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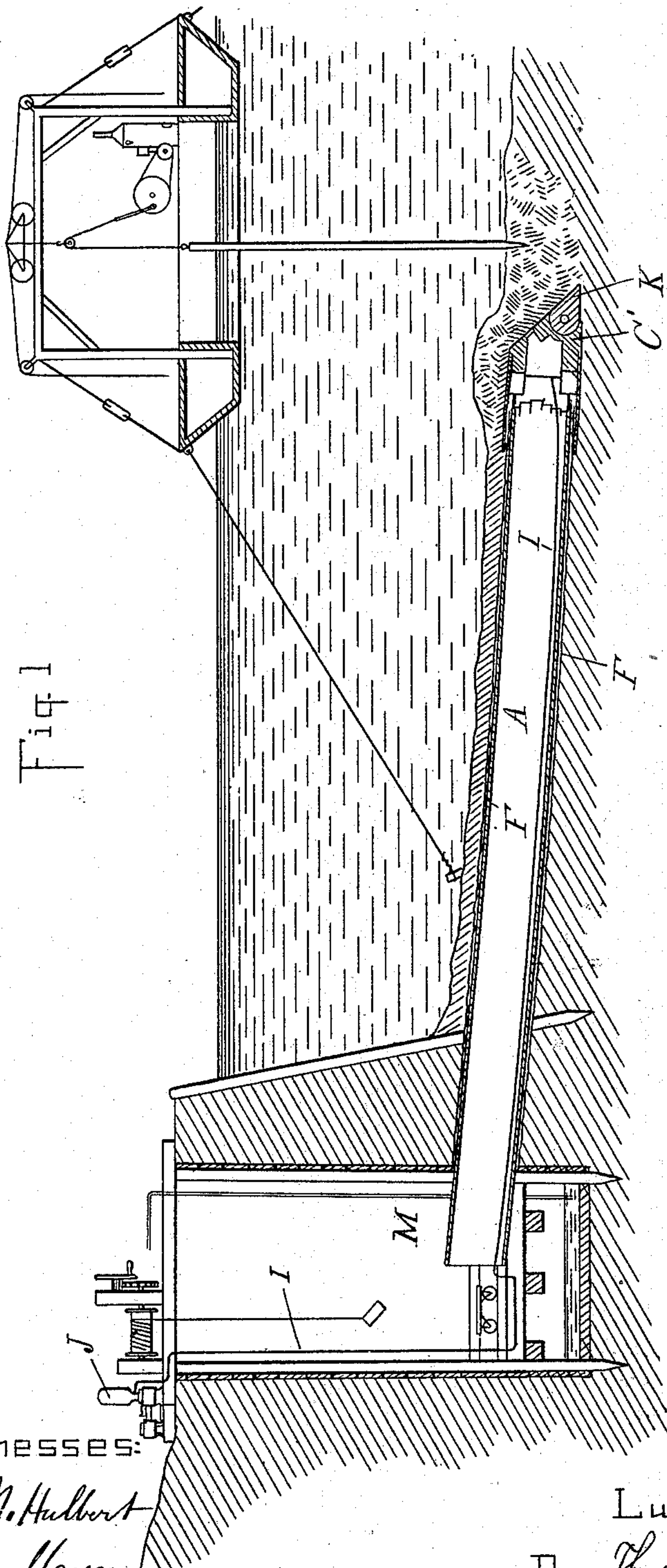
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L. BEECHER.

METHOD OF CONSTRUCTING TUNNELS.

No. 413,383.

Patented Oct. 22, 1889.



Witnesses:  
P. M. Hulbert  
J. Paul Mayer  
H

Inventor:  
Luther Beecher  
By Thos. S. Sprague, Son  
Att'y.



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3 Sheets—Sheet 2.

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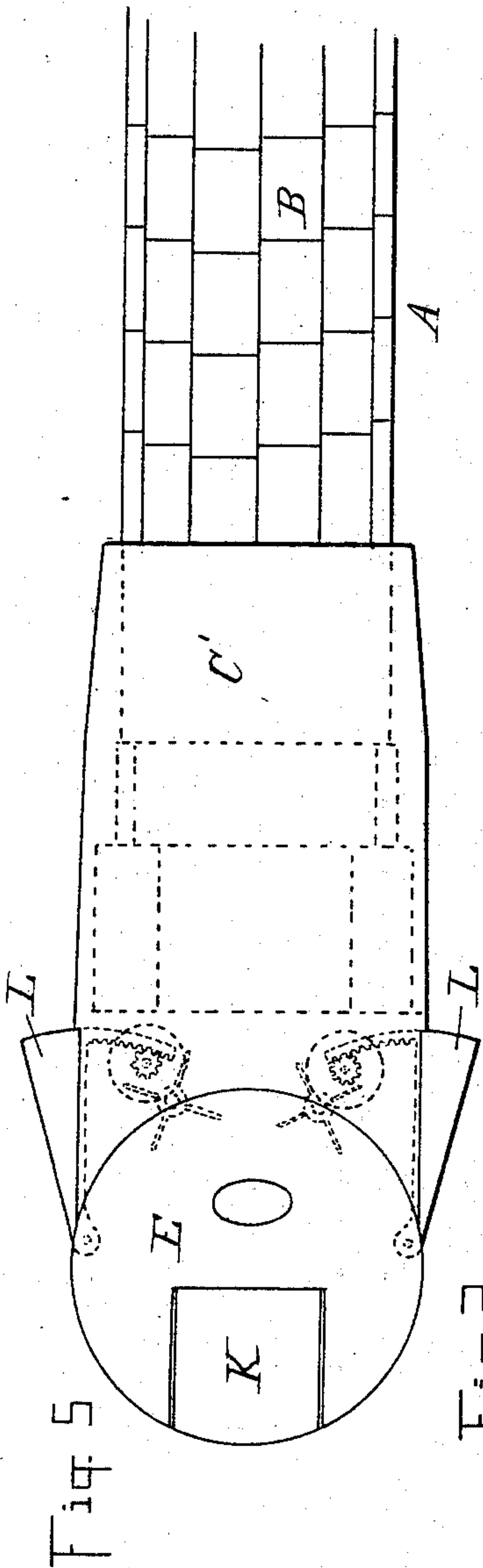


Fig. 5

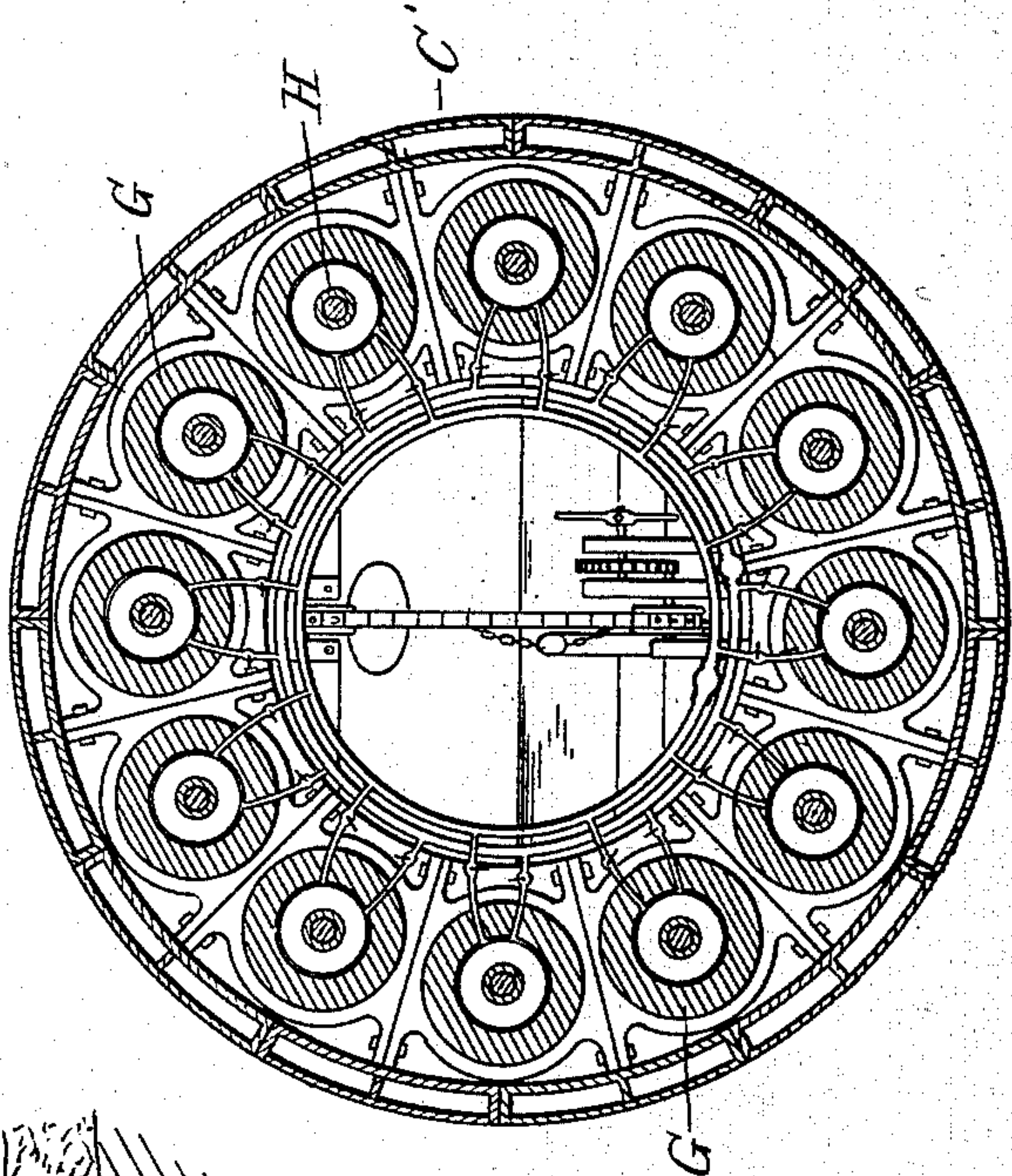
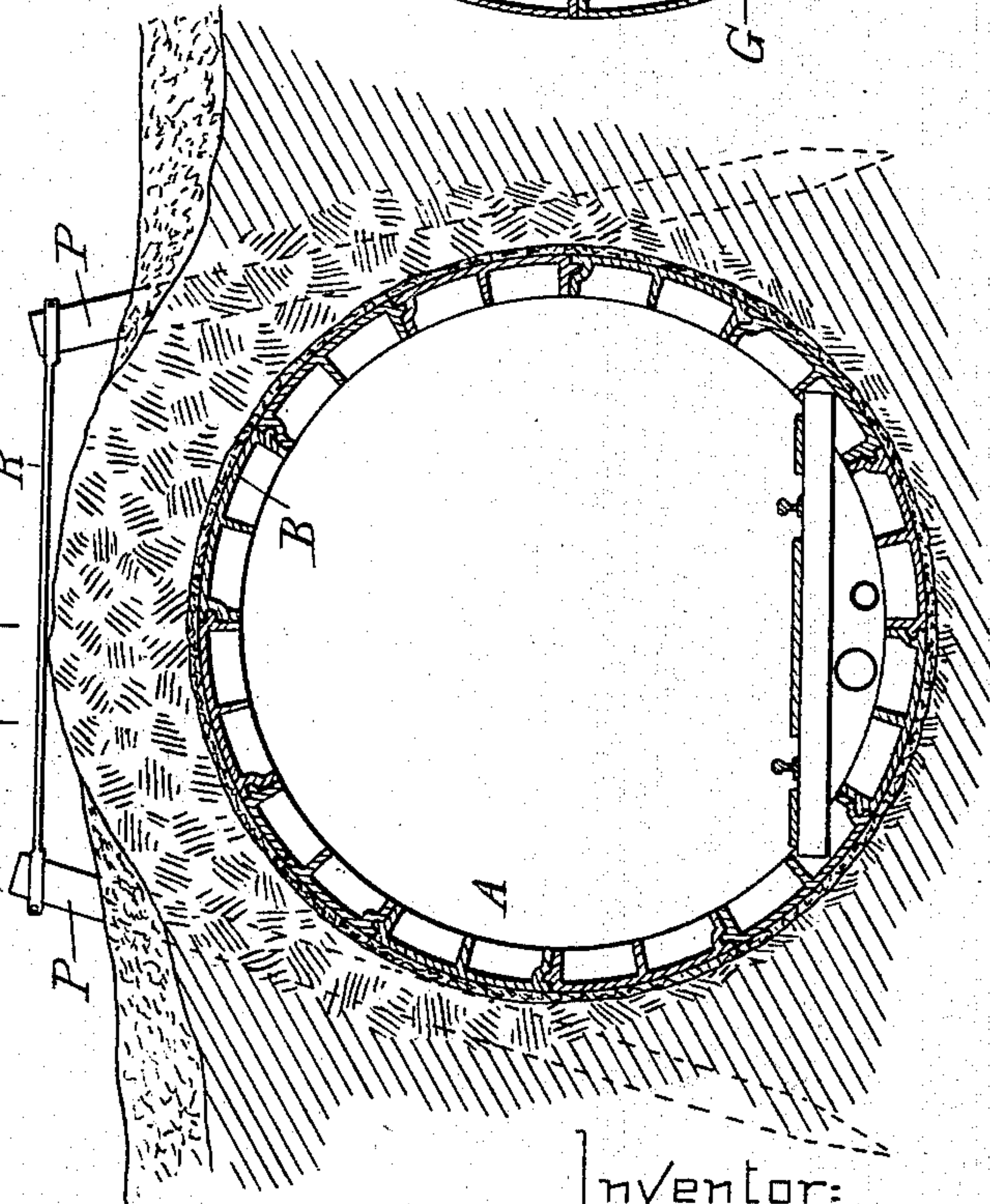


Fig. 6



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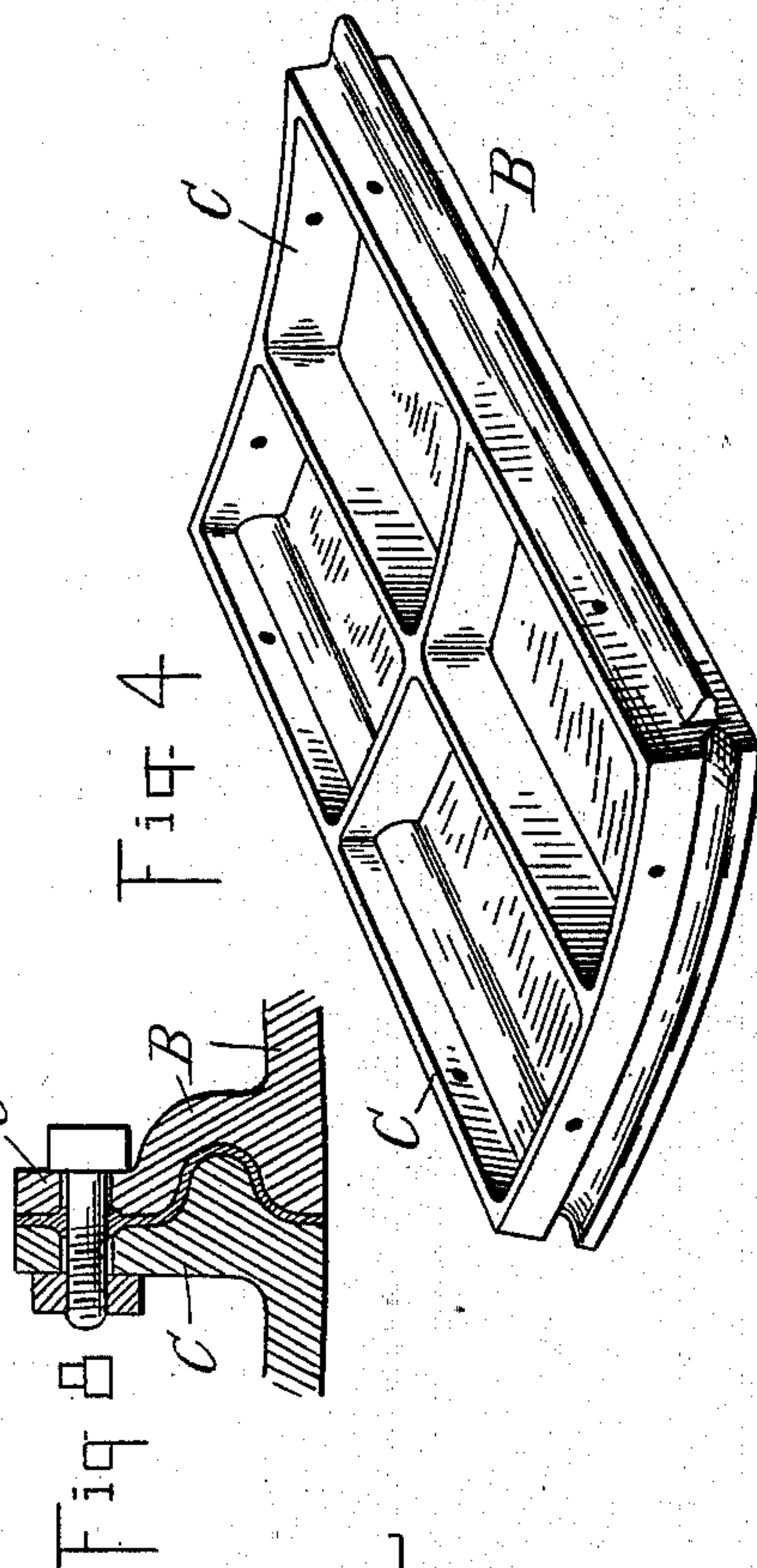
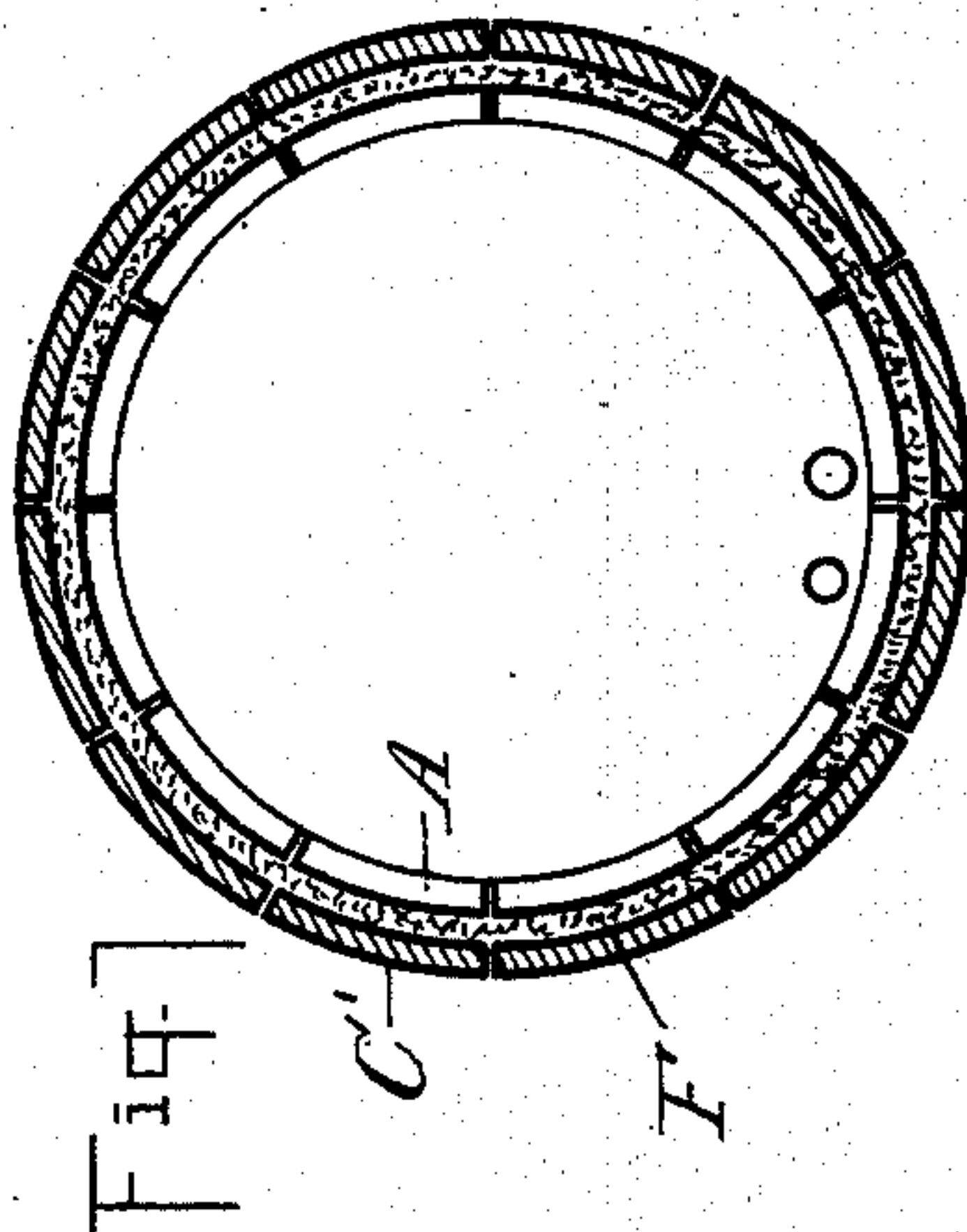
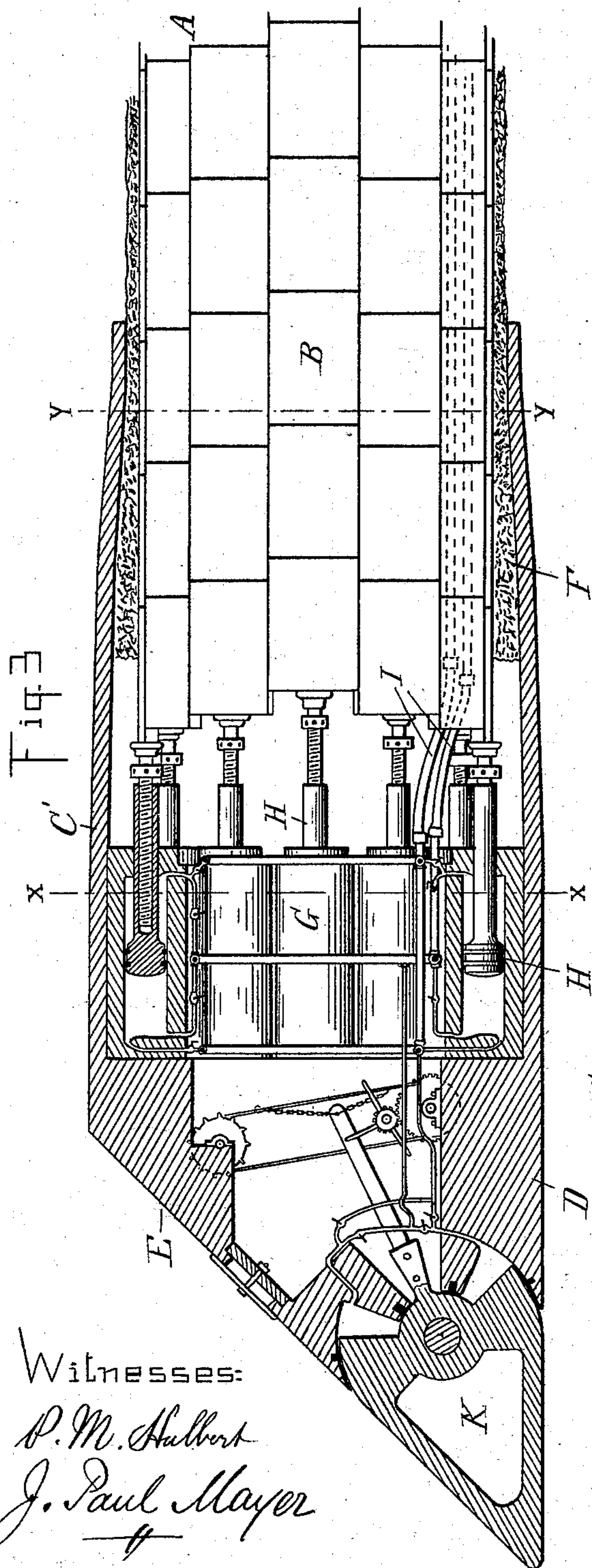
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# UNITED STATES PATENT OFFICE.

LUTHER BEECHER, OF DETROIT, MICHIGAN.

## METHOD OF CONSTRUCTING TUNNELS.

SPECIFICATION forming part of Letters Patent No. 413,383, dated October 22, 1889.

Application filed January 31, 1889. Serial No. 298,183. (No model.)

*To all whom it may concern:*

Be it known that I, LUTHER BEECHER, a citizen of the United States, residing at Detroit, in the county of Wayne and State of Michigan, have invented certain new and useful Improvements in the Method of Constructing Tunnels, of which the following is a specification, reference being had therein to the accompanying drawings.

10 This invention relates to new and useful improvements in the art of constructing subaqueous tunnels under rivers, lakes, harbors, inlets, marshes, and lowlands; and the invention consists in the improved method of construction, whereby I am not only enabled to advance the tunnel without resorting to the necessity of excavating, boring, or removing the earth, as is the case with the methods in present use, but whereby the earth, instead of being removed, becomes in my construction an element of strength and protection to the tunnel, all as more fully hereinafter described, and set forth in the accompanying drawings, in which—

25 Figure 1 is a vertical cross-section through a river, illustrating the method of building my tunnel. Fig. 2 is an enlarged cross-section of the tunnel as completed. Fig. 3 is an enlarged longitudinal central section through a portion of the completed tunnel, with the tunneling-ram in position as in the act of operation. Fig. 4 is a perspective view of one of the plates of which I preferably construct the casing of the tunnel. Fig. 5 is a diagram plan view of the tunneling-ram, illustrating the devices for steering it. Fig. 6 is a cross-section on line X X in Fig. 3. Fig. 7 is a cross-section on line Y Y in Fig. 3. Fig. 8 is a detail cross-section through two plates, showing the construction of the joint.

40 A is the main casing of the tunnel. It may be of any desired cross-section, and is constructed of metal plates, preferably of rectangular cast-iron plates B, smooth upon the outside, and provided with inwardly-projecting flanges C, for securing the plates together on their edges by bolts. These plates are of suitable curvature to form, when secured together, the desired cross-section of the tunnel, and of a size not too large and heavy to be brought in through the completed portion of the tunnel-casing and to be readily secured

from the inside. The plates are preferably made of even length and secured together to lap at the sides. To form water-tight joints, the plates are provided upon their edges with corresponding tongues and grooves, and gaskets are placed between the joints. For gaskets I choose lead plates perforated after the plates are jointed and ready to be bolted together by a pointed tool, which gradually enlarges a passage large enough for the bolt to pass through, whereby the lead displaced is crowded into the joint around the bolt-hole and prevents leakage.

65 On the construction end of the tunnel I use the tunneling-ram C', which is of similar construction and cross-section as the tunnel, but suitably larger to form a sleeve on the casing of the tunnel. The forward end of this tunneling-ram is provided with a strong water-tight bulk-head D, the front face E of which is inclined from front to rear, substantially as shown. The rear end of the ram is slightly contracted or tapering, and is built smooth on the inside and forms an annular space for the packing F:

80 Within the tunneling-ram and abutting against the bulk-head are disposed a series of hydraulic cylinders G, the pistons H of which reciprocate in the axial line of the tunneling-ram, and these hydraulic cylinders are connected by pipes I with a suitable force-pump J or head, preferably located on the shore side of the tunnel in such manner as to operate the cylinders by hydraulic pressure in the well-known application of hydraulic jacks.

85 The nose or point K of the tunneling-ram is hinged in any suitable manner, and is provided with suitable steering-gear to raise or depress it, and hinged wings L are secured to the sides of the tunneling-ram in recesses formed therein, and provided with actuating-gear to be opened outwardly to any desired degree or secured in their recesses to be flush with the sides of the ram.

90 Having now described the elements of my improvement, I will proceed to describe the construction of a subaqueous tunnel in accordance with my method.

100 I first construct a suitable tunnel-shaft M in close proximity to the water, preferably near a dock or wharf, where the water has the average depth. On the bottom of this shaft,



and projecting with its front portion through the wall of the shaft into a coffer formed by a temporary coffer-dam, I then construct the tunneling-ram at such a depth that when pushed ahead the tunneling-ram advances in solid ground. Within the rear end of the tunneling-ram, which projects inside the shaft, I then construct a section of the casing and firmly brace the same against the opposite wall of the shaft, providing ample space for unobstructed access into the tunnel. After securing a suitable packing in the annular space between the tapering rear end of the tunneling-ram and the casing, preferably as hereinafter described, and abutting the ends of the pistons against the edge of the casing by the use of suitable blocking, sufficient hydraulic pressure is applied to the cylinders to push the tunneling-ram forward the necessary distance for adding new plates to the tunnel-casing. The travel of the pistons is made, preferably, equal to the length of the plates, and proper means are provided to withdraw the pistons into the cylinders after the operation of driving the tunneling-ram ahead is completed.

It is obvious that for subaqueous tunneling great care has to be taken to provide a reliable water-tight joint between the tunneling-ram and the casing of the tunnel. To this end I have devised a novel way of packing, which consists in stuffing into the annular space between the casing and the rear end of the tunneling-ram a plastic packing adapted to form a water-proof joint. Compositions of this kind are well known and used for various engineering purposes and may be readily adapted for my purpose. A very suitable packing may be obtained with a plastic composition formed of asphalt or coal-tar made to harden by mixing it with cement and having incorporated with it some stringy or fibrous matter, such as tow, old rope, or equivalent materials. This is stuffed into the annular space for the whole length of the joint, and when the tunneling-ram is driven forward the tapering portion thereof compresses it firmly around the casing and into the joints thereof, and after a time it hardens and forms a protective covering for the main casing, which firmly adheres to it and makes it water-proof, besides strengthening it and protecting it from rusting on the outside.

After the tunneling-ram is advanced by the application of sufficient hydraulic pressure into all the cylinders the pistons are retracted and a new set of plates with new packing are secured to the end of the casing. In this operation the hydraulic pressure from the cylinders may be individually applied to force each plate into position, and the plates are preferably only temporarily secured together until the joint hydraulic pressure from all the cylinders and the outside pressure have forced the plates into a permanent relation to each other.

The various details connected with these

operations and not alluded to herein may be easily carried out by ordinary engineering skill, and obvious modifications of carrying out my method under different contingencies may be devised without departing from the spirit of my invention.

The best conditions for the application of my method of tunneling are found in ground reasonably free from rocks and obstructions and where the ground is for the most part so regular that the tunneling-ram can follow the same without producing too many or abrupt changes in the grade. By making preliminary surveys, as required for the construction of any tunnel, no matter by what method, it will be generally found easy to select a suitable profile, especially by crossing under navigable rivers or bays.

My method of tunneling contemplates constructing the tunnel a few feet (more or less) below the bottom of the river, lake, or other body of water, to enable the ram to displace the earth in an upward direction into the water, and should abrupt change in the grade require it other known methods of tunneling may be temporarily applied to meet exceptional conditions. To this end suitable provision may be made in the construction of the tunneling-ram to permit of boring, drilling, excavating, or otherwise removing the earth, as may be determined in advance.

The conditions under which my method is applicable are those ordinarily found in crossing under rivers or lakes, in which there are generally a few inches or feet of loose sand, gravel, or silt on the bottom, with a solid bed of clay or clayey soil underneath. By advancing with the tunneling-ram in the solid bed the lighter particles are lifted above the bottom and gradually washed away, while the clay or heavy soil is compacted all around the tunnel and the portion displaced upwardly is left over the top of the tunnel to form a covering, which may be rammed down from above, and which, if of a clayey nature, may become of itself a water-tight medium around the tunnel. If desired or necessary on account of insufficient covering, suitable ballast may be thrown over the tunnel from the outside.

By using the steering-gear of the ram in a proper manner it will not be found difficult to follow the rise and fall of the bottom within the allowable limits; but if the means for steering should be inadaptably or inadequately piles P may be driven at suitable intervals into the bed, preferably in pairs, far enough apart to let the tunneling-ram pass between and serve as guides. By connecting the upper end of each pair of piles with the yoke R the casing may be firmly anchored in place, if necessary, to prevent possible displacement.

The buoyancy of the tunnel and the tunneling-ram is counteracted by the use of cast-iron or other metal in the construction of all the parts, and, if need be, ballast inside applied as a lining to the tunnel-casing, or by



securing cast-iron blocks into the panels formed between the flanges of the plates of the casing.

An important adjunct of my improvement is the operation of exploring the ground in advance of the tunneling-ram. This operation is intended for the purpose of discovering bowlders, rock, or other obstructions of a nature liable to form an obstacle to the tunneling, and also for the purpose of loosening and preparing the ground in advance of the head of the tunneling-ram, so that it will offer less resistance to displacement by the tunneling-ram and become of a more plastic nature, so as to pack around the tunnel. In clayey soil it is of especial value to loosen the soil, as it is well known that by a certain amount of working or so-called "puddling" it becomes quite plastic, and then forms an excellent covering or packing around the tunnel, which of itself is water-tight. This exploring or working of the ground is easily produced or effected by the use of a suitable vessel—such as a large scow—anchored in front of the tunneling-ram, and operating in the ground with suitable tools—such as heavy spuds—working up and down in the necessary manner to find all rocks and bowlders or other obstructions, which are removed in any suitable manner.

Instead of loosening the ground with tools, the more modern way of using explosives may be made use of, which would also dispose of rocks or other obstructions. The manner of using dynamite or other explosives for similar purposes is so well known that a further description thereof may properly be omitted and left to the practical engineer.

It is obvious that although the material may be thoroughly loosened and worked up in advance of the tunneling-ram, and that it may be lifted up by the wedge-shaped end of the tunneling-ram, it will nevertheless again be firmly compacted upon the sides and top as the ram advances. Care should be taken, however, to loosen the soil not more than is needed to advance the tunneling-ram, and, if necessary, the loosened ground may be packed again afterward on top and on the sides of the tunnel-casing by the application of mechanical means.

As the presence of quicksands in the strata or in pockets does not in the least interfere with the successful operation of my method, the latter presents the most economical solution, not only of one of the most difficult engineering problems in tunneling, but in all subsequent tunnel constructions in which my method is applicable on general conditions.

The construction of my tunneling-ram in respect to the hinged nose or point and the

hinged wings on the side is devised for the purpose of having it entirely within my power to direct or steer the tunneling-ram within a permissible limit up or down, right or left. The raising and lowering of the nose of the tunneling-ram will evidently direct the ram up or down in the same manner, and the spreading or folding of the lateral wings will cause a lateral deflection of the tunneling-ram to one side or the other, as desired, and as a further means of guiding the tunneling-ram in the intended direction a judicious use of the hydraulic jacks in the tunneling-ram forms another means of accomplishing this end.

I attach importance to the fact that the forward end of the ram be upon an incline, as shown, in contradistinction to being concaved or tapered from the longitudinal center to the sides, as heretofore, so that the earth is displaced upward and compressed above the casing instead of being thrown mostly to the sides and there compressed.

No claim is here made to the apparatus shown herein, as it forms the subject-matter of my application, Serial No. 302,026, filed March 5, 1889.

What I claim as my invention is—

1. The herein-described improvement in the art of subaqueous tunnel construction, which consists in slidingly operating the tunneling-ram on the construction end of the tunnel-casing, and displacing the earth upward and extending the tunnel-casing step by step as the tunneling advances, and loosening or preparing the ground in advance of the ram by mechanical means removed from the ram, as set forth.

2. The herein-described improvement in the art of subaqueous tunnel construction, which consists in slidingly operating the tunneling-ram on the construction end of the tunnel-casing and in compressing in a tapering space between the ram and the casing an outer covering in the advancing movement of the ram, as set forth.

3. The herein-described improvement in the art of subaqueous tunnel construction, which consists in extending the casing step by step within the tunneling-ram moving over said casing and compressing suitable packing in a tapering space between the casing and the ram and into the joints of the casing by the advancing movement of the ram, as set forth.

In testimony whereof I affix my signature, in presence of two witnesses, this 22d day of December, 1888.

LUTHER BEECHER.

Witnesses:

J. PAUL MAYER,  
P. M. HULBERT.