THE GREAT DRILLING MACHINES OF THE FORTH BRIDGE.

In the Scientific American of April 4, we gave a description of the main piers of this great bridge, with the construction and method of erection, and also described and illustrated the caissons used in building the piers. From the accompanying elevation and plan views of the bridge, the general dimensions and form can be ascertained; Fig. 5 shows a cross section of one of the mammoth tubes, and Figs. 2, 3, and 4 show the machines for drilling these tubes.

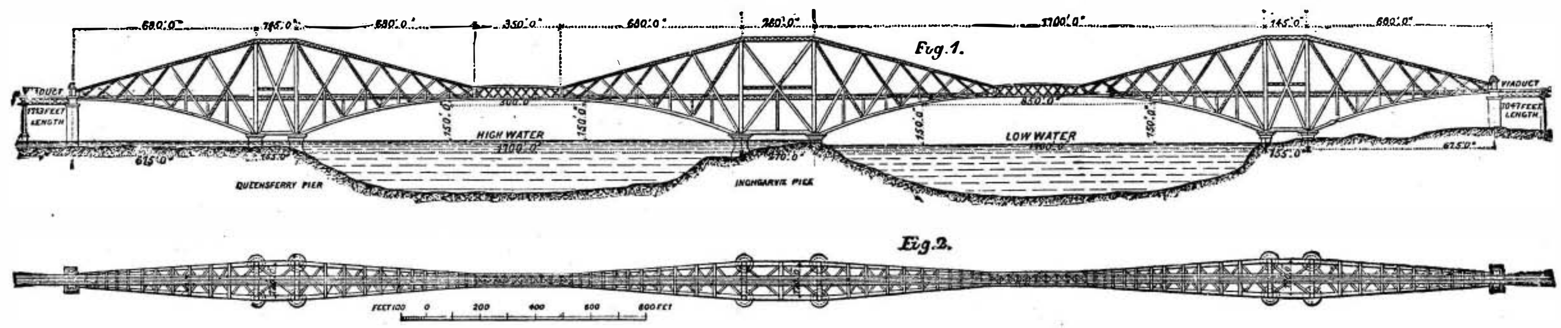

Fig. 1.—THE FORTH BRIDGE.—ELEVATION AND PLAN.

One of the well known features in the design of this undertaking demands that struts of hitherto unequaled length and capabilities for resisting thrust be employed. The form which best fulfills these conditions is the tubular. As well nigh six miles of tubes are required in the completed bridge, it at once becomes evident that the construction of them could only be effected within a reasonable time by the adoption of special plant. Owing also to their novelty of form and great size, no machinery was in existence capable of dealing with such work. On account of this, and for various other reasons, it was determined to design special plant for the whole work.

The struts required are of various dimensions, ranging from that of the largest, 12 feet in diameter, to that of the smallest, which is only 3 feet. Fig. 5 is a cross section of one of the 12 foot horizontal tubes between the piers. It consists of ten plates and ten longitudinal H beams, stiffened at intervals of 8 feet by means of the circular girders shown in elevation. The girders, again, are made up of diaphragm plates, connected to inner and outer angles, the former being riveted to the H beams, while the latter are similarly fixed to the tube plates.

One of the most difficult operations was the curving of the heavy plates, which are 16 feet by 4 feet 4 inches by 1⅛ inch and 1¼ inch thick, and weigh from 28 to 32 hundredweight each. The method now adopted is to bend them while hot in a large hydraulic press, from which they are removed, and allowed to cool slowly. When cold, they are again placed in the press and straightened finally. The edges and ends are then planed, and each plate is weighed, marked, and laid aside, ready to be placed on the tube when required. The longitudinal H beams are made up of a deep webbed tee and two angles, being partly drilled through these before erection. The circular girders are also partly drilled before being placed on the mandrel. These different parts form the main tube proper, leaving out the connections to skewbacks, the girder fixtures, tees, and other minor details, with which it is not at present intended to deal. The tubes are built round about a mandrel, being supported therefrom by temporary connections, and drilled through the various parts, while in the exact form they are intended to be when finally erected.

The mandrel, plate edge planer, hydraulic press, and hydraulic crane are very fully described and illustrated in the Scientific American Supplement, No. 478.

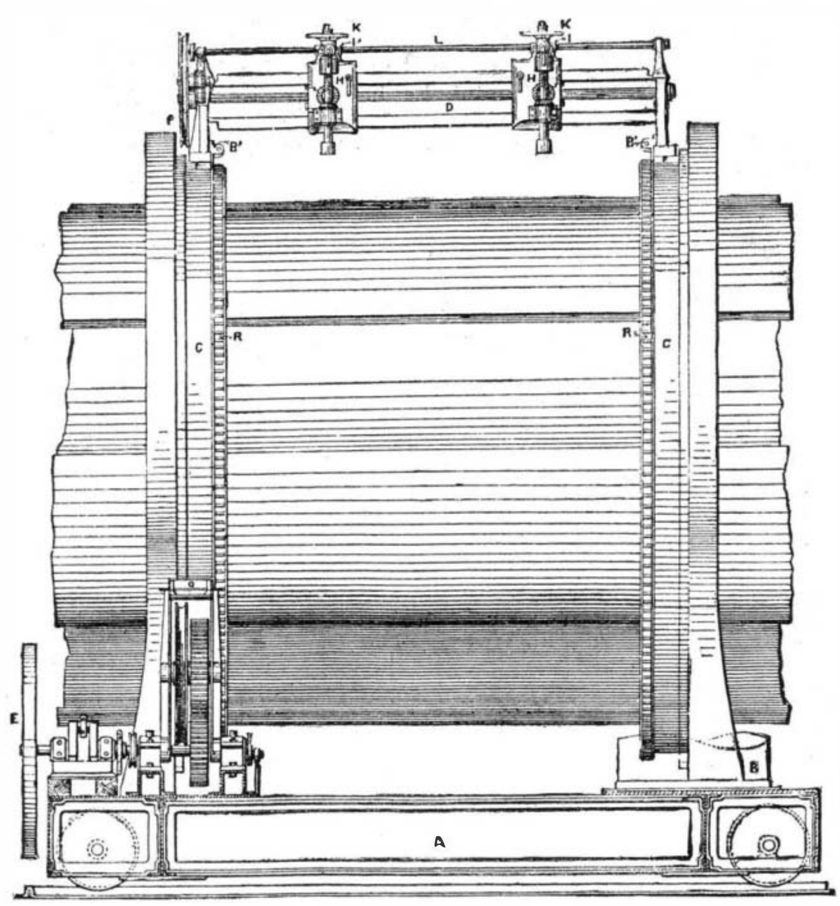

Fig. 3.—SIDE ELEVATION OF TUBE DRILLING MACHINE.

The work of building and drilling the tubes is done out in the open (Fig. 4), on what is called the drill roads. These are laid down to suit the drilling machines, and at such a distance and with such a length as to allow the bracing girders and connections thereto to be placed in position, as the work stands on the ground, prior to the final erection. The roads are so arranged as to be all equally suitable of access for the steam traveling cranes used in carrying the material to position and in building the tubes. This is accomplished by means of traversers, of which there are three, one in the center and one at each end of the drill roads, those at the ends running on rails at right angles and close to the main roads, but fully 12 inches lower, while the center one is run on cross rails, on the same level as the main roads. If it is necessary to change the position of a crane, it is run on to the traverser, and on it carried to the desired point, and there run off. In this way the whole of the ground is commanded by the cranes.

The mandrel, M (Fig. 5), is 45 feet long by 5 feet in diameter, raised on iron trestles, T, to a height, at the center, of 10 feet from the ground. This corresponds with the center of the outer rings of the drilling machines. The great length of mandrel is required to allow of its being carried up at the ends, where the H beams and plates are built in position. On this mandrel there are now secured, but in halves, temporary iron rings, R, at the horizontal distance from each

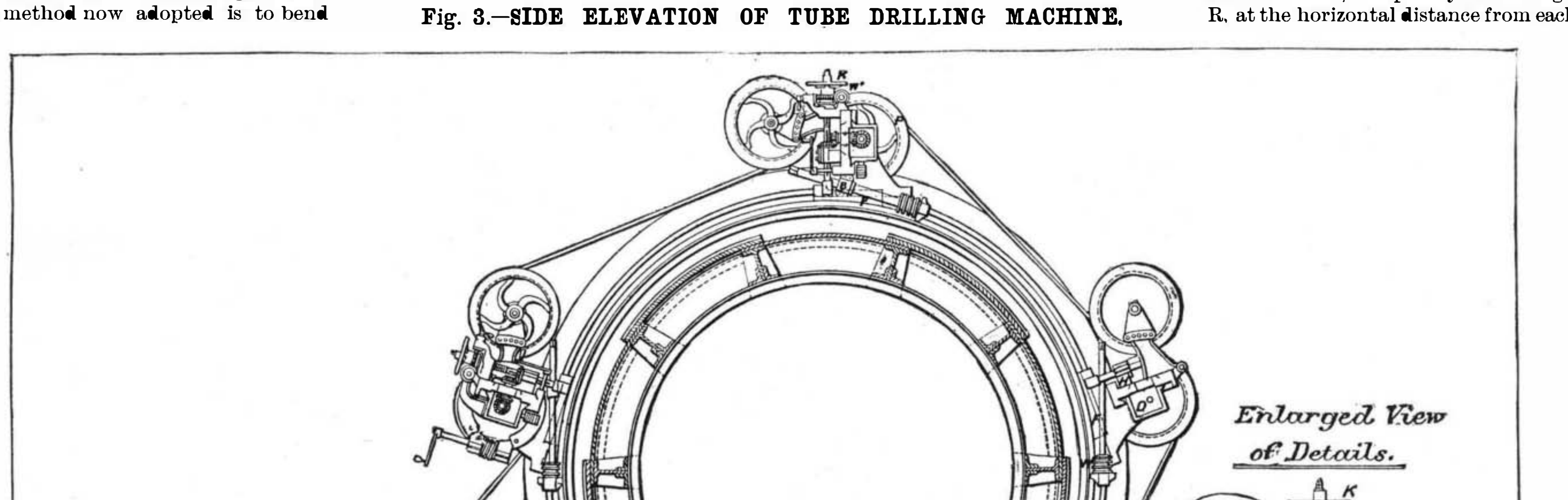

Fig. 2.—SECTION OF TUBE DRILLING MACHINE.

other of 8 feet. To these are fixed the radiating plates, P, having holes punched in the outer end for bolting on the first part of the permanent work, viz., the inner angle, A, of the circular stiffening girders. The same bolts are also made to carry the web plates, W, of these girders, on the outer edge of which are fixed the angle irons, I, for making the final connection to the shell of the tube. The horizontal H beams, H, are now placed in position, being securely bolted through the inner angle of the circular girders. On these beams are now placed the shell or tube plates, the ends forming butt joints, while longitudinally they lap one another, this taking place over the solid flange of the H beams. The end joint of the one plate breaks opposite the center, or solid part, of those on either side. The first plates to place in position are the inner, or those lying close against the flange of the beams, beginning generally at the bottom and coming up on each side. Owing to the passing of the one plate beyond the other, one-half of each remains free to put grabs and drawwashers on, without interfering with the placing of the outer ones in position. So soon as the outer ones have been put on and fixed in a similar manner, there are passed round all a couple of angle iron rings, for binding and drawing them up to their proper position. The tightening them up is done by means of iron wedges between the plates and the rings. After the bottom plates have been fixed in position, the tube is borne up by wooden blocks, built between it and the cradle underneath. The true position of the tubes, both as regards horizontal distance apart and height, is found by means of a theodolite, placed at one end of the roads, on a fixed platform, in a position such that when it is in line with a stationary point at the other end it always fixes the centers 120 feet apart throughout, and horizontally in the same plane. If the center of the mandrel is not in this line, then it is made so by being raised, lowered, or shifted sideways to suit. When the mandrel is right, the tube must of necessity be so also, seeing the centers coincide.

When the building of one ring of plates has been completed, the drilling machine is moved forward, the blocks in front being taken out of the way and rebuilt behind as it is traveled along. To enable the drilling to go on continuously, the building of the tube in front is being proceeded with while the machine is still at work on the portion immediately behind. These tube drilling machines—of which there four—are shown in Figs. 2, 3, and 4. Each is self-contained, and on being run along the rails, carries all with it. The principal parts are the wrought iron underframe or carriage, A, on the one side of which is fixed the engine, E, and boiler, B, and two large cast iron rings, C, firmly bolted to the main cross girders. These rings have an internal diameter of 13 feet, sufficient to enable them to pass freely round the tube when the machine is being moved along. Five cast iron slides, D, are fixed thereon, and held in position by means of small slipper blocks, F, fitting into a recess in each of the rings, C. On each of the slides are the two heads, H H. Each head is provided with a single drill, and is capable of being rapidly run from one point of the slide to another by rack and pinion gearing. The slides are kept in position, and also turned round the rings, C, in either direction, by means of two worms, W, carried in brackets, F, one gearing in each ring in the circular racks, R. These racks being bolted to the rings serve also as guides for steadying the whole upper portion of the machine. All the drills point to the center of the tube, and having, as shown, both a circular and longitudinal motion, can with ease be made to reach every hole in any part of the structure; some of which are through a depth of as much as 4 inches of solid metal.

It might be here mentioned that some of the slides were specially designed to overcome the difficulty of drilling, say, a flat part in any of the tubes. The difficulty lies in the fact that the drills on any of the fixed heads always point to the center of the tube, whereas in the case just mentioned the holes require to be drilled at right angles to the special or flat part. The mode adopted to overcome this was to make both ends of each slide circled, fitting them into separate heads, which in turn were bolted to the slipper blocks, F, as in the others. On the head at one end is placed a worm, while on the same end of the slide there is keyed a wheel into which the worm is geared, by turning which the slide can be made to place and keep the drill pointing in any required direction.

The whole of the drills are fed into their work by an automatic arrangement, the motion being imparted to the longitudinal shaft, L, by a band driven off the main driving pulley. On this shaft slides, and by it also are driven, the worms, W¹, necessary for turning the worm wheel, I, which at will can be made to drive the hand wheel, K, thereby feeding the drill into its work. At one end of each of the main slides is overhung the driving pulley, P, the power being transmitted from the engine to the whole of these by means of a cotton rope, guided where necessary by supplementary pulleys. The slack is taken up by a shifting quadrant, moving about the engine shaft as a center, assisted by auxiliary pulleys on a wrought iron frame close by the engine.

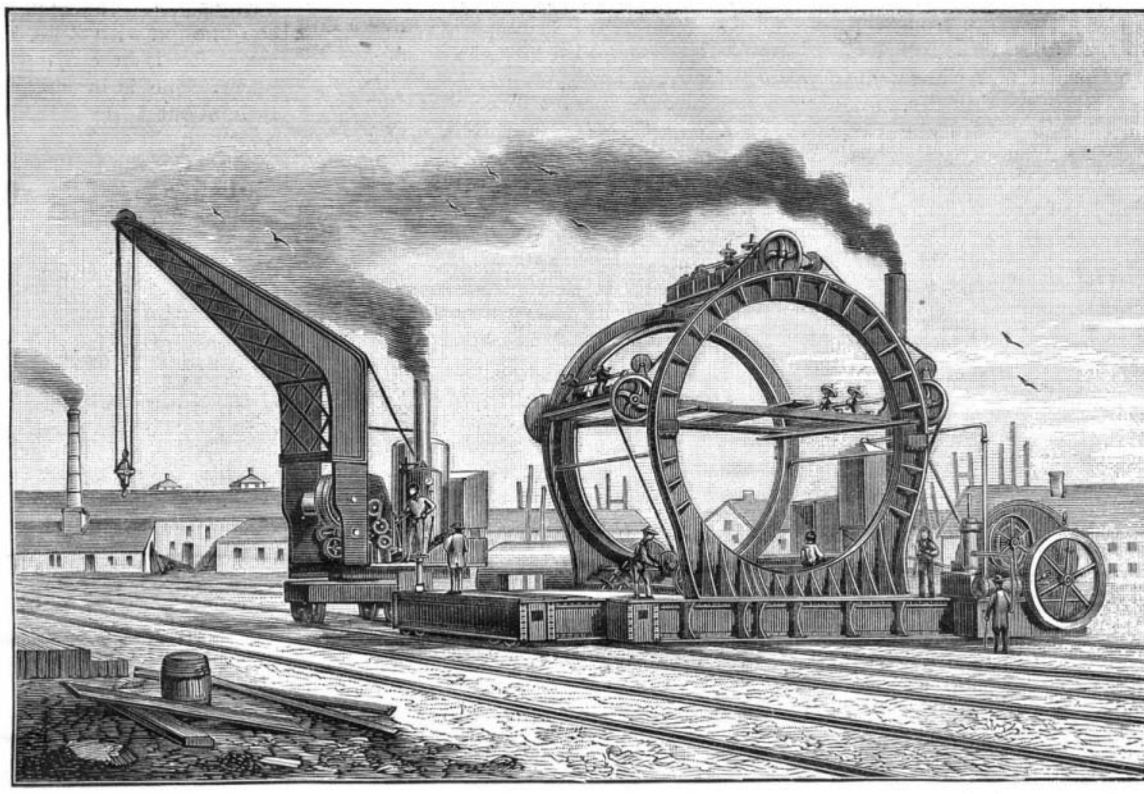

Fig. 4.—THE GREAT DRILLING MACHINES OF THE FORTH BRIDGE.

When starting work on any tube, a drilling machine is moved forward to the point at which operations are to begin. Each of the five slides is now moved around the rings until all the points of the drills face truly any series of holes in the longitudinal beams. The holes in this line, or series, are all drilled, two drills being at work on each line, then the slides are again placed so as to suit a new set, and so on until the whole of the tube commanded by the machine in its present position is finished. This is equal in length to 8 feet, and includes the full circumference of the tube. The number of holes in such is about 800, and the time required to drill all, when working continuously, is from twenty-four to twenty-eight hours, varying thus much principally on account of the difference in thickness of the various parts of the tubes. For Figs. 1 and 4 we are indebted to *La Nature;* for Figs. 2, 3, and 5 to *Engineer.*

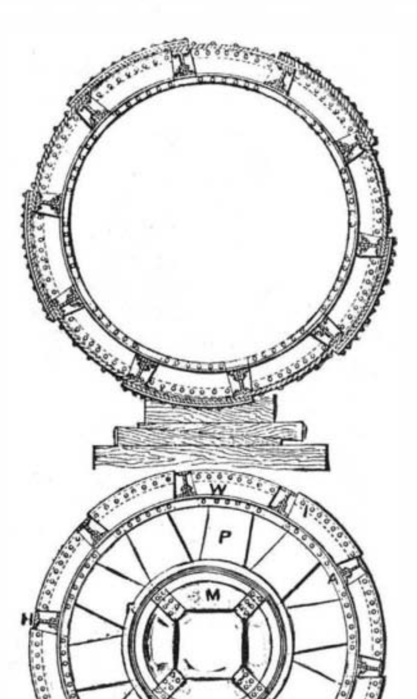

Fig. 5.—SECTION OF TUBE AND MANDREL.

Spontaneous Combustion.

The Boston Manufacturers' Mutual Fire Insurance Co. in a recent circular says:

A very considerable loss has lately been incurred by one of our members in a building used for dyeing and drying, which was not suitable to be insured by us, and on which we had refused to issue policies. This fire has been made the subject of close investigation, and is very suggestive.

The building consisted of two sections, divided by a brick party wall, in which there were wide doorways fitted with suitable fire doors. On one side the risk was considered *bad*, and this part had been fully protected with Grinnell automatic sprinklers. On the other side the risk was considered *fair*, and automatic sprinklers had not been placed therein, but were about to be.

In this "fair" section the fire occurred, and the section, with its contents, was wholly destroyed. The "bad" section was wholly saved by the automatic sprinklers, the workmen having been driven from the building without being given time to close the fire doors, so that the fire might have passed except for the sprinklers.

The circumstances were as follows: Stock known as camel's hair, dyed with chromate of iron, was in process of drying, under the action of a 56 inch fan operating at nine hundred revolutions per minute.

The fire is attributed to the spontaneous combustion caused by the rapid oxidation of the chromate of iron. In a still air it might have smouldered, but, under the influence of the fan, it burst into flame with the semblance of an explosion; the men were instantly driven from their places, and the section was totally destroyed, while the other division was saved as already stated.

The point of interest therefore is, how to stop a fan automatically, the instant a fire occurs, by the action of the heat; and this problem may be considered not only in connection with drying machinery, but in connection with all fans, and, perhaps, with some or all blowers.

This can be accomplished by automatically throwing off the belt, and it is probable that a different device may be required for each kind of fan; but in every device a fusible link can be made use of, soldered with the same solder which is used in automatic sprinklers, or with solder melting at a high degree, if exposed to more than ordinary heat.

The constant recurrence of fires caused by friction and spontaneous combustion in the processes of drying fabrics, as well as fibers, keeps us in the constant expectation of loss in the processes of drying, and we therefore again revert to the subject.

Hollow versus Solid Shafting.

A shaft made in the shape of a tube is stronger than it would be if made of a solid bar of the same dimensions. From this, however, it does not follow that a solid shaft is increased in strength or better prepared to stand a sudden twist if a portion of the material is bored out along its central line. Frequently workmen entertain the idea that the core of an axle or the bearing of a shaft is a hinderance in the way of strength, and is one of the reasons for making them hollow; this not so, as it is merely the arrangement of the material that improves its strength. Boring out a solid shaft lessens both its weight and its strength, but the material is removed from the portion where the least resistance is offered; therefore the loss of weight is greater than the loss of strength. The particles on the outer surface are tested to their utmost when those in the center barely receive any action at all, and from this line to the circumference they are gradually being brought into use until those on the outside are ready to break apart when the limit of strength is reached. In tests that have been made, results have shown that the weight may be reduced sixteen per cent by boring, while the strength would not be lessened by more than one and a half or two per cent. The success of many designs lies in so arranging the material that where any fracture is likely to occur, as much metal may be used as is likely to be wanted to stand the increased strain.—*The Garden.*