No. 764,797. PATENTED JULY 12, 1904.

E. DIEBITSCH.

TUNNEL OR LIKE CONSTRUCTION.

APPLICATION FILED OCT. 5, 1903.

NO MODEL. 3 SHEETS—SHEET 1.

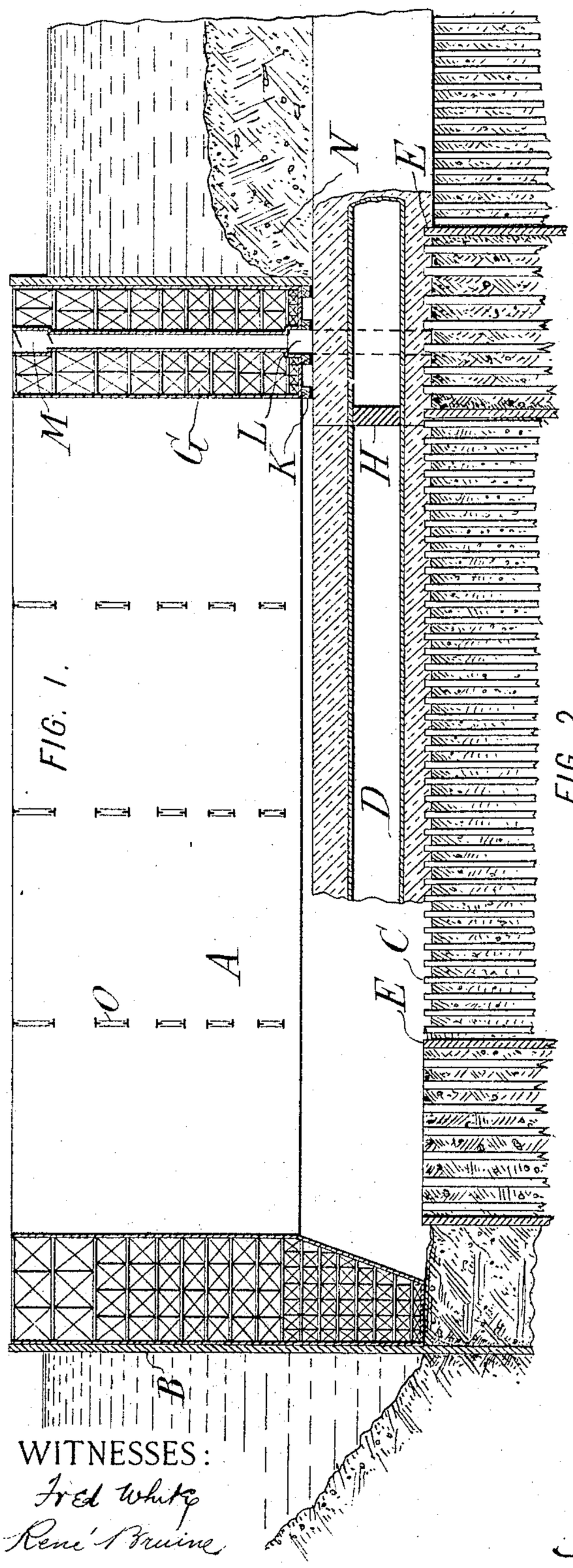

FIG. 1.

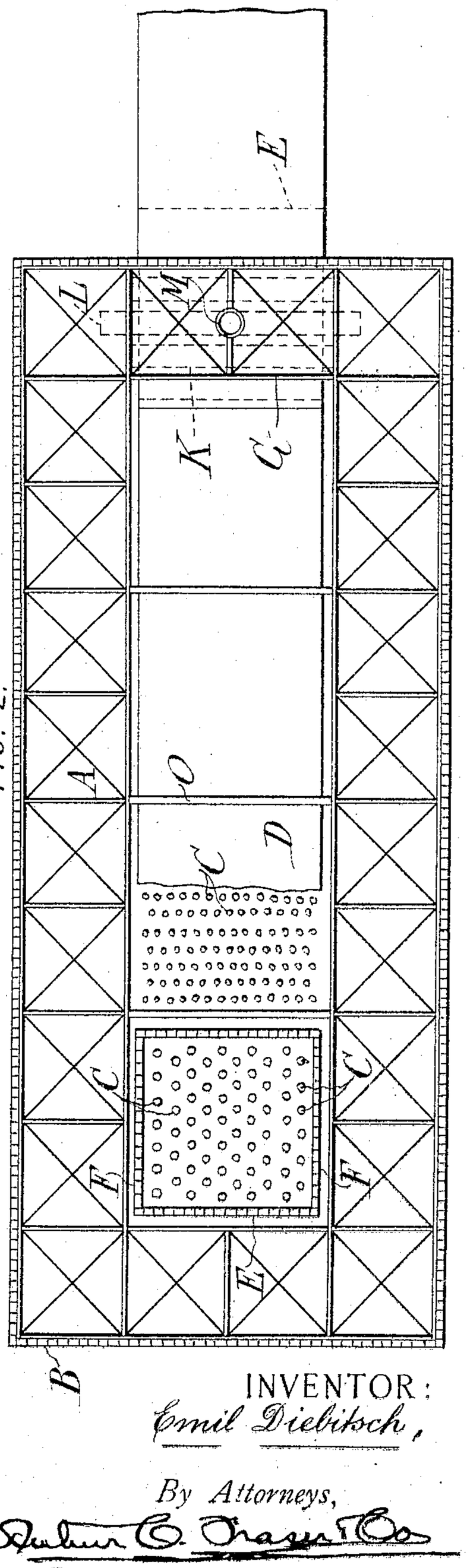

FIG. 2.

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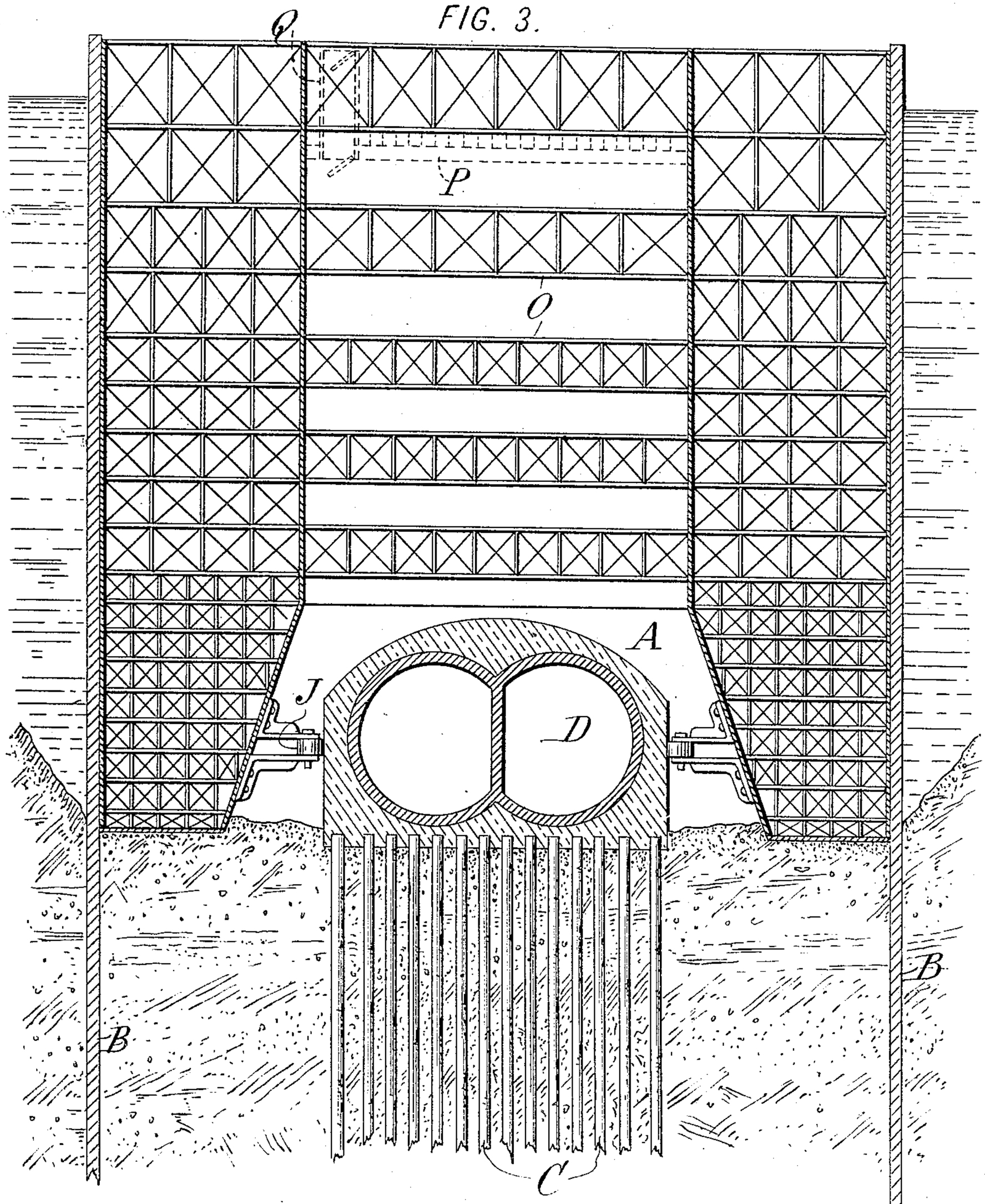
NO MODEL. 3 SHEETS—SHEET 2.

FIG. 3.



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NO MODEL. 3 SHEETS—SHEET 3.

FIG. 4.

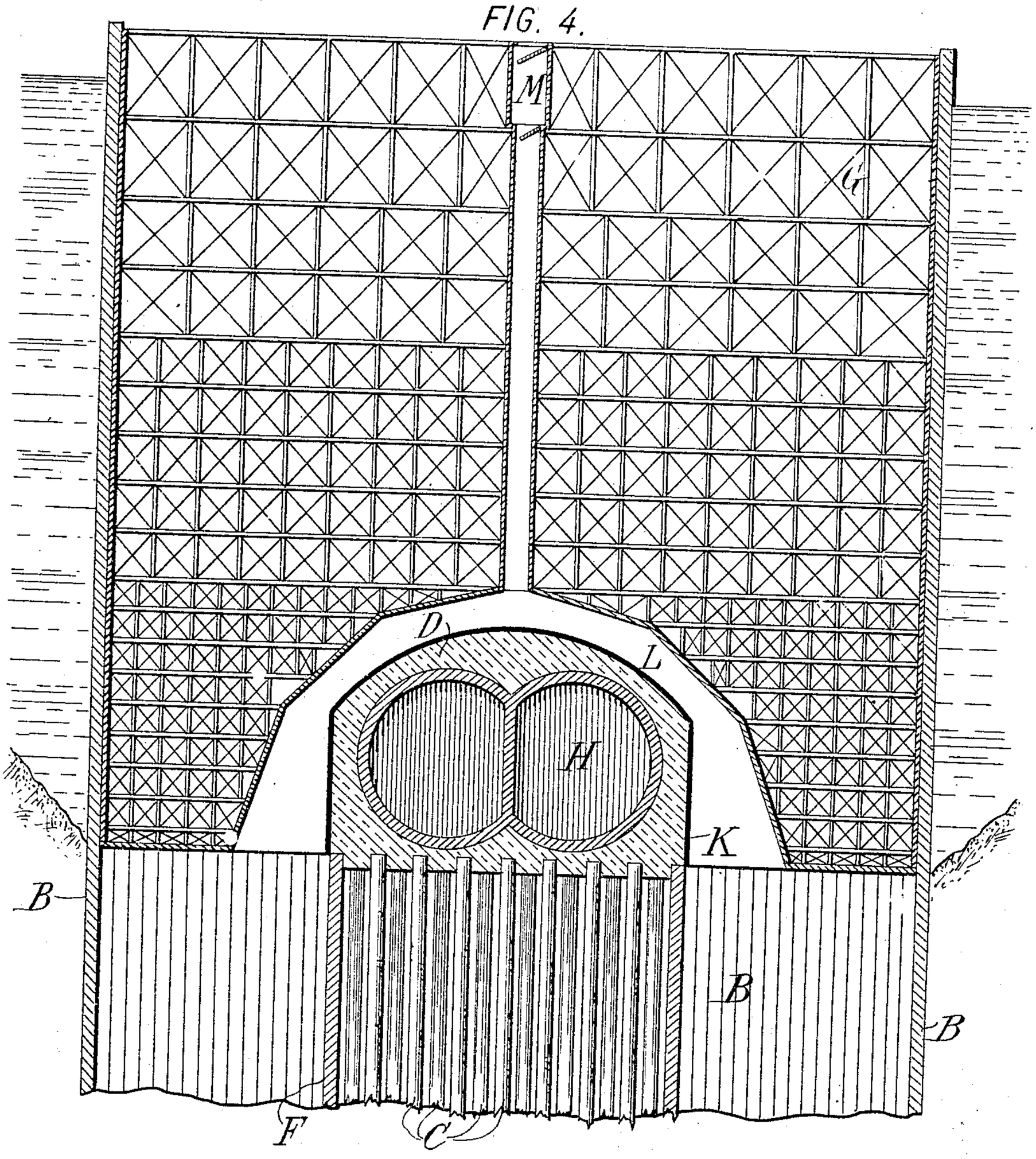
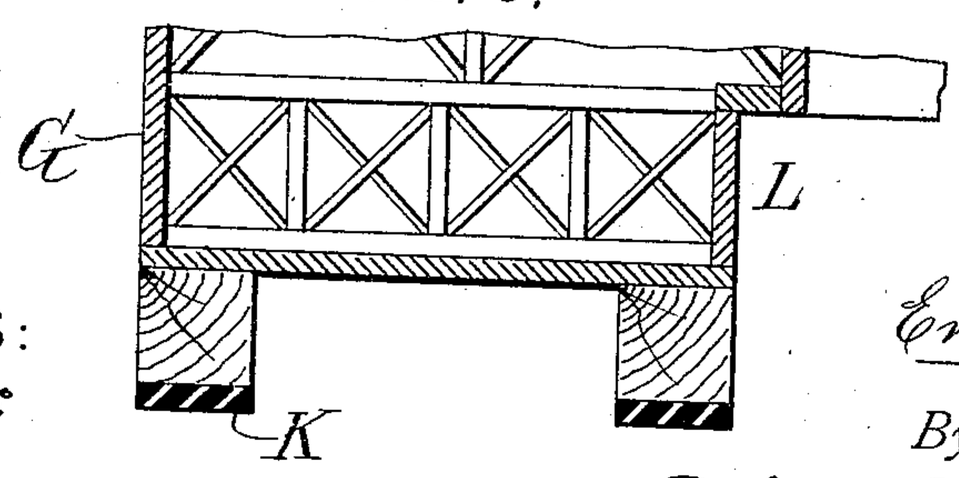


FIG. 5.



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No. 764,797. Patented July 12, 1904.

UNITED STATES PATENT OFFICE.

EMIL DIEBITSCH, OF NEW YORK, N. Y.

TUNNEL OR LIKE CONSTRUCTION.

SPECIFICATION forming part of Letters Patent No. 764,797, dated July 12, 1904.

Application filed October 5, 1903. Serial No. 175,904. (No model.)

To all whom it may concern:

Be it known that I, EMIL DIEBITSCH, a citizen of the United States, residing in the borough of Manhattan, city, county, and State of New York, have invented certain new and useful Improvements in and Relating to Building Tunnels or the Like, of which the following is a specification.

This invention relates to the construction of tunnels or other analagous submarine or subterranean structures. As shown herein, the apparatus and process are designed for and applied specially in the building of a submarine tunnel which is artificially supported.

Where a tunnel is built in soft material, it is considered dangerous to let the base of the tunnel rest directly on the earth. This is especially true where a railroad-tunnel runs under a deep river. It is believed that the transverse strains induced by running heavy trains through such a tunnel might break it, the tunnel being, in effect, a long beam supported more strongly at some points than at others, according to the nature of the earth on which it rests and which is always variable. Therefore, as stated, it is thought best to provide an artificial support of known strength, consisting, for example, of piles or of piers at such close intervals that the tunnel when acting as a beam or bridge will have abundant strength to carry the loads. Under the actual conditions encountered in practice it is very difficult to build such a structure. The tunnel of course might be built with the aid of a shield in the well-known way; but the artificial support presents serious difficulties.

According to this invention it is proposed to dam off the water from a section of the tunnel site and to build a section of the artificial support on such dammed-off site, these operations being repeated in adjacent (and preferably connecting) sections progressively to the desired length. I thus provide for the most difficult part of the job—namely, the artificial support. The tunnel itself is preferably built on the support as each section of the latter is completed, though it may be built in other ways—as, for example, by subsequently advancing it with the aid of a shield. The damming off of the water is preferably accomplished by sinking a caisson from within which the artificial support and the tunnel-section may be built. Where the river is of considerable depth and the tunnel-grade is somewhat below the bottom of the river, it will be apparent that the caisson in order to extend down to the grade of the tunnel will have to be very deep and very strong. Furthermore, the pressure will be great on account of the great head of water from the level of the river to the lower edge of the caisson. In order to provide a comparatively tight working space within the caisson which may be pumped out dry enough to allow the work to proceed with despatch, I propose to drive sheet-piling below the edge of the caisson, preferably all around on the outside thereof. This sheet-piling extending down into the mud a suitable distance below the lower edge of the caisson cuts off the inflow of water around such lower edge and permits the pumping out and maintaining dry of the working space within the caisson. When the first section of tunnel has been completed and the caisson is advanced to the end of such section, in order to commence work on the second section there is likely to be the same necessity for cutting off the water which might pass around the lower edge of the caisson and into the working chamber. This can be done by sheet-piling all around the outside (or the inside or both, if preferred) of the caisson, except at the point where the completed tunnel-section enters the end of the caisson. It is proposed according to this invention to construct a sheet-pile cut-off below the end of the completed section before such end is built, so that when the caisson is located in position for the next tunnel-section, as described, said cut-off will prevent the outside pressure from forcing water under the completed section of the tunnel, and thus into the working chamber of the caisson. In order to prevent the passage of water along the sides and top of the completed tunnel-section into the caisson, the end of the caisson fits tightly around the completed section, and means are provided in the form of a sort of subsidiary pneumatic caisson

or chamber into which a workman can descend and inspect and secure the joint at this point.

Other features of the invention are described in detail hereinafter.

The accompanying drawings illustrate a process embodying all of the several novel features of the invention and suitable apparatus therefor.

Figures 1 and 2 are respectively a longitudinal section and a plan of a caisson and a tunnel of which one section is completed and the work is progressing on the second section. Fig. 3 is a transverse section through said caisson, the scale being doubled. Fig. 4 is a transverse section through the rear end of the caisson, showing the pneumatic chamber, this scale being also double that of Fig. 1. The mud is omitted within the figure for the sake of clearness. Fig. 5 is a detail of the lower rear end of the caisson of Fig. 1.

Referring to the drawings, a floating dam or caisson is constructed, such as the open caisson A, which consists, essentially, of a double-walled box surrounding a space called the "working space or chamber" and open at the bottom. The caisson is suitably braced between its inner and outer walls by horizontal and vertical trusses of any suitable design, the strength and location of which will depend upon local conditions. It may be a covered caisson with an air-lock at the top, so as to permit working under air-pressure, if necessary, or it may be open at the top as well as the bottom, as illustrated. It is preferably also provided with internal transverse braces, such as the latticed girders or trusses O shown; but the existence or non-existence and the location and proportions of these will also depend on local conditions, such as the dimensions of the caisson and the strains to which it is subjected. The caisson is ballasted to float at a stable depth and is to be towed into place above the site of the work and secured by moorings or otherwise in such position and then sunk by the addition of ballast, either in the form of water or otherwise. Preferably the tunnel site has been previously dredged to about the subgrade of the tunnel, so that the caisson when sunk in place will rest with its bottom at about the subgrade or level of the base of the tunnel, or the caisson may rest upon the river-bottom without previous dredging and may then be sunk by dredging from within the caisson. The dimensions of the caisson will be such that when its lower edge is at about the subgrade of the tunnel the top of the caisson will be a convenient distance above high water and will furnish a convenient and stable working platform for subsequent operations. A floor covering the space between the inner and the outer walls may, for example, carry derricks, pile-drivers, &c., as well as a power plant, consisting of boilers, engines, dynamos, pumps, &c. It will also serve as a pier for the discharge of all materials necessary in constructing the tunnel and its artificial support. With the caisson sunk to working position, as shown in Fig. 1, it is apparent that the water would work down and around the lower edge of the caisson into the working chamber even though the mud lay close up against the outside of the caisson. In order to cut off this inflow of water, it is proposed to drive a line of sheet-piling all around the walls of the caisson. The sheet-piling, for example, may be on the outside, as shown at B, or on the inside wall, or on both walls. The depth to which this piling will have to be driven below the lower edge of the caisson in order to cut off the inflowing water to such an extent as to permit the inner chamber to be kept dry by a slight amount of pumping will depend, of course, upon the nature of the soil and the head of water. The sheeting may be secured in any suitable way or in any of the ways known to those skilled in the art. It should be guided so as to move vertically, but be held against lateral movement, so as to insure the tightness of the sheeting as a whole. The constructional details are not material to the process of this invention. The inflow of water being now substantially prevented, the working chamber will be pumped out and the artificial support or foundation for the tunnel will be built therein. The working chamber is of such dimensions as to afford ample space for driving piles or for carrying piers down to a satisfactory depth and bearing—as, for example, by the pneumatic process. The artificial support illustrated consists of a number of piles driven close together. The exact character of this support is not material to the present invention in its broad aspects. Piles C are shown which may be driven from pile-drivers supported upon the tops of the walls of the caisson, as previously stated, or in any other suitable way. These piles are driven close enough together and to a suitable depth to support the calculated loads, their tops are sawed off at the proper level, and the tunnel D built thereon of any desired material and design. Also before the tunnel-section is completed there is driven at the forward end of the chamber a pair of transverse rows of sheet-piling E, connected by a pair of longitudinal rows F, the whole being of a width substantially equal to that of the base of the tunnel and of a length slightly greater than the width of the rear end G of the caisson. These rows of sheeting serve as a cut-off to prevent the water from subsequently flowing along the under side of the tunnel and into the caisson, as previously described. The bearing-piles, the sheet-pile cut-off, and the tunnel-section being completed throughout the length of the working chamber, (or any desired portion thereof,) and the finished section being stopped at the end, as by a bulkhead H, the next section is to be built onto the end of the section just completed in a similar man-

ner. The caisson of course will be moved to the position of the next section. Where the conditions permit, (as where the sheet-piling B is not needed,) the caisson may be moved along horizontally in the direction of the tunnel, being guided, for example, by means of a series of rollers J, Fig. 3, bearing against the tunnel at opposite sides, so that the completed portion of the tunnel serves as a guide. Under these circumstances the caisson may be moved along little by little as small sections of the tunnel are completed without awaiting the completion of a section thereof of the full length of the caisson. However, it will generally be necessary to close both ends of the completed section of the tunnel with bulkheads, to fill the working chamber with water and to either draw out the sheet-piling or cut it off at the level of the bottom of the caisson, and then to raise the caisson by removing a part of the ballast until it rises to a sufficient distance above the botton of the river, and then to draw it into its new position. It may also be necessary to fill the completed section of the tunnel with water, depending on whether or not its weight is sufficient to keep it from floating when empty and whether or not its design provides for anchors to hold the tunnel down. Where such anchors are called for, they will of course be provided at the time of building the section. The new position of the caisson is such that when sunk it will overlap the advance end of the completed section sufficiently to enable the latter to project into the working chamber. The caisson will then be sunk as before. The caisson will then rest partly on the finished tunnel, and it is necessary to make a tight fit at this point. The sheet-pile cut-off previously described prevents the water flowing into the chamber by way of the under side of the tunnel. To prevent water entering the chamber by following the sides or top of the finished section, the tunnel-section is to be of such outside shape that it will fit closely a space left under the rear end wall G of the caisson. A substantially perfectly tight fit may be obtained by lining the opening in the end wall of the caisson with one or more gaskets K. It is proposed also to provide access to the outside of the tunnel at this point by providing a small working chamber L at the lower end of a shaft and air-lock M, constituting a smaller pneumatic caisson. Air being pumped into the chamber L under compression forces out the water and permits a workman to go down and inspect and, if necessary, tighten the joint all around the outside of the tunnel by calking or otherwise. Furthermore, the compressed air alone makes the joint perfectly tight, even after the main caisson is pumped out. This joint being made tight I then drive sheet-piling B all around the caisson in the manner previously explained. Preferably, also, I drive sheet-piling down to the top of the completed section of the tunnel, the lower end of each pile being shaped to fit approximately the outline of the tunnel-section, and a bank of clay and gravel or similar material N being placed around the toes of the piles. The caisson is now tight and may be pumped out and another section of the artificial support and of the tunnel built and connected onto the completed section, the process being continued progressively until the desired length of tunnel is completed.

The work preferably commences at one shore end of the tunnel, and the opening in the rear end G of the caisson may be closed by a temporary bulkhead during the building of the first section. Obviously the work might be commenced in the middle and might progress in opposite directions by the use of two caissons or might be commenced at more than one point and the sections be advanced toward each other. The successively-built sections are necessarily adjacent to each other, as claimed hereinafter, only in the broad sense of being near to each other, though they preferably directly abut against or connect with each other.

Under some conditions it may be impracticable to make the caisson sufficiently tight by means of sheet-piling. For example, if a stratum of rock is found not much below subgrade of the tunnel the sheet-piling cannot be driven deeply or reliably, or it may be desired for economical or other reasons to omit the sheet-piling. In such cases tightness may be secured by providing a roof on the caisson and maintaining an air-pressure inside sufficient to keep the working chamber practically dry and free from inflow of mud. The roof may be permanent like that of an ordinary pneumatic caisson; but as the piles, piers, or the like which are to support the tunnel can be constructed without expelling the water from the caisson and more easily from an open caisson than from a roofed one I may put on the roof only after these operations are completed and then expel the water and construct the tubular tunnel-sections. Such a roof of two courses of timbers is indicated in dotted lines in Fig. 3 at P and will be provided with one or more air-locks Q. The details of such a construction can be readily supplied by those skilled in the art.

An important advantage of the process is that the principal work—namely, the building of the caisson and the mounting of the machinery thereon in position for use—can all be accomplished in a sheltered position and without obstruction to traffic in a river. When this is done, the operations necessary for the building of the tunnel can go forward very rapidly, as the workmen are in the open air with no extra pressure, and there is abundant room, permitting the occupation of a great many workmen at once and of numerous and powerful machines, and these ma-

chines are always at hand and mounted upon stable supports. These conditions also insure the possibility of doing the work as well as it could be done in an open cut on land.

The longitudinal rows F of sheet-piling, since they extend beyond the inner and outer faces of the rear end G of the caisson, permit the sheet-piling B on the outer or inner face to be driven close up against them, as shown in Fig. 4, so as to insure a tight continuous line of sheeting all around.

The apparatus described is illustrated more or less diagrammatically, because the details thereof form no part of the present invention (being claimed in my application for patent, Serial No. 177,427, filed October 17, 1903) and because persons skilled in the art may supply a variety of different apparatus for carrying out the same process.

Though I have described with great particularity of detail a specific process embodying my invention, yet it is to be understood that the invention is not limited to all the details described. Various modifications in the nature of the details or subprocesses and in the relative order thereof and also by the omission of some of the steps described or by the addition of others may be carried out by those skilled in the art without departure from the invention.

What I claim is—

1. In the building of an artificially-supported submarine tunnel or the like, the process which consists in sinking a caisson, building the artificial support from within said caisson, and building the tunnel on said support.

2. In building an artificial support for a submarine tunnel or the like, the process which consists in sinking a caisson, driving sheet-piling below the edge of said caisson to provide a comparatively tight working space, and building the artificial support from within said caisson.

3. In the building of a submarine tunnel or the like, the process which consists in sinking a movable caisson, building a section of tunnel therein, advancing said caisson to the end of said section, and building a second section connected to the end of the first, these steps being continued till the desired length of tunnel is completed.

4. In the building of a submarine tunnel or the like, the process which consists in sinking a caisson, driving sheet-piling below the edge of said caisson to provide a comparatively tight working space, building a section of the tunnel within said space, and repeating said operations in adjacent sections progressively until the desired length of tunnel is completed.

5. In the building of a submarine tunnel or the like, the process which consists in sinking a caisson, driving sheet-piling below the edge of said caisson to provide a comparatively tight working space, building a section of the tunnel within said space, and also a sheet-pile cut-off below an end of said tunnel-section and extending transversely across the direction thereof, and repeating said operations in adjacent sections progressively until the desired length of tunnel is completed.

6. In the building of a submarine tunnel or the like, the process which consists in building a section of the tunnel, sinking a caisson at the end of said section with one end of the caisson fitting tightly around the end of the completed tunnel-section, and building a second section of the tunnel in said caisson and connected to the first section.

7. In the building of a submarine tunnel or the like, the process which consists in building a section of tunnel within a movable caisson, advancing said caisson horizontally in the direction of the tunnel, using the completed section as a guide, and building within said caisson in its advanced position a second section connected to the end of the first.

8. In the building of a submarine tunnel or the like, the process which consists in building a section of the tunnel, sinking a caisson at the end of said section with one end of the caisson overlying the end of the completed tunnel-section, excluding the water by air-pressure around the end of the tunnel-section, and building a second section of the tunnel in said caisson and connected to the first section.

9. In the building of a submarine tunnel or the like, the process which consists in sinking a movable caisson, maintaining a practically dry working space therein by pneumatic pressure, building a section of tunnel therein, and repeating said operations in adjacent sections progressively until the desired length of tunnel is completed.

10. In the building of an artificially-supported submarine tunnel or the like, the process which consists in damming off the mud from a section of the tunnel site excavated to the subgrade of the tunnel, building the artificial support on said dammed-off section, closing said section substantially air-tight and maintaining a practically dry working space therein by pneumatic pressure, and building a section of the tunnel therein.

11. In the building of a submarine tunnel or the like, the process which consists in damming off the water from a section of the tunnel site, and building on said section of the site a tunnel-section with a cut-off below a portion thereof to prevent the passage of water along the under side of the completed tunnel-section.

12. In the building of a submarine tunnel or the like, the process which consists in damming off the water from a section of the tunnel site, and building on said section of the site a tunnel-section with a cut-off consisting of transverse and longitudinal rows of sheeting E and F below a portion thereof to pre-

vent the passage of water along the under side of the completed tunnel.

13. The process of maintaining a tight joint under water, which consists in providing a space between the two edges of the joint and maintaining a pressure of air in said space.

14. The process of maintaining tight a joint between an open caisson and a structure which a wall of the caisson overlies, which consists in maintaining a pressure of air between the structure and the wall.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

EMIL DIEBITSCH.

Witnesses:

PETER A. GAGE,

C. B. PAINE.