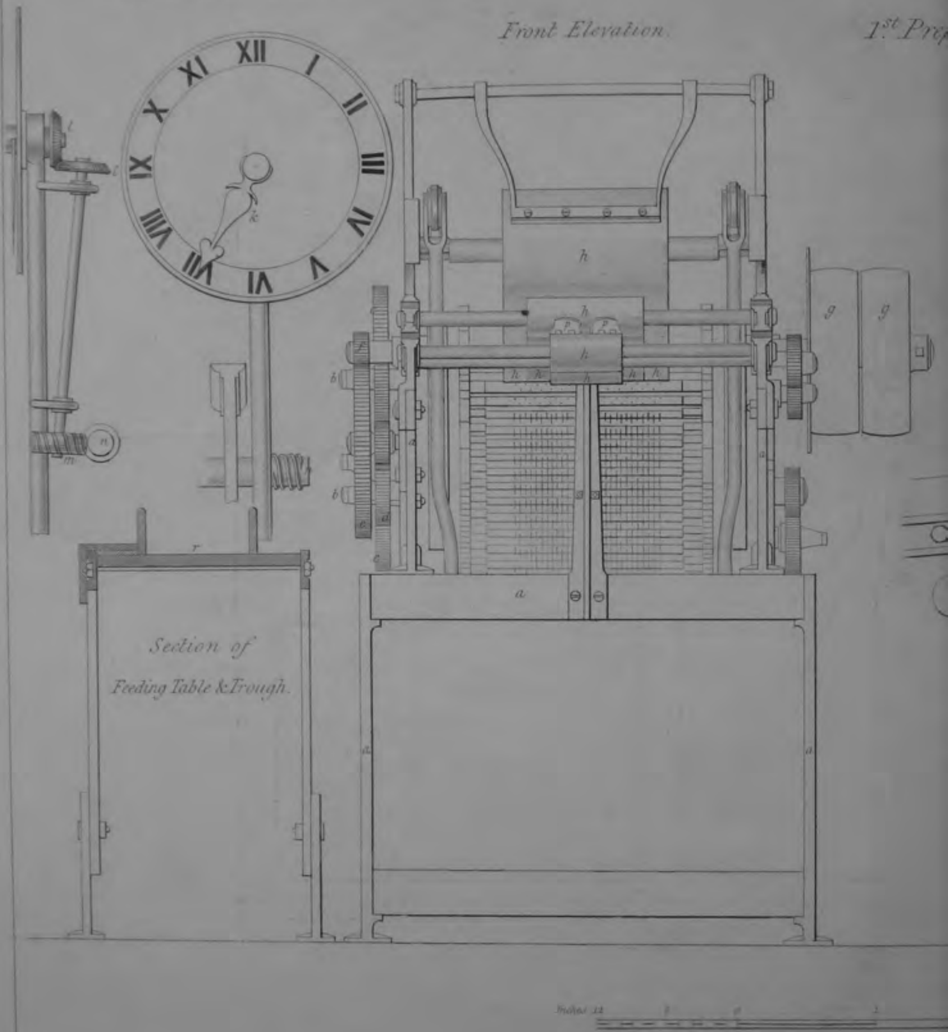
Table of the weight in pounds required to break different kinds of cordage.

Size of ropes in		Made by old method.				Made by patent register.			
girth.	diameter.	Common staple.	℔ $\frac{1}{10}$th of a circular inch in area.	Best Petersburgh hemp.	℔ $\frac{1}{10}$th of a circular inch in area.	Cold register.	℔ $\frac{1}{10}$th of a circular inch in area.	Warm register.	℔ $\frac{1}{10}$th of a circular inch in area.
in.	in.	℔s.	℔s.	℔s.	℔s.	℔s.	℔s.	℔s.	℔s.
3	0·95	5050	561	6030	670	7380	935	8640	960
3½	1·11	6784	554	8669	707	11165	911	11760	906
4	1·27	8768	548	10454	653	13108	819	15360	960
4½	1·43	10908	504	12440	614	16325	806	19440	960
5	1·59	13250	530	15775	631	20500	820	24000	960
5½	1·75	15488	512	18604	614	24806	820	29040	960
6	1·91	18144	504	21616	600	24520	820	33120	920
6½	2·07	20533	486	23623	559	34645	820	40554	959
7	2·24	22932	468	27342	558	40188	819	47040	960
7½	2·39	24975	444	30757	546	46125	820	54000	960
8	2·54	26880	421	32000	500	52480	820	61430	960

Opposite to the absolute cohesive power of different kinds of rope will be seen affixed the degree of relative strength of each sort, adopting as a standard of comparison an area of 0·078 inch, or $\frac{1}{10}$th part of a circular inch, or nearly $\frac{1}{13}$th of a square inch, that being equivalent to the rope-maker's rule in such cases, which is, to divide the number of pounds required to break a rope by the square of its girth in inches. These results offer the most undeniable proof of the superiority of the cordage made by the registering process over that laid by the ordinary method; for by the latter, from an increase of size amounting to three times its diameter, a rope will be seen to lose more than one-fourth of its strength, owing to the strain being thrown chiefly upon the more external yarns, while the registered cordage will be found to possess one uniform degree of strength throughout its entire substance, an equal strain being thrown upon all the yarns collectively, whatever be the diameter, offering most satisfactory evidence that the system is complete as regards perfection of manufacture; and on the contrary, that the system upon which the old method is founded is defective in principle, and inferior to the improved method in every point of view.

ROPE

1st Prep



Register Dial and Gear.

Front Elevation.

Section of Feeding Table & Trough.

[illegible]

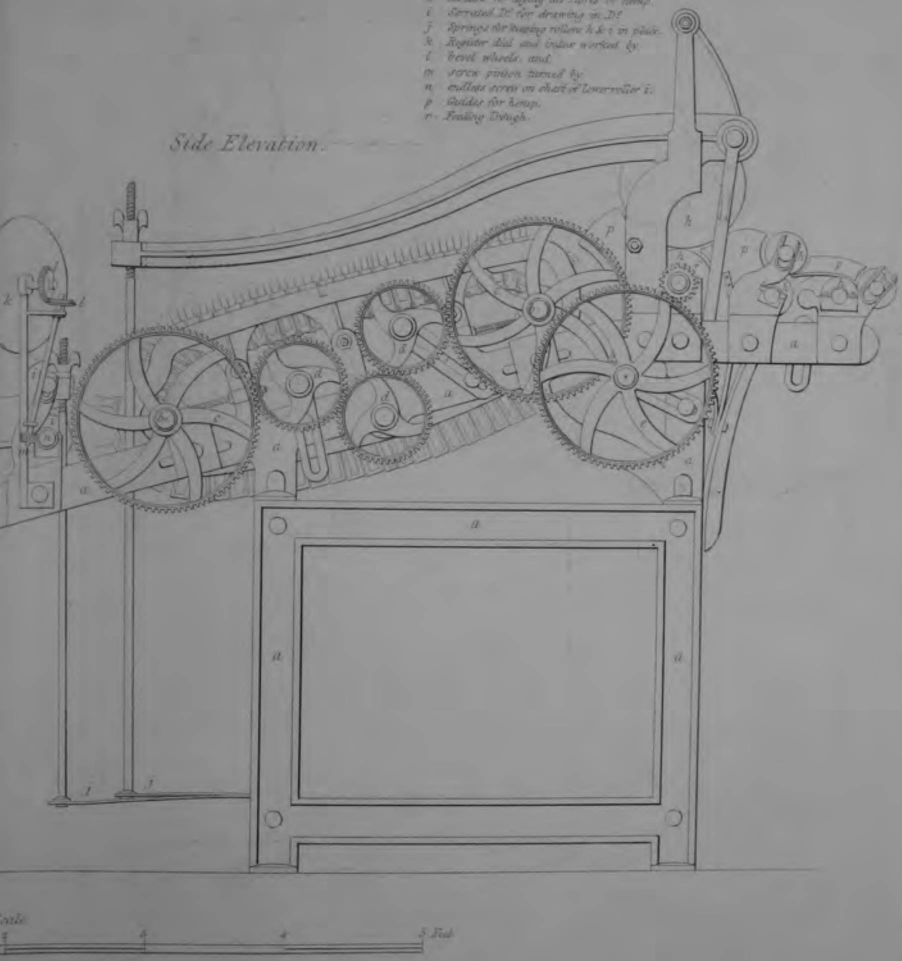
Published by John

CHINERY.

g Machine.

a Frame
b Shafts of the Wipers on which
c gear wheels are fixed.
d Intermediate gear.
e Wheel for multiplying the velocity.
f Pinion working c, and having
g riggers at other end of shaft.
h Rollers for laying the fibres of hemp.
i Serrated Do. for drawing in Do.
j Springs for keeping rollers h & i in place.
k Register dial and index worked by
l bevel wheels, and
m screw pinion turned by
n endless screw on shaft of Lower roller i.
p Guides for hemp.
r Feeding Trough.

Side Elevation.



[illegible] sculp.

, High Holborn. 1841.

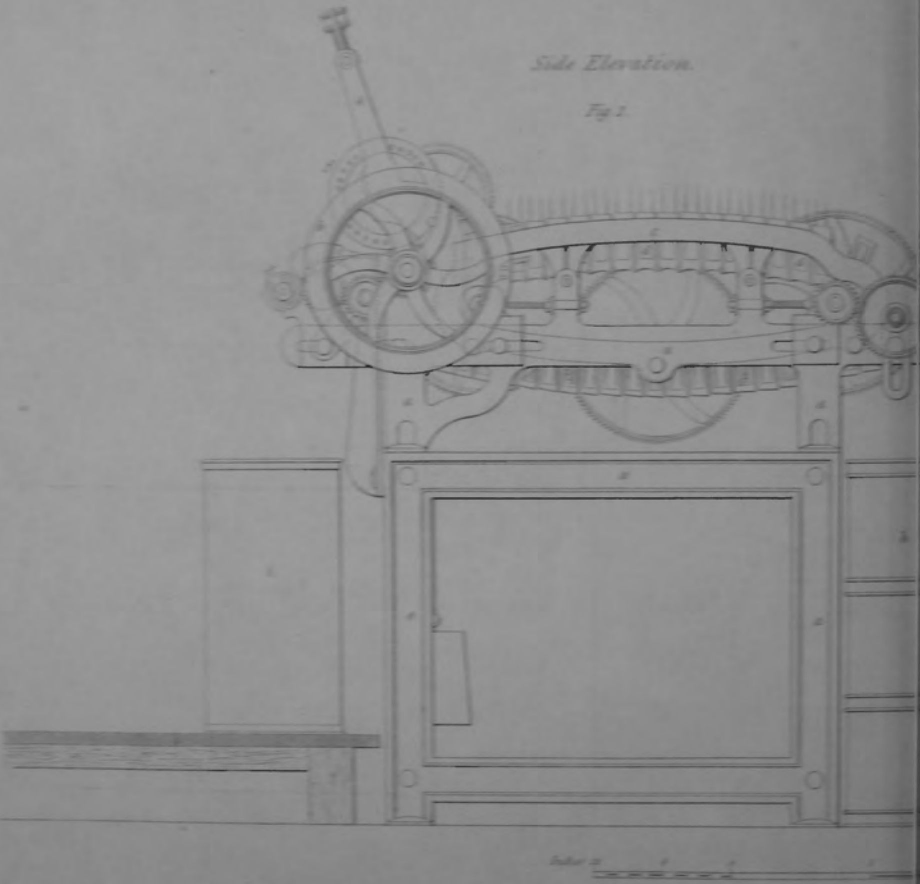
a Frame
b Rippers
c Faller
d Links
e Guides
f Rollers
g Conical die
h Delivering can
i Filling can
j Spring for pressing rollers upon Faller

ROPE MA

2nd Preparin

Side Elevation.

Fig. 1.



[illegible] del.

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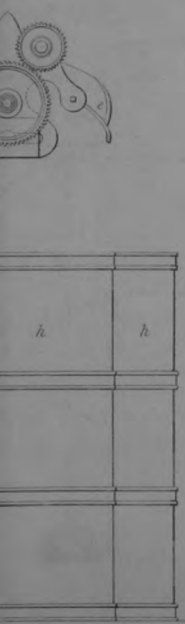
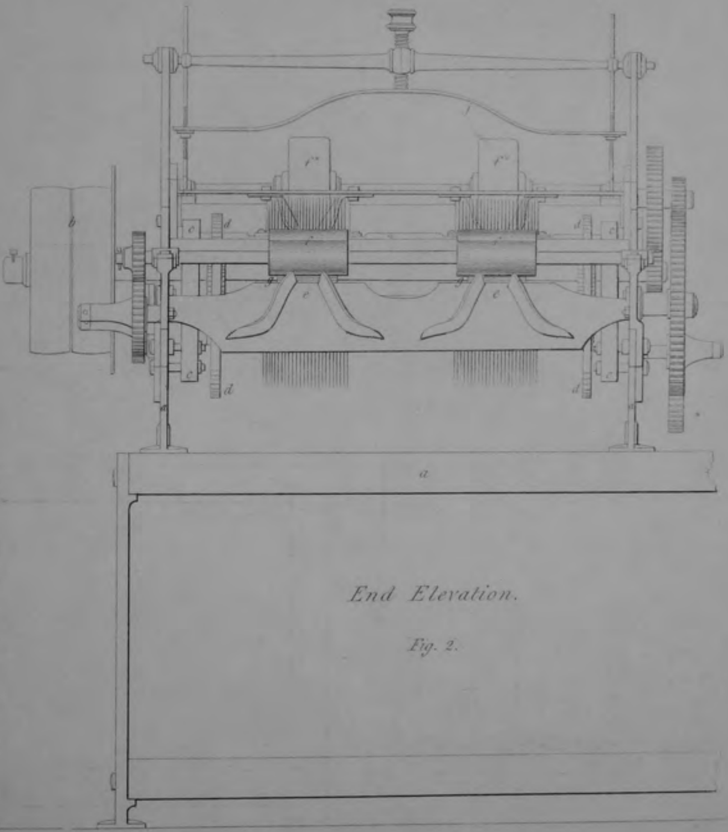
Plate 97.

INERY.

Machine.





End Elevation.

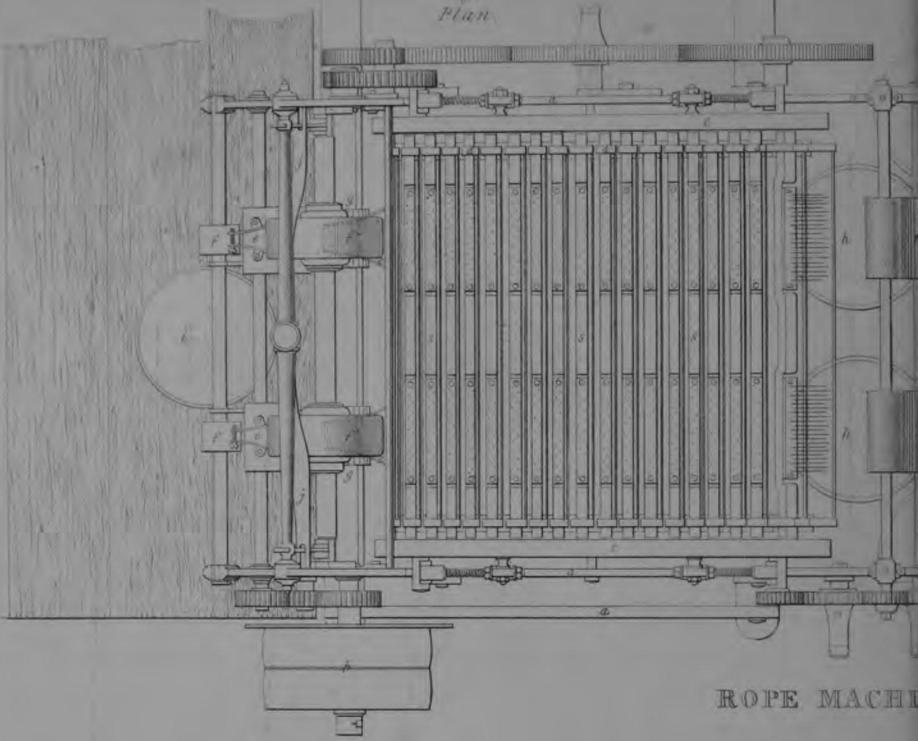
Fig. 2.

2 3 4 Feet

J. H. Le Keux sculp

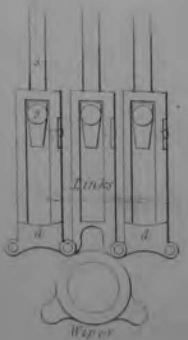
High Holborn 1841

Fig 2
Plan

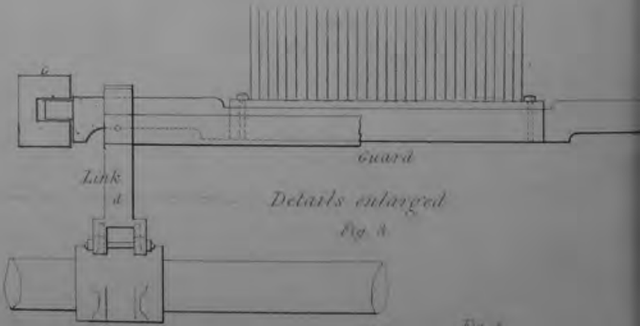


ROPE MACH

2nd Preparing M



Wiper
Fig. 5



Details enlarged
Fig. 3

Fig. 4

RY.

ie.

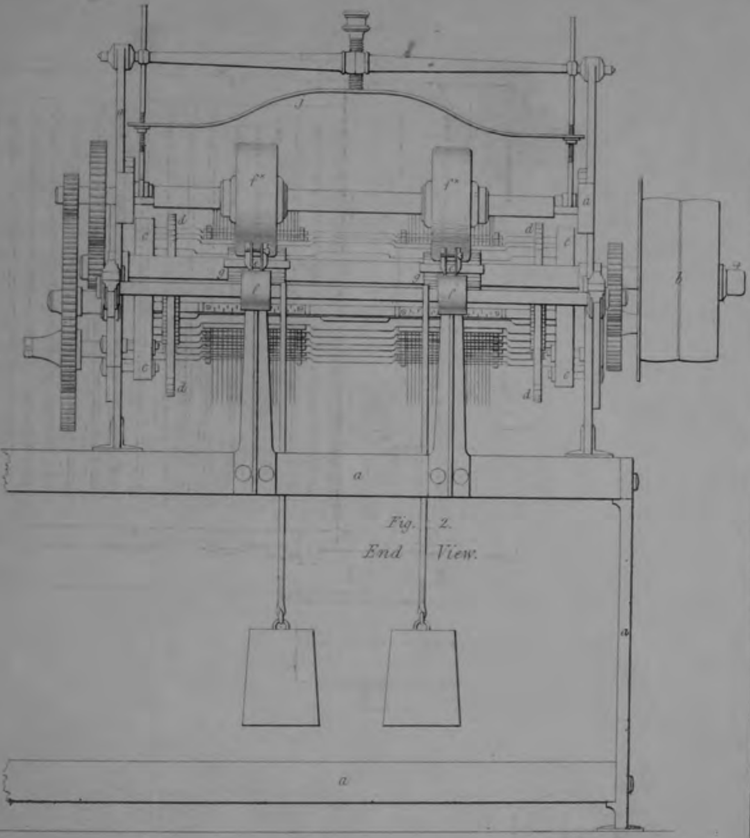
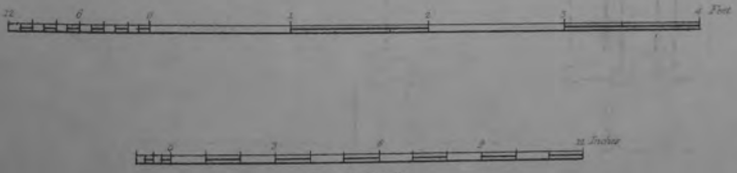


Fig. 2.
End View.



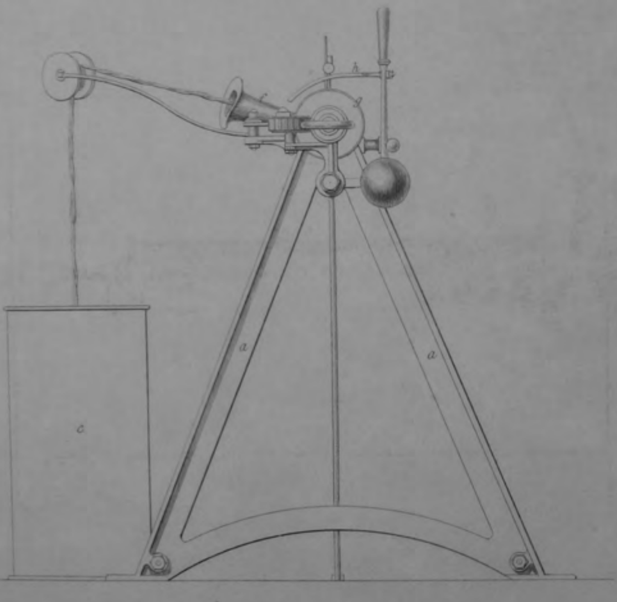
Scale for Details.

J.H. Le Keux sculp.

High Holborn 1841

ROPE MA

Sliver C



a	*Frame*
b	*Can filling*
c	*Can delivering*
d	*Traversing rod*
e	*Cover of grooved co*
f	*Vibrating feeder*
g	*Dead and live rigg*
h	*Shifting fork*
i	*Crank Pinion*
l	*Spring*
m	*Rod & shifting for*

Elevation.

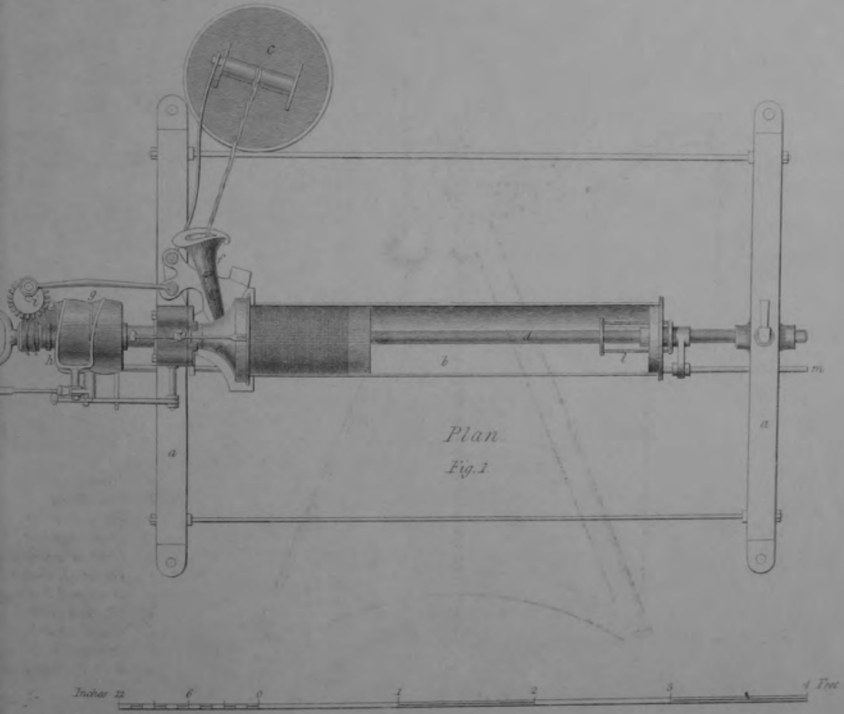
Fig. 2.

G.D. Dempsey. del.

Published by John

INERY.

resser.



Plan

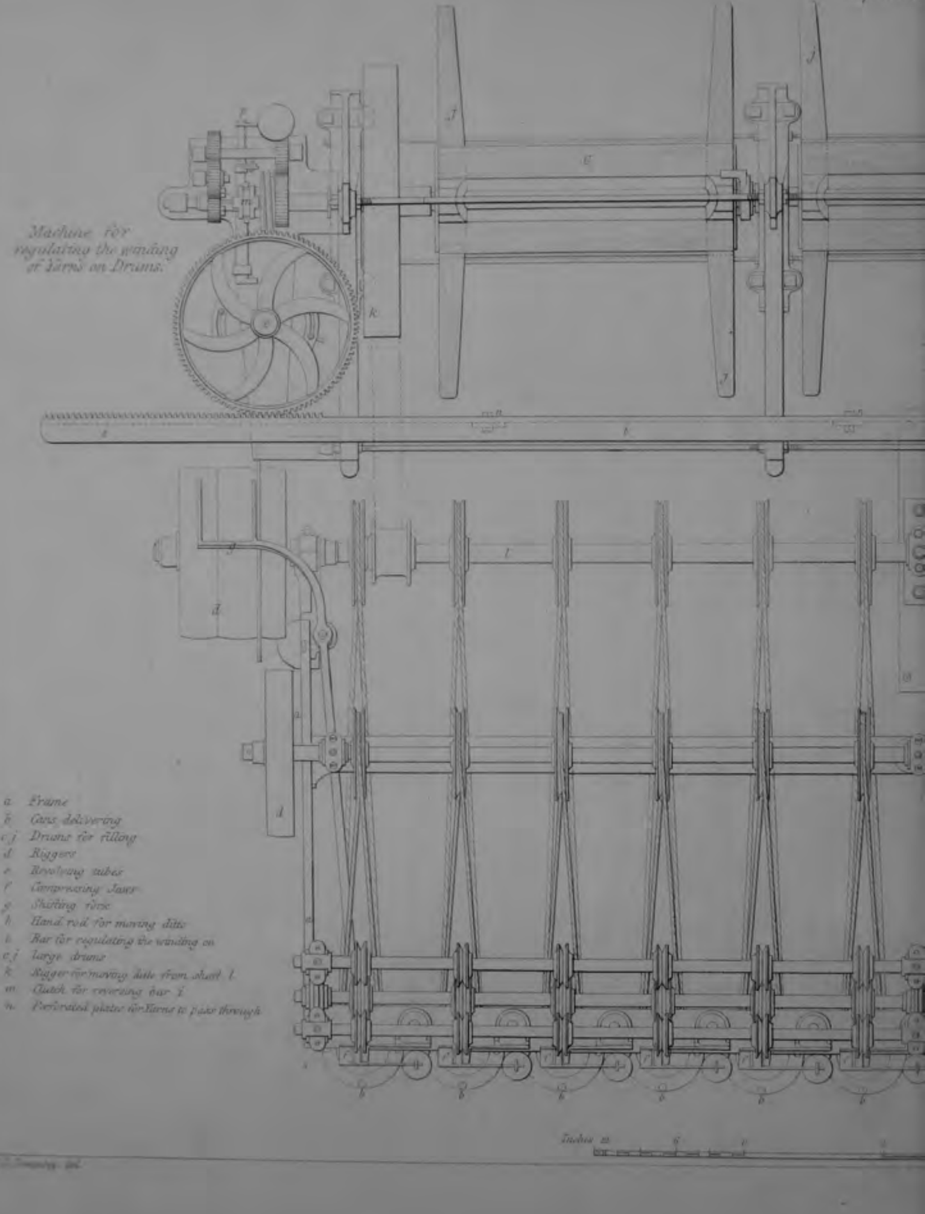
Fig. 1.

J. H. Le Keux sculp.

High Holborn. 1841.

ROPE M

Spinni



- a Frame
- b Cans delivering
- c j Drums for filling
- d Riggers
- e Revolving tubes
- f Compressing Jaws
- g Shifting fork
- h Hand rod for moving ditto
- i Bar for regulating the winding on
- c j large drums
- k Rigger for moving ditto from shaft l
- m Clutch for reversing bar i
- n Perforated plates for Yarns to pass through

[illegible] del.

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HINERY.

achine.

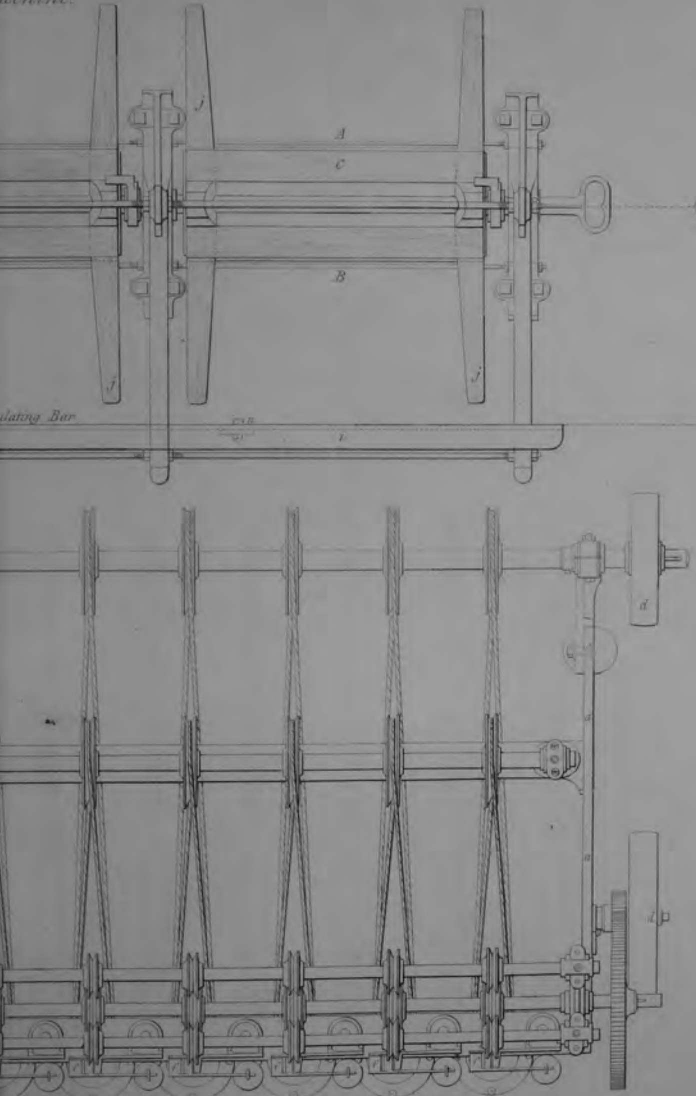
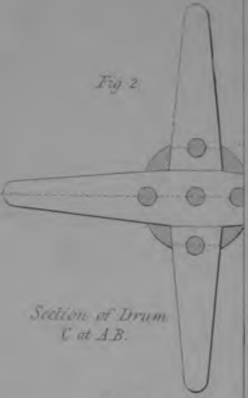


Fig. 2.



Section of Drum C at A.B.

Fig. 3.

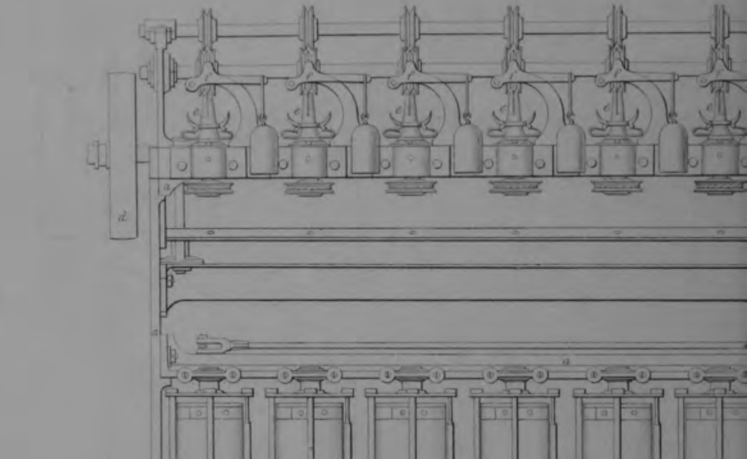
9 High Holborn [illegible]

ROPE M

Spinnin

Front

F



Inches 12 6 0

[illegible]

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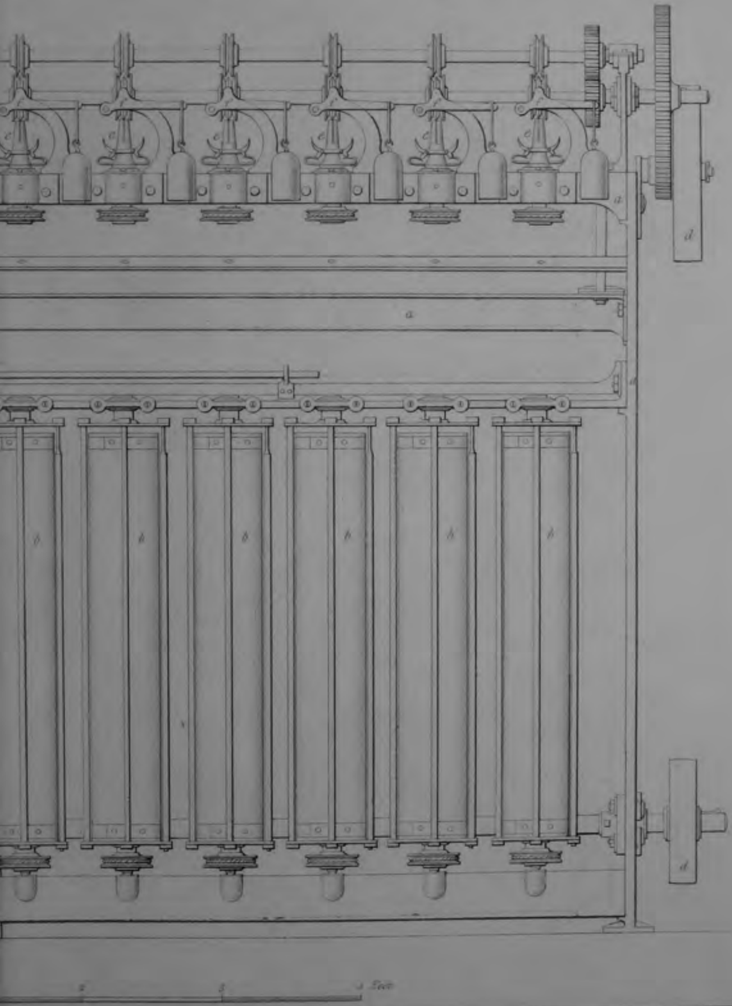
Plate 3.

HINERY.

Machine.

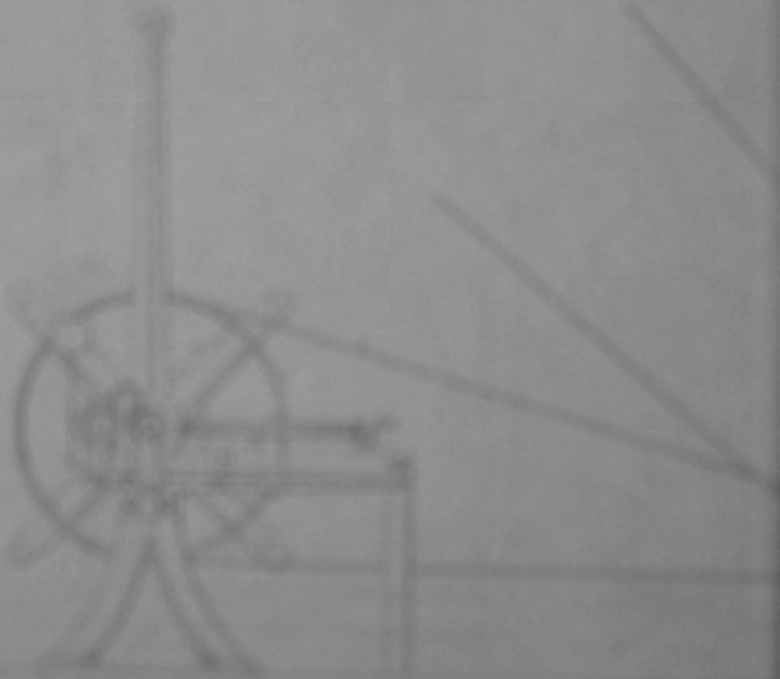
tion.



J.H.Le Keux sculp.

2, High Holborn 1841.

[illegible]

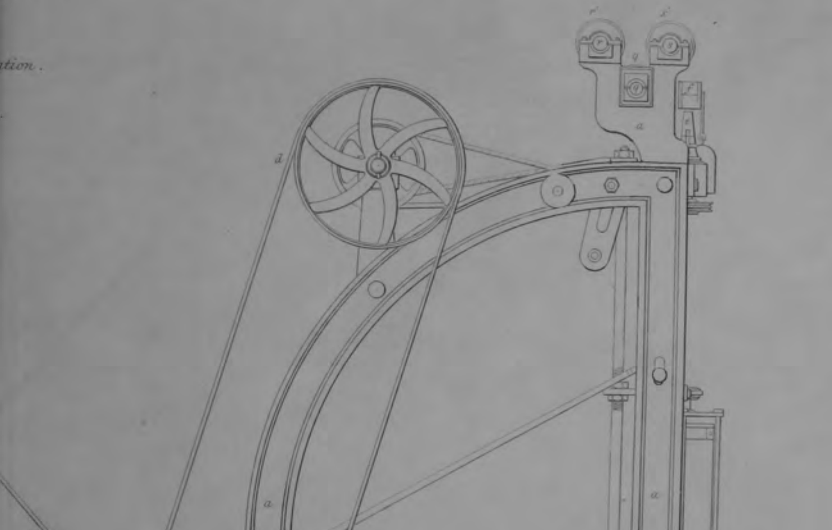


[illegible]

HINERY.

lachine.

tion.



J.H. Le Keux sculp.

High Holborn 1842.

ROPE MA

Spinnin

Shewing Brace link used instead of Springs.

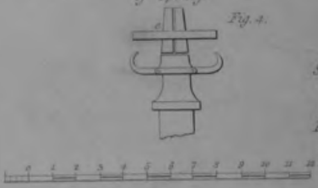
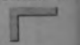


Fig. 6.

Plan of Link

Section of



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Section of

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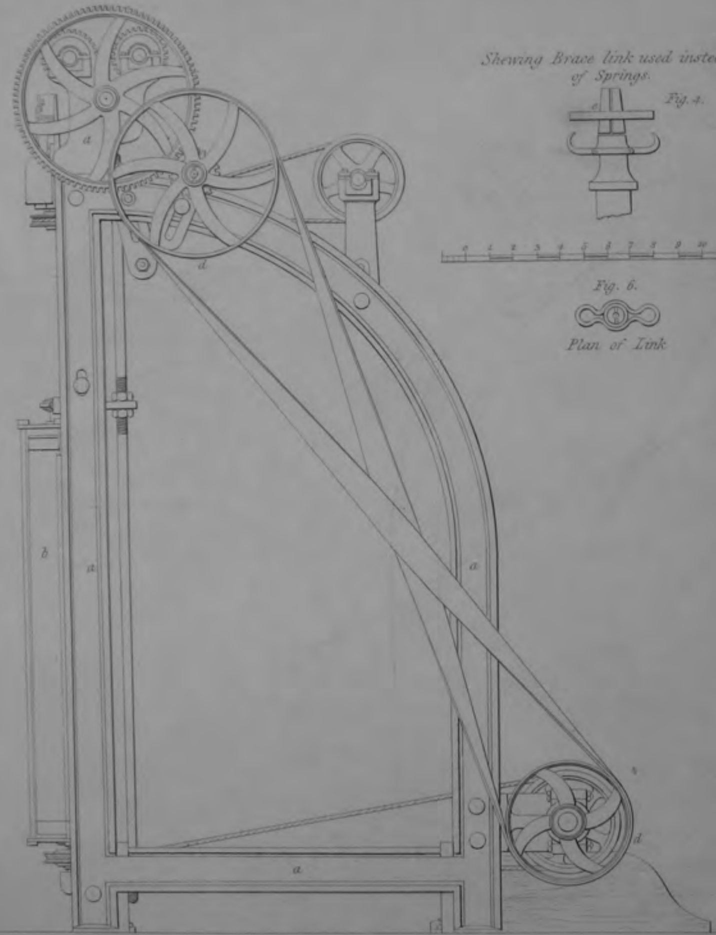
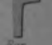


Side View.
Fig. 1.

Section of



Bar

G.D.Dempsey, del.

Published by John

INERY.

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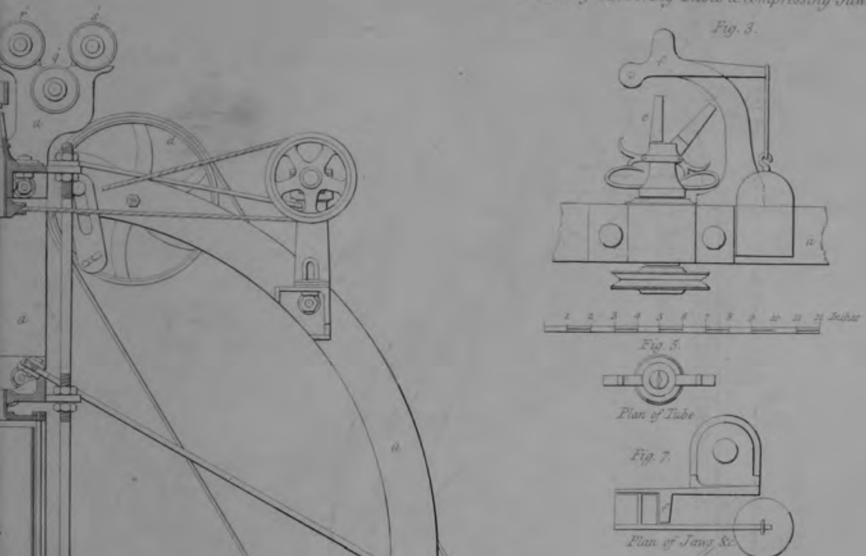


Details of Revolving Tubes & Compressing Jaws.

Fig. 3.

Fig. 5.

Plan of Tube

Fig. 7.

Plan of Jaws &c.

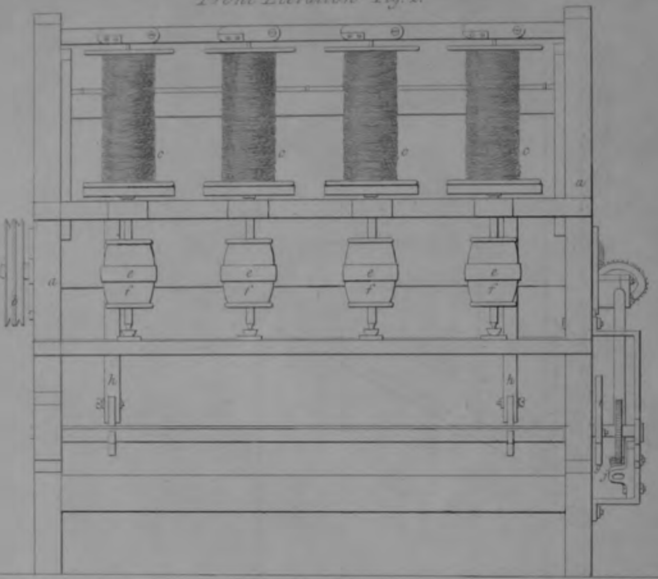
Transverse Section

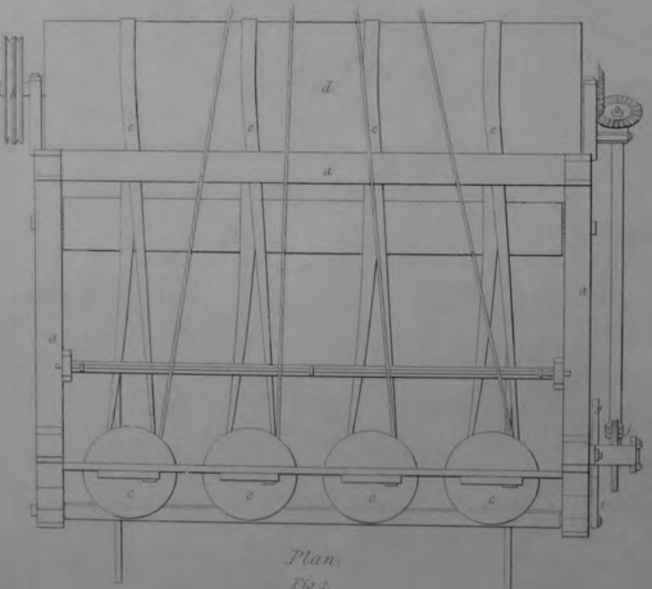
Fig. 2.

J. R. Le Keux sculp.

9, High Holborn, 1842.

Front Elevation Fig. 2.



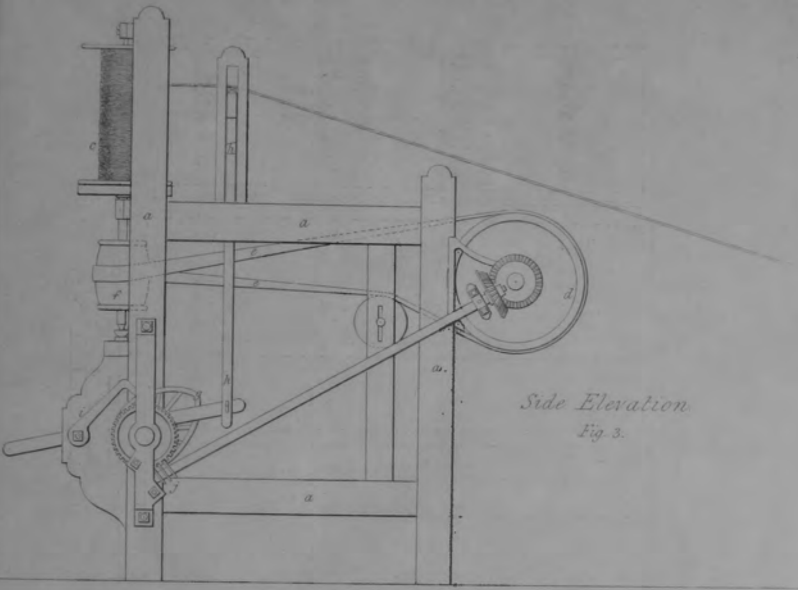


Plan.

Fig. 1.

J. D. Dempsey del.

Published by John

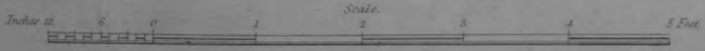


Side Elevation
Fig. 3.

ROPE MACHINERY.

Winding Machine.

a	Frame	f	Spindles
b	Riggers	g	Heart for moving
c	Reels (filling)	h	Traversing frame by means of
d	Drum for bands	i	Pall
e	Bands	j	Endless screw



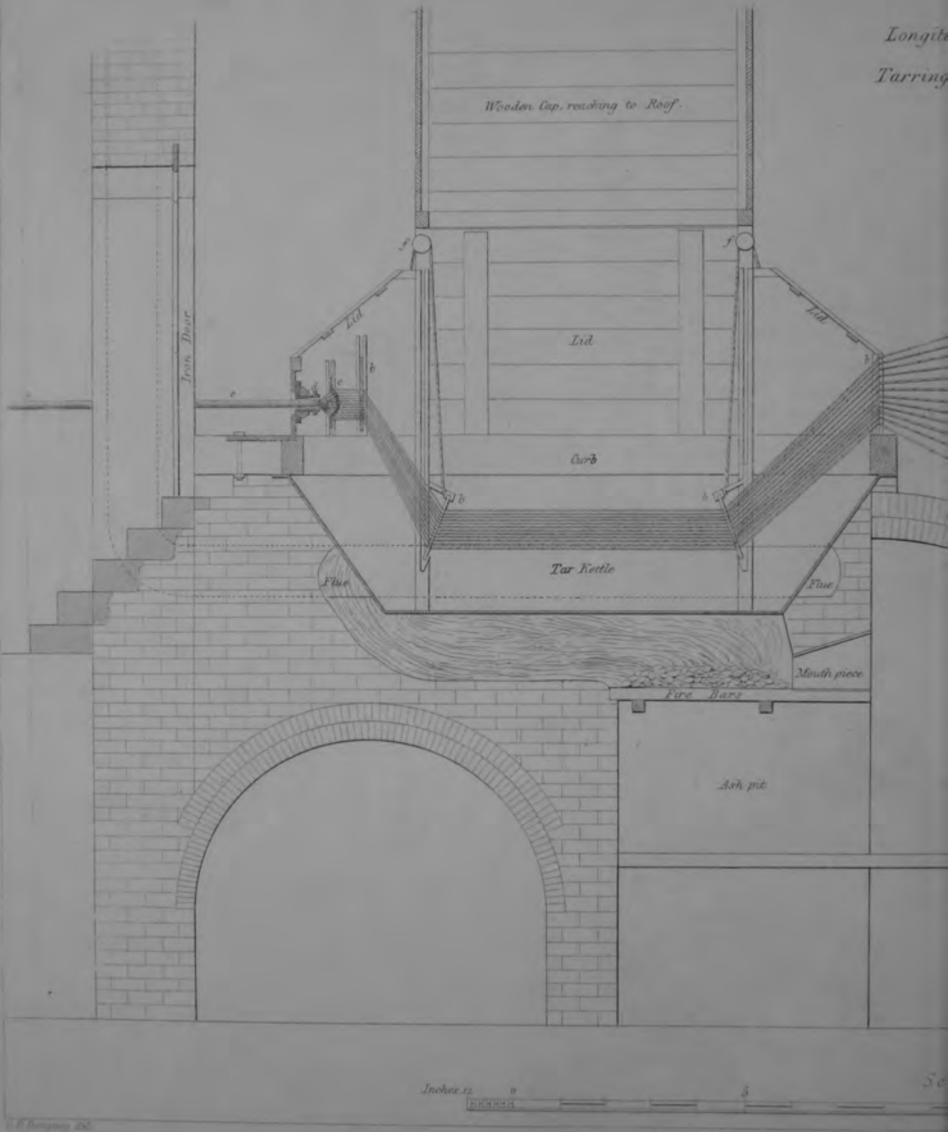
J.H. Le Keux sculp.

9. High Holborn 1841.

ROPE

Longit

Tarring

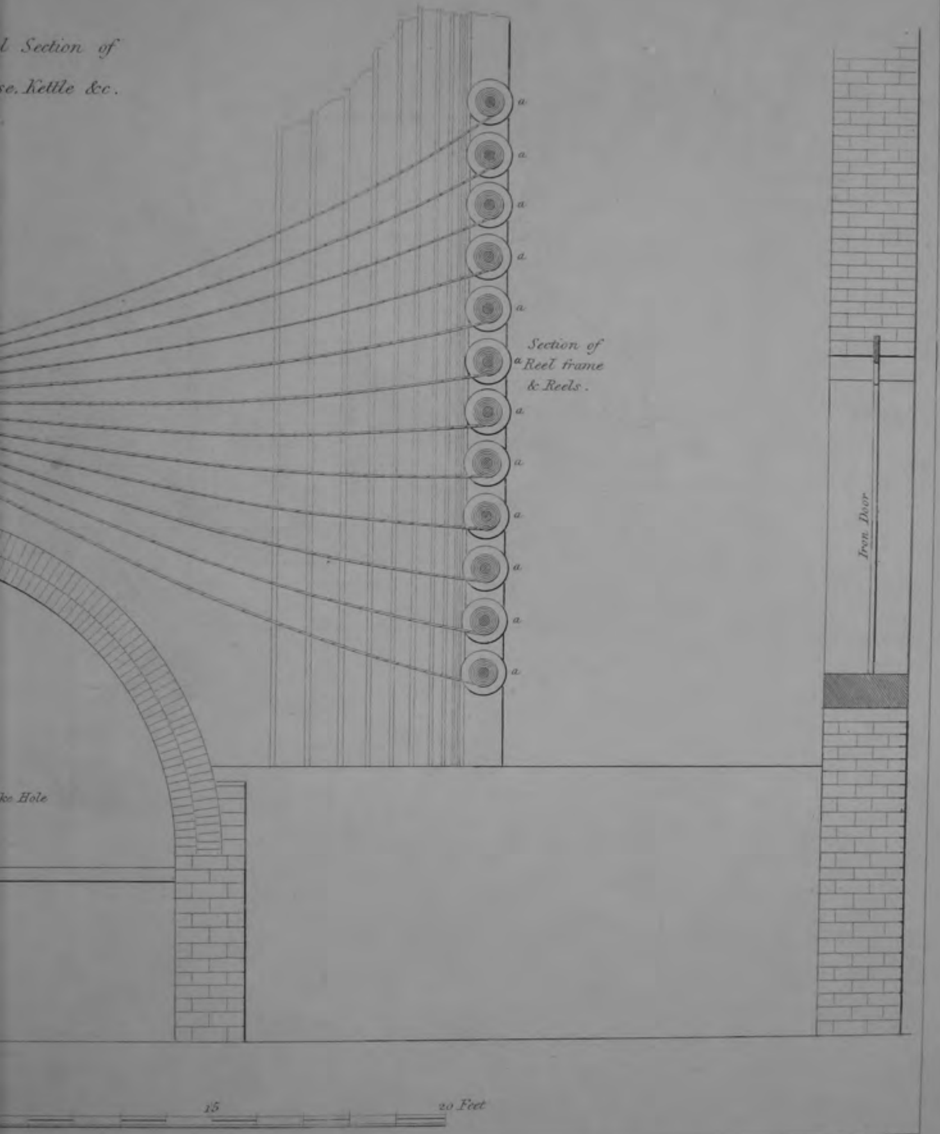


[illegible] Del.

Published by John W

CHINERY.

l Section of
se. Kettle &c.



J.H. Le Keux sculp.

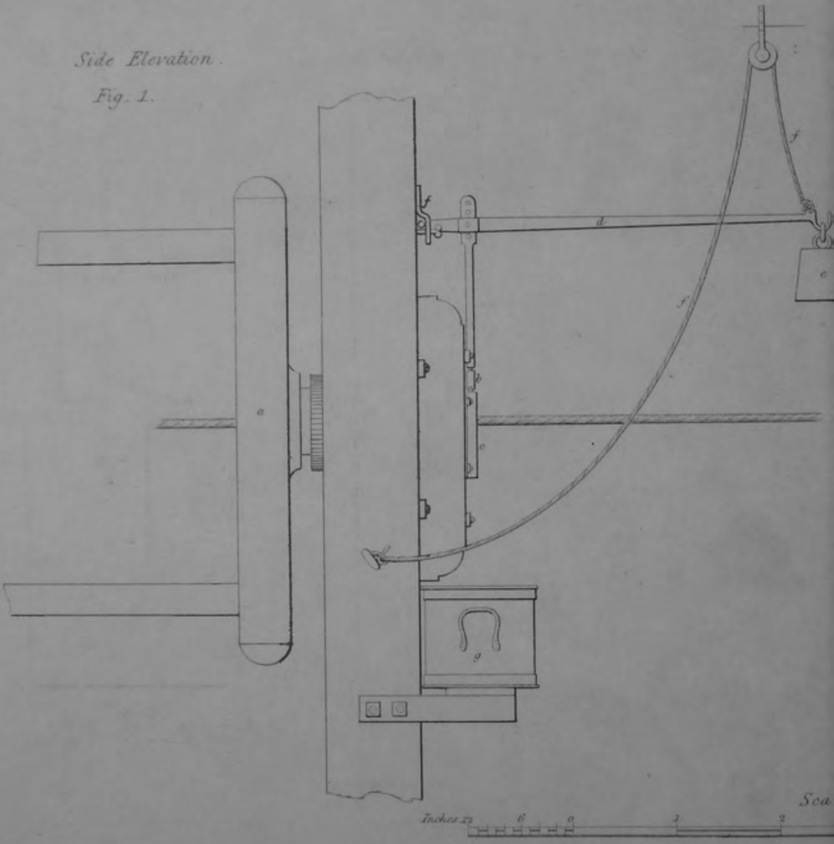
High Holborn. 1841.

ROPE M

Apparatus attached to front of Regis

Side Elevation.

Fig. 1.



G.D. Dempsey del.

Published by John

HINERY.

Machine for removing superfluous Tar.

Fig. 2_Front Elevation.

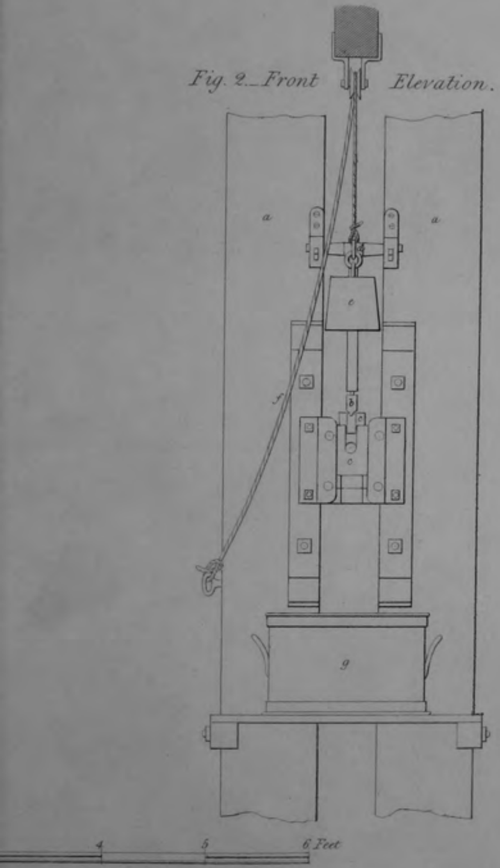
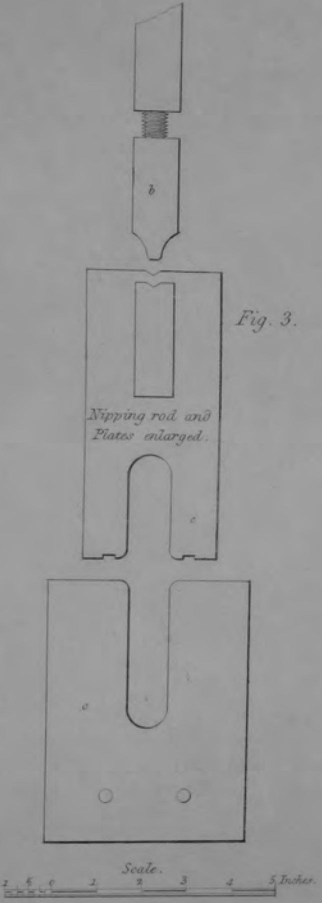


Fig. 3.



Nipping rod and Plates enlarged.

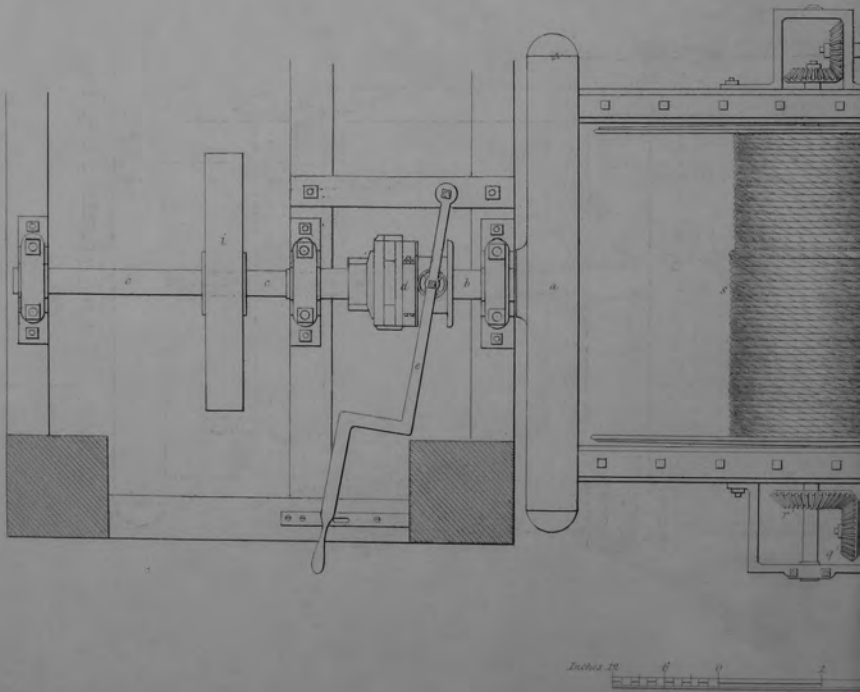
J. H. Le Keux sculp.

High Holborn. 1841.

ROPE M

Registerin

P

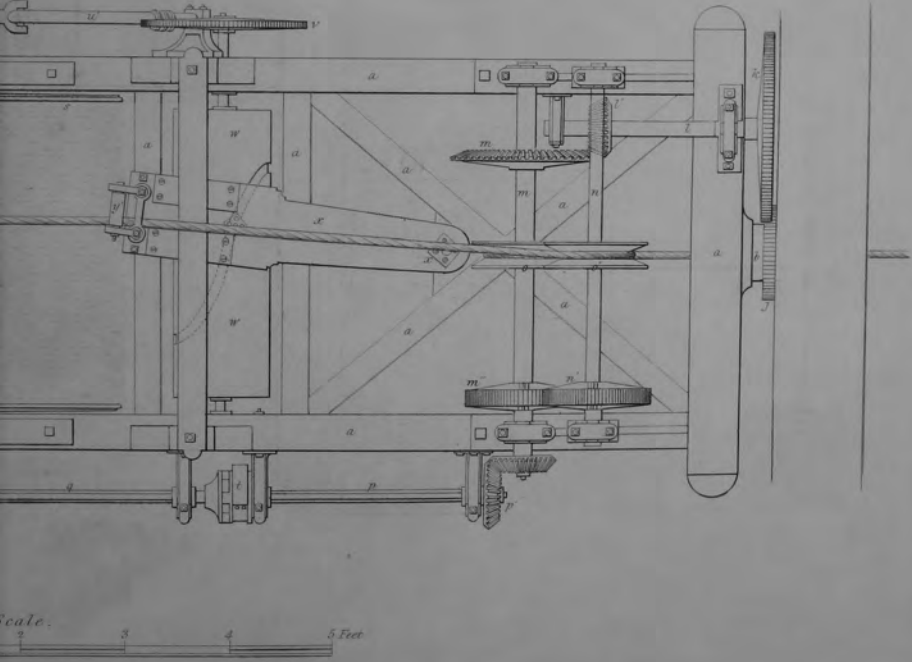


D. Dampney del.

Published by John W

HINERY.

Machine

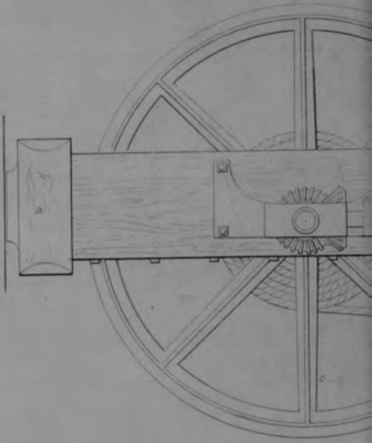


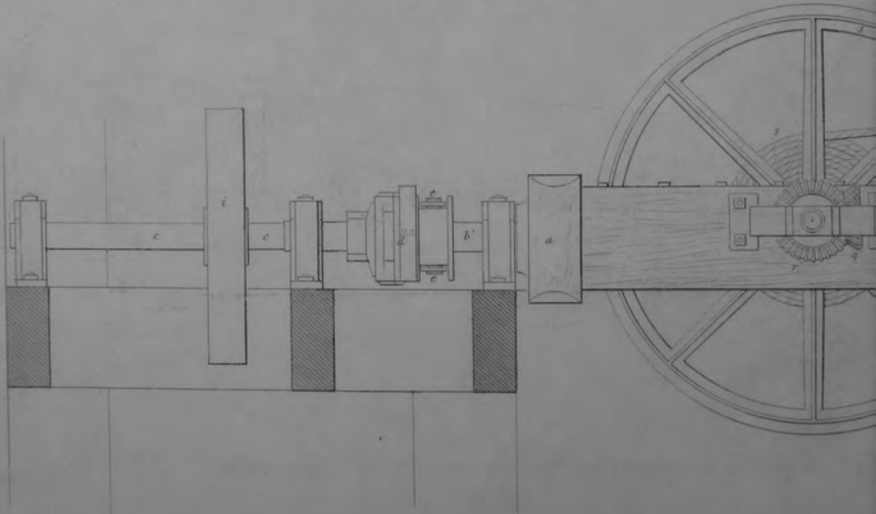
J.H. Le Keux sculp.

9. High Holborn 1841.

ROPE M

Registe



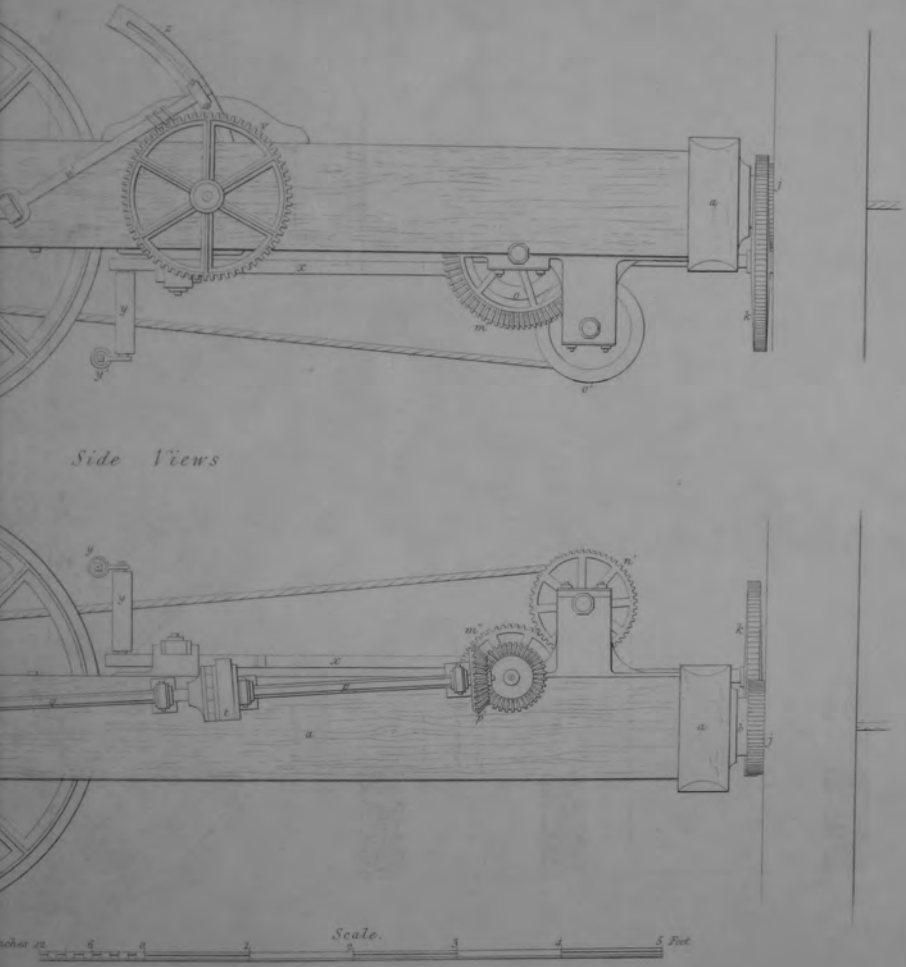


G.D. Dempsey del.

Published by John W

CHINERY.

Machine.



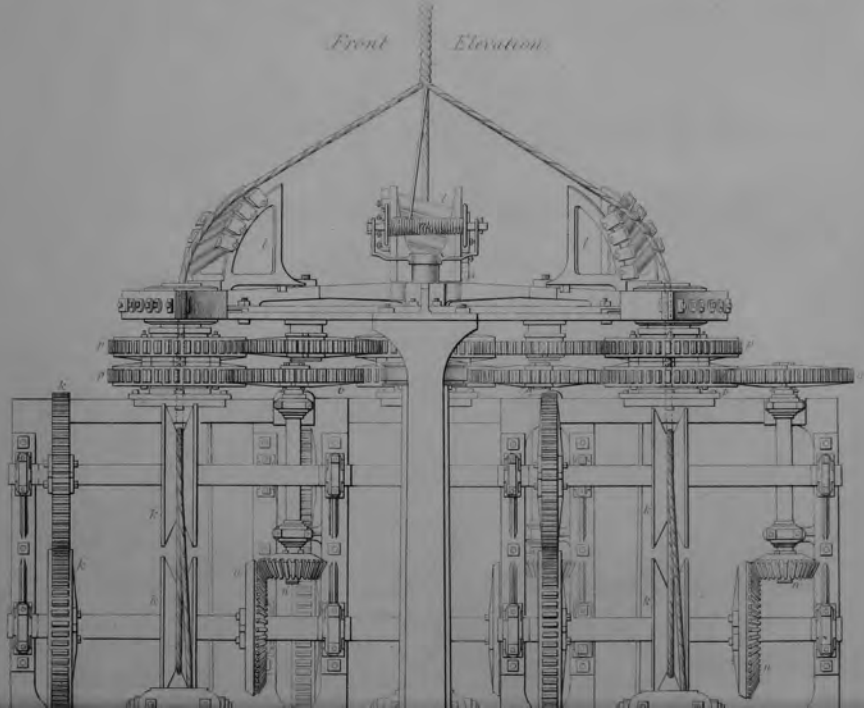
Side Views

J.H.Le Keux sculp.

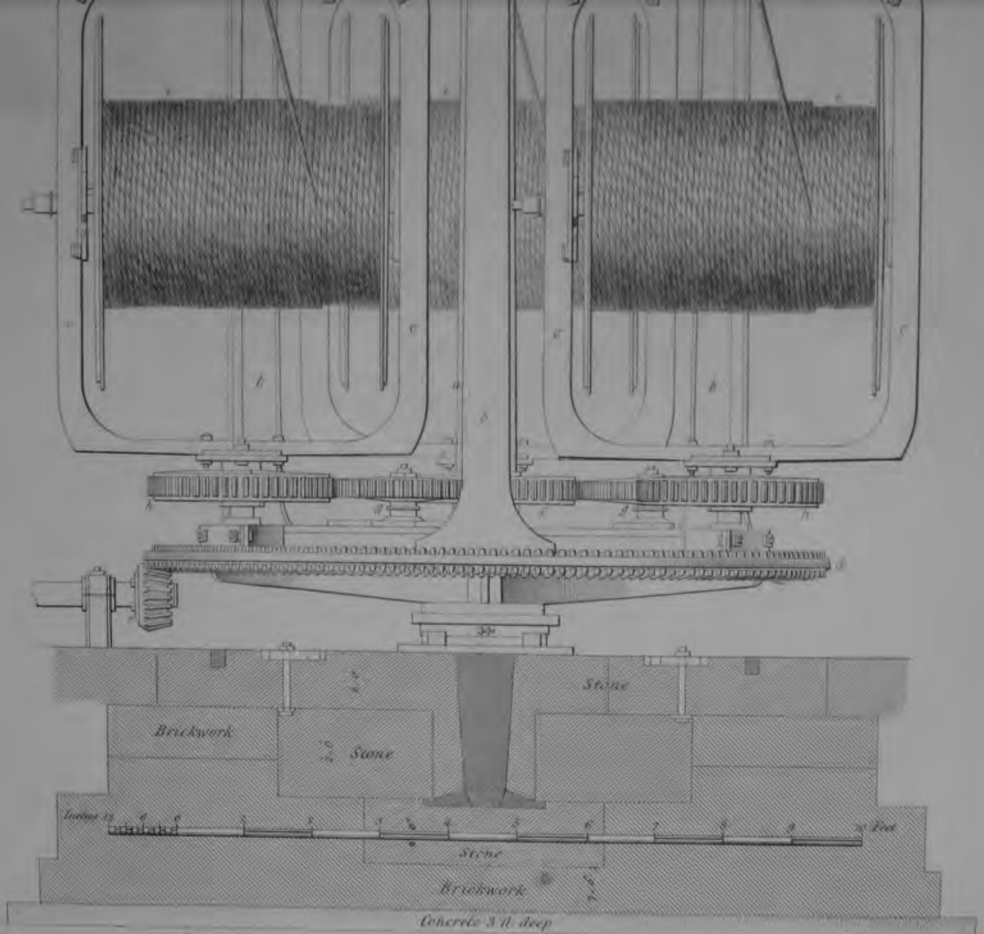
High Holborn. 1841.

ROPE MACHINERY.

Laying Machine



Front Elevation



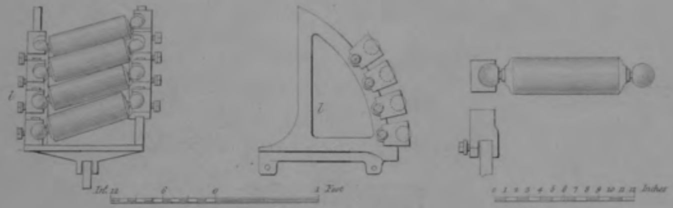
[illegible] del.

[illegible] sculp.

Published by John Weale 59 High Holborn [illegible]

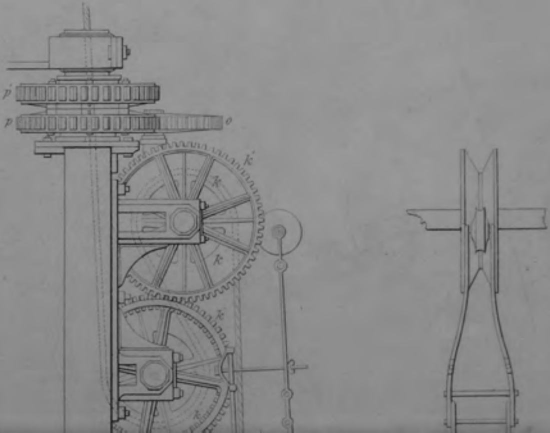
ROPE MACHINERY.

Laying Machine.



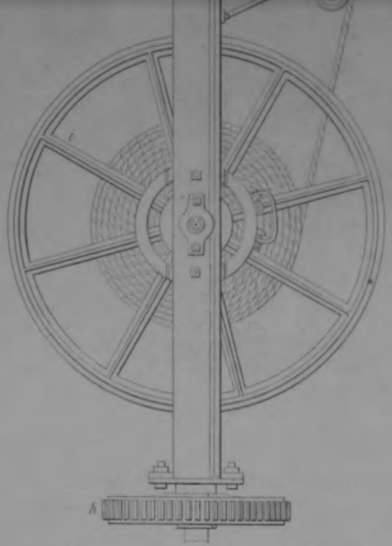
Details of Upper Guide rollers. l.

Fig. 4.



Details of

Fig. 2.



Side view of one Spoule frame.

Fig. 1.

Front View of Tightening
Pulley & Frame.

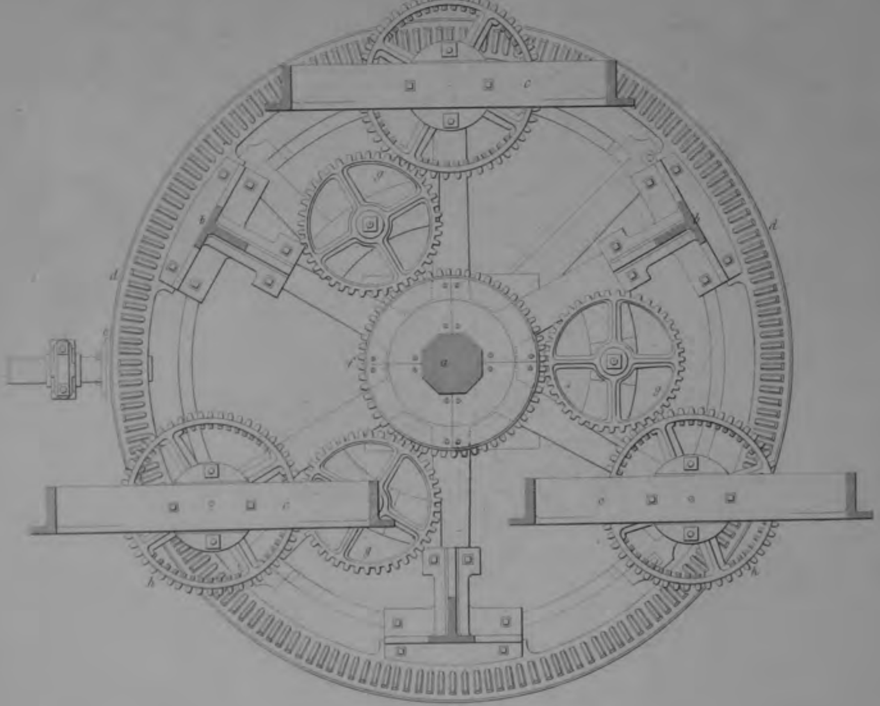
Clutch Band. j

Fig. 3.

E. D. Dempsey, del.

J. H. Le Keux, sculp.

Published by John Weale, 59, High Holborn, 1841.



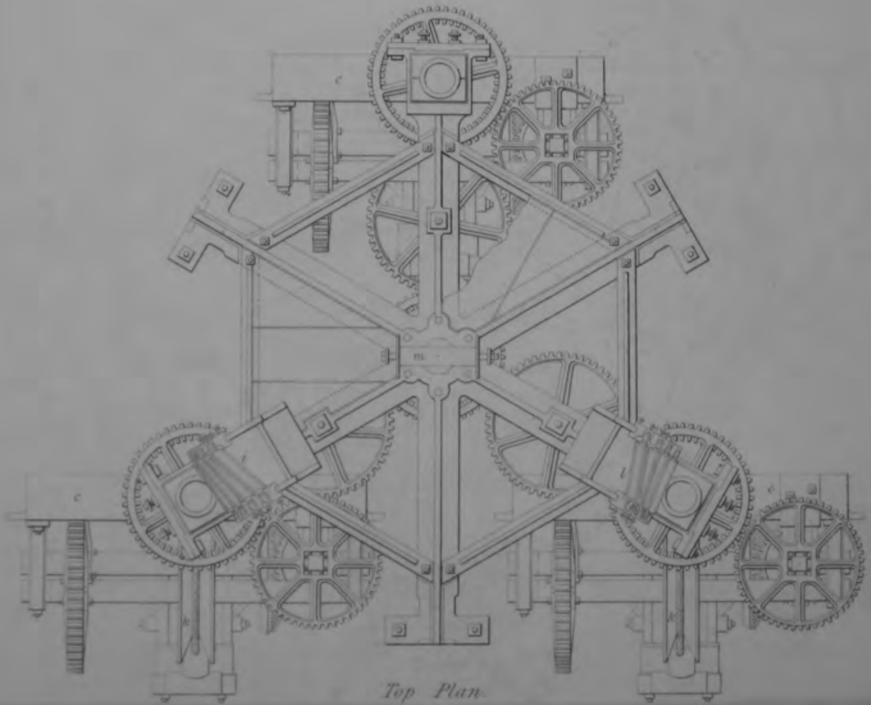
Lower Plan, sectional thro' shaft &c.

Fig. 2.

Published by John Weale, 59 High Holborn, 1841.

ROPE MACHINERY.

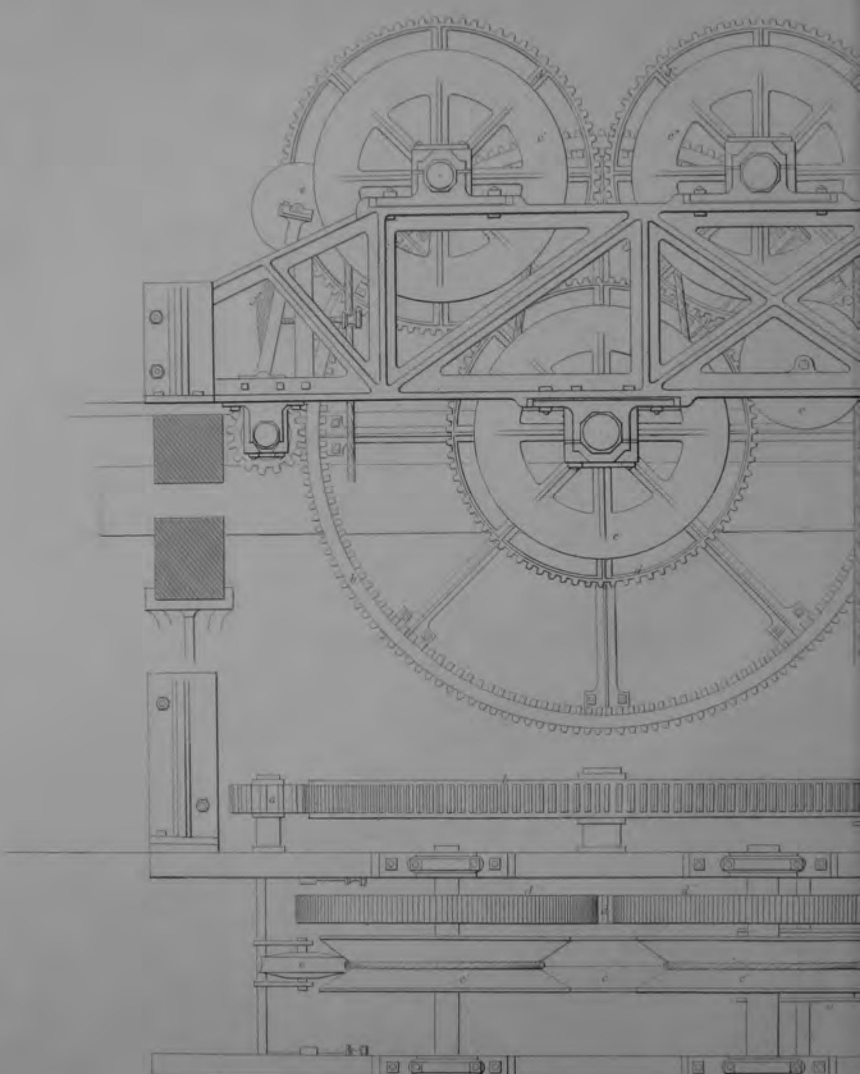
Laying Machine.



Top Plan.

ROPE M

Machine abov



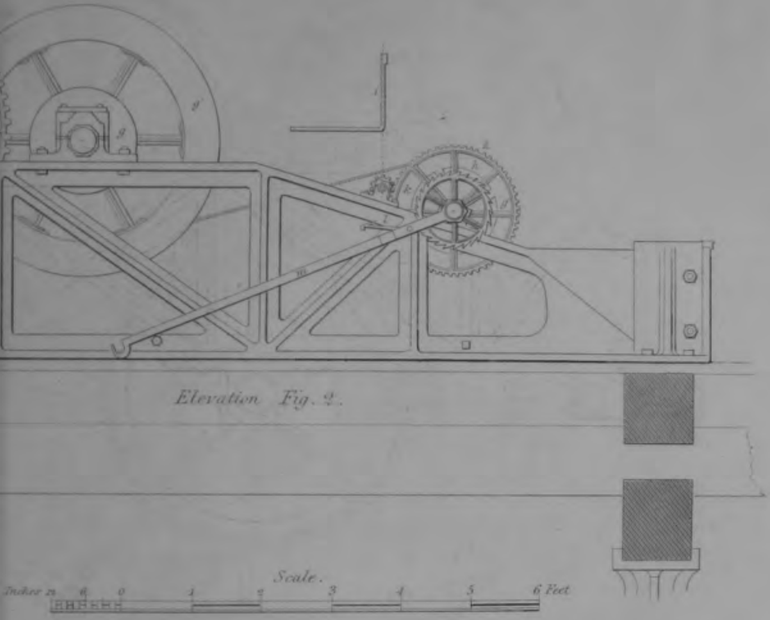
Plan Fig.

[illegible]

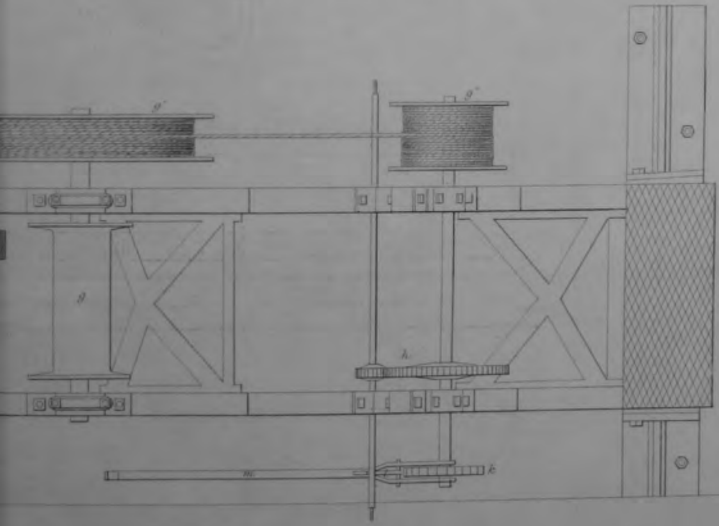
Published by John

CHINERY.

ying Machine.



Elevation Fig. 2.



J. B. Le Keux sculp.

9. High Holborn. 1841.

Another recent and striking proof of the relative superiority of rope manufactured upon Captain Huddart's principle over that made by the old system, in point of strength and durability, is afforded in the instance of the London and Birmingham Railway, where, as is well known, in lieu of locomotive engines, the trains are constantly propelled to and from Euston Square and Camden Town by an endless rope, running upon pulleys, urged by the power of a fixed steam engine.

The first rope used for this purpose was made by a respectable manufacturer in the north; it was 7⅝ inches in girth, and lasted only 12 months. For this was substituted another prepared by Captain Huddart's method, which was only 5½ inches in circumference; and although this had been in constant use for three years last August, it still continued sound, and in full operation.

I have derived much information upon this subject from the very excellent exposition of Captain Brandreth, R. E., who dedicated some time to an investigation of the merits of these inventions, and whose very able report to the Lords of the Admiralty induced Her Majesty's Government to determine upon the erection of the rope-making machinery now in operation in Deptford Dockyard: nor can this subject be passed over without rendering due credit to the late Superintendent of that naval depôt, Captain W. H. Shirreff, R. N., under whose able management the whole establishment was formed, and by whose exertions it was brought to its present state of perfection. It was at the desire of the latter officer that I have ventured to draw up these details, and in doing so I feel called upon to render my best acknowledgments for the facilities placed by him at my command.

I have also received much practical information on this subject from Mr. Chapman, the master rope-maker who was appointed to the management of this department on account of his long practice in the use of such machinery, having been for many years foreman in Captain Huddart's manufactory in Limehouse, where he acquired a full knowledge of the whole system.

Much matter has been omitted that would have tended to a more complete exposition of this subject, but I trust that sufficient has been shown to elucidate the system, and to render the details of the machinery intelligible.

XIII.—*Notes on the Theory and Practice of sinking Artesian Wells. By Major* Jebb, *Royal Engineers.*

In considering the eligibility of a site for a permanent military work or any large public establishment, the means of securing an ample supply of water is one of the first questions that engages attention. The situation may be in all other respects advantageous, but if any difficulty or doubt arises as to a command of water, the idea of occupying it will generally be abandoned. Hence it is of importance, in relation to the varied duties of the Corps, that no expedient which might possibly be applied with success under such circumstances should be lost sight of.

One of the most interesting and scientific operations connected with this subject is that of deciding upon, and executing an Artesian Well.

The object of the following brief outline is to direct attention to the principle on which such Wells operate, and to convey some little practical information on the mode in which the work is carried on; under the impression that the sources from which information on these points can be derived are so limited, that many officers may not have had an opportunity of profiting by them.[1]

The subject will be found to require not only the practical knowledge necessary for overcoming the difficulties which are met with in sinking through all varieties of soil and rock, but it opens a wide field for scientific investigation and research, on which a sound judgment must be brought to bear, before any step can safely be taken in commencing operations. It will be found that without an accurate knowledge of the geological structure of the country surrounding the proposed situation, and of the precise nature of the strata in the locality itself, no opinion can be formed of the probability of

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[1] The practice of boring for water was introduced by Colonel Pasley at the Royal Engineer Establishment at Chatham about the year 1835, and much valuable information on the subject has been gained by those officers who have attended it, and by Sappers of our own Corps, and those who have been trained at the Establishment for the service of the Hon. East India Company.

success. There is little doubt, however, that the more frequent application of the principle would lead to important results in adding greatly to the facilities of obtaining water in situations where this necessary of life is inaccessible by other means.

The name 'Artesian' has been given to these Wells merely from their having been extensively adopted in the province of Artois in France, which is the ancient Artesium. In common parlance the execution of them is called 'boring for water,' which has the merit of being more expressive, if it be less classical.

Wells on this principle are very applicable in low level districts covered with alluvial deposit or clay; in such situations springs are seldom found, and water cannot be obtained by sinking an ordinary well, unless at a disproportionate cost. The eastern part of Lincolnshire, which lies between the chalk range called the Wolds, and the sea, is a case in point. It was discovered, perhaps accidentally, in sinking through the clay to the subjacent chalk, that water rose to the surface in a perpetual fountain, and an ample supply is now obtained over the whole of that district by the simple operation of boring.

A number of wells of this description have also been executed in the neighbourhood of London by perforating the London clay into the porous beds of the plastic clay formation, and into the chalk.

The principle on which they act is simply this. The hole is bored through impervious strata that do not contain water, into lower strata that are fully charged with it, and the water rises by hydrostatic pressure.

The height to which it will rise obviously depends upon the inclination of the strata, and other causes which affect the relative levels of the hole that is made, and the subterraneous body of water that has been tapped. This will be understood by an inspection of Plate XLVI., which is a section of the London basin, taken from Buckland's Geology, illustrative of the cause of water rising in the Artesian wells near London. The water in all the strata which are shown in the section is derived from the rain which falls on those portions of their surface that are not covered by the London clay, and is upheld by clay beds of the gault beneath the chalk and fire-stone. Thus admitted and sustained, it accumulates in the joints and crevices of the strata to the line A B, at which it overflows by springs in valleys, such as that represented in the section under C. Below this line all the permeable strata must be filled with a permanent subterranean sheet of water, except where faults or other disturbing causes afford local sources of relief. When these reliefs do not interfere, the horizontal line A B represents the level to which water would rise by hydrostatic pressure in any perforations through the London clay, either into sandy beds of the plastic clay formation or into the chalk, such as those represented at D, E, F, G, H, I. If the perforation be made at G or H, where the surface of the country is below the line A B, the water will rise in a perpetually flowing Artesian fountain, as it does in the valley of the Thames between Brentford and London.

Figs. 1 and 2, Plate XLVII., will serve still further to illustrate the causes which affect the rise of water in Artesian wells, or the discharge of it in natural springs within basins, that issue on inclined strata that happen to be intersected by valleys or traversed by faults. Supposing a series of strata to be disposed as shown in fig. 1, E, F, G, being permeable strata charged with water, alternating with H, I, K, L, which are impermeable; if the margin of all these strata were all in one horizontal plane, the water which falls in rain upon the extremities of the strata E, F, G would accumulate within them, and fill all their interstices with water up to the line A B; and if a pipe were passed down through the upper into either of the lower strata at any point within the circumference of this basin, the water would rise within it to the horizontal line A B, which represents the general level of the margin of the basin. A disposition so regular as this never exists in nature; the extremities or *outcrops* of each stratum are usually at different levels (fig. 1, *a*, *c*, *e*, *g*). In such cases the line *a b* represents the water-level within the stratum G; it could never rise above it, being relieved by springs that would overflow at *a*. The line *c d* represents the level above which the water could never rise in the stratum F; and the line *e f* represents the highest water-level within the stratum E; the discharge of all the rain-waters that percolated the strata E, F, G thus being effected by overflowing at *e c a*. If common wells were sunk from the surface (*i k l*) into the strata G, F, E, the water would rise within them only to the lines *a b*, *c d*, *e f*.

The upper porous stratum C also would be permanently loaded with water below the horizontal line *g h*, and permanently dry above it.

The theoretical section, fig. 2, represents a portion of a basin intersected by the fault H L, filled with clay or matter impermeable to water. Supposing the lower extremities of the inclined and permeable strata N, O, P, Q, R to be intersected by the fault or dyke H L, the rain-water which enters the uncovered portions or outcrops of these strata between the impermeable clay beds A, B, C, D, E would accumulate to the levels A″ A, B″ B, C″ C, D″ D, E″ E. Now, if an Artesian Well were perforated into each of these strata to A′, B′, C′, D′, E′, through the clay beds which keep down the water in the permeable strata N, O, P, Q, R, the water, when released, would rise by hydrostatic pressure within a pipe ascending from the perforation to the respective levels A″, B″, C″, D″, E″.

Whenever the contact of a dyke H L with the strata M, N, O, P, Q, R, that are intersected by it, is imperfect, an issue is formed, through which the water from these inclined strata will be discharged at the surface by a natural Artesian spring; hence a series of such springs will frequently mark the line of contact of a dyke with the fractured edges of the strata from which the water rises. But to return to Artesian Wells: under most circumstances it is necessary to protect the perforation that is made by sinking iron pipes. The boring is thus secured against the accident of the sides falling in, and another advantage, which is of some importance, is obtained. It may chance that the object is to obtain a supply of soft water which has been ascertained to exist at a certain level, and that the strata which have to be pierced to get to it contain hard or impure water. In such a case the boring would be continued down to the proper depth, and the pipes being plunged into the soft water, it would rise through them, and any water or impurity which might be found in the strata through which they passed would be effectually excluded. If it so happened that at a certain depth below the soft water a mineral water could be obtained, instead of going to the expense of a fresh bore from the surface, it would only be necessary (supposing that both would flow to the same level) to bore through the pipes already fixed, to the mineral water, and insert smaller pipes within the larger ones for bringing it up to the surface.

The history of the great Artesian Well recently completed at Grenelle is one of the most remarkable instances of confidence in the principle, and of perseverance in execution, that is on record. The facts are believed to be substantially as follows:—A person suggested to the authorities that an Artesian Well would supply water in a situation where it was greatly required; and after some discussion it ended in his undertaking the work on the stipulation, "No water, no pay." He bored down far beyond the point at which he expected to have terminated his labours; but no signs of water appeared:

he persevered, however, till he found that the expenses had ruined him. Under these circumstances he consulted the celebrated Arago, who encouraged him to proceed. Again he went to work, and after overcoming unparalleled difficulties, at the expiration of six years, and at the depth of 1800 feet, the superincumbent mass was bored through, and the water came boiling up in such quantities, and with such force, as to flood the whole district.

The water, when first obtained, was extremely foul: the partial introduction of an Indian-rubber hose is said to have remedied this, and the water is now procured from the main spring quite pure, and at a very high temperature. The bore is stated to be 13 inches in diameter. It is to be hoped, however, that a detailed account of this very interesting and instructive operation will be published.

Having obtained a little insight into the theory and principle of Artesian Wells, which will be found to apply in the majority of cases, we must descend to particulars.

The mode of executing the work may be exemplified by a description of the method pursued in sinking a well of this description for obtaining a supply of water for the new prison which is now being erected in the neighbourhood of London.

The section, Plate XLVI., shows the geological conditions. The well was sunk through the London clay into the strata of the formation below it, and the boring was continued through them to the chalk, and to a considerable depth in the chalk.

The work was submitted for competition to several professed well-sinkers, and the following specification, on which their estimates and tender were to be framed, was furnished to each.

Specification for sinking an Artesian Well at the Model Prison, Caledonian Road.

To sink a well so as to be 6 feet diameter in the clear within the brickwork to the depth of 150 feet. The price for each succeeding 30 feet complete to be stated.

To be steened with 9-inch brickwork, with malm paviers, the back steening to have 3 courses in cement at every 5 feet, and the double or inner steening to have 4 courses in cement at every 10 feet.

The brickwork to be completed in successive portions of 5 feet, or less if found necessary. The bricks to be of the best quality; the Roman cement to be mixed with one equal proportion of clean sharp river sand. Should it be found necessary to sink to a greater depth (not exceeding 30 feet), the contractor will state in his tender at what price per foot he will execute the same in every respect as above specified.

To fix 9 feet of 12-inch cast-iron pipe at the bottom of the shaft, and to bore with a 10½-inch auger, and continue with the same down to the chalk, inserting in the bore cast-iron pipes 8 inches diameter, and not less than ⅜ths of an inch thick on the sides, fitted together with turned joints and wrought-iron collars, and fixed with screws: the whole to be flush inside and outside.

To continue boring in the chalk with a 7½-inch auger to such depth as will secure good water from the main spring, and in such quantity as may be considered necessary.

The whole of the above works are to be done in a workmanlike manner, with materials of the best description of their several kinds, and to the entire satisfaction of the superintending officer.

The contractor will state at what price per foot, or per 10 feet, including the iron pipes, he will bore until he reaches the chalk, and at what price per foot, or per 10 feet, he will bore through the chalk until the necessary quantity of good water is obtained; also at what price per foot he will provide and fix perforated copper pipes, 6½ inches diameter outside, weighing 6 lbs. per foot, in the chalk as far as may be necessary.

The prices stated in the tender are to include every expense, the finding all materials, scaffolding, tackle, cartage, &c.; the stopping out the land springs in an effectual manner, and every expense requisite for the entire completion of the work, excepting the removal of the earth excavated.

If pumps are required during the execution of the work, they are to be supplied by the contractor, together with labour in pumping, and troughs for carrying off the water, without extra charge.

Stone corbels for supporting permanent framing will be furnished to the contractor, to be inserted in the brickwork without extra charge.

This general specification was grounded on the fact which experience had sufficiently proved, that there was excellent water in the chalk below the London clay, and that if the boring were continued sufficiently deep in the proposed situation, an abundant supply would be obtained, which would rise to a considerable height above the upper surface of the chalk. With a knowledge of this fact, it was only necessary to sink the well to such a depth as would ensure the spring rising into it, and to bore from that point until the requisite supply was obtained. In doing this it was also essential to stop out all land springs percolating through the irregular stratum near the surface, as well as those which might be found in the permeable strata of the plastic clay formation which intervenes between the solid mass of blue clay and the chalk.

The tender of Mr. Thomas Clarke, of Tottenham, an eminent practical well-sinker, was found to be the most advantageous for the public service, and was therefore accepted.

The tender was in the following terms:

Tender for sinking an Artesian Well at the Model Prison.

Tottenham.

I hereby tender to sink a shaft so as to be 6 feet diameter in the clear within the brickwork, to the depth of 150 feet, and to provide such materials as are required by the specification, and to perform the work in every way agreeably thereto; and to fix a 12-inch cast-iron pipe 9 feet long at the bottom of the shaft, at the following prices:

			£.	s.	d.
The 1st	30 feet	for the sum of	67	10	0
The 2nd	do.	do.	57	0	0
The 3rd	do.	do.	58	10	0
The 4th	do.	do.	60	0	0
The 5th	do.	do.	61	10	0

Also to sink as many feet further as the superintending officer may consider necessary, so as not to exceed 30 feet, for the sum of £2. 5*s*. per foot.

Also to bore to the chalk with a 10½-inch auger, and fix pipes of the dimensions required, and fitted together as specified, for the sum of £2. 2*s*. per foot.

Also to bore into the chalk with a 7½-inch auger to such depth as may be considered necessary by the superintending officer, for the sum of £1. 7*s*. per foot. And if it should be determined to insert perforated copper pipes in the boring in the chalk, I hereby tender to supply the same, to weigh not less than 6 lbs. to the foot, and to fix the same in the bore, for the further sum of 10*s*. 2*d*. per foot.

And in every other respect to conform to the specification, and to complete the whole of the work in a proper and workmanlike manner, and to the satisfaction of the superintending officer.

(Signed) THOMAS CLARKE.

To CAPTAIN JEBB, Royal Engineers.

In commencing the work five men were employed, who made an excavation 9 feet 6 inches in diameter, which was to allow space for the finished shaft to be 6 feet in the clear, with a 9-inch steening and 12 inches of puddle at the back, for more effectually excluding the land springs. This excavation was carried down to the depth of 10 feet. The 9-inch steening in cement and the puddle were then commenced and completed to the surface.

The stratum of clay at this depth was so solid that it was considered the puddle might be dispensed with; an excavation only 7 feet 6 inches in diameter and 5 feet deep was therefore made, and the back steening only of half a brick in thickness completed in cement.

Similar excavations of 5 feet in depth were made in succession, the back steening only in each case being completed, until the solid mass of London blue clay was found at the depth of 30 feet from the surface. The inner steening was then brought up in cement so as to underpin the first portion which had been completed.

The land springs were found to be effectually excluded, and the work then proceeded in all respects according to the specification. Two additional hands were employed when the well was about 30 feet deep, and no difficulty was experienced until the mass of London clay was cut through, and the upper beds of the plastic clay formation, which were found at the depth of about 150 feet, were perforated. Here a stratum of dark sand was found, containing a little water. This sand was so loose that it did not afford sufficient foundation for the brickwork; and there was this further difficulty, that had the water been pumped out, the sand would have been set in motion, or, to use a technical expression, would have "blown up" in the well. Under these circumstances it was determined to substitute cast-iron cylinders, 5 feet in diameter and 1 inch thick, for the brick steening.

The specification and tender for supplying the cylinders and executing the work with them was as follows:

Tender for supplying and fixing cast-iron cylinders, to be used in lieu of steening.

Tottenham.

I hereby engage to secure the present brickwork in its place by strong elm ribs, suspended by iron rods up the shaft, and to provide and fix cast-iron cylinders of 5 feet diameter and 1 inch thick, in 5-feet lengths, with internal flanges, properly packed and bolted together, and to caulk the same with iron cement, and to carry them down through the upper sand, and drive the lower end firmly into the clay; and to concrete behind the upper cylinder with gravel and cement to form a footing for the lower steening, and for stopping out water, providing every material required for the work, at £7. 2*s*. per foot lineal.

(Signed) THOMAS CLARKE.

Before proceeding to lower the well or fix the cylinders, it was necessary to secure or tie up the brickwork which had been already executed. For this purpose a strong elm frame of the dimensions shown in Plate XLVIII. was inserted under it, and the frame being connected by 1¼-inch iron rods with two strong beams fixed over the top of the well, effectually secured the steening in its place.

In order to steady the cylinders and keep them in a right line as the work proceeded, four battens 20 feet long, 7 inches wide, and 2½ inches thick, were fixed to the lower part of the brickwork, forming a kind of frame through which the cylinders would slide.

This being arranged, the first cylinder, 5 feet in length, was lowered to the bottom, and after being properly adjusted by means of wedges, another was added on the top of it, and the joint at the flanges made good. Four others were added in succession, making a length of 30 feet of cylinders fixed, before the excavation was proceeded with.

The object of this was twofold; first, that the outer surface of the cylinders being confined within the wooden frame already described, the true direction would be maintained; and, secondly, that the weight of the mass would aid in its descending into its place as the boring or excavation was proceeded with. By these means, had the stratum proved to be a quick-sand, the difficulty would have been overcome.

A stage was then placed on the upper part of the cylinders, and an auger 4 feet 10 inches in diameter was introduced within them.

The process of boring was carried on in the usual manner, which may be thus briefly described.

The auger, the chisel, or any of the great variety of implements which are required to meet different circumstances and overcome the numerous difficulties which are experienced, are screwed to iron rods, which are usually from 2 to 2½ inches square, (figs. 18*a* to 21, Plate XLIII.)

The first rod which is attached to the tool is generally about 6 feet long, and the others are of the uniform length of 20 feet. Each rod has a screw at one end, and a tapped socket to receive a screw at the other, and they fit universally; there is also a "middle knob" in the centre of each rod, as will be described, which is used for suspending the rods already fixed, whilst others are being added or detached, as the implement is lowered into the bore, or drawn out of it.

In commencing operations a stage about 8 or 10 feet square and 20 feet high is erected, when the boring takes place from the surface. The men who work the tool stand upon this stage, and a windlass or crab is fixed, chiefly for hoisting and lowering the rods, but mechanical power is also required for assisting in the working when the depth is very great.

A boring handle, figs. 41 and 42, is attached to the rod, which is used for turning the tool round in boring with an auger, or in "jumping," as is required when cutting through rock or indurated clay with the chisel. When the boring has proceeded till it is found difficult to turn the rods, or at such times as practical experience dictates, it is necessary to draw out the implements and to bring up the loose material that may be at the bottom of the bore. Some of the most useful contrivances to effect the latter object will be noticed in Plate XLIII.

Under ordinary circumstances a common windlass, or a small crab, gives sufficient power to work, hoist, and lower the rods; but when the bore is of great depth, or the instruments of unusual size, an increase of mechanical power is necessary. This may be conveniently obtained by placing a second crab on another stage; or in extraordinary cases, horses may be applied on the surface.

But to revert to the mode of sinking the cylinders. Each time that the large auger was drawn out, the cylinders settled on an average about 2 inches, and no difficulty was experienced. The stratum of sand, which was about 20 feet in depth, was cut through, and a hard mottled clay was found under it. It was essential that the cylinders should be firmly fixed in the clay, in order to prevent the water contained in the sand from forcing its way under them, and rising into the well. The boring was therefore continued for a few feet, and the cylinders were at last driven into the clay with a heavy "dolly," made of the rough trunk of a tree. The water, which had hitherto stood above the level of the top of the sand in the cylinders, was now pumped out, and the well remaining perfectly dry, afforded evidence that the water contained in the sand had been effectually stopped out.

The 12-inch pipe mentioned in the original specification was dispensed with, and the boring was continued with a 10½-inch auger down to the chalk; 8-inch pipes were then introduced, which were firmly fixed several feet into the chalk, and were left standing 6 feet above the bottom of the cylinders. The object of this latter arrangement was, that any sediment contained in the water would settle at the bottom of the well.

Before the well was completed, it was desirable that the boring should be cleared by the percolation of water through the sides of the bore, which would of course be more or less hardened by the action of the auger; also that the supply of water should be ascertained: with this view a party of men were kept at work night and day, relieving each other every four hours. At the expiration of 48 hours the level of the water in the cylinders was accurately marked, and in one hour's work upwards of 900 gallons were drawn out. The water was lowered about 1 foot in the cylinders, and the quantity contained in that space being deducted from 900, gave the supply per hour nearly 800 gallons.

An economical mode of boring has been adopted with success on some parts of the Continent by using a heavy cast-iron bar, 2 cwt. or more, armed with a chisel at the lower end, and surrounded by a cylinder or hollow chamber, which receives through valves and brings up the detritus of the perforated stratum. This implement is suspended over a wheel or pulley fixed above the spot in which the hole is made, and is raised up and let fall by manual labour.

As the rope is raised up and down, its tortion gives the chisel a circular motion, which varies the place of cutting at each descent. When the chamber is full, the whole apparatus is raised quickly to the surface, and the material it contains discharged.

In cutting through a hard stratum, or under circumstances where iron pipes could be dispensed with, this plan of boring a hole would doubtless answer; but it is conceived that the bore could scarcely be made sufficiently straight to admit of pipes being inserted. It is, however, a much less costly method of executing the work where it can be made to apply, and is well worth attention.

In Plates XLIII., XLIV., and XLV., are exhibited some of the tools and implements which are made use of in boring.

Plate XLIII. chiefly contains the tools which are to be worked.

Plate XLIV. the implements, &c., which are employed in applying the boring tools shown in Plate XLIII.

Plate XLV. shows a variety of contrivances for cutting and raising tools, or rods, that may be accidentally broken, &c.

Plate XLIII. figs. 1, 2, and 3, are the elevation, section, and plan of an auger.

s[2] is a tapped socket for connecting it to the rods; *a* is a projecting edge called a "leading nose," for cutting; *b* a leather valve, fitted so as to assist in retaining the material bored out, so that it may be brought up when the auger is raised.

Figs. 4, 5, and 6. A similar auger of a larger size, the "leading nose" of which (*a*) is riveted on so as to be easily detached for repair; *b* is a leather valve for the purpose above explained.

This sized auger is used with the strong shanks or rods shown in figs. 19, 20, and 21. The end of the rod in fig. 21 is bolted to the shafts of the auger (see fig. 4); the ends marked *v* and *w* of the rod, shown in figs. 19 and 20, are then connected by the projecting tenons and mortises which appear in the figure, and the two coupling ferrules (*x x*), fig. 22, are driven tightly over the joint. Ordinary rods with a screw may then be attached to the socket at *s*.

Figs. 7 and 8. A small auger with longitudinal slit, used for boring through clay or loam.

Figs. 9, 10, and 11. Elevation, plan, and section of an S chisel, for cutting edges of flints and other hard substances.

Figs. 12 and 13. A "spring rymer" for dressing the edges of a boring preparatory to sinking the pipe; *c*, cutting edges placed reversely so that both act while the tool is turned round; *a* and *b* are a screw and swivel for regulating the size of the "rymer."

Figs. 14, 15, and 16. Large "shell" for following the auger in hard strata, to bring up the materials bored out, or to be used for boring through sand, &c.; *a a* are two valves opening upwards to admit the material, which are closed by the weight of it above them, when the shell is raised, and thus the material bored or cut out is brought up.

Figs. 17 and 18 show a similar shell of smaller size provided with *one* circular valve; the lower edge also is at right angles with the length of the shell, but in the large one, figs. 14, &c., it is placed in an inclined position.

Fig. 18*a* shows a length of boring rod usually of 20 feet long, with one intermediate welded joint or "half knob" at *a*; each length has a tapped

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[2] The letter of reference *s* in all of the implements denotes a tapped socket, adapted to receive the screw ends of boring rods.

socket at *s*, and a projecting screw to fit at *t*, by which the lengths are connected together to any extent that may be required.

Figs. 19, 20, 21, and 22, are already described under figs. 4, 5, and 6.

Plate XLIV. Implements employed in applying the boring tools, &c., shown in Plate XLIII.

Figs. 23 to 26 show wrenches of different sizes used for screwing the rods together.

Figs. 27 and 28. Spanner for turning six-sided nuts on bolts.

Figs. 29, 30, 31 show a forked instrument, technically termed the "large dogs," used for sustaining the rods while they are being lowered into the bore. The dogs are allowed to rest in the vertical position shown at fig. 30, in a square aperture in a horizontal platform erected over the well-hole (see fig. 61, Plate XLV.) The latch *a* (fig. 31), which turns on *b*, is opened, and when the rod is embraced within the side prongs, this latch is turned down on them, and the projecting sockets, &c., on the rods will of course prevent them dropping through. By the ring *c* the dogs are made fast to tackle above, and thus kept securely at any required height.

Figs. 32 and 33 show a heater consisting of two circular plates of iron attached by a bolt; used for making lead joints in pipes.

Fig. 34. Iron rod, hooked, for using the heater.

Figs. 35 and 36 show a smaller heater for copper pipes or tubing, and a rod for lowering it into the well.

Figs. 37 to 40. Two forms of "caulking" tools used for cement joints of pipes.

Figs. 41 and 42. The iron handles used for turning the boring rods: *a* shows the rod, which the handles are made to embrace firmly by screwing the bolts shown in the figure; the handles or winches are then turned in a horizontal plane by the workmen. These handles are made of various sizes, according to the size of perforation and rods, and the power required for working them.

Figs. 43 to 46 show two kinds of "hand dogs," used for similar purposes to which the "large dogs" are applied, but when less precaution and power is required. Figs. 43 and 44 are adapted for pipes, and are made of various sizes.

Fig. 47. A spring and swivel hook, attached by a ring to the rope tackle. In using this hook to connect it with a chain, the spring *a* is forced open against the shoulder *b*, and the link introduced. On the closing of the spring again, it is evident the link is firmly retained, and cannot become detached without again opening the spring.

Fig. 48 shows a wooden plug used for loosening the pipes: the part *a* is put within the pipe until the iron ring or shoulder *c* rests upon the edge of it, and the iron stop pieces (*b*) rest in notches cut in the pipes, as shown in fig. 48*a*.

Figs. 49, 50, and 51. The bucket used for raising the materials, &c. extracted, firmly hooped with iron.

Plate XLV. Contrivances for cutting or raising broken rods, &c.

Figs. 52 to 55 show a "spring latch tool" adapted for raising a rod, in case of the socket breaking, &c.: *b* the latches turning in *c* against the spring (*a*). Fig. 54 is a sectional plan showing the latches. Fig. 55 shows the manner in which the implement is used. It is forced down until the latch *b* passes the projection or half knob *d* on the rod *e*, and the rod may then be raised by the workmen above.

Figs. 56 to 59 show an implement of similar construction, used for cutting a rod without raising it; *b b* are steeled cutters turning on centres at *c c*, and are kept down by strong springs *a a*; fig. 59 shows the manner in which these cutters operate on a rod upon which the implement is lowered; by turning it round, the rod is cut through.

Fig. 60. Spiral instrument for getting hold of, and raising a rod that may have fallen aside into a soft or faulty stratum.

Figs. 61 and 62. The stage or platform referred to in figs. 29 to 31; *b b* are the bearers placed across the well-opening to sustain the platform; *a* is the hole in which the dogs are fixed; and *c c* are strong ribs for attaching the planks together.

Fig. 63 is one length of pipe of small size, made of sheet copper or iron, and having brazed joints at *b b*; *a* shows part of it in section.

Fig. 64. One length of common cast-iron pipe employed in well boring; *a a* shows it in section with a socket at one end *b*, and spigot-piece at the other

end, by which the lengths are connected together with bolts nutted inside, and having counter-sunk heads, so that no external projections may impede the sinking of the pipe.

The size of augers varies from 2 inches to 7 feet 6 inches in diameter. Augers of the latter size have been used very successfully by Mr. Clarke. In ordinary soil, eight men are required for turning them round.

In boring with the larger sized augers, smaller ones are generally used first; the difference in the size of each auger to be used in succession depending upon the tenacity of the soil, and other circumstances which affect the power required for turning them.

The chisels used for perforating rock are also of various sizes, and of different forms. A very useful form is that in which three cutting edges radiate from a centre, or when two cutting edges intersect each other at right angles, forming a cross; but the best is in the form of an S. Figs. 9, 10, and 11.

Officers desirous of obtaining further practical information on the use and application of the implements, &c., are recommended to visit Mr. Clarke's establishment at Tottenham, where they will have the opportunity of seeing other approved tools and many ingenious contrivances which must be seen to be understood. They cannot also fail to derive much valuable information both as to the application of the principle, and the practice of sinking Artesian Wells, from the proprietor, who will be found more anxious to impart the extensive knowledge and experience he has on those subjects than to make a mystery about them.

J. Jebb,
Major Royal Engineers.

London, Dec. 1841.

TOOLS FO

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Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

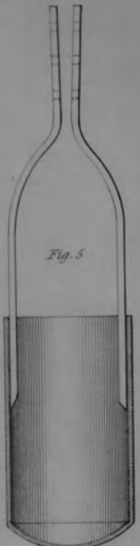


Fig. 7

Fig. 8

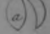


Fig. 6

Fig. 10

Fig. 9

Fig. 11

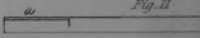
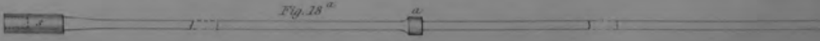


Fig. 17

Fig. 18

Fig. 18 ^{a}



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BORING.

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Plate 43.


Fig. 14

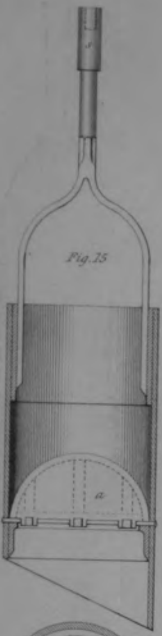


Fig. 15

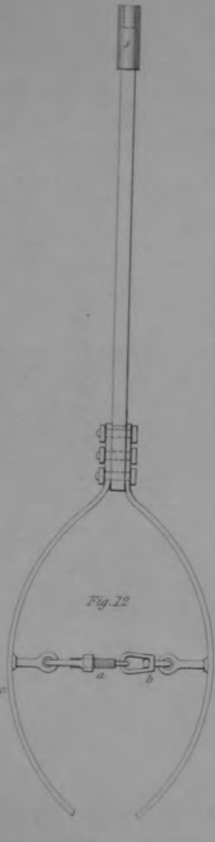
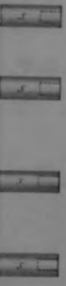


Fig. 12


Fig. 13



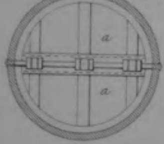


Fig. 16

Fig. 22

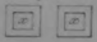


Fig. 19

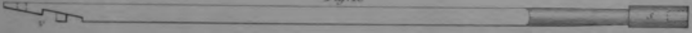


Fig. 20

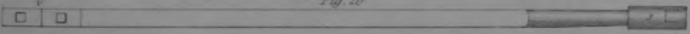


Fig. 21

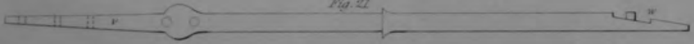


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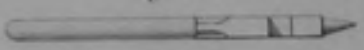
Fig. 23.

Fig. 24.



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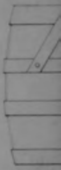

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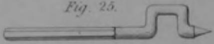

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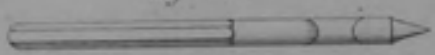


Fig. 50.

Fig. 27.

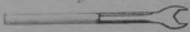
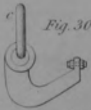


Fig. 28.

Fig. 51.

Fig. 29.

Fig. 30.



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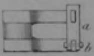

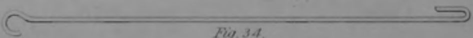

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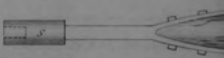

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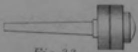

Fig. 33.

Fig. 47.

Fig.

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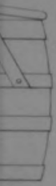
Tools, for cutting, &c.



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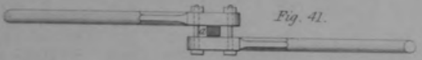
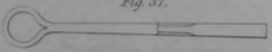


Fig. 41.

Fig. 37.



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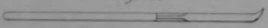

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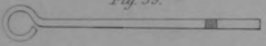

Fig. 40.

Fig. 36.

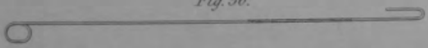

Fig. 48.

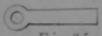

Fig. 35.

Fig. 43.

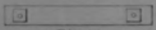

Fig. 44.

Fig. 45.

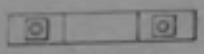

Fig. 46.

et.

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Contrivances for cuttin


Fig. 52.


Fig. 53.


Fig. 54.


Fig. 55.


Fig. 56.


Fig. 57.


Fig. 58.


Fig.

G. D. Dempsey del.

John Weale, Architectura

raising broken rods, &c.

Fig. 60.

Fig. 61.

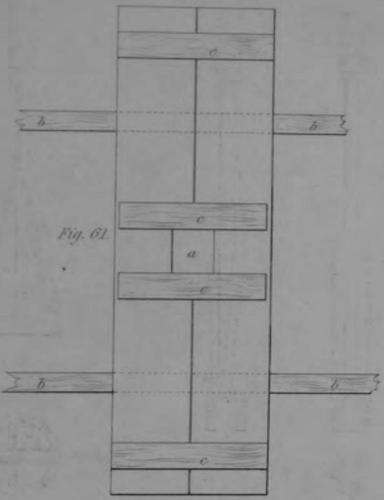

Fig. 61.

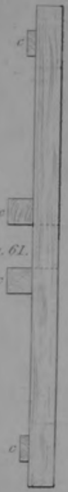

Fig. 64.

4.

Feet.

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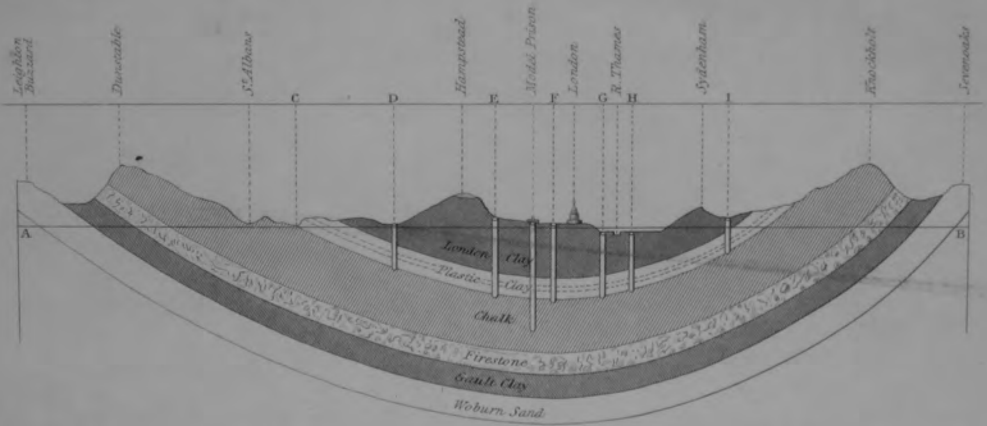
Plate XLIV



Section shewing the cause of the rise of water in Artesian Wells in the basin of London

Sections illustrating the Theory of Artesian Wells.

Fig. 1.

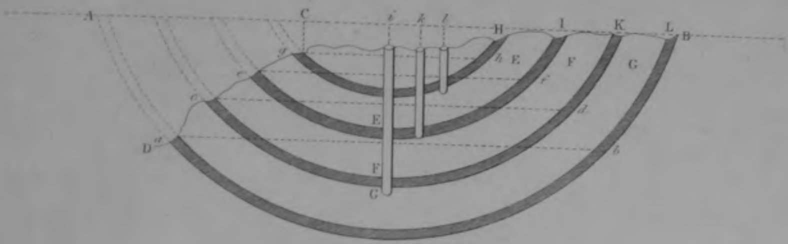
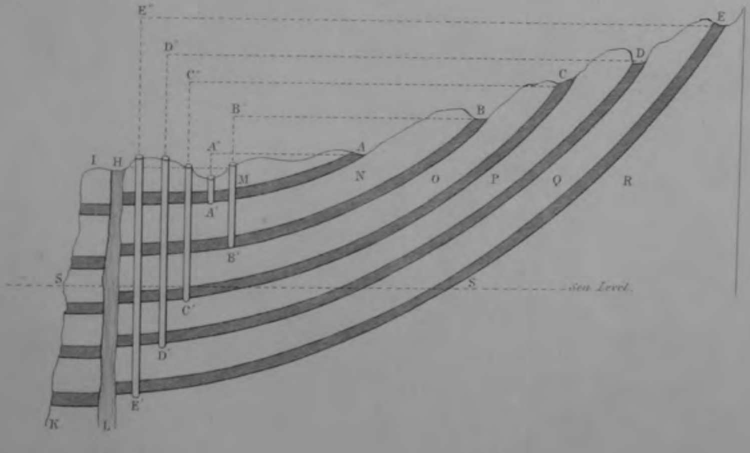


Fig. 2.



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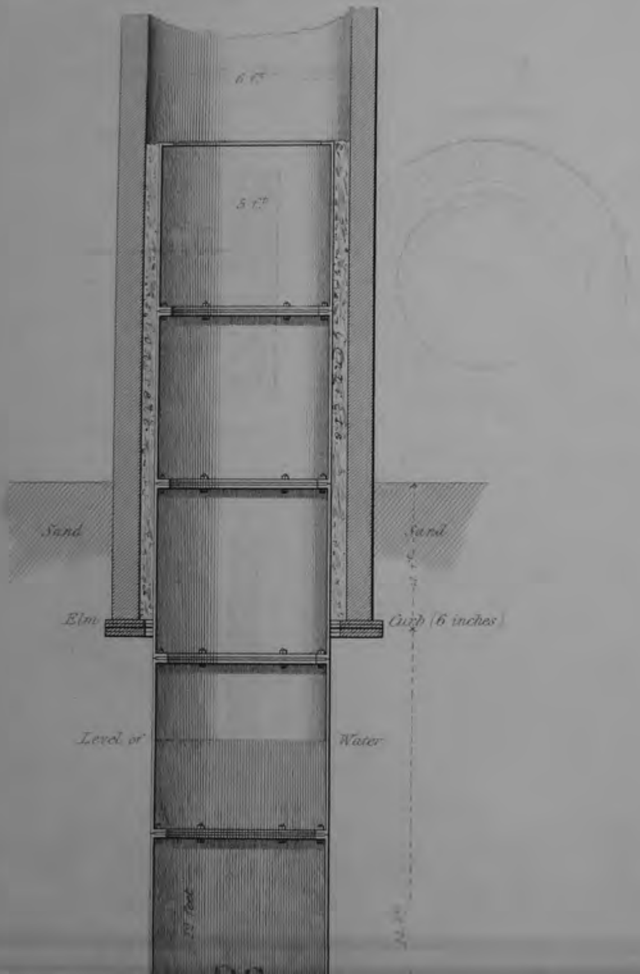
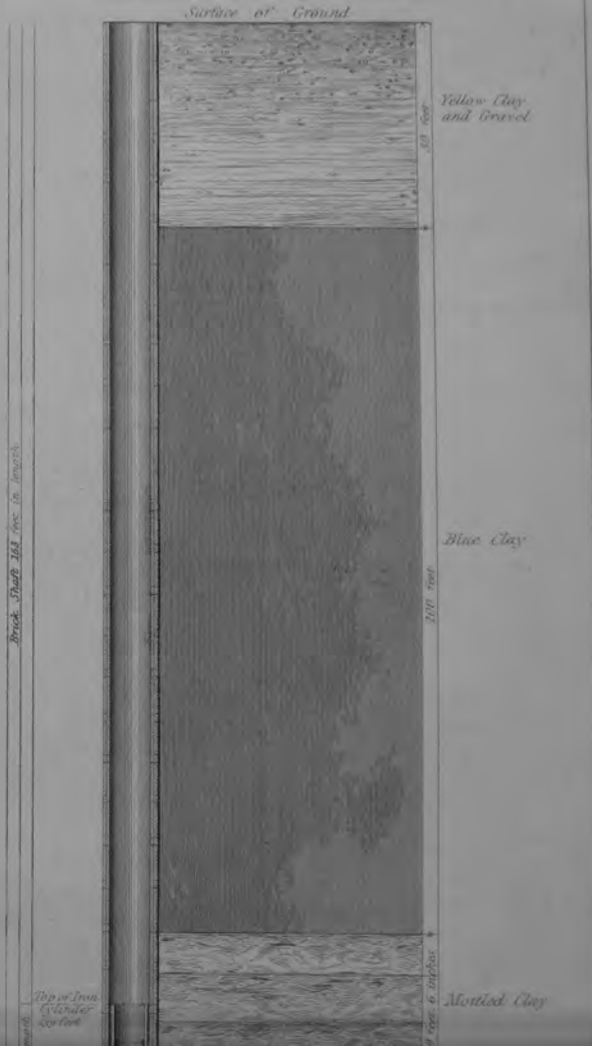
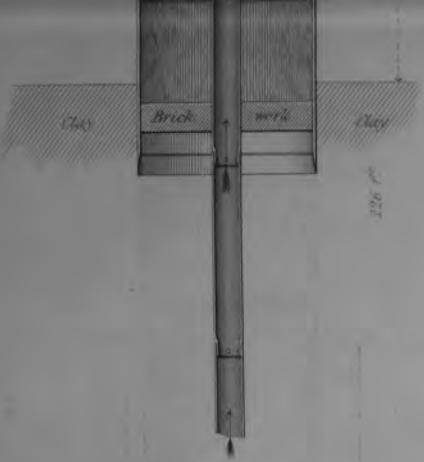
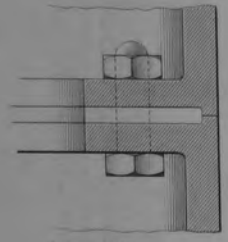
SECTION SHEWING THE IRON CYLINDERS, &c.





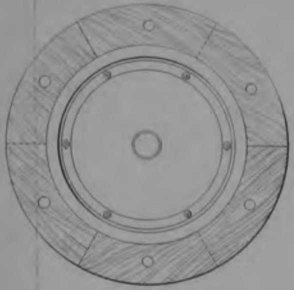


Joint Flanges Enlarged

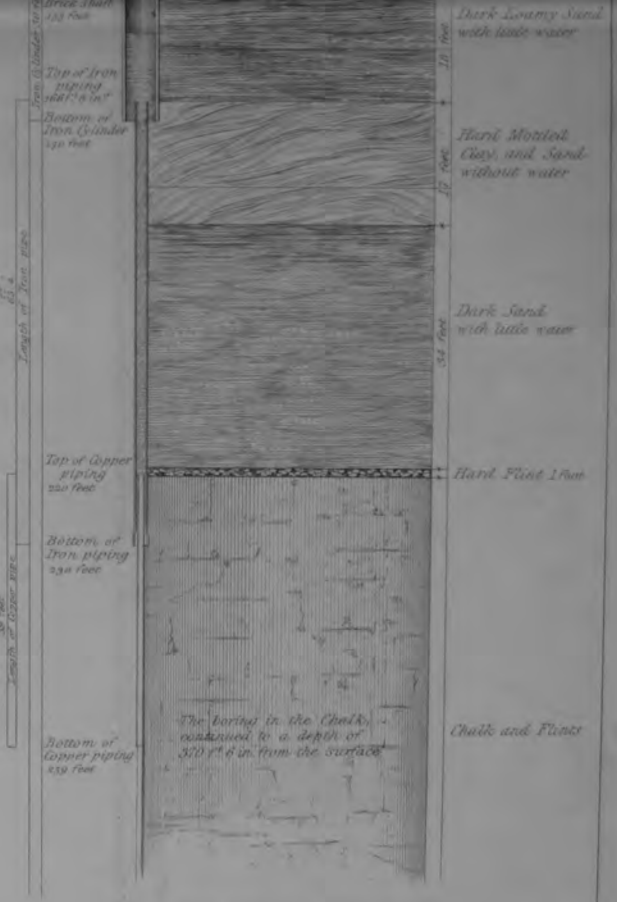


1 Inch thick

Plan above Elm Curb



6 Inches thick



The boring in the Chalk, continued to a depth of 370 ft 6 in. from the surface

Executed under the direction of
Major Jebb, R.l Engrs by
Thomas Clarke, of Tottenham

XIV.—*Observations on Painting Timber, when exposed to Damp.*

By W. Lander.

The following useful practical observations concur fully with my experience, and I recommend them, with Mr. Lander's permission, for insertion in the Royal Engineer Professional Papers.

E. Fanshawe,
Colonel Royal Engineers.

Devonport, October 15, 1839.

Sir,

I beg leave to lay before you a few observations which I have made on the construction and causes of decay in bridges on the works at this place; having been employed on the erection of the bridge at the north-west barrier in the years 1812 and 1813, and also on a large repair in 1837; and I am now employed on a similar repair at the north-east barrier bridge, which, I think, was built in 1816; which has induced me to make the following remarks:

1st. These bridges were paved with Guernsey pebbles, which, I think, was one cause of decay, as the wet constantly dripped through the joints; an evil which may be avoided by Macadamizing, by which such a compact body is formed that the wet cannot get through, and the joists and girders, &c., are thereby kept perfectly dry, besides the advantage of the vibration being very much reduced, as is the case now at the north-west barrier.

2nd. The whole of the wood-work below, as well as the under side of the flooring, was frequently payed over with coal tar, which, forming a thick body on the surface, was another, if not the greater cause of decay, as it completely prevented the air from acting on the wood, thereby keeping all moisture within, which of itself is sufficient to decay it. It must be observed that the plank or flooring was so rotten, that in many places it would not bear the weight of the men to work on it, and many of the joists and girders broke in two or three pieces in removing them; some of them were found to be quite dry, and in a similar state to snuff.

3rd. As a further proof of the bad effects of paying and paving bridges, I may state that the bridge at the south-east barrier across the old works leading to Stonehouse, the girders, joists, &c. of which have never been payed or painted, and the road above always Macadamized, remains sound and good at this time; and I know this to be a much older bridge than either of the former.

4th. I should state that the timber alluded to above is oak, but I think the same observations will apply to other timber, and in other situations, such as fences; for many posts and rails of the stockade fence here have frequently been found decayed, while in other and older fences, although much worn by time, yet not having been payed or painted, the fibre of the wood remains in a healthy state.

5th. I am also of opinion that skirting to walls, and linings to storehouses and other buildings, if not painted, would last much longer, as the damp from behind would then be allowed to evaporate by the action of the external air.

I am, Sir, your most obedient
and very humble servant,
WILLIAM LANDER.

XV.—*On Copying Maps and Plans.* *By* SAMUEL B. HOWLETT, *Esq., Chief Draughtsman, Ordnance.*

My principal object is to direct attention to a kind of paper lately introduced into this drawing room, chiefly for copying maps and plans, instead, for many purposes, of either the very thin paper or the usual kinds of drawing paper.

Necessity having forced me to find means of getting plans copied with the greatest possible rapidity, it may be acceptable if a description of the paper in question be given in connexion with a description of the method of copying that has been adopted.

From the surprise expressed by many persons who have visited this Office, I have reason to think that the information about to be given is far from being generally known; and, humble as the subject may be, it is of some official importance, (considering the great number of drawings required in the Ordnance service,) to determine the most rapid method of copying, and the sort of paper best adapted for transmission by post to all parts of the British dominions.

Formerly, drawings were copied in this Office upon thick drawing paper, either by pricking them through, or by first tracing them upon oiled paper to be afterwards transferred by the tracer and black-lead paper, or by tracing with a pencil at a glass such lines as could be seen, and then finishing the work in ink from the pencil tracings obtained by either of these means. Sometimes the pentagraph was resorted to for even obtaining a copy to the same scale. By either of these methods much time was necessary to make copies; but now, in nearly all cases of copying, thick drawing paper is thrown aside, and medium Bank post paper, measuring 23 inches by 18, used in its place, joining several sheets together with gum, in narrow seams, when required for large drawings. With this paper every plan can be seen through distinctly at the glass.

The thin paper, used through necessity for copying, was found to take up so little room in estimates and correspondence, and to be so convenient


IOHAN WEALE

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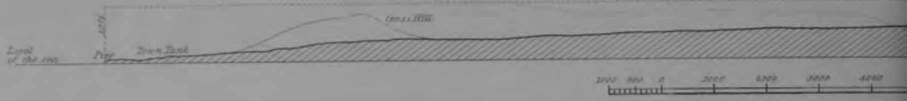
Fig. 1

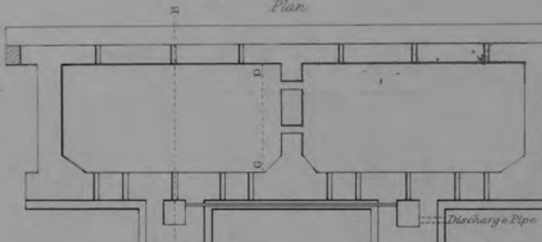
Section of the Ground on which



Bate's Tank Dampier's Spring

Fig. 2

Plan



A Sunken Tank

Section

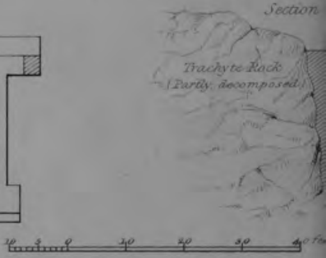


Fig. 4

Plan

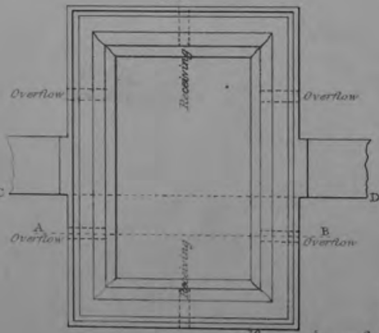


Fig. 5

Section & Elevation through AB.CD

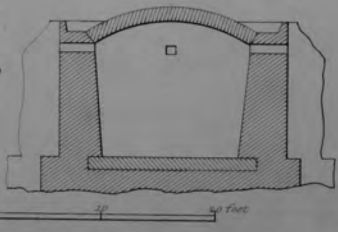
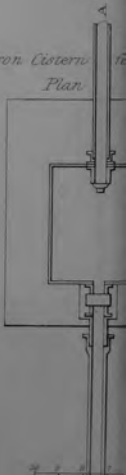


Fig. 8

Iron Cistern

Plan



E.A. Bernays del.

John Weale, Architectu

SCENSION.

ater Pipes are laid

Fig. 3

ation of AB.CD

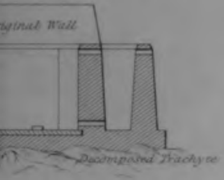
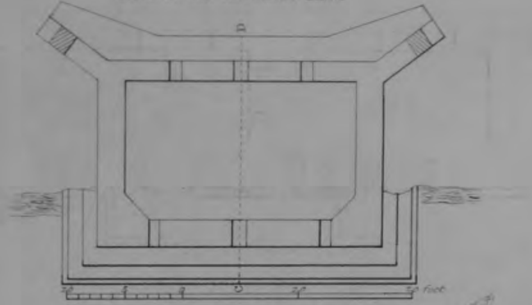


Fig. 6

Plan of the Mountain Tank



Section of Mountain Tank through C.D

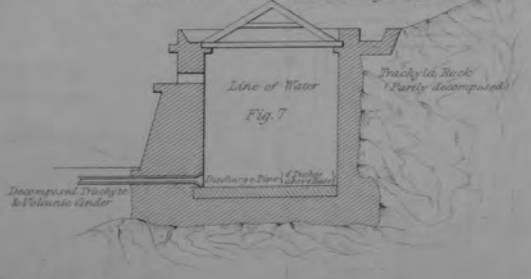
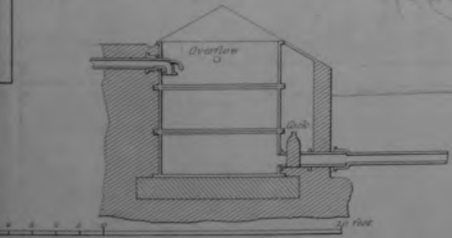


Fig. 7

of Pipes

Fig. 9

Section through A.B



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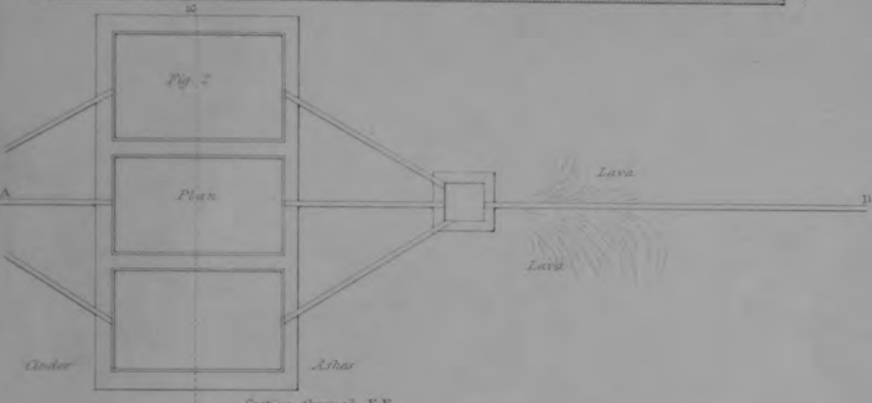
PRINCIPAL RESERVOIR NEAR THE SHORE.

Fig. 1

Section through E.F



Section through E.F

Fig. 3

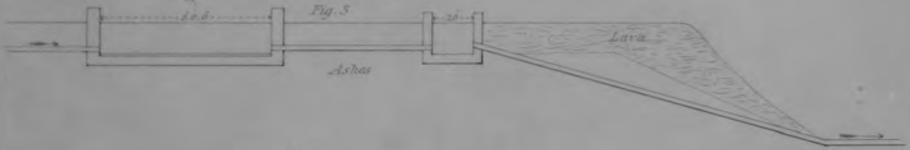


Fig. 4

Section shewing the mode of securing the Pipes across the small Water Courses

Section of the mode of securing the Pipes over Rocky Ground

Fig. 5

Section of Dry Wall for the Pipes

Fig. 6

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3. General Plan.
4. The South Front.
5. The East Front.
6. The North Side.
7. The West Front of the Upper Ward.
8. The South Side of the Upper Ward.
9. Section from North to South through the Upper Ward.
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12. Plan of the Principal Story of the Upper Ward.
13. View of the South and East Sides.
14. North-East View.
15. North-West View.
16. South-West View.
17. A View of the Upper Ward, (looking East.)
18. A View of the Upper Ward, (looking West.)
19. View of the Riding House and Stables.

VOL. II.

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3. The Victoria Tower.
4. The East Front of the Victoria Tower.
5. The Clarence Tower.
6. The Chester Tower.
7. The Prince of Wales's Tower.
8. The Brunswick Tower.
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10. George the Fourth's Tower.
11. The Winchester Tower.
12. Henry the Third's Tower.
13. King Edward the Third's Tower.
14. The Round Tower.
15. The Inner Side of George the Fourth's Gateway.
16. The Sovereign's Entrance to the Private Apartments.
17. The Kitchen Court Gateway.
18. The State Entrance Tower.
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2. Principal plan.
3. Elevation of the front.
4. Elevation of the back front.
5. Longitudinal section through A to B.
6. Longitudinal section through C to D.
7. Details of the principal front: Windows, ground floor, section of cornice, section of window head, section of under part of window, section of ornament in string course, elevation of console, balustrade to area front.
8. Details of the principal front: Section of principal cornice, elevation of cornice, plaster cap and entablature to window, elevation of one-pair window, elevation of cornice, &c.
9. Details of rear front: Elevation of one-pair window, section of window head, elevation of block, elevation of cornice, section of principal cornice, section of window cornice, &c.
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17. John Gower. *St. Saviour's Church, Southwark.*—1408.
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19. Effigy of the same.
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