

(*Paper No. 1699.*)

**"Cleopatra's Needle."**

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As the work of transporting and erecting Cleopatra's Needle was initiated and completed by members of the Institution, it may be thought that the Minutes of Proceedings should contain a brief record of the operations, and of any facts of general engineering interest deducible therefrom.

So far as the inception of the work is concerned, it will suffice to state that, six years previous to the conclusion of the arrangement with Mr. Erasmus Wilson, Mr. John Dixon and his brother, Mr. Waynman Dixon, began patiently and persistently to direct public attention, both in this country and in Egypt, to the question of the removal of the obelisk, and that General Sir James Alexander worked zealously to the same end. Early in 1877 Mr. Wilson and Mr. Dixon met and agreed, the former to pay £10,000 upon the erection of the Needle on a satisfactory site in this country; and the latter to take all risk, and to accept, in Mr. Wilson's own words, the "no cure no pay" principle of reimbursement. Mr. Dixon then requested the Author to co-operate with him in giving practical effect to his idea of a cylindrical sea-going vessel to be built around the prostrate obelisk, and launched by rolling instead of in the usual manner, and in considering the best method of erecting the Needle; and to his brother he entrusted the responsible duty of conducting the operations in Egypt.

In the middle of March 1877, a contract was concluded with the Thames Iron Works for the building of the "Cleopatra," and the work proceeded so promptly and smoothly that within five months all was ready for the launch in Egypt. On September 8th the "Cleopatra" was safely in dock at Alexandria; on October 15th she was on her beam ends and tenantless amidst the waves of the Bay of Biscay; on January 20th, 1878, she was once more safe and in the Thames; and on September 12th, or exactly eighteen months after the order to build the "Cleopatra" was given, the Needle was erect on its pedestal on the Thames Embankment.

M. Lebas, who conducted the operations for the transport of the Luxor obelisk to Paris, concludes his large work on the subject by drawing a parallel between his own mode of procedure and that of Fontana, who erected in 1586 the last previous obelisk. The Author, therefore, will only be following precedent, if he briefly records a

few facts, to enable a similar parallel to be drawn between the proceedings in the instances of the Luxor and of the Cleopatra obelisks.

The special transport, the "Luxor," ordered to be built in 1829, left Toulon with a crew of one hundred and thirty-two sailors and artisans on April 15th, 1831, and arrived opposite Thebes on July 12th of the same year. Three and a half months of "constant labour and fatigue" were occupied in the preparations for lowering and embarking the obelisk; and when all was ready the capstans were manned and the needle was lowered  $60^{\circ}$  in 25 minutes, and the remaining  $30^{\circ}$  in eighteen days. A month later, that is to say, on December 19th, the obelisk had, by the constant labour of the men, working fifteen hours a day, been slid down the 1,500 feet of incline to the ship, and on the last day of 1831 the stowage was completed, the bow of the vessel replaced, the ship masted and rigged anew, and all made ready for the voyage to France. From one cause and another, but chiefly from the operations being ill-timed, the ship did not float for nearly eight months, nor get to Alexandria until the first day of 1833. The officers apparently had not much confidence in the sea-going qualities of the "Luxor," as they waited three months at Alexandria for favourable weather; the result of all this delay was that the ship did not reach Paris until December 23rd, 1833. In August 1834 disembarkation was effected by the aid of two hundred and forty artillerymen; and at last, on October 25th, 1836, in the presence of 200,000 spectators, the Luxor obelisk was successfully erected. It will be seen, therefore, that the proceedings were spread over seven years, and that the time occupied in simply moving the Luxor obelisk across the Place de la Concorde, and erecting it, was about 50 per cent. greater than the whole time of the operations in the instance of Cleopatra's Needle, from the building of the transport to the swinging of the obelisk. As regards cost, the comparison, as might be anticipated, would be even more favourable to the recent work. Looking at M. Lebas' design now, it appears almost incredible that it should not have occurred to him that a few traversing jacks, costing say £50, would have done his work more quickly and efficiently than the formidable inclined causeways and capstans, costing many thousands of pounds.

The following are the leading dimensions of the two obelisks:—

LUXOR.		CLEOPATRA.
Base . . .	8·0 × 7·9 feet.	7·72 × 7·22 feet.
Top . . .	5·2 × 4·9 „	5·1 × 4·9 „
Height . .	68·7 + 6·3 = 75 feet.	61·0 + 7·7 = 68·7 feet.
Weight . .	225 tons.	186 tons.

If the English obelisk had been of the heavier weight, the only extra cost involved would have been that of about 10 tons of wrought iron in the vessel, or say £200. No increase in the power of the jacks or in the strength of the scaffolding would have been necessary.

Many other obelisks have been transported from Egypt to Europe, and it is worthy of note that in every instance a special transport has been designed and built for the work. Thus, the Emperor Augustus transported two obelisks in a single vessel of "immense size," from Alexandria to Rome, and erected one in the Circus Maximus and the other in the Campus Martius. Caligula transported a third obelisk also to Rome, and it is alleged that the ship or raft employed for the purpose was of so vast a size, that it served under the Emperor Claudius as the foundation for a tower in the port of Ostia, similar to the Pharos of Alexandria. Constantine removed a still larger obelisk from Thebes to Alexandria, intending to take it to Constantinople, but on his death his son changed its destination to Rome; the vessel employed being, it is stated, the largest up to that period constructed, taking three hundred rowers to propel it, and having a mast so large that "two men could not embrace it." The efforts of several thousand men, and an apparatus of immense beams, cords, and pulleys, "resembling a forest," were required to erect this obelisk. Many of these Roman obelisks were thrown down by the barbarians, and remained prostrate for centuries. Sextus V. instructed Fontana to re-erect the obelisk of Caligula, as already mentioned, in 1586, and this was successfully effected by the aid of one thousand two hundred men, eighty horses, one hundred capstans, and the usual forest of timber and tackles.

A special transport was also used for the English Needle, but it was insignificant in size and cost compared with any of the former vessels, and the erection was completed without the use of a single creaking rope or capstan, but quietly and surely by a few light hydraulic jacks which a couple of men could easily handle. The intention of the engineers from the first was to do the work in the most simple and direct manner, without a timid reliance on precedent on the one hand, or a studied avoidance of it, with a view to originality, on the other hand, and this intention was strictly adhered to throughout.

The special vessel contrived for the English obelisk differed essentially in principle from previous ones, as it had to perform the double functions of transporting the obelisk on land and at sea. It was the first duty that determined the cylindrical form of

vessel; but on investigation the Author found that such a form incidently offered not only increased strength in the event of collision or grounding, but great advantages as regards steadiness amongst waves. The first thing to be settled was the size of the ship. Widely differing dimensions had been published of the fallen Needle, but on laying it bare and taking exact cross sections, the probable weight was estimated at 186 tons. Adding to this, the weight of the ship, say 70 tons, that of the stores and ballast, say 34 tons, and allowing a surplus buoyancy of 40 per cent., which is in excess of the usual margin, the given dimensions of 92 feet long, inclusive of the wedge-shaped ends, by 15 feet diameter were arrived at (Plate 9). The vessel had collision bulkheads at the bow and the stern, and seven intermediate watertight bulkheads, through six of which the Needle passed and was wedged thereto by a species of "spring beam" wooden packing, of such strength, or rather weakness, as to break under a considerably less blow than could by any chance injure the Needle. Plating  $\frac{3}{8}$  inch and  $\frac{7}{16}$  inch thick was riveted to these bulkheads and to intermediate frames of reverse angle-irons spaced 3 feet 6 inches apart. A cabin 18 feet by 8 feet, somewhat resembling a large omnibus, with the recess for the feet let into the top of the cylinder, was placed amidships, where its occupants would be least inconvenienced by the pitching. From the steering deck on the top of this cabin a gangway or hurricane deck was carried forward to a small turret at the bows, which served the double purpose of splitting the waves and throwing them off the back of the cylinder, and of affording an independent access to the interior of the vessel in the highly improbable event of the strong iron cabin being carried away by a heavy sea. All these accessories, with the bilge keels, mast, and rudder, were of course added after the cylinder had been rolled into the sea and dry-docked at Alexandria.

One of the first points to be considered was the amount of stability which it would be desirable to give to the ship.

In the first stage of the process—rolling into the sea—it was obvious that the cylinder and its load should be nearly balanced, or in other words, it was not optional to place the Needle far from the axis of the cylinder. For sea-going purposes it was no less obvious that a certain amount of stability must be provided, and that it would be most conveniently and directly obtained by placing the Needle below the axis. A compromise, therefore, was necessary, and it was finally decided to place the axis of the Needle 4 inches below that of the cylinder, to balance this eccentricity during rolling by filling in the cabin recess with old rails, and to give the

necessary increased stability at sea by taking out these same rails and placing them with others at the bottom of the vessel. This arrangement proved perfectly convenient and satisfactory in practice, and the experience gained did not suggest in any respect a modification of the amount of stability given, which was that due to a metacentric height of 9 inches, or what is practically the same thing in the instance of the circular ship, to the centre of gravity being that amount below the centre of the cylinder.

It was hoped and believed that the cylinder, when once set rolling on the shelving and fairly smooth beach of the Mediterranean, would run down with accelerated velocity into the sea. Indeed back stays were provided to control this movement; but, on the other hand, provision was also made for the contingency which really did happen, namely, the sticking fast of the cylinder, and its exposure during some days to the possible effect of a heavy sea breaking against it when grounded. Great strength was given to the cylinder, and the Needle, as already explained, was packed in such a way that the whole ironwork could be smashed to pieces by bumping without exposing the stone to any risk of fracture. It is hardly necessary to add, that the consciousness of this provision was very reassuring to the engineers, when the appearance of some indentations of considerable size on the rotating cylinder showed that several large stones on the sea bottom had been overlooked by the divers, and that the "spring beam" wooden packing between the stone and the bulkheads was undoubtedly being called upon to fulfil its function of mitigating shocks.

To protect the iron shell during rolling, the cylinder was lagged with 6-inch planking for a length of about 12 feet at each end, so that except where stones projected more than 6 inches above the general level the plating was untouched. The Cleopatra was thus temporarily a gigantic 270-ton road-roller, 16 feet in diameter by 24 feet long, and it was surprising how little the planking showed signs of the enormous pressure; in fact the beach was rolled splendidly level, but the wood was hardly scratched.

The launch was commenced on August 28th, 1877, and though the cylinder, urged on by the screw-jacks and by tug-boats, made two promising starts of a quarter of a turn each, in the evening it rested in but 3 feet of water. The next day led to a still greater disappointment, as the cylinder, amidst great cheering, took an apparently final roll seawards, but pulled up in 7 feet of water—about 2 feet short of what was required to float it. By this time the Arab and Maltese workmen had apparently abandoned the idea of the "Cleopatra" rolling into the sea at all, as they were

clustered unconcernedly on the top all the time the two heavy tugs were being run at the hawsers to attempt to start it. Being there, however, the noise of escaping air quickly informed them that the cylinder was filling with water, and it was correctly inferred that a hole had been knocked through the bottom by an overlooked stone. The Author, who was on one of the tugs with Mr. Dixon, at once saw that it would be useless to attempt to start by the tugs the waterlogged mass of nearly 300 tons, resting on a bottom which, although originally inclined in favour of the load, would probably be heaped up against it by the lapping of the waves and under current; and he suggested that a cribwork of wood, about 9 feet square, should be weighted and sunk close behind the cylinder, so as to enable the workmen to rotate the latter, as before, by the jacks. It was considered desirable, however, to adhere strictly to the original programme, and some days were thus spent in futile attempts to continue the launch. Finally the cribwork was made, and on September 7th the cylinder, once more staunch and sound, was easily rolled into deep water and towed to a sheltered spot, where the iron rails were removed from the cabin recess, and the ship was made ready for towing the following day round the breakwater into Alexandria harbour.

Notwithstanding these mishaps, the Needle was removed from its position high and dry on shore to the dry dock 10 miles off in eleven days, so the delay was practically immaterial. Mr. Dixon's original idea of rolling the Needle into the sea proved, therefore, perfectly satisfactory in practice, and the only modification in detail the Author would make, with his present experience, would be to double the thickness of the timber lagging so as to leave a greater margin for projecting stones, and to lay down a few baulks on the beach to enable the cylinder to acquire sufficient velocity to carry it without stopping over the somewhat rough sea bottom.

The first experience of the "Cleopatra" as a sea-going vessel was obtained in towing her the above 10 miles on September 8th. A heavy beam sea caused the tug to roll sponsons under, but the cylinder ship remained so absolutely steady, that a crowd of Arabs and Maltese made the journey on her rounded back with perfect safety, though they had nothing whatever to hold on by. This entire freedom from rolling afforded an interesting confirmation of the Author's previous calculations as to the probable behaviour of a cylindrical ship with low metacentric height. The late Mr. W. Froude and others have clearly established the fact, that what-

ever quality will make a ship stiff in still water will make her a heavy roller amongst waves. Thus, a raft will obviously follow the slope of each wave, and, as exemplified by the behaviour of the earlier ironclads, a ship with the weights too low down may roll three times as fast and three times as deeply as another ship with sufficient but much smaller stiffness. Now a cylinder has no stability of form either afloat or ashore, so it was to be anticipated that the "Cleopatra," unless too heavily ballasted, would allow the waves to pass under her without herself being rolled. On the passage round the breakwater the stability was simply that due to the Needle being placed 4 inches below the centre. On the voyage home the stability, as already stated, was that due to a metacentric height of 9 inches, and this proved perfectly satisfactory; for whilst, on the one hand, she was stiff enough to stand up against the wind acting on the cabin and top-hamper, she was, on the other hand, so lightly ballasted as to make the voyage, according to Captain Carter, her commander, without a single roll, until she was caught in the storm in the Bay of Biscay.

The number of rolls a ship makes in a minute is directly proportional to the square root of the metacentric height, and inversely proportional to the radius of gyration. The length of pendulum which would oscillate in the same time as a given ship would roll in still water is obtained by dividing the square of the radius of gyration by the metacentric height. In the case of the "Cleopatra" the metacentric height was 0.75 foot, and the radius of gyration 4.75 feet, so the corresponding length of pendulum would be 30 feet, and the number of double rolls which she might be expected to make in a minute, if forcibly set in motion by the wind or otherwise, would thus be something under 10. This is a slow rate for so small a vessel—indeed, the rate of the considerably larger gunboats in the French Navy ranged from 10.3 to 15 per minute—and it was fully anticipated, therefore, that the "Cleopatra" would prove in every respect an exceptionally good ship in respect to rolling.

As regards pitching and steering, it must be admitted that she was somewhat disappointing. To mitigate the effect of the necessarily heavy weights towards the ends of the ship, the bow and stern were made very full, and this reacted on the towing and steering qualities. Of course, the longer the cylinder the greater would have been the risk during launching; but having reference to all the circumstances of the case, the Author is of opinion that had the ship been only 10 feet longer, with a finer bow and stern, her increased speed would have taken her clear of the Bay

of Biscay before the occurrence of the storm, which resulted in the loss of six lives, a delay of four months, and an additional cost to Mr. Dixon eventually of £9,000. Had the iron rail ballast not broken loose, the "Cleopatra" would not have been abandoned, as Captain Carter knew she could ride out any storm, and only left her on account of the panic-stricken condition of his Maltese crew. Had she even been painted some conspicuous colour, instead of that of the wave crests, she would have been seen the next morning from the "Olga," and the salvage costs would have been avoided.

It was on the 21st of September, 1877, that the "Cleopatra," towed by the "Olga," started upon her eventful voyage to this country. Her crew consisted of eight Maltese, with Captain Carter<sup>1</sup> in command. All went well for the first 2,400 miles. Captain Carter reported that the "little vessel justified in every respect the confidence of her designers, for even in the rough weather experienced from the time she entered the Bay of Biscay, not a drop wetted the steering deck over the cabin." As the vessel lay so low in the water, the prow was of course "covered by every wave with which it came in contact, but the small turret at the bows supporting the hurricane deck split each wave, and throwing the halves on each side, left the deck-house clear." Though "the pitching was considerable, the rolling was practically none; the cylindrical form of hull allowed the sea to slip over it without causing the smallest disturbance." On Sunday, the 14th of October, a furious squall, accompanied by hail and rain, came up from the S.S.W., and at noon it was blowing a heavy gale. The sea becoming very high and more quarterly, broke heavily against the deck-house, and Captain Carter signalled to the "Olga," "Prepare to heave to head to wind." Captain Booth, of the "Olga," replied, "Great risk to tow-line if hove to." At 7.30 P.M., in latitude 44° 53' N., and longitude 7° 52' W., the ballast having broken adrift, the "Cleopatra" signalled, "Am foundering; send a boat." After two hours' attempt, a boat—manned by the following volunteers, Askin, second mate; Gardner, boatswain; Benbow, Burns, Donald and Patan, able seamen—was successfully lowered and got clear of the "Olga." At 1 A.M. on the morning of the 15th, Captain Booth heard a cry from the "Cleopatra:" "We are foundering fast; boat adrift; send a boat to take us on board;" and he then learnt for the first time that the boat despatched by him had never reached

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<sup>1</sup> This able and universally respected officer of the P. and O. Company has since died of dysentery at Bombay.



the "Cleopatra." At daylight a 5-inch line was with much difficulty made fast to the dismasted vessel, and her crew rescued by hauling a small boat towards them. The "Olga" then steamed to windward, looking out for the lost boat, and came across the "Cleopatra's" mast, a boat-hook, and a cork buoy, but failed to see any other wreckage. In the afternoon, after steaming to leeward, the search was abandoned, and as nothing was seen of the "Cleopatra," it was concluded that she, as well as the "Olga's" boat, had foundered in the heavy sea still running.

The news of the abandonment was brought home by the "Olga," and though the public generally accepted the view of those on board that vessel, both Mr. Dixon and the Author declared through the press their firm confidence that the "Cleopatra" was still afloat. Their confidence was quickly justified by the welcome news that she had been picked up and taken into Ferrol by the "Fitzmaurice." The captain of the latter steamer reported that, after laying to in a "fearful gale" on the night of the 14th, he put on his course again, and at 5 P.M. on the 16th, observed on the lee beam what he thought to be a ship bottom upwards. He bore down and saw that he had found the Needle ship, but as the sea was rolling too heavily to venture aboard, he hove to for the night. At day-break on the 17th, a boat was lowered and hawsers got aboard, and after some partings of tow-line and other minor mishaps, the "Cleopatra" finally reached Ferrol at 9.30 P.M. on the 18th of October, 1877.

At 7.30 A.M. on the 16th of January, 1878, the Needle ship was once more got under way, this time in tow of the steam-tug "Anglia," and at 10 A.M. on the 20th she was safely moored off Gravesend. After some further delay in settling the site, she was finally brought alongside the Embankment, opposite the Adelphi stairs, and there grounded upon a platform of wooden baulks. The cabin was first removed, and the cylinder rotated a quarter of a turn to bring the least worn side of the obelisk towards the roadway; the shell-plates were then cut away, and the Needle was lifted by hydraulic jacks and slid forward by screw traversers until it rested horizontally upon timber packing, with its centre of gravity over the centre of the pedestal. A timber staging about 50 feet high, consisting of four uprights with bracing and raking struts, was erected round the pedestal, and a loosely-fitting wrought-iron jacket 20 feet long, with knife-edge trunnions, was riveted around the Needle and firmly wedged to it. The trunnions rested upon box-girders, at the ends of which were ordinary hydraulic jacks, and the Needle was thus lifted in a horizontal position until the

necessary height was obtained to admit of its being swung into a vertical position. It may be interesting to note that the Needle and jacket, weighing together about 200 tons, were so nicely balanced on the knife edges as to be easily movable with one hand. In fixing the length of the jacket at 20 feet, the Author was satisfied that the transverse stress upon the Needle during the process of erection as described would then certainly be less than it had already sustained when being handled in Egypt. Had the Needle been of brick in cement, like the celebrated brick beam tested by Brunel in 1837, the stress would have been exactly equal to the breaking weight, so that the margin of safety, with the 20-foot jacket, was represented by the difference of strength between Egyptian syenite and good English brickwork in cement.

It only remains to add that the whole of the operations connected with the erection proceeded without a hitch, and that the Needle was swung slowly and imposingly into a vertical position on September 12th, 1878. The strains on the jacket and its knife edges during this half-hour were of course complex and severe; but as they occurred only once, the Author felt justified in subjecting the metal, though exposed to jerks, to the unusually high strain of  $7\frac{1}{2}$  tons per square inch. At every stage of the operations, in Egypt and in this country, the work could be easily advanced by a single man working at a hydraulic jack. This feature in the design constitutes perhaps the most characteristic difference between the proceedings of the English engineers and those of their predecessors, who were unable to move their obelisks even an inch without the capstans being fully manned by several hundred men.

The necessity of attending to the smallest details could not be more forcibly illustrated than by the case of the "Cleopatra." Clear instructions were given by the engineers for everything but the fixing of the ballast, but that unfortunately was left to the discretion of the crew. The iron rails fitted between the frames were but slightly secured by 1-inch planking, so the very first roll the ship took in the Bay of Biscay sufficed to break everything loose, and permit the rails to slide round the cylindrical inside of the vessel. Even then all would have been well had the Maltese crew not been too panic-stricken to succeed in their attempts to secure the rails which had broken loose. The Needle being placed 4 inches below the centre, the ship would of course be effectually prevented from turning completely round, or even from taking a further list than she did; but it is perhaps no matter for surprise that Captain Carter, on this being pointed out to him by the Author, replied, "I had every confidence in the calculations, and was quite

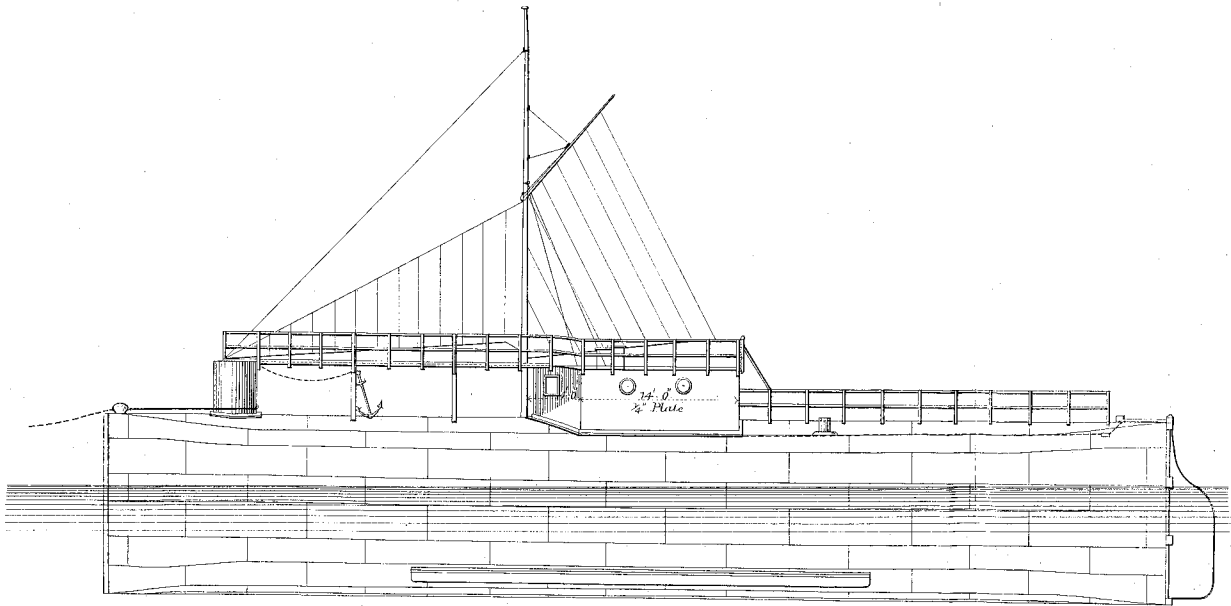
sure the 'Cleopatra' would come right side upwards sooner or later; but during the fury of the storm, and with my Maltese crew on their knees praying around me, I couldn't help reflecting that she might be an inconveniently long time in doing it."

The loss to Mr. Dixon from the twenty-four hours' abandonment of the "Cleopatra" amounted ultimately to upwards of £9,000, and it is ever to be regretted that nearly the whole of that sum has been expended in lawsuits and in heavy salvage claims for services costing but a nominal sum. Although it was known to the world that the work was, in a certain sense, a national one, the "Cleopatra's" cargo was dealt with by salvors and lawyers as if it had been a remunerative cargo of cotton or grain, instead of an old stone that Mr. Dixon was bringing home from Egypt.

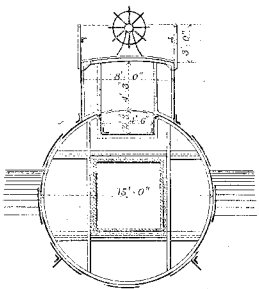
It may be worthy of note that the "Duke of York's column," the shaft of which is 94 feet high by 11 feet 6 inches diameter, and the total height 123 feet 6 inches, was erected during the period of the removal of the Luxor obelisk at a cost of £15,760, the time occupied being twenty months. The operations in the instance of Cleopatra's Needle and the Duke of York's column were thus practically identical as regards time, and cost also if the legal proceedings be excluded.

The sister obelisk to that on the Thames Embankment is now being removed to America, at the expense of Mr. Vanderbilt. Mr. Dixon was solicited by the latter gentleman to undertake the work for the sum of £15,000, but, it is hardly necessary to say, he declined to do so at the price. The mode of procedure adopted by the American officers in charge of the work is a combination of previous systems: thus the jacket and trunnion system of the English engineers, the timber raft of Caligula, and the ordinary shaped vessel of Lebas are all pressed into the service. Owing to the position of the trunnions not coinciding with the centre of gravity of the Needle, the latter, when being lowered into a horizontal position from its pedestal at Alexandria, came over with an unexpected rush, cracking the cast-iron jacket and the Needle also narrowly escaping fracture. Great difficulty and delay were experienced in launching the raft constructed to carry the obelisk from its original site to the dry dock at Alexandria, where the ocean-going steamer destined to carry it to America was awaiting it, and it is understood that the sum of £15,000 will be much exceeded before the work is complete.

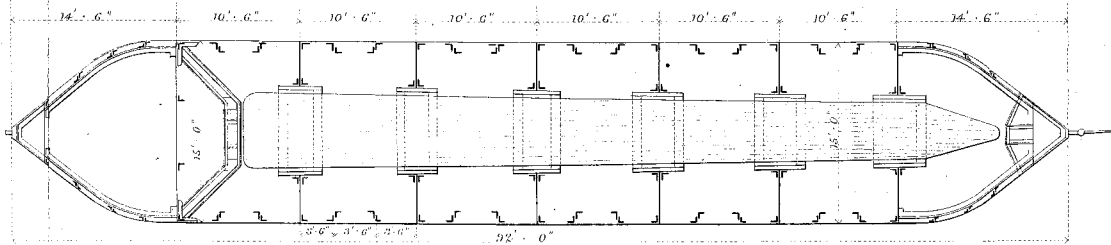
The Author has supplied a small scale tracing from which Plate 9 has been engraved.



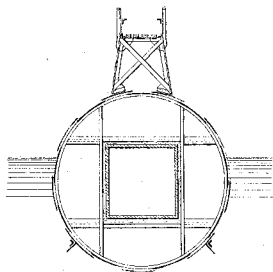
SIDE ELEVATION .



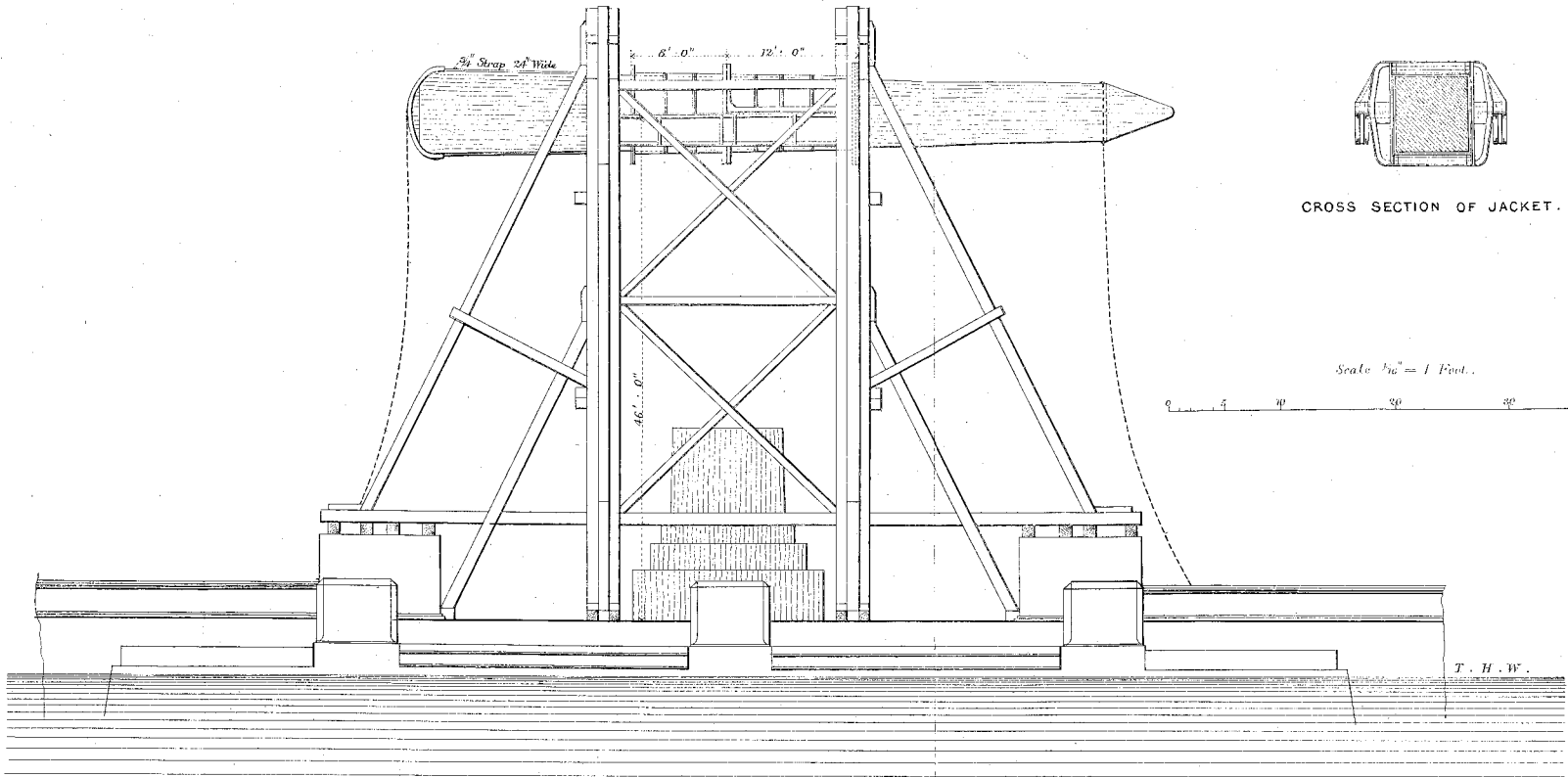
CROSS SECTION THROUGH CABIN .



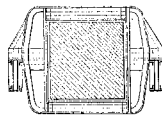
SECTIONAL PLAN .



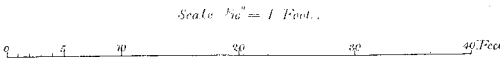
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AT STANDARD .



MODE OF ERECTION .



CROSS SECTION OF JACKET .



T. H. W.