(No Model.) 3 Sheets—Sheet 1.

L. BEECHER.

TUNNELING RAM.

No. 413,384. Patented Oct. 22, 1889.

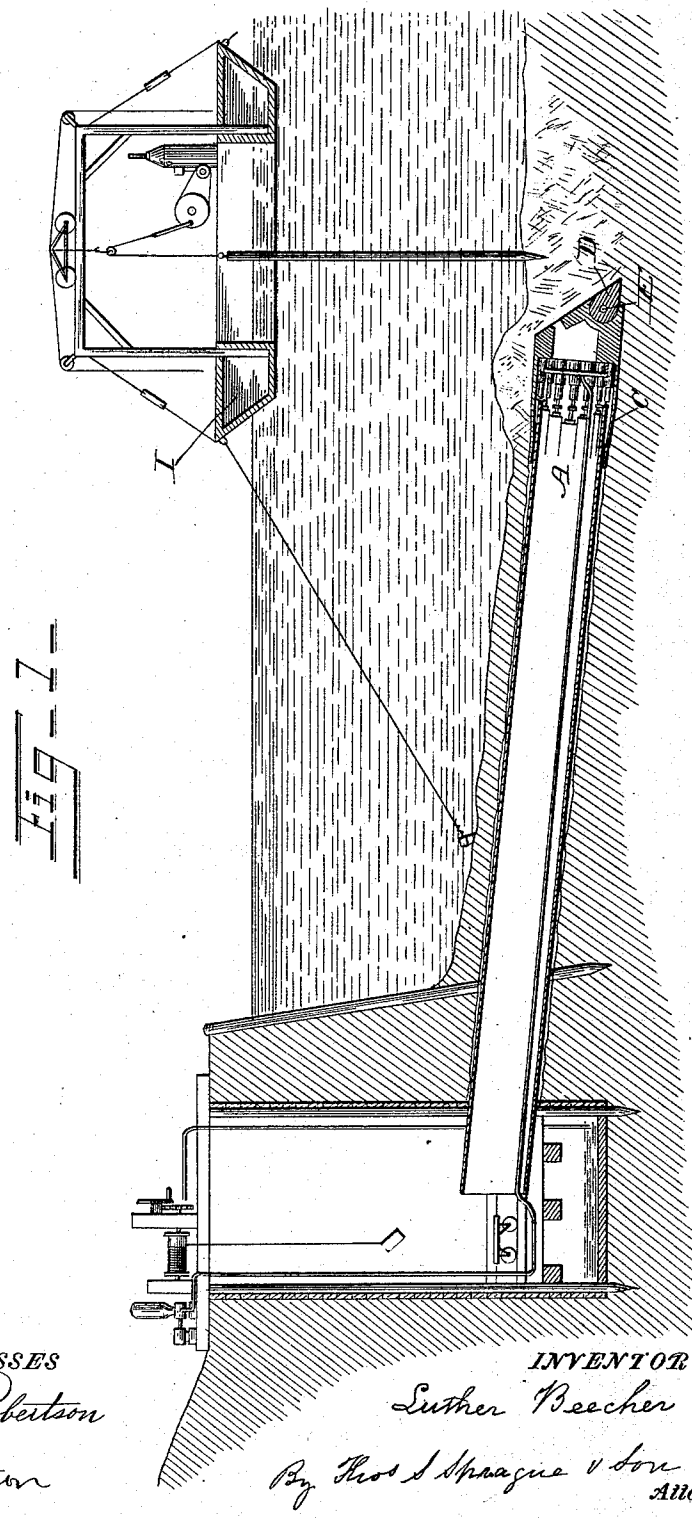

Fig. 1.

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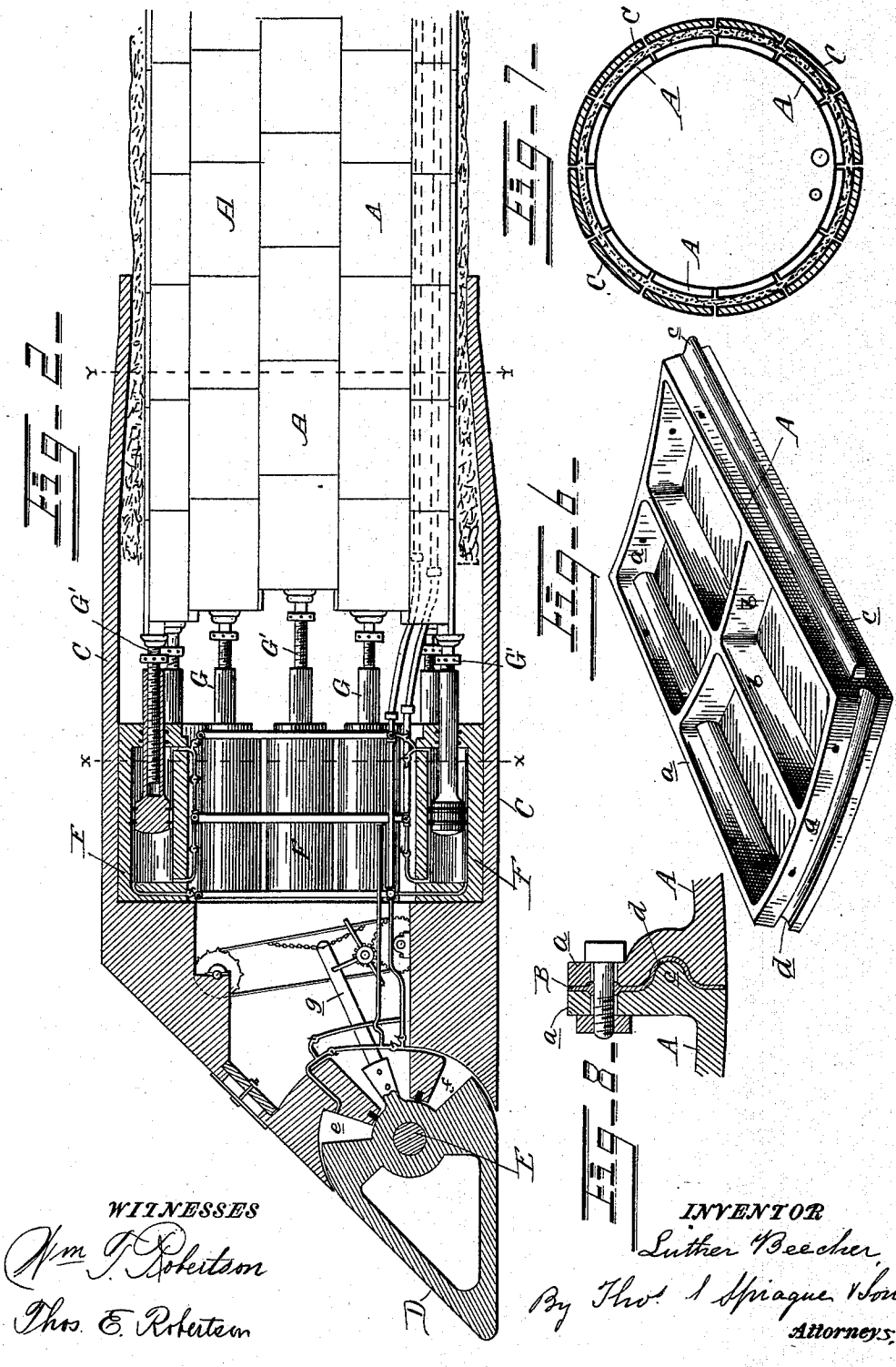

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TUNNELING RAM.

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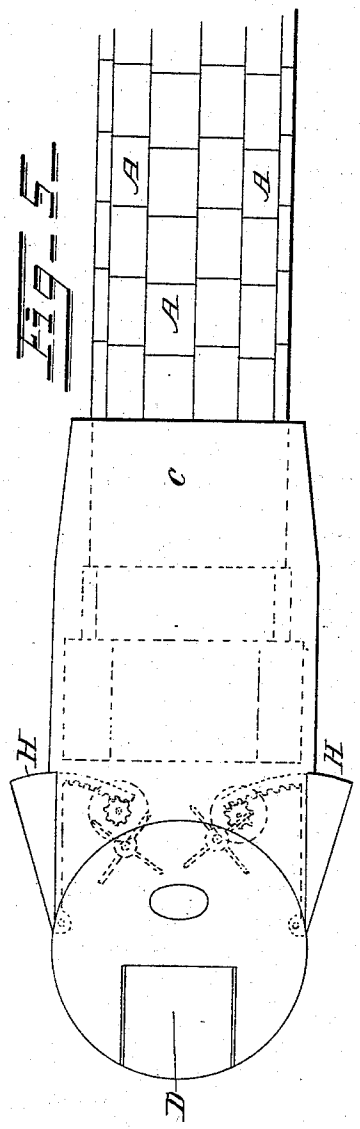

Fig. 5.

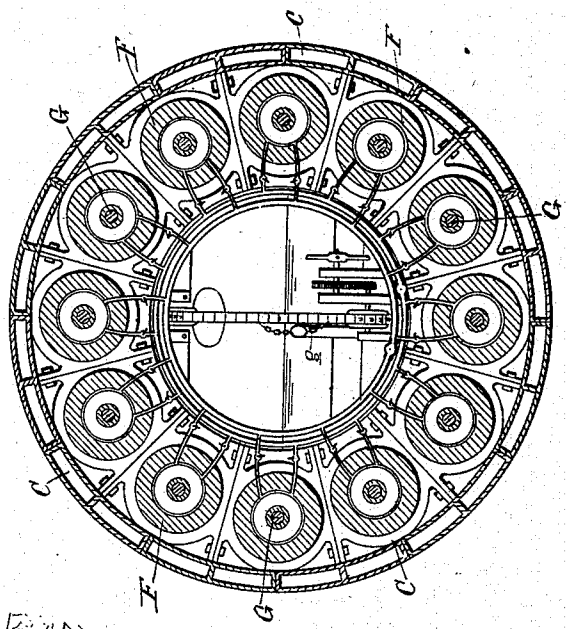

Fig. 4.

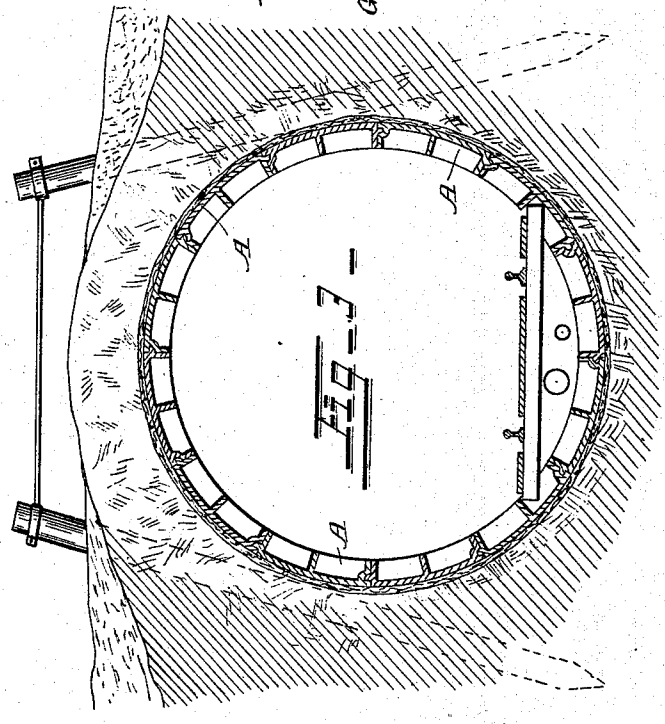

Fig. 7.

WITNESSES

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UNITED STATES PATENT OFFICE.

LUTHER BEECHER, OF DETROIT, MICHIGAN.

TUNNELING-RAM.

SPECIFICATION forming part of Letters Patent No. 413,384, dated October 22, 1889.

Application filed March 5, 1889. Serial No. 302,026. (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 Tunneling-Rams, of which the following is a specification, reference being had therein to the accompanying drawings.

This invention relates to new and useful improvements in the art of constructing subaqueous tunnels; and the invention primarily consists in the mechanical means and appliances by which I intend to carry out a method of tunneling, for which I have concurrently applied for Letters Patent; and it further consists in the peculiar construction of the tunneling-casing, all as more fully hereinafter described, and shown in the accompanying drawings.

My method of tunneling contemplates the construction of subaqueous tunnels without the necessity of removing the earth, as in the present methods of constructing such tunnels. To this end the way for the tunnel-casing is forced by means of a wedge-shaped bulkhead, or what I call a "tunneling-ram," which slides with a water-tight joint on the construction end of the tunnel-casing, and which is driven forward with sufficient power to displace the earth in front of it upwardly, so as to cover the top of the tunnel, the latter passing in suitable proximity to and below the bottom of a river or body of water to permit this displacement of the earth. To assist the operation of the tunneling-ram the earth in front of it, if necessary, is loosened up to the required depth, and stones, rocks, or other obstacles are removed or broken up by the use of explosives. This work is accomplished with the help of a vessel provided with the required outfit and operating in advance of the tunneling-ram. Plastic packing is used to form a water-tight joint between the casing and the sliding end of the tunneling-ram, and this packing remains permanently on the outside of the casing.

Devices are provided for steering the tunneling-ram, and other provisions are made to meet contingencies necessitating the temporary use of other modes of tunneling.

In the drawings, Figure 1 is a vertical cross-section of a tunnel in process of construction in accordance with my invention. Fig. 2 is an enlarged vertical central longitudinal section of the construction end thereof. Fig. 3 is a cross-section of the tunnel as completed. Fig. 4 is a cross-section of the tunneling-ram on line X X of Fig. 2. Fig. 5 is a plan thereof. Fig. 6 is an enlarged perspective view of a plate of the casing of which I intend to construct my tunnel. Fig. 7 is a cross-section on line Y Y of Fig. 2; and Fig. 8 is a detail cross-section through two plates, showing the construction of the joints.

A are segmental rectangular plates of cast-iron, smooth on the outside and provided on the edges with inwardly-projecting flanges *a* for bolting the plates endwise and sidewise together to form a tunnel of the desired cross-section. Similar flanges or ribs *b* may be provided centrally to strengthen the plates.

To form water-tight joints I provide all the plates alike upon their ends and sides with tenons *c* and grooves *d*, whereby in joining the plates together the tenons on one plate will engage into the corresponding grooves in the adjoining plates. The plates are preferably bolted together to break joints, and soft-metal gaskets B are inserted between the joints. For the purpose I use, preferably, lead plates, through which the bolt-holes are formed by means of a pointed tool, which gradually enlarges the bolt-hole to force the lead into the joint between the flanges around the bolt-hole. In addition to this metallic packing, the joints may be coated with paint, asphalt, coal-tar, or any other compound usually used in constructions of this kind. These metallic plates I make of a size and shape convenient for handling and to be readily transported through the interior of the tunnel as its construction advances.

I deem cast-iron to be the most suitable material for constructing the plates; but I do not intend to limit myself to this material alone, or to its exclusive use, for if occasion should require or I should deem it expedient I intend to provide the casing with a suitable lining on the inside—such as masonry, terra-cotta, cement, or other heavy material—or fill the openings formed between the flanges of each plate with solid cast-iron blocks, firmly wedged or keyed in as may be required to

give the necessary strength, weight, and stability to the structure and to overcome the buoyancy thereof and the pressure of water upon it.

While building this tunnel on land I proceed, as usual, by excavating the earth, and in lengthening the tunnel I add the sections on top first to form a protecting-hood, and gradually add plates to the sides and bottom, keeping the top plates always advanced. In building this tunnel under the bed of a river, lake, &c., I proceed after the method described above, by building on the open end of the tunnel-casing the hollow sliding bulk-head or tunneling-ram C, which is wedge-shaped at its forward end and slightly tapering at its rear end and sufficiently larger than the tunnel to loosely embrace it and form an annular space for packing. This tunneling-ram I construct in a similar manner of sectional plates, as described for the casing of the tunnel, except that the tapering end is smooth on the inside. The front edge or wedge-shaped portion I construct, preferably, in a solid manner, and with a movable point or nose D, which is connected by a strong knuckle-joint, which turns on the steel shaft E, and is solidly backed in circular bearings on the head. This movable nose is adapted to be raised or lowered by providing it with hydraulic chambers *e* and *f*, or with suitable mechanical devices—such as the lever *g*—adapted to be worked from the inside and having a sufficient amplitude of motion to raise or lower the point within the easy grades permissible for tunnels. The whole point or wedge-shaped portion of the tunneling-ram is solidly constructed of cast-iron or steel to resist the hydraulic pressure exerted against it by a series of hydraulic cylinders F, placed against its bulk-head and disposed near the outside of the shell, and forming a strengthening part thereto, and being integral therewith or forming an inner lining therefor. The pistons G of these hydraulic cylinders, which correspond in number with the number of plates composing the circle, operate in the longitudinal direction of the ram, and are in a line corresponding with the casing of the tunnel, whereby in operation the force of the piston may be exerted endwise and in a line with the casing or walls of the tunnel, each piston being suitably blocked or abutted against the contiguous portion of the casing or walls of the tunnel to exert a direct thrust upon it when the hydraulic pressure is exerted upon the piston. The hydraulic pressure can be applied for two purposes—first, for forcing the tunneling-ram the necessary distance ahead to lengthen the tunnel-casing, and, secondly, to force each individual plate into position when the tunnel is lengthened out, as it requires some power to compress the packing sufficiently to make the tongue-and-groove joints with the soft-metal packing between, as described. By constructing the pistons with the screw-extension G′, as shown, they may be readily abutted against the plates. When hydraulic pressure is applied to all the pistons to drive the tunneling-ram the necessary distance forward, all the plates will be firmly compacted endwise and sidewise; also, on account of the pressure on the casting and of the slightly-tapering shape of the tunneling-ram, the bolts are uniformly tightened on all the joints wherever necessary.

To form a tight joint between the overlapping ends of the tunneling-ram and the casing of the tunnel I compact into the annular space a plastic packing or cement, preferably composed of asphalt, coal-tar, or other bitumen mixed with cement and with a fibrous material—such as tow or old rope—and this packing is of an adhesive nature and hardens and sets after a while. As the tunneling-ram advances by being forced forward, the packing is compressed onto the casing by the tapering rear end, and is thereby forced into all the joints of the casing and forms an outer protective layer around the tunnel. New packing is added whenever the casing is lengthened out.

As my method of tunneling contemplates the building of the tunnel just below the bottom of the body of water as nearly as is possible without making too many or abrupt changes in the grade of the tunnel, I raise or lower the hinged nose of the tunneling-ram in a proper degree to steer the tunneling-ram up or down, as required. The power of the hydraulic pistons may also be applied to effect the steering of the tunneling-ram up or down or to one side or the other by applying the pressure unequally to the bulk-head.

To effect the lateral steering of the tunneling-ram by mechanical means I provide the latter, near the forward end, with the hinged wings H, which fold into suitable recesses provided upon the side of the tunneling-ram and are provided with hydraulic-pressure chambers or other mechanical devices to open them laterally when required to crowd the tunneling-ram to one side or the other.

The advantage obtained by keeping always in the same proximity below the bed of the river or other body of water, or nearly so, is that I thereby make it possible for my tunneling-ram to displace the ground in front thereof upwardly when forced ahead by suitable hydraulic pressure. At the same time the ground is firmly compacted all around and forms a protective layer over the top of the tunnel, which is composed of the solid soil raised up from the bottom of the tunnel, and which may be afterward further compacted from the outside in any suitable manner. The light material—such as silt and other débris usually found on the bottom of rivers, &c.—is raised up from the bottom to be carried away by the water.

My method of tunneling in close proximity to the bottom of the water permits me to simultaneously carry on the operation of loos-

ening the soil in advance of the tunneling-ram. This I carry out by anchoring a suitable scow, boat, or raft I in advance of the tunneling-ram, which is provided with suitable mechanical devices to loosen, work, or puddle the ground in advance of the ram from above, such as by means of suitable tools lowered into the ground to the required depth. By this operation I also discover any obstacles to the progress of the tunneling-ram, and remove the same in any suitable manner, such as by means of explosives or otherwise. This operation of loosening the soil in advance of the tunneling-ram may be entirely accomplished, if desired, by the use of explosives, as in the usual operation of deepening channel-beds in rock-bottom. By loosening and working the ground in this manner not only bowlders and other obstacles are discovered, but the work of the tunneling-ram becomes at once possible under all conditions of soil, and, as clayey soil is thereby transformed into a plastic cement, a new element of strength and durability is added to the structure, as the clay, after becoming compacted again, forms a water-proof covering around the tunnel.

For such contingencies as are found in subaqueous constructions, where liability exists from being undermined, as where channels are changing, I introduce a new element of protection, which consists of driving piles alongside the casing of the tunnel, slightly inclined, so as to pin or hold the tunnel to the bed, and placed in pairs opposite to each other to permit of their being yoked together over the top of the tunnel by suitable cross-pieces or iron yokes. This piling may be carried out in advance of the tunnel to guide the tunneling-ram in its operation, in which case the side wings for steering are not required.

In the practical construction of my tunnel, I start the subaqueous portion of the tunnel preferably from the bottom of a vertical shaft of suitable size to afford a convenient entrance into the tunnel for lowering the material, and serving also as an air-shaft. On the bottom of this shaft I provide a cistern or well suitable to receive the ordinary leakage or drainage from the tunnel, and from which it may be pumped out. This I cover over with a strong platform in line with the bottom of the intended tunnel, and upon this I begin to construct my tunneling-ram, projecting out through the sides of the shaft. If necessary, a suitable coffer is constructed outside around the tunneling-ram to protect the shaft against the ingress of water. After the tunneling-ram is completed I begin to construct a section of my tunnel-casing inside of the rear end of the tunneling-ram, and after securing the packing in place the rear end of the casing is abutted against the rear side of the shaft, and the front end of each plate of the casing I abut against its corresponding hydraulic piston. After having made all the necessary provisions for allowing the tunneling-ram to be pushed ahead in the manner intended, this operation is then proceeded with by forcing water by means of a large force-pump—preferably placed in proximity to the shaft—into the hydraulic cylinders until the tunneling-ram has advanced the necessary distance required for securing new plates to the tunnel-casing after the pistons are withdrawn into the hydraulic cylinders. By alternatingly driving the tunneling-ram ahead and lengthening the casing, adding to it a new set of plates all around with the necessary packing to maintain a water-tight joint, the construction of the tunnel is carried out substantially after the method described.

It is obvious that I intend to avail myself of all the facilities and modern appliances of which engineers in carrying out such construction generally avail themselves—such as laying a temporary track inside the tunnel, for running a truck or trucks thereon to transport the material, the construction of suitable drains and pipe systems to afford drainage, and to convey the hydraulic pressure into the hydraulic cylinders, and other suitable provisions for lighting, heating, or whatever may be required for the comfort of the workmen and for expediting the work.

There may be sections of work where my method of tunneling is not available or would be at a disadvantage compared with other known methods; but it will be an easy matter to make suitable provisions in the construction of the tunneling-ram to permit of using excavating machinery applied through suitable openings provided for in the bulk-head. As the nature of the work and the difficulties to be encountered can all be known in advance through a careful survey, which ought necessarily to precede the commencement of the work, no contingencies are liable to arrive for which no adequate provisions can be made or which engineering skill is not able to meet, and while quicksand is generally accounted to be the most troublesome factor in tunnel construction no difficulty at all arises from this source in my method of tunneling.

No claim is made to the process herein described, as it forms the subject-matter of my application, Serial No. 298,183, filed January 31, 1889.

What I claim as my invention is—

1. In subaqueous tunneling, a tunneling-ram provided with a wedge-shaped bulk-head adapted to displace the ground upwardly, having a hinged point or nose and forming a water-tight compartment slidingly operating on the head of the tunnel-casing, substantially as described.

2. In subaqueous tunneling, a tunneling-ram provided with a solid bulk-head constructed in the form of a wedge, adapted to displace the ground upwardly when pushed through it, and with a movable point or nose for steering it, said tunneling-ram being

adapted to slidingly operate on the head of the tunnel-casing, and forming a water-tight compartment for extending the tunnel-casing within said tunneling-ram, substantially as described.

3. In subaqueous tunneling, a tunneling-ram provided at its front end with a solid bulk-head, having its front face rearwardly inclined from the bottom to the top and having a hinged point or nose and laterally-extensible wings, substantially as described.

4. The combination, with the casing and tunneling-ram slidingly secured thereon and formed with tapered rear end, of the plastic packing applied between the tunneling-ram and casing to form a water-tight joint, substantially as described.

5. In subaqueous tunneling, the combination, with the casing, of a tunneling-ram provided with a tapering rear end and a plastic packing applied in the annular space between said tapering rear end and the casing of the tunnel, said tunneling-ram forming a water-tight compartment on the head of the casing and provided with means for advancing it to permit of extending the casing within the tunneling-ram, substantially as described.

6. In subaqueous tunneling, the combination, with a casing constructed of rectangular segmental cast-iron plates smooth on the outside and interiorly flanged on their edges for securing said plates together by bolts, of the tunneling-ram provided with a tapering rear end smooth on the inside and slidingly engaging with the end of the tunnel-casing by means of plastic packing adapted to form a permanent covering on the outside of the tunnel-casing, substantially as described.

7. In subaqueous tunneling, the combination of a tunnel-casing consisting of rectangular segmental iron plates adapted to be interiorly bolted together with intervening gaskets by means of interior flanges provided with corresponding tongues and grooves, a tunneling-ram provided with a solid bulk-head wedge-shaped at its outer face and with a tapering rear end sliding on the head of the casing, with a water-tight joint formed of a plastic material adapted to form a permanent covering on the outside of the tunnel-casing, and a series of hydraulic rams grouped around the inner wall of said tunneling-ram and adapted to operate with their pistons against the inner ends of the plates of the casing to force the same in place and advance the tunneling-ram, substantially as described.

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.