(No Model.) 2 Sheets—Sheet 1.

J. H. GREATHEAD.

APPARATUS FOR EXCAVATING TUNNELS, SUBWAYS, AND SHAFTS.

No. 360,959. Patented Apr. 12, 1887.

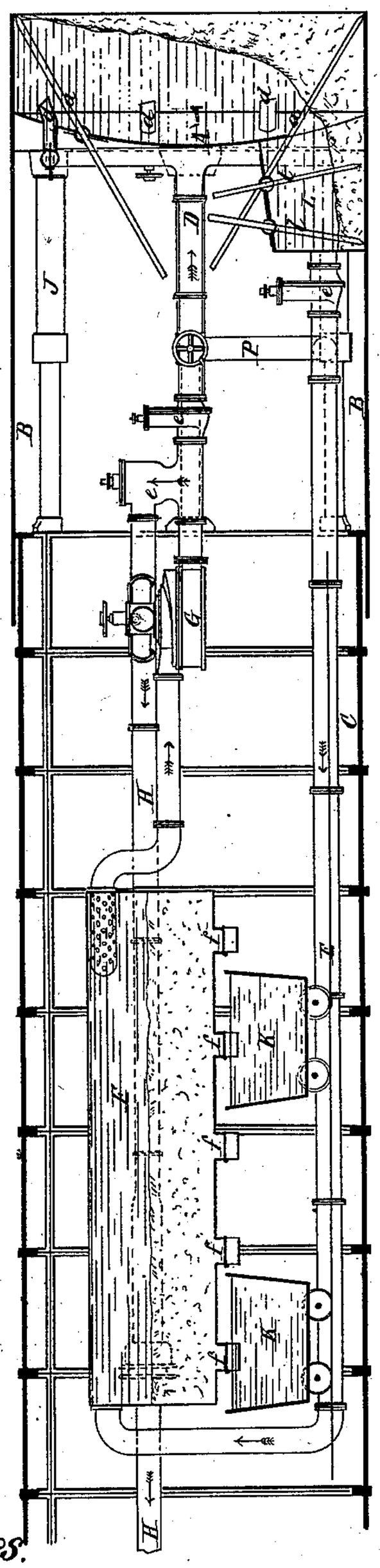

Fig. 1.

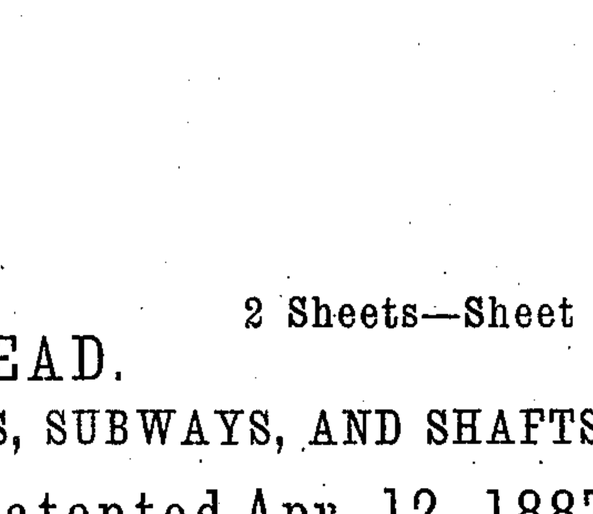

Fig. 2.

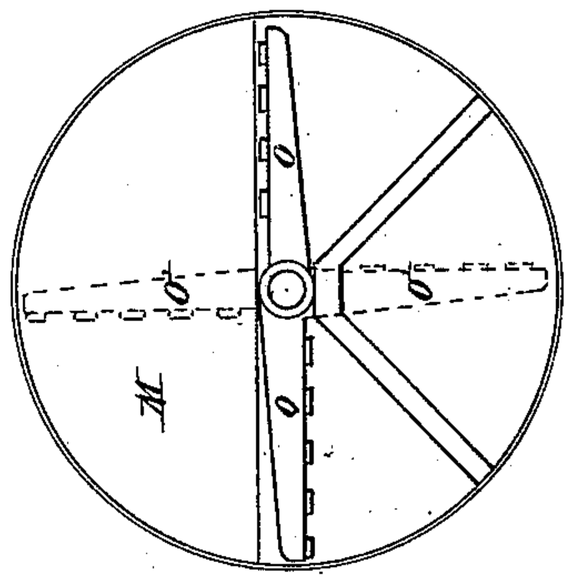

Fig. 3.

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(No Model.) 2 Sheets—Sheet 2.

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APPARATUS FOR EXCAVATING TUNNELS, SUBWAYS, AND SHAFTS.

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Fig. 4.

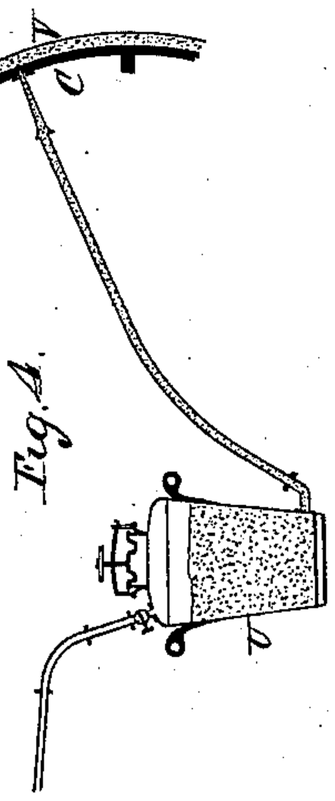
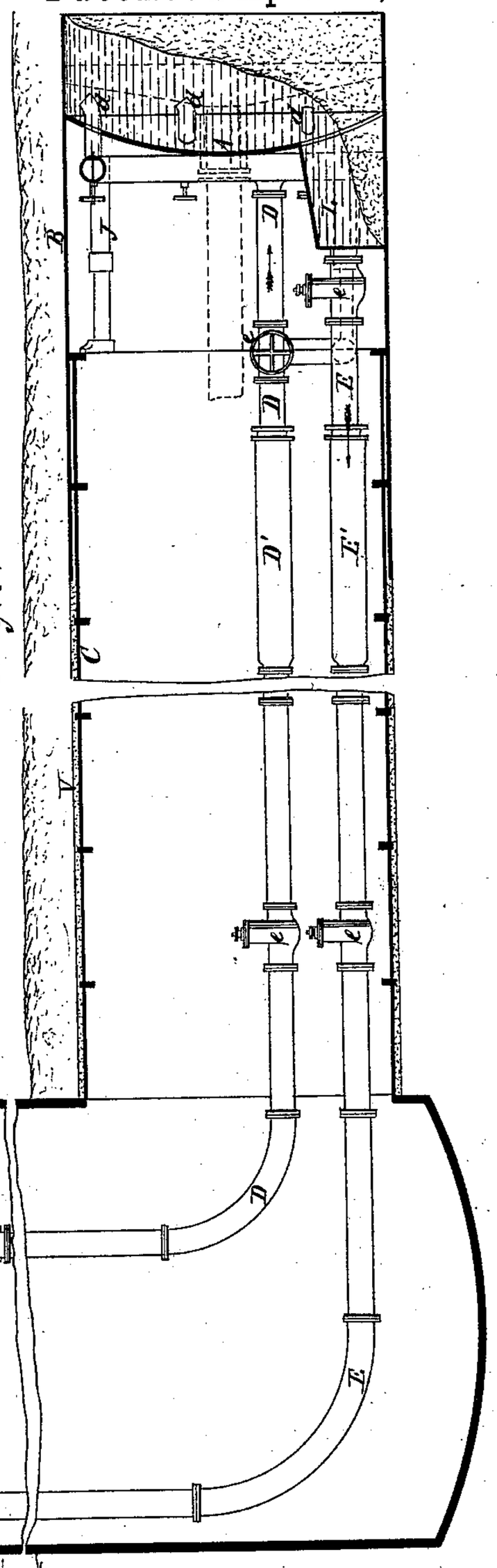


Fig. 1a.



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UNITED STATES PATENT OFFICE.

JAMES H. GREATHEAD, OF WESTMINSTER, COUNTY OF MIDDLESEX, ENGLAND.

APPARATUS FOR EXCAVATING TUNNELS, SUBWAYS, AND SHAFTS.

SPECIFICATION forming part of Letters Patent No. 360,959, dated April 12, 1887.

Application filed August 14, 1886. Serial No. 210,941. (No model.) Patented in England March 29, 1884, No. 5,665.

To all whom it may concern:

Be it known that I, JAMES HENRY GREATHEAD, a citizen of England, residing at Westminster, in the county of Middlesex, England, have invented a new and useful Improvement in Apparatus for Excavating Tunnels, Subways, and Shafts, (for which I have obtained a patent in Great Britain, No. 5,665, dated March 29, 1884,) of which the following is a specification.

My invention relates to apparatus for excavating a tunnel, subway, or shaft which, as the excavation advances, is lined internally, it may be, with metal segments bolted together. For effecting such excavations it has been proposed to apply in front of the completed part of the excavation a shield overlapping like a box-lid the front part of the lining, to displace the material in front of the shield by currents of water directed on it from within the excavation, employing tools for loosening it or a rotating boring-head to cut through rock or hard material, and then to advance the shield by forcing it forward by means of screw-jacks or hydraulic presses abutting against the completed lining, to extend the lining by placing fresh segments within the casing of the shield, and thus to proceed step by step in a horizontal, vertical, or more or less inclined direction, as the case might be. In excavating in this manner through soil more or less porous under a water-way, or through ground in which there is water, the currents directed through the shield, to act on the material in front of it, are opposed by the pressure due to the height of the external water-column, and consequently, in many cases where the excavation is at considerable depth, great power is wasted in giving the currents the necessary force to overcome the external pressure. Again, when water under pressure is present in front of the shield, there are great difficulties in getting access to the boring-tools for the purpose of repairing or replacing them; and when the shield is advanced the part of it which overlaps the completed lining leaves an annular vacuity around the lining which, unless it were filled in, might allow dangerous settlement or disturbance of the lining itself or of the soil through which the excavation is made.

My invention relates to arrangements by which these difficulties can be overcome, as I will explain, referring to the accompanying drawings.

Figure 1 is a longitudinal section of part of a tubular tunnel lined with metal, showing arrangements according to my invention for balancing the external water-pressure and disposing of the débris of excavation. Fig. 1ª is a longitudinal section showing a modification of the arrangements in cases where the débris of excavation can be conveniently disposed of externally. Fig. 2 is a part longitudinal section, and Fig. 3 is an end view, of the arrangement for giving access to repair or replace the tools of a boring-head in front of the shield. Fig. 4 is a section of the apparatus for injecting material to fill the vacuity around the metal lining.

Referring first to Fig. 1, A is the front of the shield, from which extends backward a cylindrical part or lip, B, which, like the lid of a box, overlaps and can slide along the metal lining C. In the front plate, A, are provided several spherical joint stuffing-boxes, through which tools *a* may be passed to loosen the material in front of the shield. In excavating clay or sandy, gravelly, or loamy ground, boulders often occur which have to be broken up. In such cases the shield is made with a backwardly-projecting pocket, L, for reception of a boulder which may be broken up by tools *l*. When the boulders are such as cannot easily be broken up, an air-lock, such as will presently be described with reference to Figs. 2 and 3, may be provided above or behind the pocket L, which in that case would be made with a removable lid or end, so that a boulder could be taken bodily out of the pocket.

D is a pipe supplying water to issue through nozzles *d*, so as to scour out the material in front of the shield, causing a backflow of water and débris along the pipe E. In order to balance the external pressure acting against the outflow from the nozzles *d*, I form a closed circuit of the pipes D and E, including a tank, F, in which the débris is allowed to subside. At any convenient part of the pipe D, I employ a helical or other pump, G, to create a current along the pipe D. The water issuing

by the nozzles *d* against the material in front of the shield detaches débris, which returns along with water by the pipe E, and is delivered into the settling-tank F, from the upper part of which the supply to D is drawn. Thus, whatever be the external water-pressure, the power required for effecting circulation in the closed circuit is only that which is necessary to create the current. A backflow-pipe, H, communicating at its hinder end with the external water, or with a discharge under equivalent pressure, allows the water displaced by the advance of the shield to find its way out without being forced through or disturbing the material through which the shield is advanced. By means of a pipe, P, provided with a valve, D can be put in communication with E, for scouring out the latter. The débris and mud deposited in the tank F is from time to time run out into trucks K, charged with water, through outlets *f*, provided with valves. Each of the outlets *f* has a lip projecting down into the water in the truck, so that on the valve being opened the débris descends from the tank F into the truck K below, while water ascends from the truck to take its place in the tank. While this operation is performed, valves *e* in the pipes D and E are kept closed, so that the tank is not subject to the external pressure.

The arrangement shown in Fig. 1 for removing débris into trucks within the tunnel is more particularly applicable when the excavation has been carried far forward from the shaft.

In order to get the trucks K past or under the spouts *f*, the latter may be so constructed that they can be telescoped sufficiently for the purpose, or a flexible section might be inserted. In some cases, however, it might be preferable to construct the spouts in two sections and hinge the latter together.

When only a comparatively short portion of the tunnel has been formed, and when it is desired to keep space in the interior free, the arrangement shown in Fig 1ª is adopted. In this case the two pipes D and E are carried up the shaft R and put in communicatien with the external water, so that the pressure in front of the shield is still balanced, as when the circuit is closed, as above described. The pipe D has a suction-nozzle, S, immersed in the water, and the pipe E has a discharge-branch, T, which is also immersed either in the water or in a barge or floating-vessel, in which the débris becomes deposited, as shown in Fig. 1ª. When there are tidal or other variations of the water-level, the branch T should be jointed to E in such a manner as to allow of it accommodating itself to the change of level, its mouth remaining immersed in the water, or being lowered to the water-level, so as to maintain the balance of pressure in the circuit.

In order to allow for the advance of the shield from time to time, the pipes D and E are at the parts D′ and E′ made telescopic, so that while the shield A is being pushed forward by the hydraulic or other jacks J, the pipes D and E are telescopically extended, and then, their valves being closed, the telescopic parts can be closed in, and additional lengths can be introduced.

As shown in Figs. 2 and 3, I provide for repairing or replacing the tools of a boring-head, O, when such is used, in the following manner: In front of the shield A, I fix a diaphragm or partition, M, extending down from the upper part nearly to the axis of the tunnel, and I thus form an air-lock which can, when required, be charged with compressed air, expelling the water down to the level of the lower edge of the partition M. By means of an air-lock communicating by a man-hole with the space between A and M a workman can enter this space. The boring-head O, being turned so that its arms lie horizontally, as shown in Fig. 3, is drawn backward and then turned partly round so as to bring one of its arms up into the air-space, as shown in Fig. 2 and by the dotted lines O′ in Fig. 3. The tools on this arm can then be dealt with by the workman, and by turning the head half round those on the other arm can in like manner be dealt with. In a similar way, by providing an air-lock over the pocket L, access can be got to a boulder or other obstruction that may become lodged there.

The letter N in Fig. 2 represents a pipe by which air may be supplied to the air-lock between A and M.

It will be seen that when the shield is advanced the backwardly-extending lip B leaves behind it an annular vacuity, V, around the lining C. In order to fill this vacuity, I provide through several of the segments of the lining C holes fitted with plugs, which can be removed, when required, to permit of connecting, by a screw-union or otherwise, of a pipe from a vessel, U. (Shown in Fig. 4.) This vessel is charged with liquid cement and closed air-tight. Compressed air is then forced into it, and this causes the cement to flow from the vessel U into the vacuity V, where it sets, thus making a solid filling to the vacuity and covering the lining C with a protecting coat. Instead of using compressed air for discharging the cement from the vessel U, water under pressure may be employed, and in this case it is preferred to use a floating piston to keep the water separate from the cement.

Although I have shown in the drawings arrangements suitable for excavating a horizontal tunnel or subway, obviously those shown in Fig. 1 would be suitable for a tunnel or subway somewhat inclined, and those shown in Fig. 1ª would be suitable for a vertical shaft or for a tunnel or working at a considerable inclination.

Having thus described the nature of my invention and the best way I know of carrying the same into practical effect, I claim—

1. In apparatus for excavating tunnels or subways, in combination with a shield capa-

ble of being pushed forward as the excavation advances and provided with nozzles by which water-currents are directed on the material to be excavated, a pump, pipes, and their connections arranged so as to form with the external water a closed circuit, substantially as and for the purpose herein set forth.

2. In apparatus for excavating tunnels, subways, or shafts, in combination with a shield capable of being pushed forward as the excavation advances, and provided with nozzles by which water-currents are directed on the material to be excavated, a pump and pipes extending backward, and a settling-tank having outlets which are controlled by valves and dip into water contained in trucks for reception of the settled débris.

3. In combination with the shield employed in conjunction with a boring-head in excavating a tunnel, subway, or shaft, a diaphragm or partition, M, and a partition, A, forming an air-lock for giving access to the tools of the boring-head, substantially as described.

4. The combination, with a shield capable of being pushed forward and a lining for a tunnel which follows the advance of said shield, of an air-tight vessel containing liquid cement, a pipe extending from the bottom of said vessel through the lining of the tunnel, and a pipe entering said vessel from the top and connected with a reservoir of compressed air or fluid under pressure, whereby the cement may be forced into the annular space around the lining, substantially as described.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 8th day of July, A. D. 1886.

J. H. GREATHEAD.

Witnesses:

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