(No Model.) 5 Sheets—Sheet 1

H. S. CRAVEN.

TUNNELING MACHINE.

No. 307,379. Patented Oct. 28, 1884.

Fig. 1.

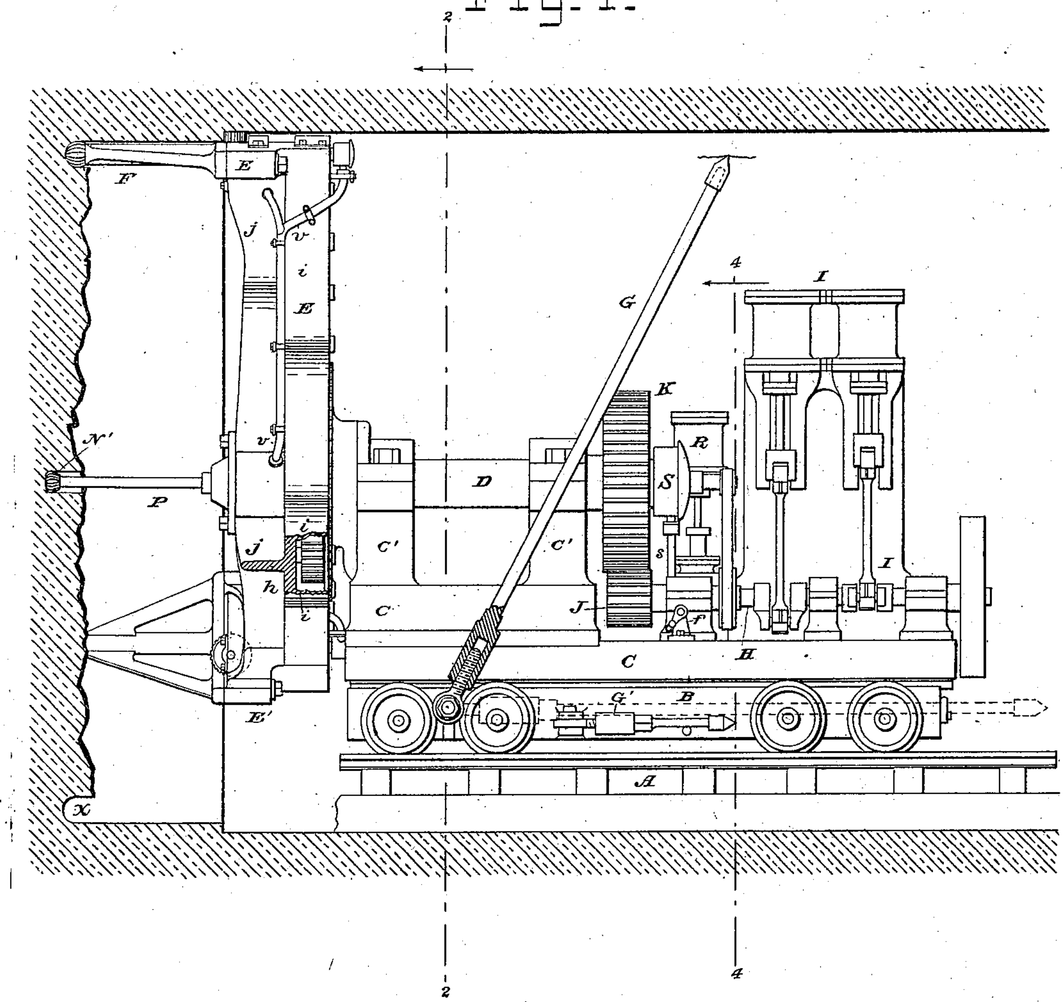
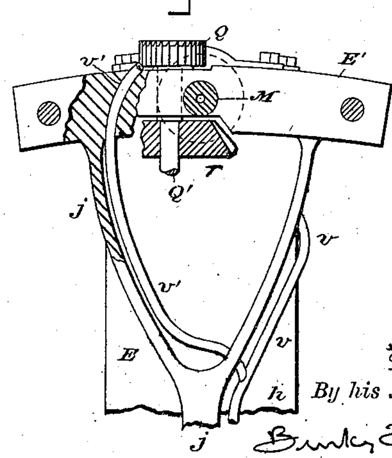


Fig. 8.



WITNESSES:

E. B. Bolton

C. K. Fraser.

INVENTOR:

Henry S. Craven

By his Attorneys,

Burke, Fraser & Connett

(No Model.)

5 Sheets—Sheet 2.

H. S. CRAVEN.

TUNNELING MACHINE.

No. 307,379. Patented Oct. 28, 1884.

Fig. 2.

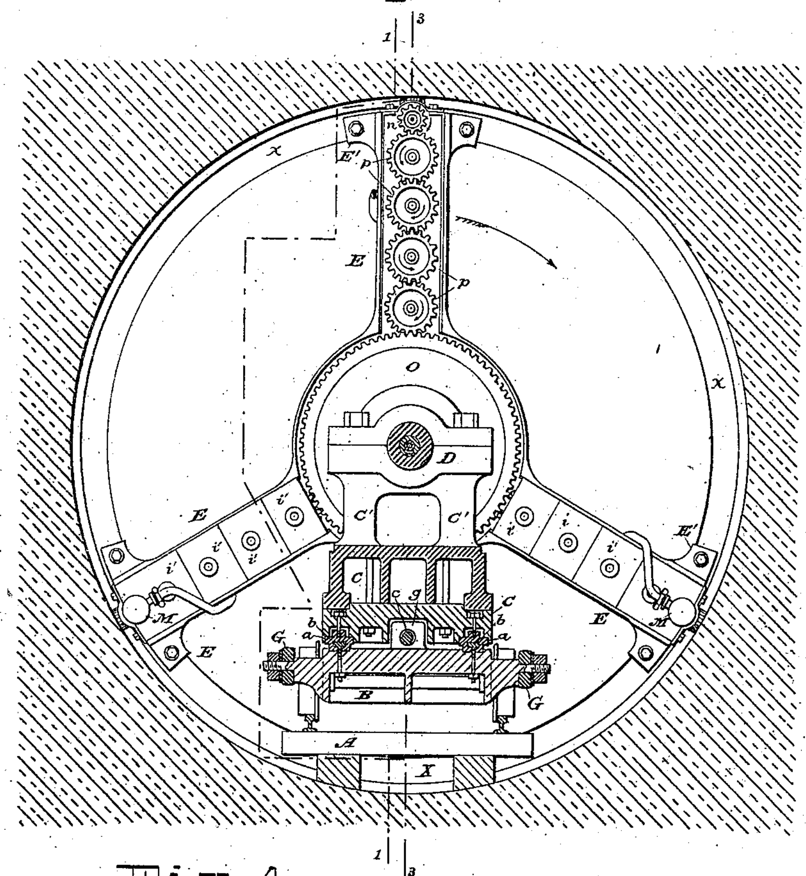
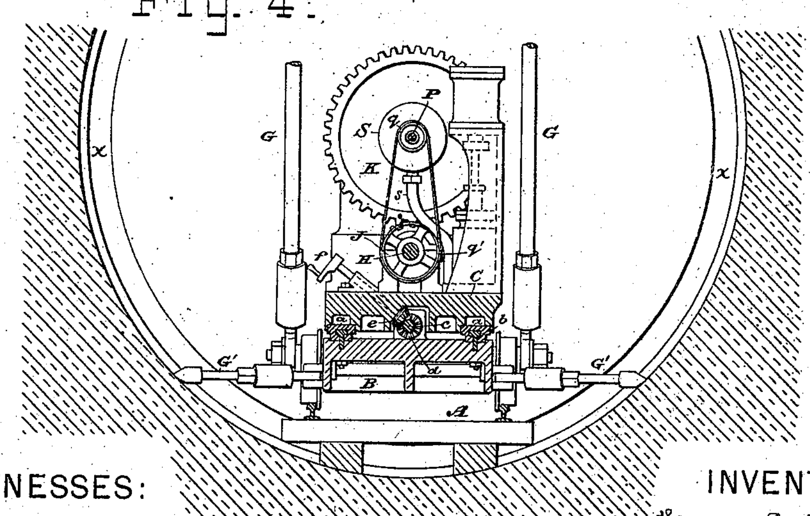


Fig. 4.



WITNESSES:

E.B. Bolton

C.K. Fraser.

INVENTOR:

Henry S. Craven

By his Attorneys,

Burke, Fraser & Connett.

(No Model.)

5 Sheets—Sheet 3.

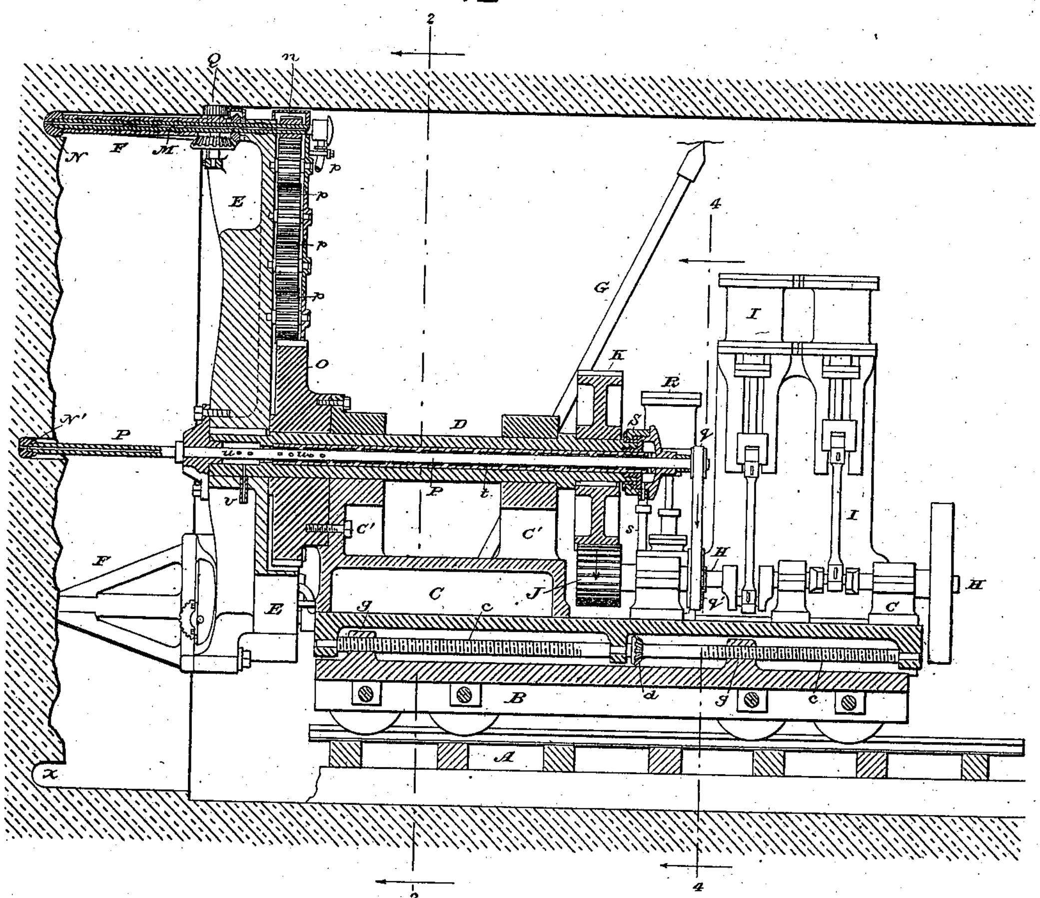
H. S. CRAVEN.

TUNNELING MACHINE.

No. 307,379.

Patented Oct. 28, 1884.

Fig. 3.



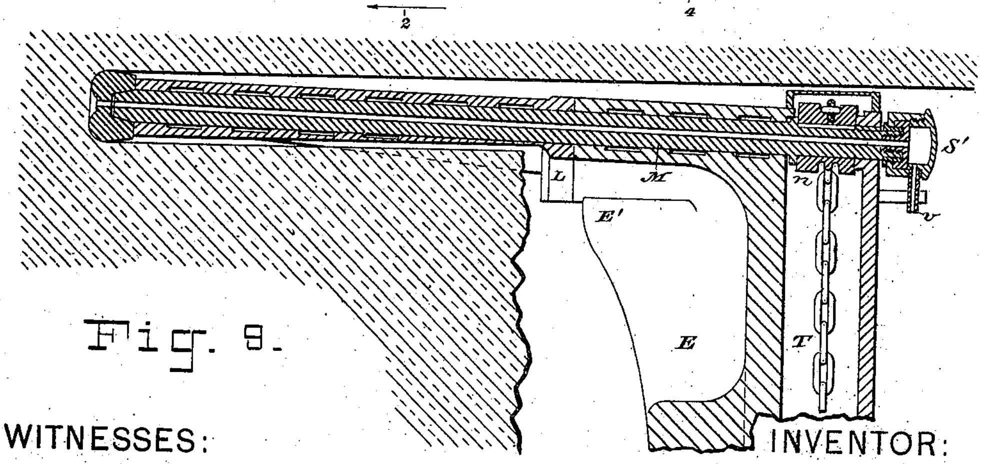


Fig. 9.

WITNESSES:

E. B. Bolton

C. K. Fraser.

INVENTOR:

Henry S. Craven

By his Attorneys,

Burke Fraser Connett

(No Model.)

5 Sheets—Sheet 4

H. S. CRAVEN.

TUNNELING MACHINE.

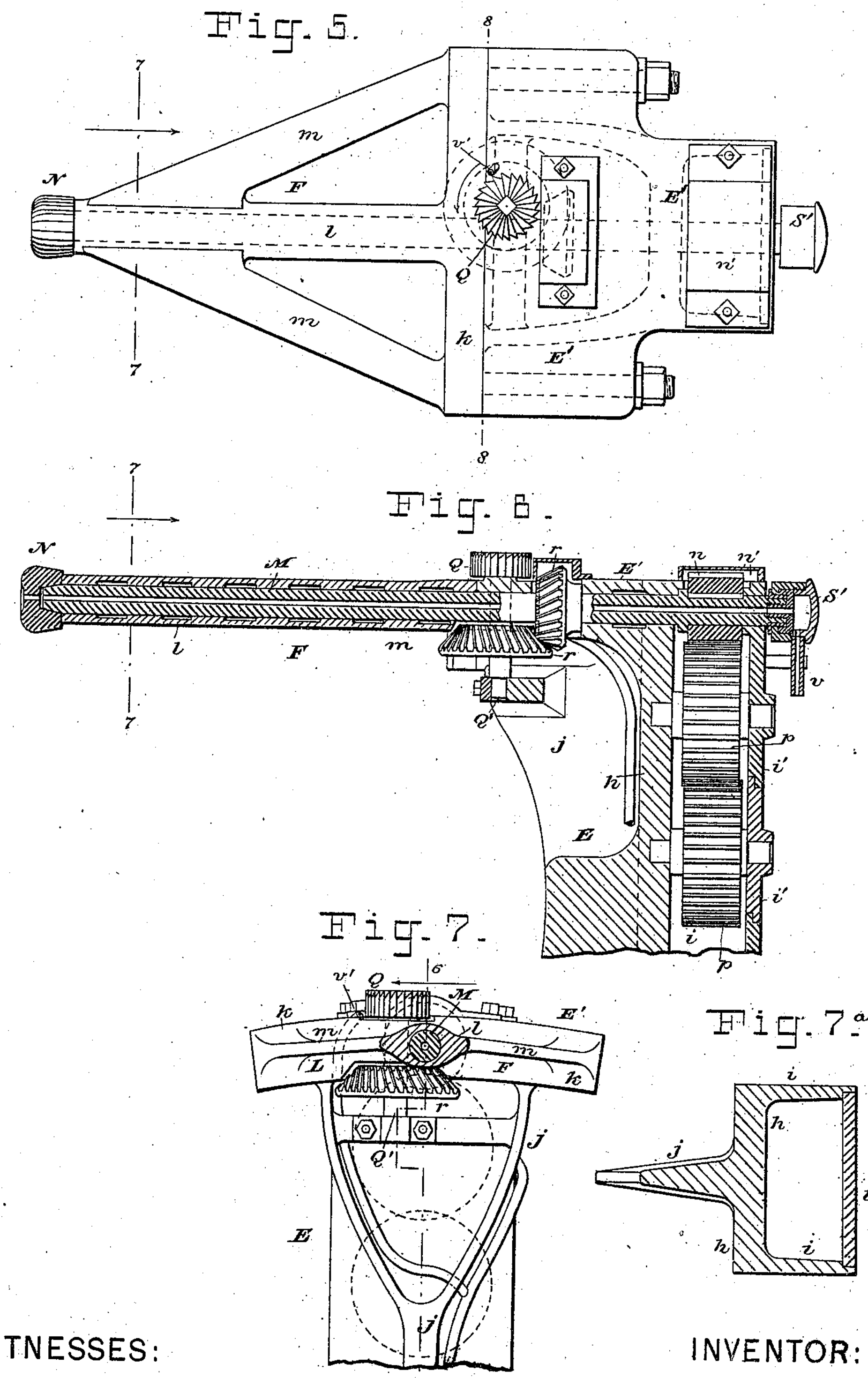
No. 307,379. Patented Oct. 28, 1884.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 7a



WITNESSES:

E. B. Bolton

G. K. Fraser

INVENTOR:

Henry S. Craven

By his Attorneys,

Burke, Fraser & Connett

(No Model.)

5 Sheets—Sheet 5.

H. S. CRAVEN.

TUNNELING MACHINE.

No. 307,379. Patented Oct. 28, 1884.

Fig. 10.

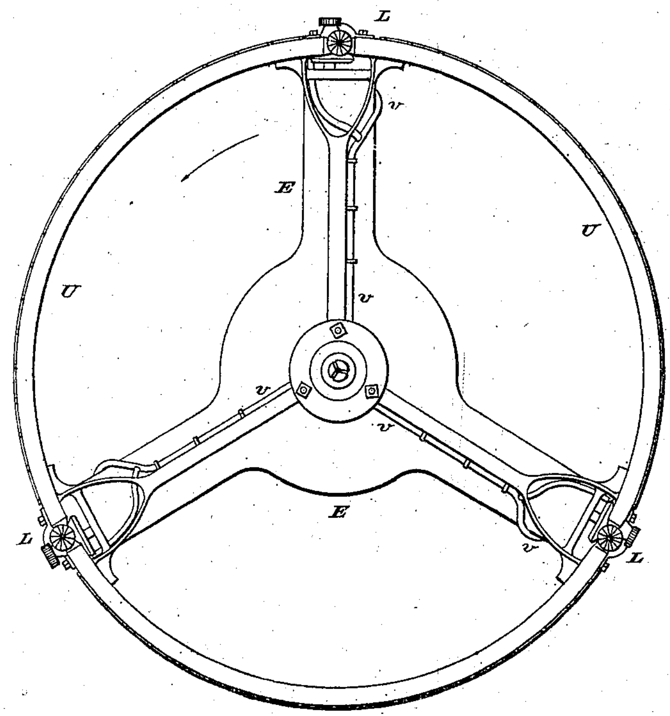


Fig. 11.

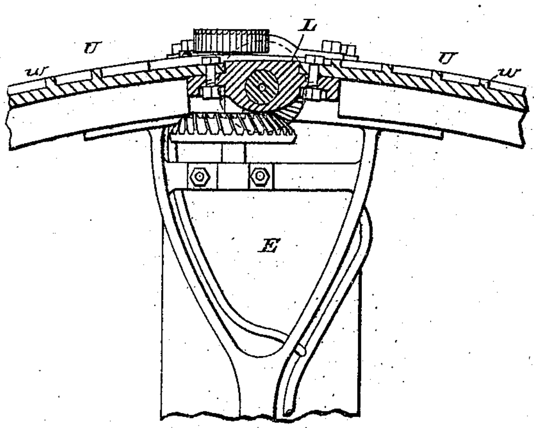
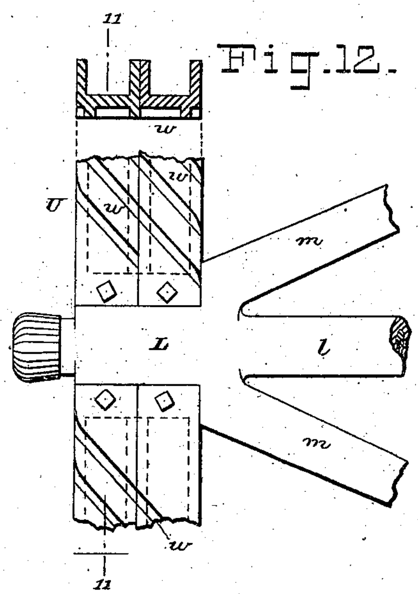


Fig. 12.



WITNESSES:

E. B. Bolton

C. A. Fraser.

INVENTOR:

Henry S. Craven

By his Attorneys,

Burke, Fraser & Connett

UNITED STATES PATENT OFFICE.

HENRY S. CRAVEN, OF IRVINGTON, NEW YORK.

TUNNELING-MACHINE.

SPECIFICATION forming part of Letters Patent No. 307,379, dated October 28, 1884.

Application filed October 22, 1883. (No model.)

To all whom it may concern:

Be it known that I, HENRY S. CRAVEN, a citizen of the United States, residing at Irvington, in the county of Westchester and State of New York, have invented certain new and useful Improvements in Tunneling-Machines, of which the following is a specification.

My improved machine is designed to effect the cutting of tunnels through rock or other hard material with greater facility and expedition than heretofore. It relates to that class of machines which employ a drill or combination of drills constructed to cut or bore an annular groove the full size of the contemplated tunnel, or very nearly so, leaving a cylindrical mass of rock at the end of the bore to be blasted out by a charge of explosive introduced in a central drill-hole.

My machine consists, in general, of a central shaft supported in bearings so that its axis coincides with the axis of the tunnel, with means for rotating it, and with one or more radial arms (preferably three) projecting from its end and bearing drills or cutting ends which abrade the rock as the arms revolve. These drills are preferably caused to rotate on their axes, and a central axial drill is also provided to drill the hole for the charge of explosive. The entire machine is borne upon a table or carriage which slides upon a car which is fastened in place in the tunnel, this table being fed forward over the car as the cutting proceeds.

In the accompanying drawings, which illustrate my invention, Figure 1 is a side elevation of my machine, the tunnel being shown in longitudinal mid-section as denoted by the line 1 1 in Fig. 2. Fig. 2 is a transverse section of the machine and tunnel cut in the plane of the line 2 2 in Figs. 1 and 3. Fig. 3 is a vertical longitudinal section of the machine and tunnel cut in the plane of the line 3 3 in Fig. 2. Fig. 4 is a transverse section cut in the plane of the line 4 4 in Figs. 1 and 3. Fig. 5 is a plan view of the end of one of the drill-arms. Fig. 6 is a vertical mid-section thereof cut along the line 6 6 in Figs. 5 and 7. Fig. 7 is a front elevation thereof, partly in section on the line 7 7 in Figs. 5 and 6. Fig. 7ª is a transverse section thereof. Fig. 8 is a view in section along the line 8 8 in Fig. 5, and partly broken away back of the plane of the section. Fig. 9 is a sectional view corresponding to Fig. 6, and illustrating a modification. Fig. 10 is a front elevation of the cutting-tool, showing a further modification. Fig. 11 is a sectional front view of one of the drill-arms shown in Fig. 10, cut along the line 11 11 in Fig. 12, and Fig. 12 is a plan of the drill-arm shown in Fig. 11. Figs. 5, 6, 7, 8, 9, 11, and 12 are drawn to a scale three times greater than the other figures.

Referring chiefly to Figs. 1, 2, and 3, let A designate a railway-track laid in the unfinished tunnel; B, a car mounted upon eight wheels (more or less) running upon that track; C, a table or bed mounted on said car and capable of sliding longitudinally thereon; D, a shaft the axis of which coincides with the axis of the tunnel, and is mounted in bearings on the bed C; E E E, three radial arms fixed to the end of said shaft, and F F F three drills mounted on the arms E E E and projecting in a direction parallel with the axis of the shaft D. The track A should be laid with some accuracy, its rails being kept at a certain definite distance from the axis of the tunnel and exactly parallel with that axis. The car B is mounted on its wheels through the medium of unyielding axle-boxes, and when rolled into position close to the end of the tunnel is fastened rigidly in place by clamps, struts, shares, or other devices. The means which I have shown, and which I prefer, are the adjustable screw struts or shares G G′. (Shown in Figs. 1 and 4.) The struts G G are long bars hinged to the sides of the car, and capable of being turned up so that their ends shall touch the roof of the tunnel. When thus turned up at about the angle shown, they are elongated by being screwed out until their points penetrate the rock and they press down upon the car, holding it firmly down upon the track. The struts G′ G′ are hinged to the sides of the car and turn outward, so that they project laterally, as shown in Fig. 4, and engage the sides of the tunnel, and when screwed out hold the car firmly in place laterally. The car may also be clamped to the track, if desired. The table C slides upon guides or runners upon the car B, and is confined down thereto. The undercut grooved guides *a a* (seen in Fig. 2) are bolted to the under side of the table, and the headed guides or rails *b b*, which enter them, are bolted down to the car. Any other means of effecting this result may be adopted. A screw, *c*, is arranged in a cavity beneath the table, extends longitudinally thereof, and has bearings therein. On it is fixed a miter-gear, *d*, which meshes with a like gear, *e*, on an inclined crank-shaft, *f*, Fig. 4. The screw *c* passes through fixed nuts *g g* on the car B, and when turned by means of the crank-shaft *f* the table C is caused to move longitudinally on the car B. This constitutes the feed for controlling the advance of the tool in cutting the rock. Any other form of feed may be used, such as a rack and pinion, or a ratchet and pawl, or a hydraulic cylinder and piston. The table C is provided with projecting frames C' C', affording bearings for the shaft D, and upon it are formed bearings for the crank-shaft H of a steam-engine, I, the frame of which rests upon the rear end of the table. The steam for driving this engine may be brought from a boiler located at any convenient point; or the table C may be made larger and the boiler may be mounted upon it; or compressed air or other gas may be used to drive the engine. A pinion, J, is fixed on the front end of the shaft H, and meshes with a gear, K, fixed on the rear end of the shaft D, so that the latter shaft and its arms E E are rotated from the engine. The arms E E are preferably all cast in one piece and fixed upon the front end of the shaft D by keying or otherwise; but, if preferred, a socketed hub may be fixed upon the shaft, and removable arms may be fitted into the sockets; or any other construction may be adopted having sufficient strength. One, two, four, or other number of arms may be used; but three are preferable. The arms must be so few in number or their interspaces must be so wide that they will not interfere with the track when the machine is rolled back. These arms are cast of the form shown in cross-section in Fig. 7[a], with a flat plate or web, *h*, having flanges *i i* projecting rearwardly from both edges, and a flange, *j*, projecting forward from its middle. The flange *j* divides in a **Y** toward the end of each arm, and the two branches form brackets to support a head, E', formed on the end of the arm. This head E' extends forward and to each side, as shown best in Figs. 5, 6, and 8, and to its front side is bolted a frame, L, consisting of a broad base, *k*, which rests against the front face of the head E', a central tubular bearing-arm, *l*, which projects to the front from the middle of the base, and two diagonal braces, *m m*, which support the front end of the arm *l*. This tubular arm *l* forms a bearing for the drill-spindle M, which is passed through it, and the squared and tapered front end of which projects beyond the front of the arm and receives the drill-head N, which, when at work, seats back against and is re-enforced by the front end of the bearing *l*. When dulled or worn out, it may be driven off from the spindle by striking it from behind. The spindle M and head N constitute the drill or cutter F, before referred to. The spindle M extends back through the head E' and plate *h*, and on its rear end is fixed a pinion, *n*, which receives motion from a large gear, O, through the intermediation of four or other number of idler-gears, *p p*, as best shown in Fig. 2. The gear O is stationary, being made fast to the front bearing, *c'*, and as the shaft D and arms E E revolve the idlers *p*, intermeshing with it, are caused to revolve in the same direction, and the motion is transmitted to the pinions *n n* and spindles M M, which revolve thus in the same direction as the shaft D, but much faster. The proportion which I propose to adopt is ninety revolutions for shaft H, thirty for shaft D, and two hundred and forty for drills M N per minute. The drill-heads M N have, in consequence of the gearing just described, a double motion: first, a rapid rotation on their own axes, and, second, a slow revolution around the axis of the shaft D. As they abrade the rock they plow an annular groove, (shown at *x* in Fig. 2,) and they are slowly fed forward into the rock by the feed-screw *c* until this groove has reached a depth of about three feet. The entire machine is then run back into the tunnel, and the projecting core of rock thus cut around is removed by blasting.

In order to facilitate the blasting out of this core of rock, I provide for drilling a central hole into it at the same time that the annular groove is being cut by the drills F F. I arrange a central drill-shaft, P, to pass through the axis of the shaft D, which is made tubular for this purpose, and to project beyond the same at both ends. On its front end it bears a drill-head, N', and on its rear end it bears a belt-pulley, *q*, which is driven by a belt from a larger pulley, *q'*, on the shaft H, as shown in Figs. 3 and 4; or cog-gearing may be substituted. This drill-shaft P should revolve faster than the shaft D, and may revolve in either direction. As shown, its speed will be about seven times greater than that of the shaft D, or about two hundred and ten revolutions per minute. But for the necessity of driving this drill faster, it might be fastened to and project from the front of the shaft D.

The spindles M M (shown in Figs. 1 and 8) are arranged with their axes parallel to the axis of the shaft D, and consequently parallel to the wall of the tunnel, as shown in Fig. 3. As the size of the drill-head N, and consequently the width of the groove *x*, is practically limited, and as it is desirable to have the pinion *n* of at least as great diameter as the drill-head, it is necessary to enlarge the diameter of the tunnel between the drill-head and the pinion. This result I accomplish by introducing a supplementary drill-head or cutting-wheel, Q, fixed on the outer end of a short shaft or spindle, Q', having bearings in and under the head E', crossing the spindle M close to it, and driven from said spindle through skew bevel-gears *r r*, as shown in Figs. 5 to 8. This cutting-wheel enlarges the tunnel sufficiently to make room for the pinion *n*, and also gives the rock a final dressing or finishing, and removes any irregularities that may be occasioned during the blasting, as it is placed so far behind the drill-head N that its action is on the portion of the tunnel from which the core of rock formed by the previous operation has been removed by blasting. This enlargement of the tunnel also greatly facilitates the removal of the débris during the operation of the machine, so that it shall not accumulate on the under side of the bore and impede the revolution of the arms E E as they pass the bottom.

It is highly necessary that all the drills and cutters shall be supplied copiously with water, in order to keep them from heating, to facilitate their abrasive action, and to continually wash away the débris or detritus as fast as it is formed. For this purpose I provide a pump and a series of water ducts or passages leading thence through the moving parts to the drill-heads or cutters, so that the action of the pump forces a jet of water to issue at each cutter and pass between the cutter and the rock, after which the water flows away over the rock and keeps the latter continually freed from detritus. This pump R is seen in Figs. 1 and 4, and may be any ordinary steam-pump or other force-pump worked by suitable power. From its delivery a pipe, *s*, leads to a hollow cap, S, on the rear end of the shaft D, which cap is connected by a water-tight packing to the shaft, and remains stationary while the shaft revolves. Its interior communicates with the interior of a bearing sleeve or tube, *t*, (preferably of brass,) which is fitted in a longitudinal bore through the shaft D, and which serves as a journal-bearing for the drill-shaft P. The latter is supported at intervals by means of ribs on the interior of the sleeve *t*, and the water passes between the shaft and sleeve through grooves or apertures in these ribs. The shaft P is hollow, and has perforations *u u*, Fig. 3, communicating with the water-space in the sleeve *t*, through which perforations the water passes to its bore and flows forward to the drill-head N'. Three pipes, *v v*, tap the cavity in the front end of the shaft D, beyond the sleeve *t*, one of them being shown in Fig. 3 and all of them in Fig. 10. Each of these pipes passes up one of the arms E and around to the rear face thereof, where it connects with a hollow cap, S', constructed similarly to the cap S and mounted on the projecting rear end of the spindle M, as best shown in Fig. 6. The spindle M is tubular, and the water passes through its bore to the drill-head N. Thus water is supplied to the four drill-heads N N N and N'; and, as each of these is formed with a central bore and with radial grooves across its cutting-face, the water passes through it and between it and the rock in all directions, keeping it cool and facilitating its cutting. Water is also supplied to the cutters Q Q, but by means of jets playing on them, instead of streams passing through them.

From each pipe *v* a branch, *v'*, is taken and carried up the front of the arm E to the head E', through which it passes, as shown in Fig. 5, and terminates in a nozzle directed toward the front side of the cutter Q, as also shown in Fig. 5.

Instead of pipes *v v'*, the arms E may be cored out to form suitable water-passages.

The pinion *n* is housed by a cap, *n'*, on the end of the arm E, and it and the idlers *p p* are also housed and protected by being arranged in the space between the two flanges *i i* of the arm E. A series of plates, *i'*, are also fitted to the rear side of the arms E, as shown in Figs. 2, 6, and 7ª, thereby completely inclosing these gears. The idlers *p p* have their bearings on the one side in the plate or web *h*, and on the other in the plates *i' i'*, as shown in Fig. 6.

Having now described the preferred form of my invention, I will now more fully describe its operation. In commencing a tunnel it may be cut in any usual way until a working-face is obtained. Then the track A is laid, the last section, close to the end of the tunnel, being laid with care in the manner hereinbefore described. This section must be removable, and should be specially constructed for that purpose. The machine is then rolled into the tunnel on the track, its arms E E being held in the position shown in Fig. 2, so that the lower arms clear the track, and it is stopped with the drill-heads N N not quite touching the rock in the end of the tunnel. The table C has been previously moved back on the car B to its utmost limit, as shown in Figs. 1 and 3. The machine is then fastened solidly and firmly in position by means of the struts G G', and the engine I and the pump R are started. When the machine has attained a sufficient speed to give it the desired momentum, the table C is fed forward by turning the crank-shaft *f* until the drill-heads reach the rock and begin to abrade it. First, they will cut through the projecting portions, and gradually, as they are slowly fed up by the crank-shaft *f*, they will have plowed out a well-defined annular groove. The machine is then well at work, and its operation is continued until this groove reaches a depth of about three feet or other depth, according to the capacity of the machine. An attendant stands constantly at the side of the machine, watching its operation, and feeding it up slowly by turning the shaft *f*, his aim being to keep the arms E E revolving at as nearly a uniform speed as possible. The cuttings or detritus from the drills are continually washed out, and the water carrying them flows back beneath the track through the channel X in Fig. 2. When the machine has been fed forward three feet or other predetermined limit, its further advancement is prevented by abutting stops. It should then be stopped, the struts G G' taken down and turned in alongside the car, and the machine run back upon the track sufficiently far to be safe from injury during the blasting. A charge of explosive is then put in the central drill-hole and fired, disrupting the core of rock. The fragments of rock are then gathered up and carried back, being taken past the machine through the spaces between the arms E E. When the heading has been cleared of débris, the section of track A is then moved forward three feet, a short section is placed behind it, between it and the permanent track, and the machine is again rolled up to the heading, when the same operation is repeated.

Fig. 9 shows a modified construction of drill F, whereby the cutter Q is dispensed with, and a chain is used to drive the spindle M, instead of toothed gearing. On the rear end of the spindle is fixed a small chain-pulley or sprocket-wheel, *n*, in place of the pinion shown in Fig. 6, and over this passes an endless chain, T, the links of which drop into depressions on the wheel. This chain passes over a large stationary sprocket-wheel, (not shown,) which corresponds to the gear O, and has on its periphery three different series of depressions, arranged side by side, for the reception of the three chains T for the three arms E. Thus by the rotation of the arms the drill-spindles are driven in the same way as if by gears, although in the opposite direction. Room is provided for the sprocket-wheel *n* by tilting the spindle M, its rear end being nearer the axis of the shaft D, and consequently farther from the wall of the tunnel, than its front end, which bears the drill-head. In other respects the construction and operation of this form of drill are the same as of the one before described.

In some cases it may be found necessary to brace and support the front ends of the three drills F F by connecting them together by means of a direct connection within the annular groove *x*. Ordinarily the diagonal arms *m m* will be relied upon to withstand the strain to which the drills will be subjected when in operation; but when these prove inadequate the construction shown in Figs. 10 to 12 may be adopted. Three curved bars of channel-iron, U U U, are bolted to the front end of the frames L L L, and extend each from one to the next. These bars are bent to the same curve as the groove *x*, in which they turn, and are provided with inclined ribs *w w* on their outer or back sides to act as sweeps to push back the débris which accumulates in the groove. One of these bars must be unbolted and removed before the machine can be rolled back on the track after completing a cut, as otherwise it would collide with the track. Before removing the bar the cutting-head will be fed back until the bar is withdrawn out of the cut, and so made accessible.

My machine is susceptible of some modification of construction without departing from its essential features. For instance, the cutting-wheel Q might be keyed on the spindle M and work through a slot in the head E′, and any other method of imparting rotary motion to the spindles M M may be adopted, such as cranks and pitmen, or radial shafts bearing miter-gears at their outer ends meshing with miter-gears on the spindles M M, and driven from the gear O at their inner ends. It is not even essential that the drills F F be rotated by the same power that rotates the shaft D, as they might be rotated by independent gearing, or even by a separate engine, it being immaterial that their speed bear any definite proportion to that of the shaft D. The latter may revolve very slowly by a hand-feed or by hydraulic pressure or otherwise, and the drills be rotated rapidly; or the drill-heads may be mere non-rotating cutting ends, and their revolution around the axis of the shaft D may be very rapid and be wholly relied on to effect the cutting; but I prefer the combination of the two movements as described.

I claim as my invention—

1. In a machine for boring tunnels by cutting a circumferential groove in the heading, the combination, with the central shaft in the axis of the tunnel, of the separate radial arms E E, fixed to its front, and terminating in heads E′ E′, bracket-frames L L, fixed to said heads, and projecting forward, and drill-shafts M M, having bearings in said frames, whereby said drill-shafts are supported at their cutting ends and the cutting of a deep groove is rendered possible, substantially as set forth.

2. In a machine for boring tunnels, the combination, with central shaft, D, of radial arms E E, terminating in heads E′ E′, and with drill-shafts borne by said heads, and suitable gearing traversing said arms to rotate said drill-shafts, each arm being formed with a Y-shaped flange, *j*, on its front side, the branches of which form brackets supporting said head, and with marginal flanges *i i* on its rear side, which serve both to stiffen the arm and to protect said gearing, substantially as set forth.

3. In a machine for boring tunnels by cutting a circumferential groove in the facing, the combination, with the axially-arranged shaft, its tool-bearing arms, and the groove-cutting drills borne by the latter, of supplementary cutters borne by said arms, arranged behind the drills, and acting against the wall of the tunnel, whereby the tunnel is enlarged to a greater diameter than that cut by the grooving-drills, substantially as set forth.

4. In a machine for boring tunnels, the combination, with the central axial shaft, the radial arms fixed thereto, the groove-cutting drills borne by said arms, and mechanism for rotating said drills, of supplementary cutting-wheels borne by said arms, arranged on radial axes geared to the shafts of said drills, and acting to enlarge the diameter of the tunnel, substantially as set forth.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

HENRY S. CRAVEN.

Witnesses:
ARTHUR C. FRASER,
HENRY CONNETT.