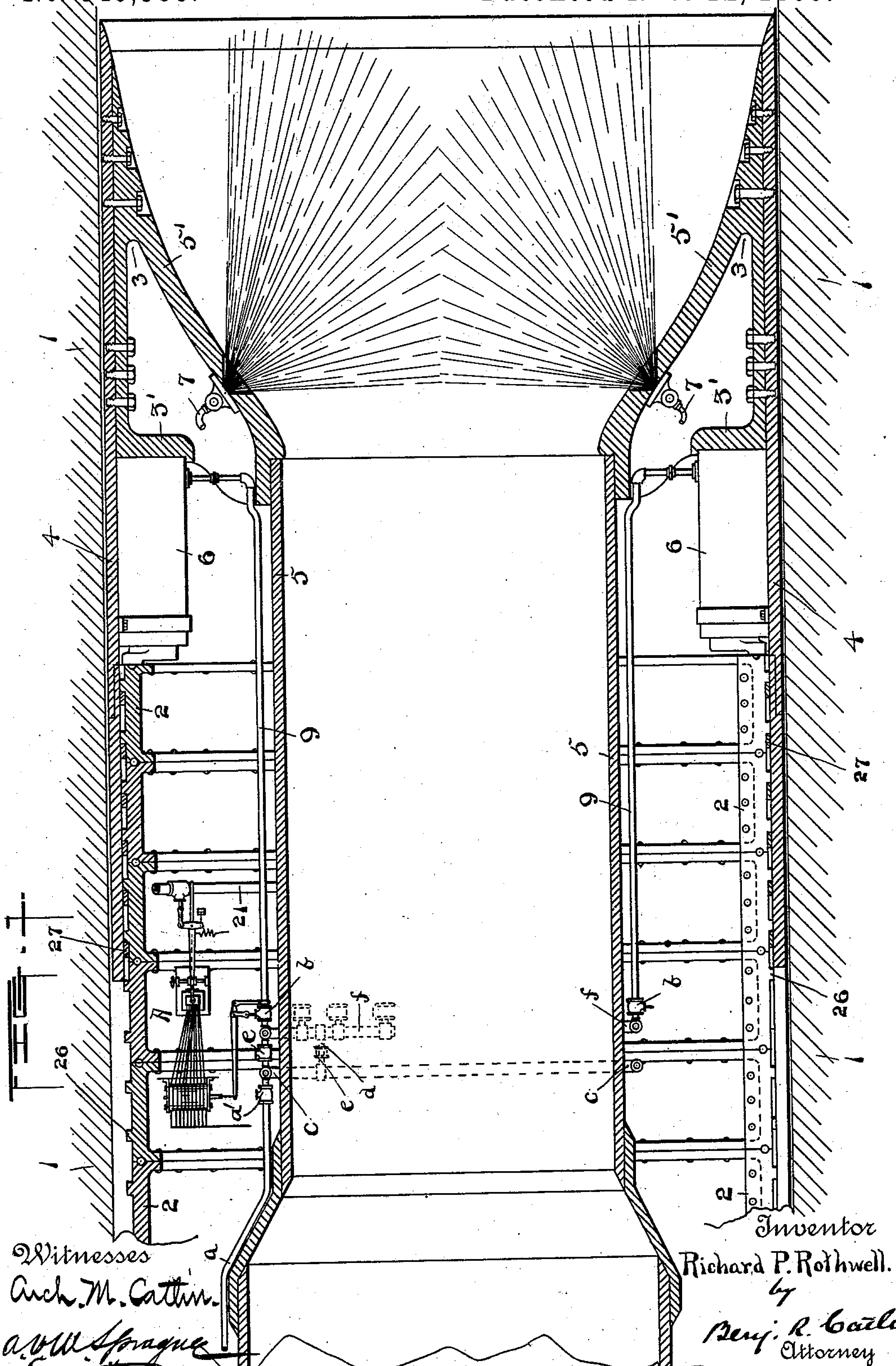
(No Model.) 3 Sheets—Sheet 1.

# R. P. ROTHWELL.

## APPARATUS FOR SINKING SHAFTS OR DRIVING TUNNELS.

No. 549,586. Patented Nov. 12, 1895.

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(No Model.)

3 Sheets—Sheet 2.

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FIG. 2.

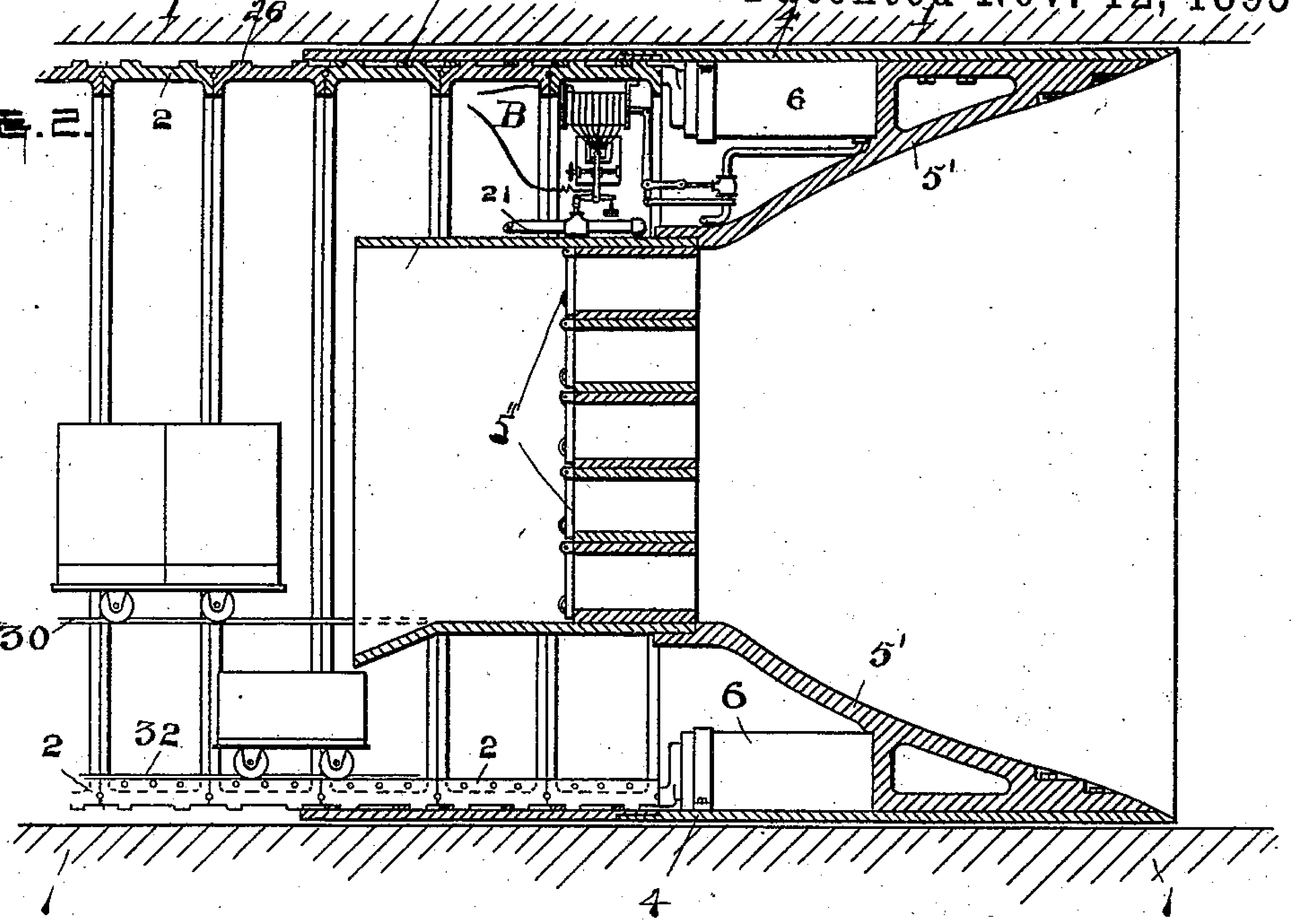



FIG. 7.

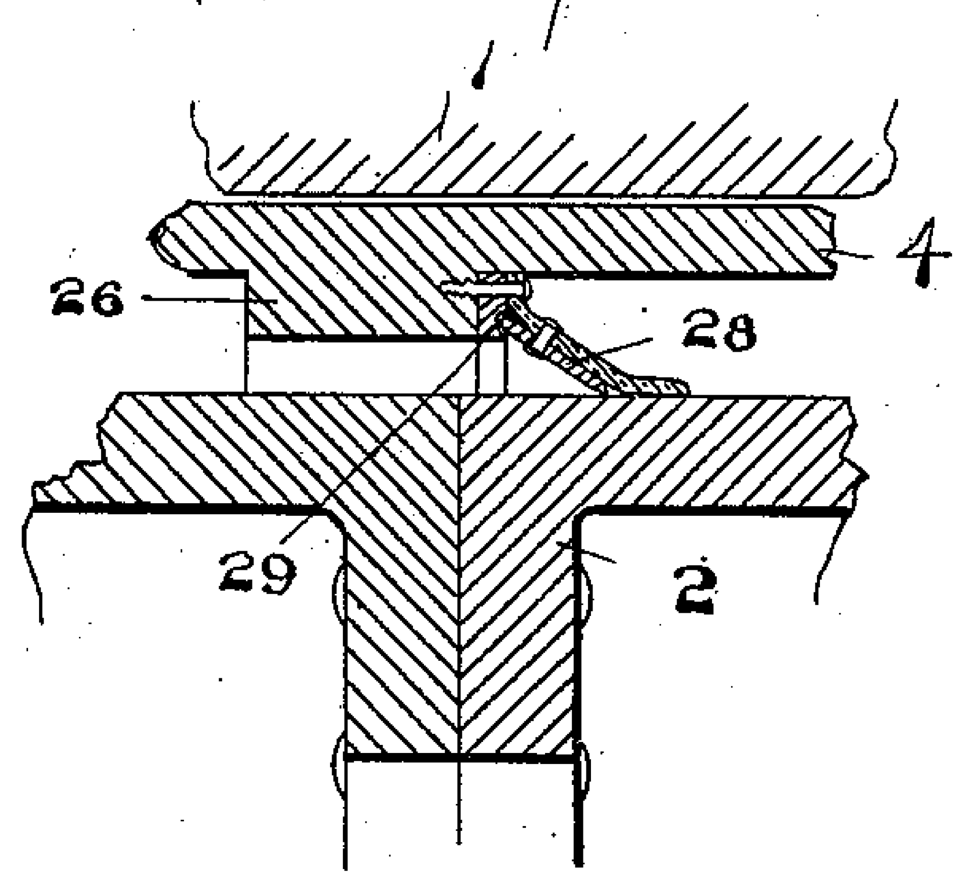
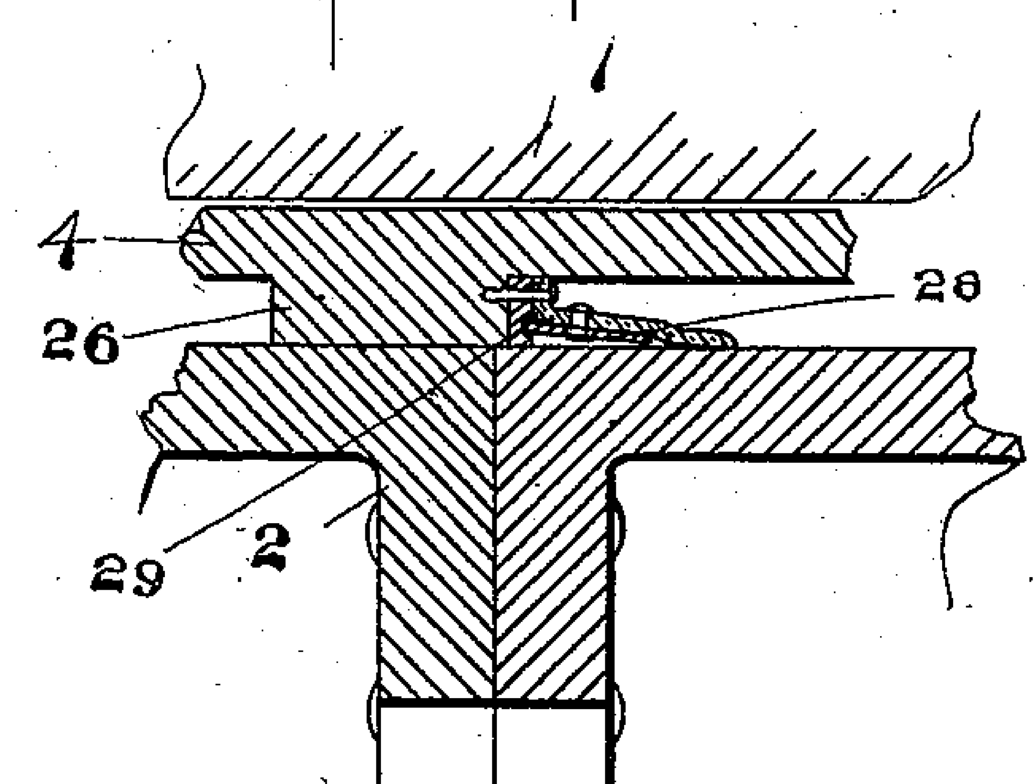



FIG. 8.

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(No Model.) 3 Sheets—Sheet 3.

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## APPARATUS FOR SINKING SHAFTS OR DRIVING TUNNELS.

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FIG. 3.

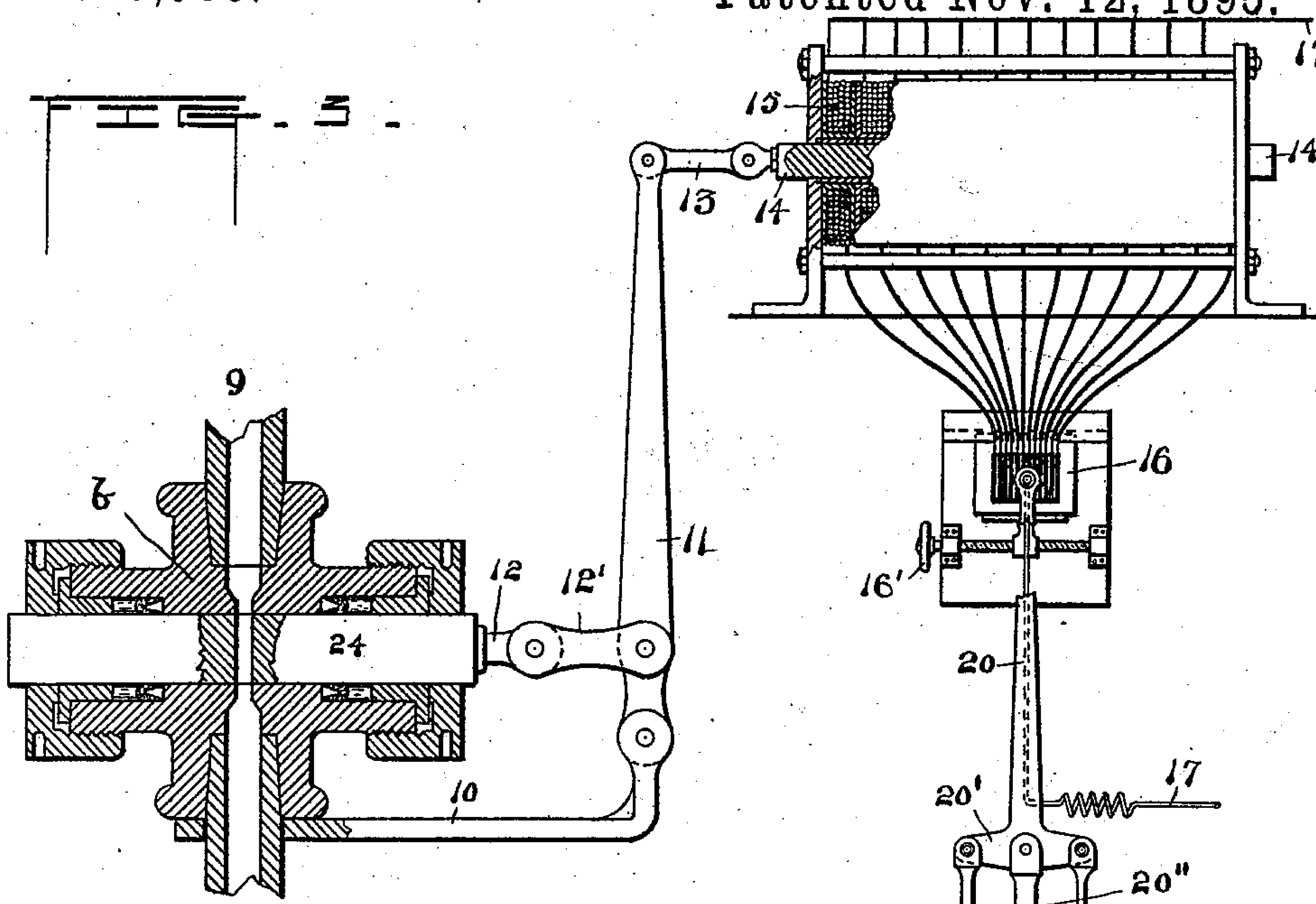
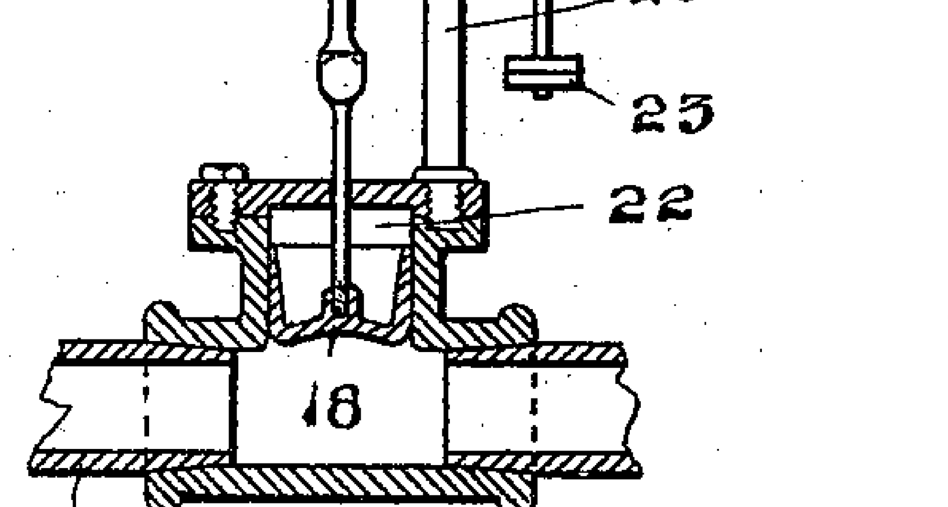




FIG. 4.

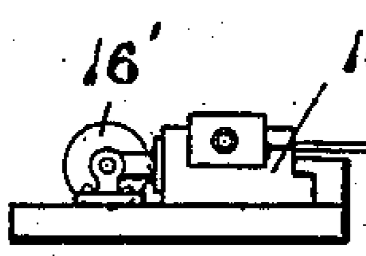



FIG. 5.

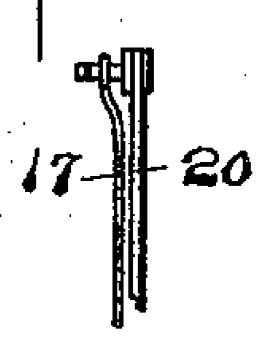
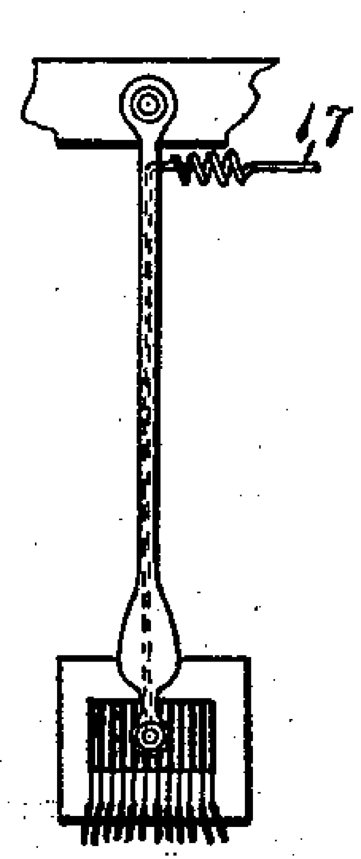



FIG. 6.

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# UNITED STATES PATENT OFFICE.

RICHARD PENNEFATHER ROTHWELL, OF NEW YORK, N. Y.

## APPARATUS FOR SINKING SHAFTS OR DRIVING TUNNELS.

SPECIFICATION forming part of Letters Patent No. 549,586, dated November 12, 1895.

Application filed March 9, 1893. Serial No. 465,313. (No model.)

*To all whom it may concern:*

Be it known that I, RICHARD PENNEFATHER ROTHWELL, a resident of New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Apparatus for Sinking Shafts and Driving Tunnels; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it pertains to make and use the same.

The invention relates to means for sinking shafts and driving tunnels; and it has for its objects to automatically guide a movable caisson or shield; to pack the joint or joints between a shield and a shaft or tunnel lining; to stop or pack the space between the shaft or tunnel wall and the lining, and to provide for the continuous removal of excavated material without interference with the introduction of the lining-segments and the continuous building of said lining; and it consists in the construction hereinafter described and particularly pointed out.

In the accompanying drawings, Figure 1 is a central longitudinal section of a portion of a lined shaft and of a movable caisson or shield, jacks for pushing the shield being shown in full lines. Fig. 2 is a similar view of a tunnel, both figures embracing a diagram of valve-controlling devices. Fig. 3 is an enlarged view, partly in section, of a valve and valve-controlling devices. Figs. 4 and 5 are side elevations of details. Fig. 6 is a partial elevation of a modification. Figs. 7 and 8 are sectional views of modified packings.

Numeral 1 indicates the rock or native wall of a shaft, and 2 a lining for the same, built of segments bolted together in manner too well known to need further description.

3 denotes a shield or caisson having double walls 4 and 5, and 6 denotes hydraulic jacks adapted to force the shield forward into and through the material to be excavated. These jacks are situated between a seat 3′, made fast to the shield, and the front of the lining. The two walls 4 and 5, which are separated sufficiently to permit workmen to enter between them to bolt together the lining-segments, are joined by a curved wall 5′, having a contour, substantially as illustrated, to present as little obstruction to the movement of the shield as practicable. Any suitable apparatus for forcing the shield forward may be employed.

7 indicates pipes adapted to throw jets of water toward the axis of the shaft or tunnel within the front part of the shield, for the purpose of aiding in the disintegration and removal of the material.

In sinking shafts through soft ground by the method described in my patent dated May 30, 1890, and numbered 428,021, and also in the operation of making tunnels it is very important that the shield or caisson such as herein illustrated be pushed forward evenly all around. When the admission of power to the jacks which push the shield is regulated directly by the workmen, this is difficult of attainment, some of the jacks being pushed out faster than others. This deflects the direction of the shield movement, causing undue strains in its back end and in the shaft or tunnel lining and binding the shield, rendering it very difficult to put in the lining-segments and causing delays and dangers to the work. To overcome these difficulties I regulate the admission of power to the jacks automatically, so that if one side of the shield advances a small distance ahead of the other the admission of power to the jacks on that side will be automatically throttled or altogether cut off until the other side has caught up, when the power will again be automatically admitted and the shield will go forward at practically the same rate all around. This automatic regulation I can apply equally well to the case of a tunnel-shield pushed forward horizontally or at any angle of inclination. I accomplish this very desirable object by utilizing the force of gravity in any convenient manner, as by the devices next to be described. Such devices are in dicated at A in Fig. 1 and at B in Fig. 2, and are shown on a larger scale in Fig. 3.

In Fig. 1, *a* denotes the main pipe for a fluid under pressure, and *a′* its valve. *c* denotes a transverse or annular pipe communicating with the inlet-pipe *a* and with several branches, one of which is indicated at *d*, its valve being denoted by *e*. Each branch *d* communicates with a short transverse pipe *f*, which latter communicates with a group of preferably from four to six or more pipes

9, each having a valve $b$. The automatic regulation herein described is applicable either to the valves in individual pipes 9 or to valves $e$ in pipes $d$ mediately controlling admission of fluid to the groups of pipes supplied from transverse pipes $f$. In practice the various pipes may also be supplied with valves adapted to be manipulated by hand.

Referring to Fig. 3, $b$ denotes a valve casing situated in a conduit 9, through which a medium of power, such as water or other fluid, is conveyed under pressure to the jacks. 10 is a bracket, and 11 a lever pivotally supported thereon and also pivotally connected, as by a link 12′, with a valve-stem 12. To the upper end of the lever 11 is connected by a link 13 an armature 14, which is extended axially through a series of coils 15 of insulated conducting-wire. Each coil is connected by a conducting-wire with a switch-table 16 in a well-known manner. 17 denotes an electric cable leading to and from a battery (not shown) constituting, together with the switch-bar 20 and a coil 15, an insulated circuit. As shown in the present instance, this bar is moved to the right or left for the purpose of varying the coil included in the circuit by the effect of variations of the level of the mercury in a receptacle 21 by the medium of a diaphragm or float 18, resting on the surface of the mercury in said receptacle, the float being transversely movable in a branch or chamber 22 of said receptacle. In the present instance this is represented as a branch of a three-way coupling. (See Fig. 3.) The float is pivotally connected with an arm 20′ of the switch-bar suitably pivoted in a post 20″ and said float is counterbalanced by a weight 23. The construction and arrangement are such that a variation in the level of the mercury moves the bar 20 over the switch board 16 to include within the electric circuit any one of thewires leading from the switch board to the coils, and thereby including the corresponding coil. By this means the armature 14 is moved to the right or left, according to the situation of the coils by which it is magnetized. The switchboard can be moved to the right or left to vary the effective range of the switch-bar by means of the screw having a handle 16′, as indicated. The mercury-receptacle is attached to or connected with the shield, so that any deflection of the latter from a right line will alter the mercurial level and suitably regulate the admission of power to one or more of the jacks by the action of the devices just described upon the valve 24 through the medium of lever 11 and links 12′ and 13. The particular devices for automatically controlling the amount of power exerted at different points are not the gist of the invention which include all devices operated in substantially like manner or by gravity to vary the amount of power applied by changes in the direction of the shield-movement. Thus it is obvious that the particular form of valve or of mercury-receptacle or of connecting devices is immaterial. In some cases I propose to use an insulated pendulum as a part of the electric circuit, such pendulum being suspended in contact with a switchboard and adapted to vary the magnetizing-coil in the circuit by its automatic movements across the face of the board, as indicated in Fig. 6. Where shafts are to be sunk or tunnels driven through wet ground by means of a movable shield, it is very important that the water be effectually prevented from entering between the shield and the shaft-lining. Various means have been proposed to effect this but owing to the fact that the shield is made of plates riveted together and never forms an absolutely true circle and that the shaft-lining, made of iron or steel castings, also never makes a true circle it is difficult to secure an effective packing between the shield and shaft-lining. To overcome this difficulty I adopt for that portion of the shield containing the lining-rings a true bored-out cylinder, whether of cast-iron, cast-steel, or other material, and I make the lining-rings true by casting facing-strips on them, so that when the ring is bolted up these strips can be turned off to a true circle, which will leave but the very little necessary clearance between them and the inside bored surface of the shield. The clearance thus being very small and uniform, it is easy to pack it successfully and cheaply by cellulose, or a soft wood or other suitable material that will rest on the facing-strips and by expanding when wet will make efficient tight packing between the shield and lining.

In the drawings, Fig. 1, 26 denotes a strip fixed on a lining-section, and 27 a movable packing. Said strips are narrow and require much less labor in making them perfectly true than would be required for an entire section forming part of a ring of uniform external diameter and as wide as a section. They also furnish convenient supports for the packing. It is immaterial whether the strips be on the exterior of the lining or on the interior of the shield, provided the opposing surface be correspondingly true. Where the projecting strips are on the inside of the shield, I sometimes use a flap or packing made of pieces 28 of metal or other strong material, covered with leather, rubber, or other suitable material resting on the projections 26 on the inside of the shield. These pieces of metal, leaning against the shaft or tunnel lining, form the support for the flexible covering, which, being pressed tightly against the shaft-lining by the pressure of the water or material from above, makes a tight joint or packing between the shield and the shaft or tunnel lining. The pieces of metal simply rest in a groove 29 on the fitting-strip, being held there by the leather or other covering which is riveted to them and to the shield. These pieces of metal are usually curved steel segments and are covered with rubber, leather, canvas, or other suitable material constituting a flap surrounding the shaft or tunnel lining and closing the space between it and the shield. I may also use a flap of similar construction to make a stopping between the outside of the shaft-lining and the rock above the shield, so as to prevent sand and clay from descending in this space and interfering with the injection of cement through holes in the shaft-lining above the shield and to prevent the cement from passing down between the shield and the rock, thus cementing in the shield. This use is only temporary, to allow the injection, through suitable holes in the lining, into the space between the shaft-lining and the rock above the shield of hydraulic cement or sand and some solidifying solution or other suitable material, which material, filling the crevices in the rock and the space between the rock and the lining, makes a tight joint and prevents the passage of water down around the lining of the shaft and its entrance into the shaft below the lining and shield. The flap is inserted in a recess in the lining-segments of the shaft, and when these have passed up out of the shield said flap opens and is pressed out against the rock, preventing the passage of sand or other material.

In driving tunnels through soft ground by means of a movable shield or caisson pushed forward from the tunnel-lining it is customary to make the front of the shield with doors, which are left open when the shield is in firm, dry ground, and workmen go out in front of it and dig the ground, throwing it back through these doors, when it is again handled and thrown into the cars, which convey it out of the tunnel. When the shield is in soft ground, some of the doors are closed and the soft ground is allowed to come back through those which are left open, the material being squeezed back by the forcing forward of the shield. The material falls down onto the bottom of the shield and on the segmental lining of the tunnel, and from there is loaded into the cars, as before. While this handling of the material is going on, the lining-segments cannot be put in, but the act of lining and the movement of the shield and handling of material alternate. The clay, mud, and water coming into the shield where the lining-segments are put together renders that operation slow, difficult, and expensive, and the digging and handling of all the material by hand is also slow and expensive.

By the adoption of the following devices which I have invented the speed of driving tunnels through soft ground can be very greatly increased and their cost diminished. I use a double or annular shield, as shown in the accompanying drawings. In the annular space I place extremely-powerful jacks or other motors, and I design the shape of the shield so as to offer the least possible resistance to piercing the clay, gravel, or other soft material to be traversed. I place in the front of the shield jets of water worked under great pressure to cut radially and loosen the mass of material compressed in front of the shield and allow it more easily to be forced back through the center tube. I use a center tube about ten feet less in diameter than the main shield, so as to leave sufficient space between them for handling and bolting up of the segments of the tunnel-lining. The center tube has its forward end provided with doors, (indicated at 5″.) These may be of usual construction, and need not be particularly described herein. They may be opened, or closed as occasion requires, as in existing shields; but my object is to do the work of excavating largely by the power of the jacks or other propelling force which will push the shield forward, forcing the soft material back into the car, back of the annular working chamber, without interfering with the work of putting in the segments of the lining, which work goes on continuously in the annular space or working chamber. The segments come in on a track on each side of the center tube and out of the way of the material passing from the shield into the cars, so that not only is the work of excavating thus done by machinery much more expeditiously and economically than by hand, but the work lining is greatly facilitated by being done in of a comparatively clean chamber and by being made continuous. The form of the front of the annular shield is such as to offer the least resistance to its forward movement. When the ground becomes too firm to allow the shield to be pushed through it, or when obstructions are met with, men can dig out in front of the shield and remove the obstruction, or excavate the ground in the usual manner.

In the drawings, 30, Fig. 2, denotes tracks or equivalent devices for bringing in the sections of lining into the working space, and 32 a track for the removal of excavated material.

Having thus described my improvements, what I claim is—

1. In combination a shaft sinking or tunneling shield, power mechanism for advancing the shield and a gravity device to automatically vary the action of said mechanism, substantially as set forth.

2. In combination a shaft sinking or tunneling shield, mechanism for advancing the shield and devices for varying the action of the mechanism adapted to be automatically operated by the departure of the shield from a desired direction consisting of a valve and an electro-magnet and a circuit maker and breaker adapted to be operated by gravity to make or break the magnetizing current, substantially as set forth.

3. In a shaft sinking or tunnel driving apparatus the combination of the shield, the lining, the narrow fixed strips, said strips and the surface opposed to them being made substantially true, and the expansible packing adjacent to the strips, substantially as set forth.

4. In a shaft sinking or tunnel driving apparatus the combination of the strips, the

curved pieces 28 supported thereon, the elastic cover on said pieces and the tunnel lining, substantially as set forth.

5. In a tunnel driving apparatus the shield having double walls joined at their front and curved backwardly and inwardly and connected to a tubular part provided with doors 5″ to close the same at will, a track for moving a car in a plane below said tubular part, a car to remove excavated material, and mechanism for pushing the shield forward whereby the advance of the shield may be made to automatically load the car, substantially as set forth.

6. In a tunnel driving apparatus a shield having double walls joined at their front, the inner wall being inclined inwardly and backwardly and connected to a tubular part, hydraulic jacks or the like situated between said walls and a track for carrying lining segments situated above the bottom of the shield and between its walls, substantially as set forth.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

RICHARD PENNEFATHER ROTHWELL.

Witnesses:
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AUGUSTUS J. CAISON.