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W. BUTLER.
TUNNEL.
APPLICATION FILED MAY 7, 1909.

Patented May 17, 1910.

2 SHEETS—SHEET 1.

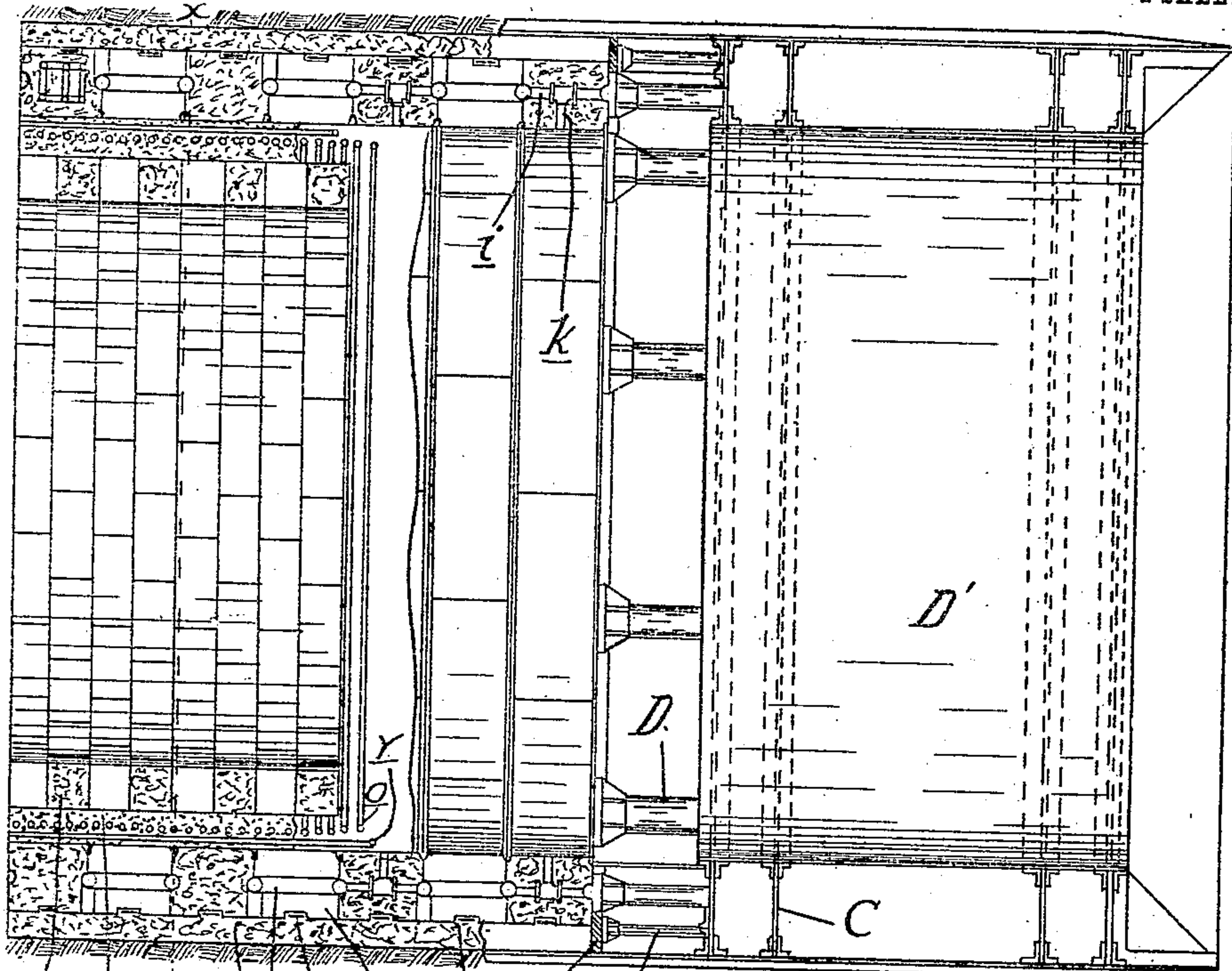


Fig. 1.

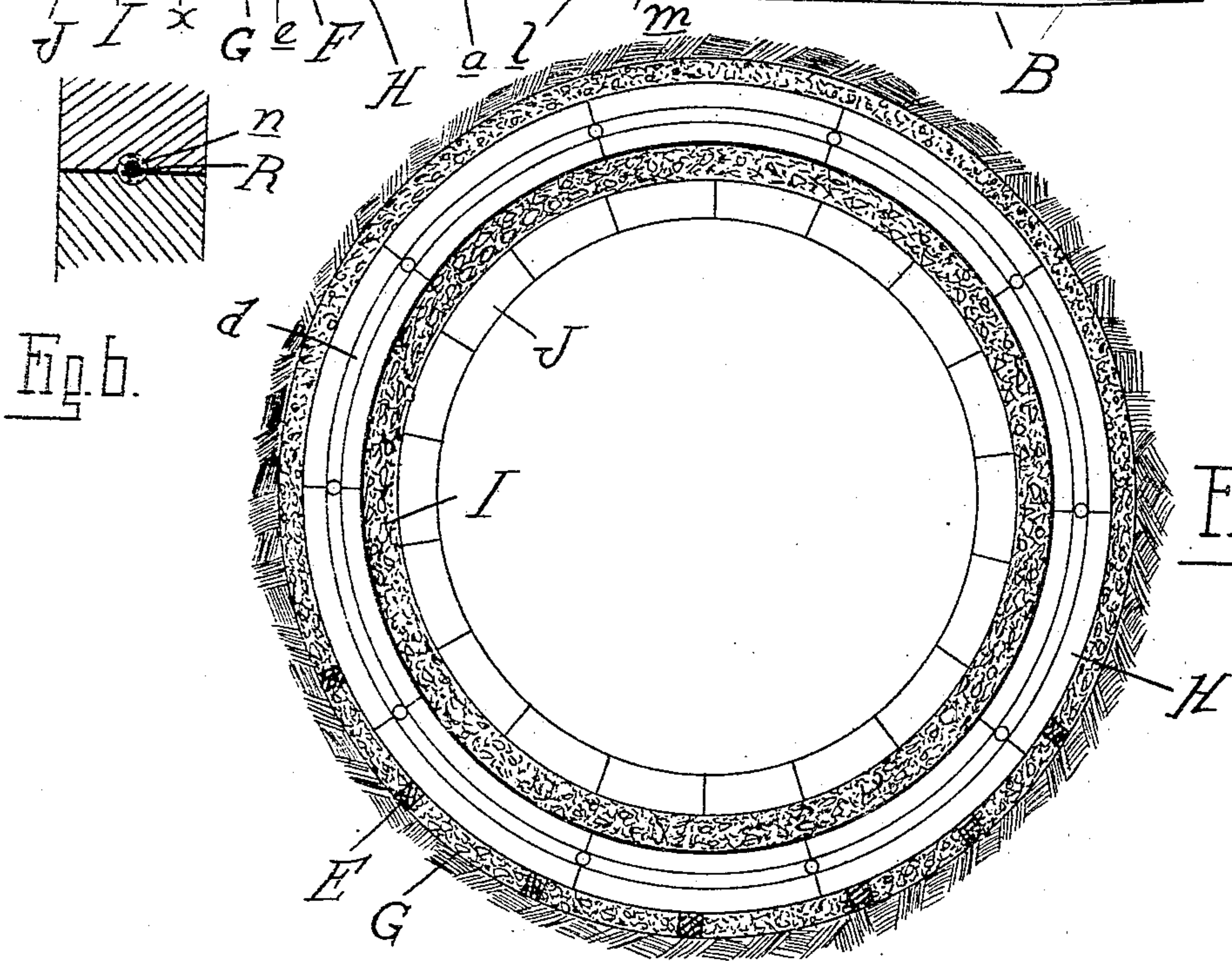


Fig. 2.

Fig. 2.

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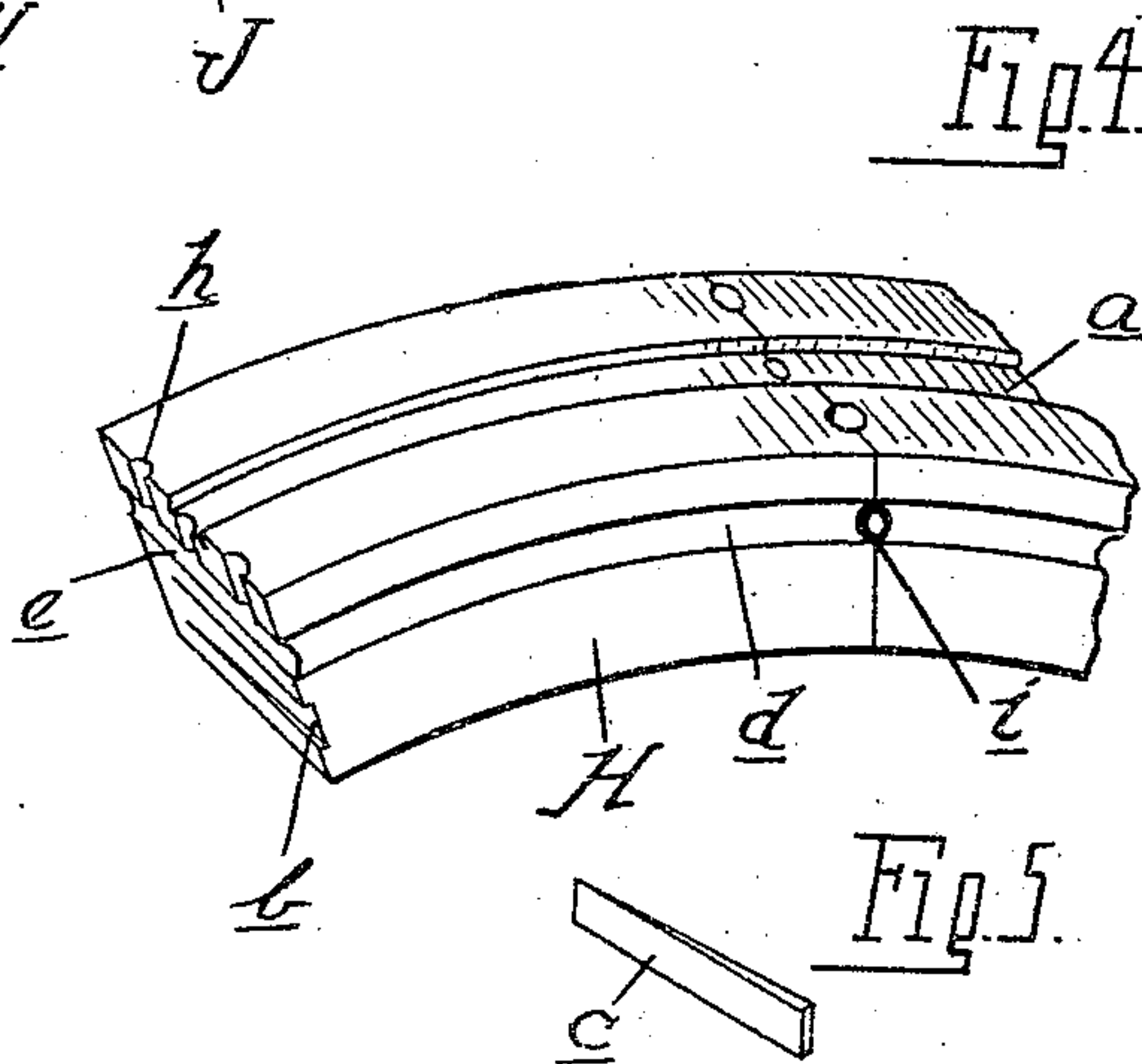
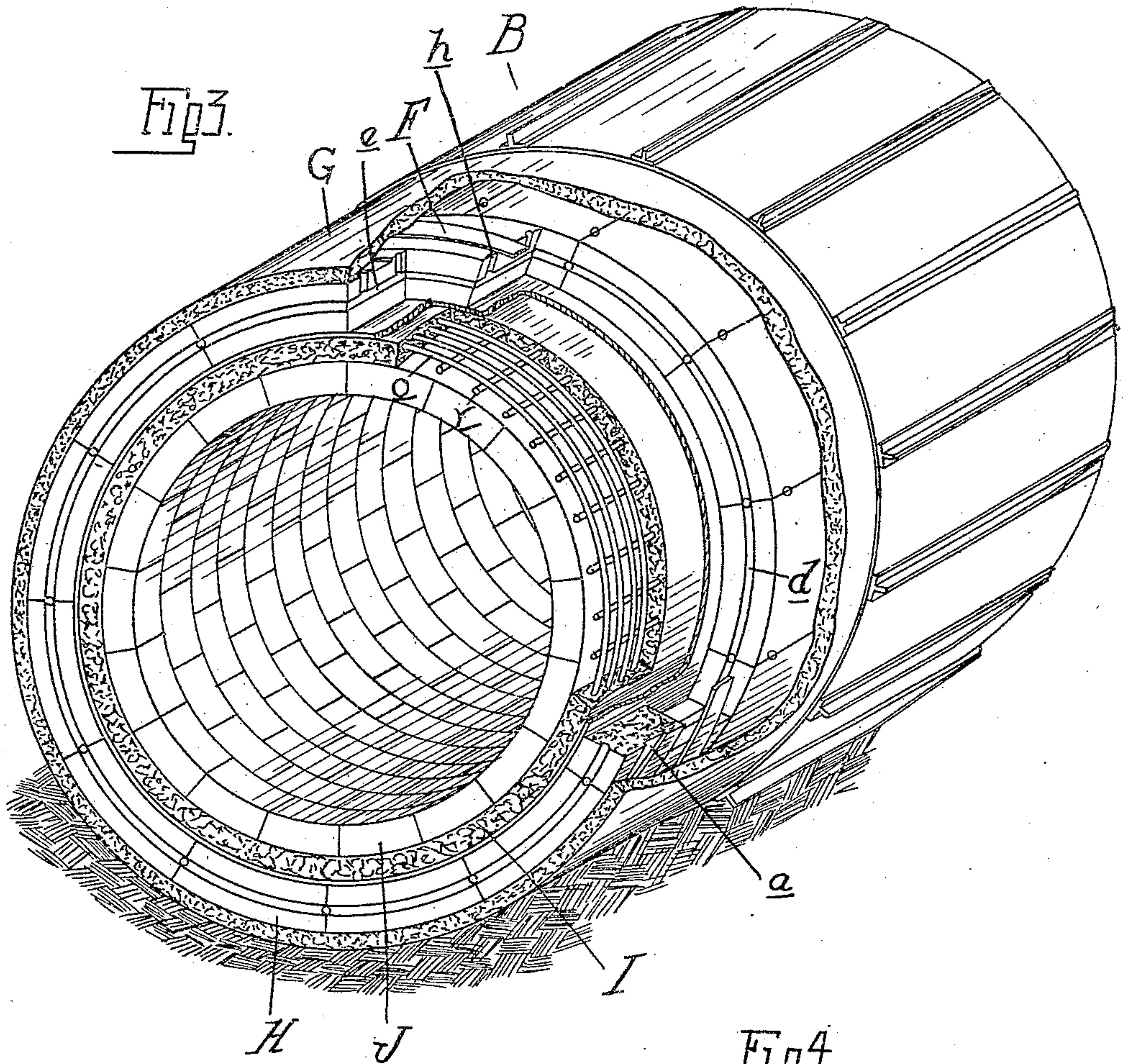
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UNITED STATES PATENT OFFICE.

WALTER BUTLER, OF ST. PAUL, MINNESOTA.

TUNNEL.

958,592.

Specification of Letters Patent.

Patented May 17, 1910.

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To all whom it may concern:

Be it known that I, WALTER BUTLER, a citizen of the United States of America, residing at St. Paul, in the county of Ramsey and State of Minnesota, have invented certain new and useful Improvements in Tunnels, of which the following is a specification, reference being had therein to the accompanying drawings.

10 This invention consists in the method of building a tunnel by pushing a shield forward and building within the shield a permanent lining against which the hydraulic jacks for forcing the shield may be buttressed; this lining being built up of ring sections of blocks without the necessity of false work or timbering.

15 My invention consists further in applying to the outer face of this lining applied from the inside, a layer of grouting or cement, and also in cementing the joint between the blocks of this lining after they are laid in position; and in the manner of supporting the blocks of a section until the entire ring is completed, without the necessity of using timbering or false work.

20 My invention consists further in the construction and the mode of operation; all as more fully hereinafter described and particularly pointed out in the claims.

25 In the drawings: Figure 1 is a vertical central longitudinal section through a tunnel embodying my invention, showing the shield in position; Fig. 2 is a vertical section on line $x-x$ of Fig. 1; Fig. 3 is a sectional perspective of the end of the tunnel, more or less broken away to illustrate more clearly the construction; Fig. 4 is a perspective view of two of the blocks of the lining; 35 Fig. 5 is a perspective view of the wedge used for expanding the ring of blocks laid; and Fig. 6 is a section through a portion of two of the blocks, showing the passages n with the reinforcing hoop therein.

40 B represents the shield, which is a cylindrical shell centrally reinforced, and having a forward cutting edge, so that it may be pushed forward through the soil by hydraulic jacks, in the well-known manner. The shield is provided with any suitable abutments, such as ribs C, against which the hydraulic jacks D can abut, for forcing the shield forward, there being an inner lining D' within the shield. As the work progresses and the shield is moved forward, 45 pushed by the jacks in the usual manner, the

lining is built within the tail of the shield, or just beyond the end thereof. In the construction here shown, I add the lining sections within the tail of the shield, and in putting in the lining proceed as follows: I first place around the tail of the shield on the lower portion thereof a series of spacing-blocks E, shown in Fig. 2, and on these spacing blocks I place a hoop of band iron, 50 F. The hoop will be spaced from the shield shell a distance equal to the thickness of the blocks E, which space I have lettered G. I then lay on this hoop segmental blocks H of cement or concrete, or similar material. These blocks are preferably provided with a groove a on their outer faces, adapted to engage the hoop. I first lay the lower half of a ring or circle of these blocks upon the hoop F, filling the space G with grouting, or 55 plastic cement. This may be put in behind and below the blocks in any desired manner. When I reach a point above the middle line, where the blocks H would not be retained by gravity, I lay the blocks of the upper half 60 of the ring, one at a time, and hold each temporarily in place by a jack, such as D, bearing against the outer edge of the block and pressing against the abutment in the shield; the blocks being pressed against the last laid row of blocks and thus held in position. The key-block is provided with a 65 tapering groove b (Fig. 4) adapted to receive a wedge c which is then driven in and tightly clamps the ring of blocks in position, all within the hoop and all spaced from the inner face of the tail of the shield, by the space G. For the purpose of distributing the cement and causing it to fill the space G as well as spaces between each block and 70 the meeting faces of adjoining blocks, I provide each block with passages which will permit this to be done. The construction I have shown for this comprises grooves d on each side face of the block, extending the full length thereof, and grooves e , at each end of the block, in the same line as the grooves d ; and also a groove h , leading from the groove e to the outer face of the block. Preferably, in one or more of these blocks, 75 in the process of manufacture, I cast in a pipe i which extends transversely of the block and communicates with the grooves d at the opposite sides thereof; and I provide at its middle a supply-pipe k , leading to the inner face of the block, preferably at or near the middle. It is obvious that the forward

end of the space *G* is open, and I close this in any suitable manner, before any grout or cement is placed, preferably by means of segmental strips *l* held in place by small jacks *m*, abutting at their outer ends against the abutments *C* of the shield. I also plug the outer end of the passage made by the complementary grooves *e* in the forward faces of the blocks. With these passages and spaces closed, all egress except to the space *G* is closed; and I attach to the pipe *k* a suitable pump for forcing the liquid cement or concrete, or grouting, which will pass into the annular passageway formed by the complementary grooves *d* in the newly laid ring of blocks and that last previously laid, which passageway I have marked *n* (Fig. 6). In passing around this passageway, the liquid cement will find exit into the space *G* through the grooves *h*. This operation is continued until the space *G* is completely filled with cement, and also all of the passages *n* and those formed by the grooves *e* and *h*. When this cement thus flows in as described, sets and hardens, it will form a solid structure comprising the blocks laid and the cement in the space *G*. It will be observed also that the metallic hoop will form a reinforcement, entirely embedded within the cement and protected from corrosion. The lining thus described may be the complete lining for the tunnel, in some cases, or it may, as in the construction here shown, be the outer layer only of the lining. If it is not necessary to make a water-tight tunnel, the outer covering of cement in the space *G* may be omitted, and the passages in the blocks may be omitted; in which case the blocks would simply be laid, in the manner described, until the key-block was secured in position, and then the next row or ring be laid. Such a mode might be useful, for instance, for sewer construction.

Where other lining is required or desired for the tunnel, I may proceed as follows: I preferably place on the inner face of the blocks laid as described a layer of cement or concrete *I*, which may be applied by any of the known and usual methods of applying such cement. I prefer to reinforce this concrete filling or layer, and this may be done in any desired manner. I have shown such reinforcement as comprising circumferential rods *o* and longitudinal rods *r*. Thus it will be seen that the blocks, preferably of cement, laid as described, are embedded between layers of cement, so as to make a practically solid structure from the shell inward to the inner face of this filling or cement layer last described. Within the lining thus described, any desired finishing lining may be applied. This may be of brick or cement blocks,—and I have shown cement blocks *J* therefor, which may be

manufactured and put in place in the usual manner. The shield is then moved forward by means of the jacks in the usual way, and the operation described is repeated. A tunnel produced by the method described is simpler to build and cheaper in cost, as each layer or ring of blocks put in place forms the abutment against which one end of the jacks may be engaged, the other end being placed against a shoulder on the shield to move the shield forward; and the permanent masonry lining performs all the duties of the false work or timbering usually employed.

The method of placing segmental blocks in their permanent position can be accomplished by any of the well-known mechanical appliances in use for work of similar kind. Immediately upon the proper placement of each block the hydraulic jacks used for advancing the shield can be placed against it with sufficient pressure to hold it in position until the entire ring is completed and keyed, which keying makes each ring, by the aid of exterior reinforcement band or hoop, self-supporting; thus dispensing with any centering or false work usually used in the construction and placing of tunnel lining, clearly establishing the economy of this method of tunnel construction.

The blocks which I employ to space the hoop *F* from the shell may be blocks of cement, if desired, so that there will be no lack of homogeneity in the material outside of the blocks.

In Fig. 6 I have shown a metal hoop *R*, placed in the passage *n*. This should be placed before the new ring of blocks is laid, and when the cement is forced into that passage and hardens, acts as a reinforcement.

It will be obvious that the successive rings of blocks actually contact each other (although a thin layer of cement may be placed between as they are laid) and thus the jacks for forcing the shield can be placed directly against the masonry rings as soon as laid, without damage to the lining—as would be the case if ordinary masonry were laid for the lining.

What I claim as my invention is:—

1. The method of lining a tunnel in which the bore is made by driving forward a shield, consisting in laying a ring of cement blocks conforming to the shape of the tunnel and forming the permanent lining of the tunnel, holding the upper blocks of the ring by clamping them between the shield and the end of the tunnel lining until the key-block is placed.

2. The method of lining a tunnel in which the bore is made by driving forward a shield, consisting in laying a ring of blocks conforming to the shape of the tunnel and forming the permanent lining of the tunnel, holding the upper blocks of the ring by

jacks pressing against the shield and forcing the blocks against the already-laid lining until the key-block is placed, and then in applying cement in the joints of the blocks from inside the tunnel.

3. The process of lining a tunnel in which the bore is made by driving forward a shield, consisting in forming a lining of blocks within the tail of the shield, spaced therefrom, and filling said space with plastic cement from within the shield.

4. The process of lining a tunnel in which the bore is made by driving forward a shield, consisting in forming a layer of blocks within the tail of the shield, spaced therefrom and with passages between the blocks leading into the outside space, and filling said space and passages with plastic cement from within the shield.

5. The process of lining a tunnel, consisting in laying rings of blocks within the tunnel bore, provided with passages for liquid cement, and then forcing liquid cement into the passages to solidify the ring.

6. The process of lining a tunnel, consisting in laying rings of blocks within the tunnel bore, but spaced therefrom, and then forcing liquid cement from inside the tunnel into the space outside the blocks, to render the same solid.

7. The process of lining a tunnel in which the bore is formed by forcing forward a shield, consisting in laying rings of blocks having passages therein within the bore, spaced therefrom, and then forcing liquid cement into the passages and the space outside to fill the same to thereby render the whole a monolith.

8. The process of lining a tunnel, which consists in laying a ring of blocks within the bore by first laying the lower half of the ring and then in laying the upper half and holding the blocks in the upper half in position by the pressure of jacks at the sides thereof, until the key-block is in position.

9. The process of lining a tunnel in which the bore is made by driving forward a shield, consisting in laying rings of blocks having passages in their meeting faces, within the bore but spaced therefrom, closing up the end of the space between the shield and blocks and the outwardly opening passages, then forcing liquid cement through the passages to fill the space between the shield and blocks and the passages, and allowing the same to harden into a monolithic structure.

10. The method of lining a tunnel in which the bore is made by driving forward a shield, consisting in placing a hoop within the tail of the shield, spaced therefrom, and next laying a ring of blocks in the hoop conforming to the shape of the tunnel.

11. The method of forming a tunnel in which the bore is made by driving forward

a shield, consisting in placing a hoop within the tail of the shield, spaced therefrom, laying a ring of blocks in the hoop conforming to the shape of the tunnel, and rendering the whole solid by grouting or cement in the space outside the ring.

12. The process of lining a tunnel in which the bore is made by forcing forward a shield, consisting in supporting a hoop concentrically within the shield and spaced from the walls thereof, laying a ring of concrete blocks within the hoop, and filling the space between the shield and blocks with plastic cement, and allowing the same to harden.

13. The process of lining a tunnel in which the bore is made by driving forward a shield, consisting in supporting a hoop in the tail of the shield, laying a ring of blocks therein, conforming to the shape of the tunnel, and then expanding the ring of blocks against the hoop.

14. The process of making a tunnel tube, consisting in laying a hoop of lesser diameter, within the bore, laying a ring of blocks within the hoop, and cementing the ring sections together and to the adjoining ring section.

15. A tunnel comprising a series of rings of blocks, and a hoop for each ring of blocks, in which the blocks are locked.

16. A tunnel comprising a series of rings of blocks, a hoop for each ring of blocks, and means for expanding the rings of blocks in the hoop.

17. A tunnel comprising a series of rings of blocks, and cement inside and outside the blocks, binding the rings together.

18. A tunnel comprising a series of rings of blocks, a hoop embracing each ring of blocks, and cement outside the blocks and hoop.

19. The combination in a tunnel of spacing blocks or ribs, a layer of concrete blocks on said blocks or ribs, said concrete blocks having grooves in their meeting edges and passages leading to the outside face of the blocks, and cement applied to fill said passages and the space outside the blocks.

20. A tunnel comprising a tube of blocks, laid free from the shield or bore, and concrete applied outside the blocks and between the same.

21. A tunnel comprising the tube of blocks free from the bore or shield and concrete applied outside the blocks and between the same, and a layer of reinforced concrete within this tube.

22. A tunnel comprising a tube of blocks spaced from the bore or shield, concrete outside and between the blocks, a layer of concrete within this layer of blocks, and annular and longitudinal metallic reinforcing rods in said layer.

23. A tunnel comprising a built-up mono-

lithic tube, comprising rows of concrete blocks spaced from the shield or bore, ring-shaped metallic bands with which the blocks of each row are engaged, the blocks having
5 distributing channels in the meeting faces, and a filling of cement outside the blocks and in the passages between the blocks.

24. A tunnel comprising a series of rings of blocks, having circumferential passages

in their meeting faces, reinforcing hoops in said passages, and cement filling the passages.

In testimony whereof I affix my signature in presence of two witnesses.

WALTER BUTLER.

Witnesses:

FRED SOMMERS,
G. LENZER.