cends the valley over gradients of $\frac{1}{5}$ of an inch per foot at a maximum and curves of 490 ft. radius at a minimum up to a tunnel 2,700 ft. in length. It afterward enters the valley of the Lassi, which it ascends with gradients of $\frac{3}{16}$ in. to the foot as far as to the secondary summit of Solok, at an altitude of 1,360 ft. The line afterward follows the border of the lake with mean gradients of $\frac{1}{10}$ of an inch, avoiding as far as possible the cones due to the erosion of the rocks that are met with in great numbers in the plain. From Baton-Tabol to Padang-Pandjang, the land has such a slope that it would have been necessary to give an excessive length to a simple adhesion line, and it was therefore decided after a careful study to admit a gradient of $\frac{3}{5}$ of an inch, and provide it with a rack.

of Padang, which, outside of the central quarter, presents the aspect of a large park, with its isolated houses surrounded by gardens and extending over a wide area.

The establishment of the substructure of this important 106 mile line necessitated the formation of much earthwork, upon which we shall not dwell, but shall merely mention the curious application made of the property possessed by running water of carrying along earth and depositing it at the place where the velocity of the current diminishes.

The water is led, says Mr. Post, by small canals whose length sometimes reaches several miles. The laborers dig the earth and the water carries it to long distances, owing to the steep gradients. At the place

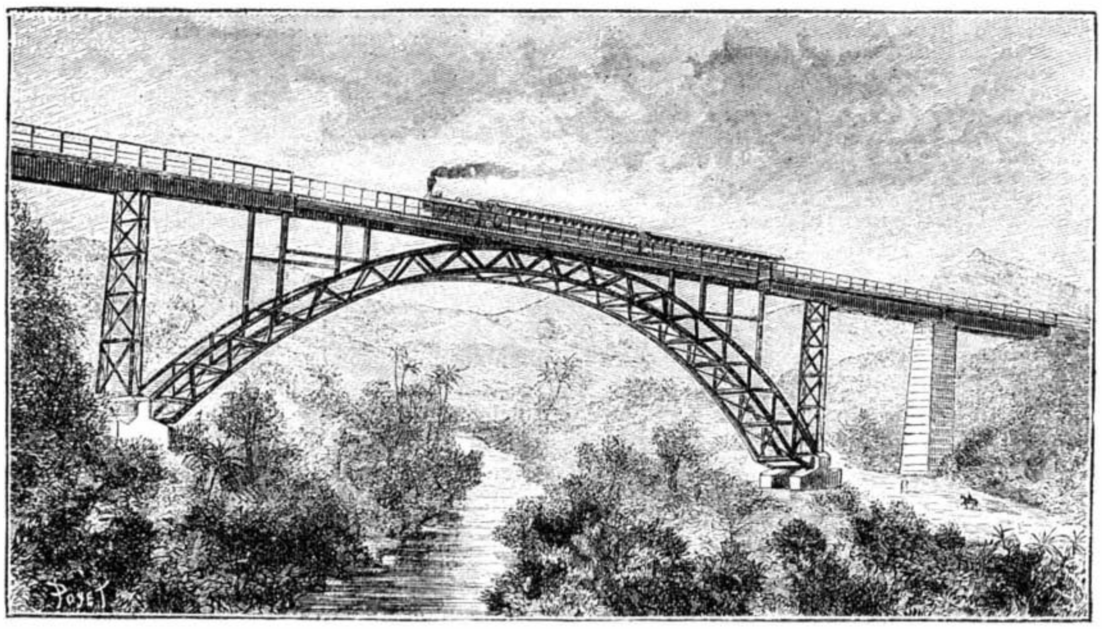


FIG. 1.—RAILWAYS IN SUMATRA.

It must be observed, however, that this solution of the question, which has permitted of considerably diminishing the cost of the first establishment, did not, so to speak, introduce any difficulty in the way of the exploitation, for the mixed locomotives employed are capable of hauling over this $\frac{3}{5}$ of an inch gradient provided with a rack the same load as upon the $\frac{16}{100}$ inch gradient admitted for the ordinary road. It will be at once seen that the speed of running of the parts is diminished in a ratio inverse to the stresses thus developed.

At Padang-Pandjang, situated at an altitude of 2,530 ft., there starts a branch that runs to Fort de Kock. This military center is the principal garrison place of the Dutch troops of occupation. The direction line ascends to an altitude of 3,785 ft. above the level of the sea and crosses at Kota-barou the neck that separates the formidable volcano of Merapi, Moro-Api, or "Destroying Fire," from that of Singalang. Thence it descends to the fort, situated at an altitude of 3,017 ft. This section presents gradients reaching one inch to the foot, and is provided almost wholly with racks.

As far as to Padang-Pandjang, the line runs over the high, populous and healthful plateau of Menang-Kabreo, which is in a measure the *sanatorium* of convalescent officers and functionaries. Mr. Post observes that these very rich districts have a population as dense as that of the most populous countries of Europe. Padang-Pandjang, which is the residence of the functionaries and the chief place of the "Quatre Kota," occupies the edge of this plateau.

On leaving this city, the line descends the side of the plateau by an abrupt gradient extending as far as

where it is desired to establish the embankments, barriers of bamboo are set up which allow the water and mud to pass, while the solid earth, gravel and sand deposit. These embankments, which are so to speak washed, are very solid, and it is possible even during the execution of the work to traverse them on foot and horseback. The loss of material reaches 25 or 30 per cent.

The line includes, besides, a large number of bridges and culverts, and especially iron plate aqueducts or cast iron siphons, the installation of which became necessary in order that the rice fields traversed should not be disturbed.

Among the metallic bridges we represent in Fig. 1 the viaduct that crosses the river Anei at its confluence with the Ponti between Pandjang and Kaiou-tanam. This viaduct, which is located in a most picturesque situation, presents a very beautiful aspect, as may be judged from the figure. It is on a gradient of $\frac{9}{10}$ of an inch, and carries a rack. In order to ease the bridge, the rack is made fast to the extreme piers, which thus receive the lateral thrust transmitted by the reaction of the toothed wheel of the locomotive; the bridge, on the contrary, supports only the vertical weight. In order to resist this longitudinal stress, the uprights are arranged at right angles with the track, and consequently present an inclination upon the vertical.

As regards the superstructure, we may mention in particular the metallic ties, the use of which is necessary in hot countries, since wood there rots too rapidly.

The ties have a variable profile, calculated according to the theoretical stress, supported at each point. This type, which is well known and justly appreciated, is due to Mr. Post. It has received numerous applica-

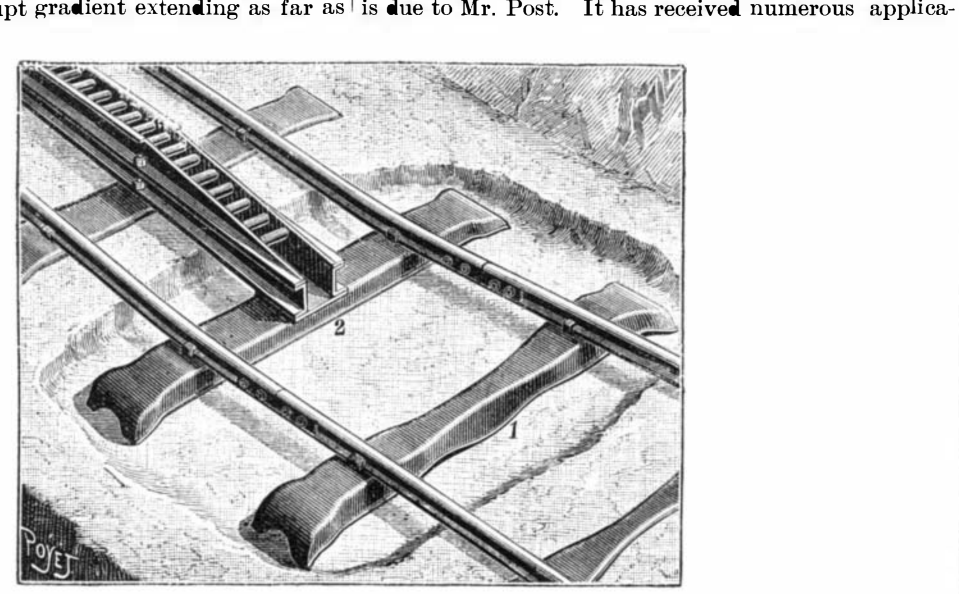


FIG. 2.

to Kaiou-tanam, and afterward runs toward the port of Padang upon the ocean, one of the busiest markets of Sumatra. The section from Padang-Pandjang to Kaiou-tanam is almost entirely provided with racks with gradients of $\frac{3}{5}$ of an inch to the foot. On the ordinary road the gradient reaches $\frac{17}{100}$ of an inch. Beyond Kaiou-tanam the line has no racks. The gradient is limited to $\frac{18}{100}$ of an inch to the foot in going toward Padang, but it reaches $\frac{11}{100}$ and $\frac{16}{100}$ in the opposite direction. On reaching Padang the line bifurcates, one branch running toward Poulon-Ayer and the other toward Port Emma, which is the terminus. But these two points must be considered rather as dependencies

tions in Europe, and it is under trial in France, too, upon certain sections of the government railways.

Fig. 2 shows two types of ties employed. Those of the ordinary track are contracted in the center (No. 1); Those of the rack sections, on the contrary, have parallel sides, and are provided in the center with two holes, that serve for fixing the rack (No. 2). The ties weigh 85 lb. each, and the ordinary track weighs 75 lb. to the running foot.

The Riggenbach rack consists, as well known, of a sort of metallic ladder, the rounds of which are riveted to two vertical U-shaped uprights fixed upon the ties. At the entrance of the sections provided with a rack,

the latter presents a beveled, movable part resting upon a spring, which gradually yields under the action of the toothed wheel of the locomotive in order to facilitate the gearing.

Traction is effected by means of two types of locomotives, one consisting of simple adhesion engines, with two coupled axles, which are capable of running only upon the plain sections, and the total weight of which in service reaches about 26 tons, and the other comprising mixed engines of a total weight of 26 tons, capable of running both upon the plain and rack sections. These latter engines have three coupled axles, and an axle in front capable of a certain displacement on account of curves. Two of the axles are provided with simple adhesion wheels and the third carries the toothed wheel. In the arrangements of the most recent mixed engines, we meet, on the contrary, with two mechanisms and even two pairs of entirely independent driving cylinders; but in Sumatra, where engineers of but little experience are available, the simplest arrangements have rightly been preferred.

The engine is provided with three types of brakes—spring brake, air brake, and an auxiliary toothed wheel, which is capable of arresting the mechanism. The locomotive is always coupled to the rear of the train, which it pushes during ascents and holds back during descents. The cars are of the American type, and are arranged for two classes of travelers. The freight cars are each capable of carrying 20 tons of coal.

The work of constructing the line is done in great part by Chinese laborers and also by transported criminals, and Mr. Post points out that, owing to the vigilance, tact, and courage of the engineers and overseers, a regular and satisfactory work is got out of these prisoners.

The section from Poulon-Ayer to Padang-Pandjang was delivered up for exploitation on the first of last July, and the line must now reach the station of Fort de Kock.

The results of the exploitation are very satisfactory for so short a time. The aborigines themselves, says Mr. Post, have not shown that hesitation to travel by *carreta api*, "fire cars," that it was feared they would.

An ornamental time table, in colors, bearing inscriptions in Dutch, Malay, Japanese, and Chinese, gives the hours at which the trains arrive and depart, the height and temperature of the principal health stations, and exhibits in pretty landscapes the country traversed and its products, etc.—*La Nature.*

[FROM ENGINEERING.]

A SHORT HISTORY OF BRIDGE BUILDING.*

By C. R. MANNERS.

IN America iron was used to a small extent as far back as 1835, but its use is now general. Accustomed to trussed timber bridges, they naturally employed iron in that form also. In one common form a cast iron cylindrical pipe is used for the compression member. In 1848 the Whipple truss (Fig. 81) was introduced.

A truss now in very general use is, I think, that designed by Mr. Albert Fink, of which I give an example (Fig. 82).

The top member and the vertical struts are cast iron pipes, octagonal in external form, the top being about 12 in. in diameter externally and the struts about 8 in. in diameter. The tension bars are of wrought iron 4½ in. by 1¼ in. The Americans would appear to have been rather too saving of material in the construction of their bridges, as Mr. C. F. Stowell, bridge engineer of the New York State Railway Commission, states that during the ten years ending December 31, 1887, no fewer than 251 railroad bridges failed in the United States and Canada, from weakness, overwork, collision, etc. This number embraces truss bridges only, and includes only those which involve the wreck of the whole or part of a train. A gradual preference is, however, now being shown for the plate girder in place of the truss. In the ordinary plate girder we seem to have reached the limits of simplicity. What could be more simple than a top and bottom plate united by a vertical web plate?

When, however, the great development of the railway systems necessitated larger spans, this form of girder was found liable to distortion through twisting, expansion, etc., and in designing the Britannia Tubular Bridge over the Menai Straits, Mr. Robert Stephenson had not only to face the difficulty of arranging his material to resist a transverse strain, but also the difficulty of obtaining suitable material, and of devising a beam sufficiently strong and rigid to maintain its form during construction as well as when in place. A tubular girder is very much like two simple plate girders side by side, with their top and bottom flanges united.

The Britannia Bridge (Fig. 83) consists of two independent and continuous wrought iron tubular beams each 1,511 ft. long and weighing 4,680 tons each. They are 15 ft. wide and 23 ft. deep at the ends and 30 ft. deep at the center. There are two spans of about 460 ft. and two of 230 ft., resting on piers 100 ft. above high water. The tubes were built at some distance from the site of the work, then floated on pontoons to the base of the towers and hauled up by four chains by hydraulic pressure.

The bridge was opened in 1850, and cost 601,865*l*. This and the Conway Tubular Bridge were the first great examples of properly designed wrought iron girders. The Victoria Bridge over the St. Lawrence, 7,000 ft. long, is another good example of this construction.

The solid or continuous vertical plate of the wrought iron girder soon led to the introduction of the lattice or trellis girder, in which the vertical plate is superseded by a series of diagonal bars, of one or more systems, crossing each other and forming a more or less open trellis work with, at regular intervals, vertical stiffening pieces introduced. The simplest form of this girder is that known as the Warren girder, which has a single system of diagonals.

The Newark Dyke Bridge (Fig. 84) is one of the earliest and I believe is still one of the largest constructed on this system. It was erected in 1852 from designs by Mr. Charles Wild.

* Continued from SUPPLEMENT, No. 854, page 13644.

The span is 259 ft., and the depth 16 ft. It consists of four independent girders, two for each line of rails. The top member is a series of cast iron pipes, butting end to end and bolted together, and is 18 in. in diameter at the center, tapering off to 13½ in. at the ends. The bottom member is of wrought iron links 9 in. deep and ⅞ in. thick. There are fourteen of these links at the center, the number diminishing toward each end. The tension bars are of wrought iron, and the struts of cast iron. The bearings at the ends are strong cast iron triangular frames.

One of the finest examples of Warren girder is the great Crumlin viaduct by Mr. T. W. Kennard. The length is 1,500 ft., and the height of the viaduct is 200 ft. The piers are clusters of cast iron columns braced together. Each span of 150 ft. has four girders about 15 ft. 6 in. deep. The bridge was opened in 1857 and cost 62,000*l*. (Fig. 85.)

In Germany the general construction for large span bridges is the lattice, in some one of its various forms, and in fact the lattice system was introduced into this

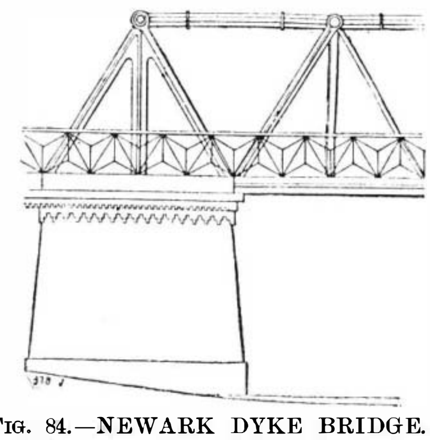


FIG. 84.—NEWARK DYKE BRIDGE.

country from Germany by Sir John Macneil. There is a large bridge over the Vistula of six spans, each 397 ft. 6 in., the depth of the girders being 38 ft. 9 in. The webs are lattice work of two rows, crossing each other at right angles. I may here mention that the method of sinking iron cylinders for piers, by means of compressed air, was invented in 1841 by Mr. Triger, and was first used on a large scale by Mr. Hughes, at Rochester.

At a comparatively early date in the history of iron bridge building it was proposed by a Mr. Pope to construct bridges to 1,000 ft. span on what he claimed as a new principle and called the "flying lever pendent bridge." They were to consist of a combination of struts and ties, so arranged that one-half of the bridge was a huge cantilever and the abutments were to act as a counterpoise. They were to be built prognosively from the abutments toward the center, and without centering or scaffolding, and in either wood or iron. It was, however, reserved for Sir John Fowler and Sir Benjamin Baker to show what could actually be done by the application of the cantilever and continuous girder system in the great Forth Bridge just completed and so fully described in the engineering journals that any lengthy description would be superfluous. The original design for this bridge, by Messrs. Fowler & Baker, was approved of in 1881, and in the following year an act of Parliament was obtained for its construction. In December of the same year contracts were entered into with Messrs. Tancred, Arrol & Co. The length of the cantilever arms, six in all, is 680 ft., and the two central connecting girders are each 350 ft. The two main openings have each a span of 1,710 ft. from center to center of the vertical columns, or 1,912 ft. 6 in. from center to center of the towers. The length of the cantilever bridge is 5,330 ft., and the total length of the bridge is 8,295 ft. 9 in. The rail level is 157 ft. above high water and the height of the towers, from center of bottom member to center of top member, is 330 ft.

(*To be continued.*)

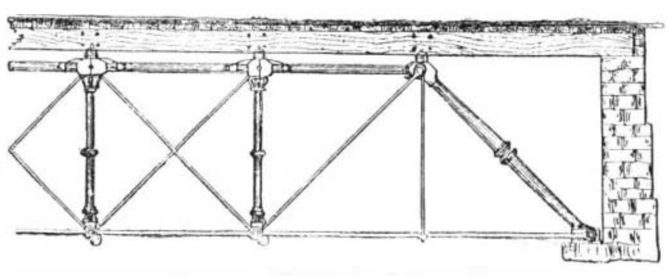


FIG. 81.—WHIPPLE TRUSS.

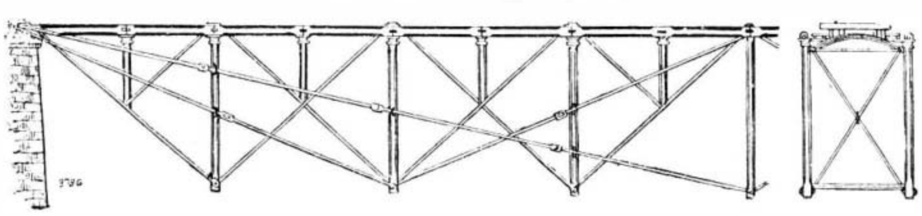


FIG. 82.—FINK TRUSS.

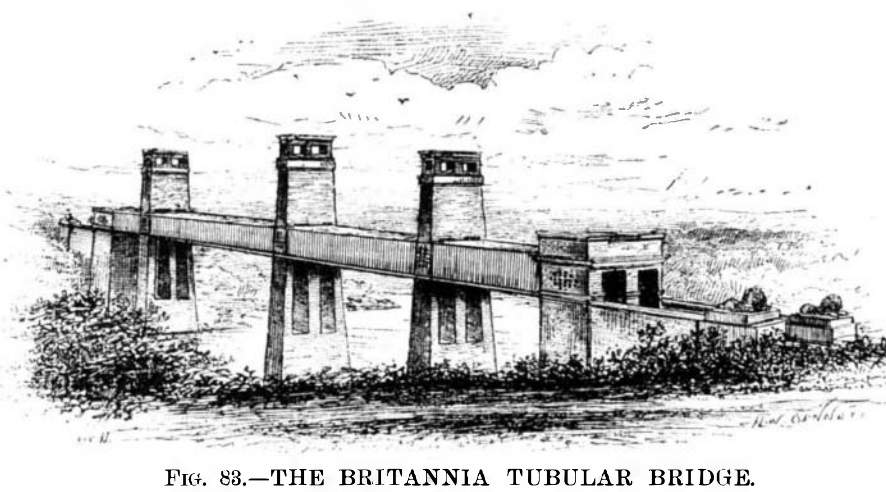


FIG. 83.—THE BRITANNIA TUBULAR BRIDGE.

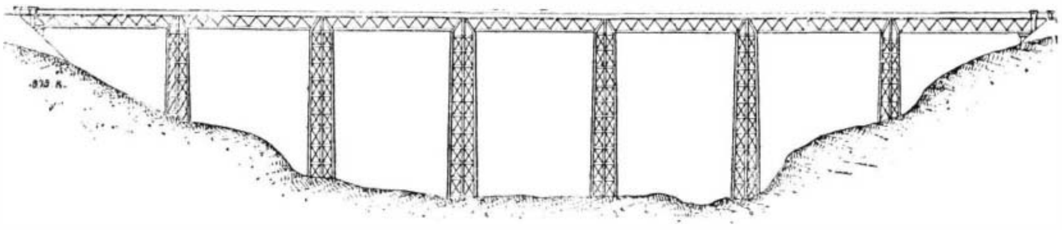


FIG. 85.—CRUMLIN VIADUCT.

A NEW SUCTION PUMP.

WE illustrate herewith an apparatus which was operated at the last Exposition of Work as a lift pump, and which has the merit of completely suppressing clack valves, which always constitute the weak elements of a pump, whatever be the care taken in setting them.

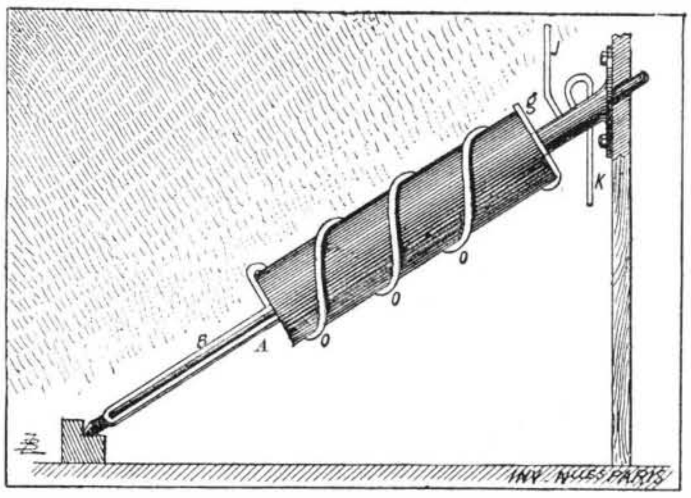


FIG. 1.—NEW SUCTION PUMP (FIRST MODEL).

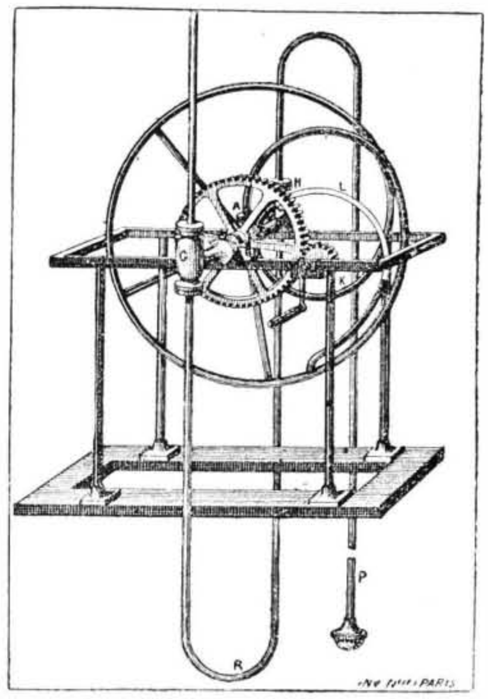


FIG. 2.—IMPROVED MODEL.

In order to well understand the mode of operation, it suffices to take a glance at Fig. 1, which shows the first model of the apparatus, and which had the sole inconvenience of being somewhat cumbersome. It consists of a glass or wooden cylinder surrounded with a spiral tube, O, which makes about three revolutions, the end of the last spiral dividing into two branches, B and C. The tube, B, descends to the pivot of the apparatus, returns along the axis, and communicates with the first spiral at the point, G. The tube, C, traverses the cylinder, passes above the apparatus, and ends like the other at the first spiral at the point, G.

A quantity of mercury sufficient to fill half of the spirals is introduced through the orifice, M, which is then closed. If the tube, K, be then put in communication with the liquid to be raised, and the apparatus be given a rotary motion, the water will be observed to rise and gradually fill the remaining portion of the tubes. Starting from this moment, the first spiral, at every revolution of the cylinder, empties its contents into the second, and this into the third, and the latter empties the mercury and the water that it contains into the tubes, B and C. Then the water is forced again into the tube, C, and makes its exit from the extremity of the tube, K, while the mercury, through the effect of its weight, falls back into the tube, B, to recommence the same motion indefinitely.

It will be seen that it is possible at every revolution to lift a volume of water equal to half the volume of the spirals, and to a height dependent upon the diameter of the spirals and the number thereof.

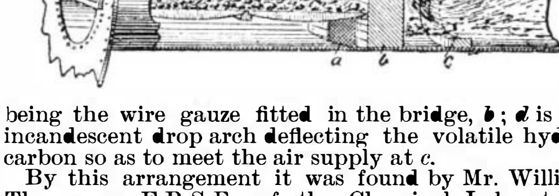
It will be conceived that the operation would be identical if the tube, K, were put in communication with a closed vessel in which it was proposed to create a vacuum. Every revolution of the cylinder would expel a quantity of air equal to half the volume of the spirals and to the pressure existing in the vessel.

As we have before said, this apparatus is somewhat unwieldy, and so the inventor has very happily modified it by replacing the tube spirally wound upon a cylinder by a simple tube, I J K L, forming a spiral of 1·2 meters, whose branches are in very approximate planes, and mounted upon an iron axis which revolves upon two journals, with tight joint. Two cast iron boxes, G and H, put the spiral in communication with the rest of the apparatus. These boxes are connected with a return tube about one meter in length. In order to prime the pump, a quantity of mercury sufficient to fill this tube and a third of the spiral is introduced through the box, G. A rotary motion is given the latter by means of the wheel, A, actuated by a pinion set in motion by means of a winch. At the end of two or three days the pump will be primed.

We shall not dwell upon the operation of the pump, as that is the same as in the primitive apparatus. We think that what has been said will suffice to show the ingenuity of this apparatus, which will probably find numerous applications in laboratories and the industries.—*Les Inventions Nouvelles.*

IMPROVED SMOKE ANNIHILATOR.

THE principle followed by Mr. Thwaite, in his appliance for the prevention of smoke in steam generators, consists, says the *Engineer*, in the admission of a secondary air supply through a wire gauze of a specific mesh, adapted to offer the requisite frictional resistance to the passage of such air, so as to accord accurately with the "pull" on the grate which remains unaffected. The form in which this invention has hitherto been applied by the Gaseous and Liquid Fuel Supply Company, of Manchester, who have acquired Mr. Thwaite's patent, has been in that of a box or casing of iron fitted with the necessary gauze, which is built in the bridge below the firebars, but so that it can be withdrawn and replaced at pleasure for the purpose of cleaning. Furthermore, a drop arch was provided, which, becoming incandescent, assisted in maintaining the secondary combustion which arose through the means of the air admitted as described. The accompanying sketch shows this arrangement, *a*



being the wire gauze fitted in the bridge, *b*; *d* is the incandescent drop arch deflecting the volatile hydrocarbon so as to meet the air supply at *c*.

By this arrangement it was found by Mr. William Thompson, F.R.S.E., of the Chemical Laboratory, Royal Institution, Manchester, that with coal containing so high a proportion of volatile hydrocarbons as 28·35 per cent., these constituents were entirely con-