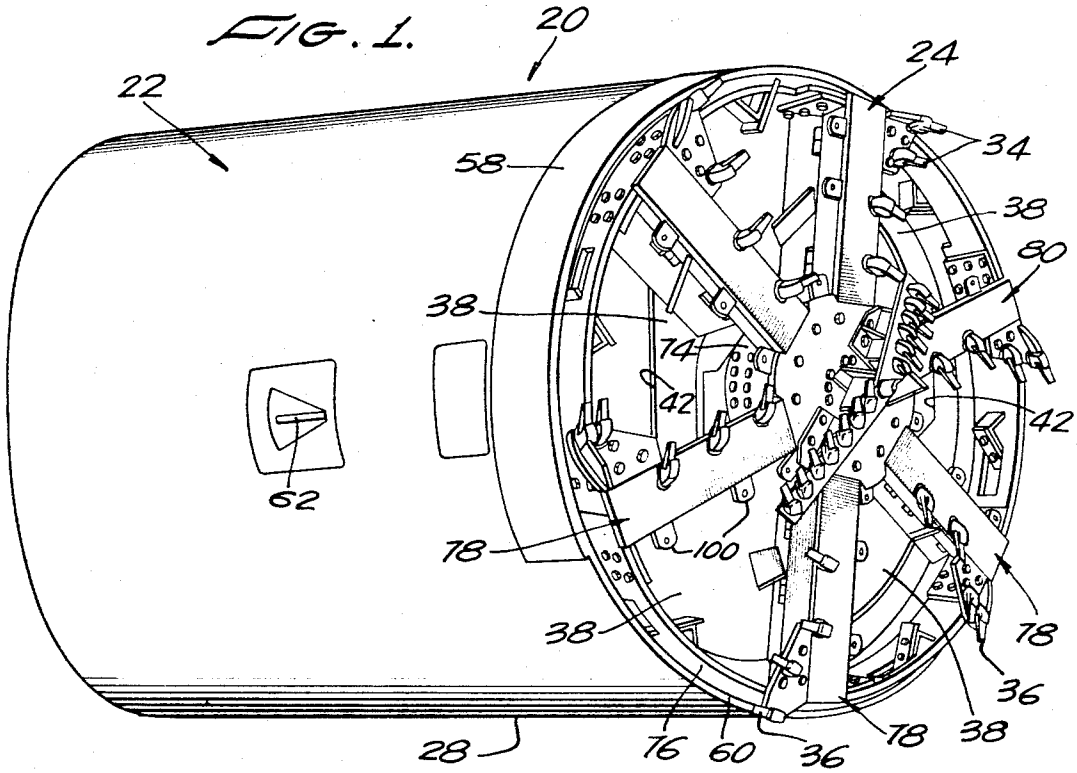
Nov. 26, 1968 H. L. CLARK 3,413,033

ROTARY TUNNELING MACHINE HAVING IMPROVED DEBRIS DISPOSAL MEANS

Filed Sept. 9, 1966 5 Sheets-Sheet 1

FIG. 1.



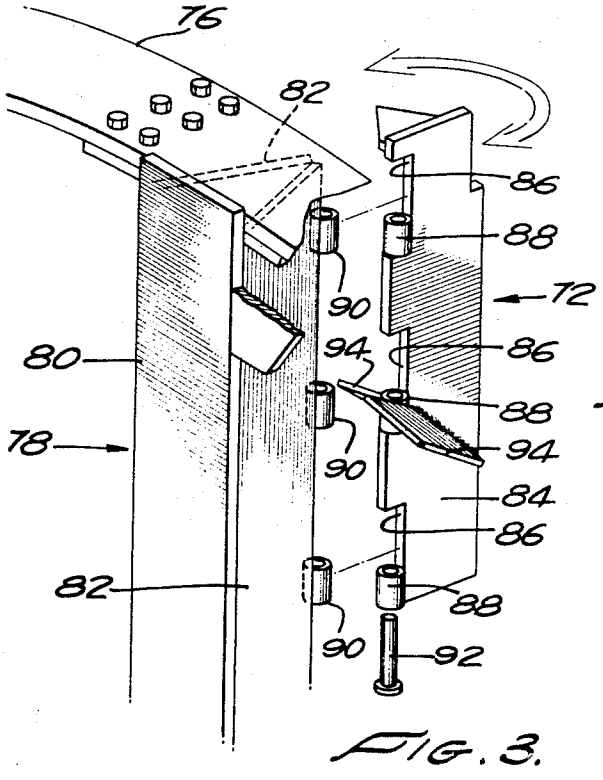


FIG. 3.

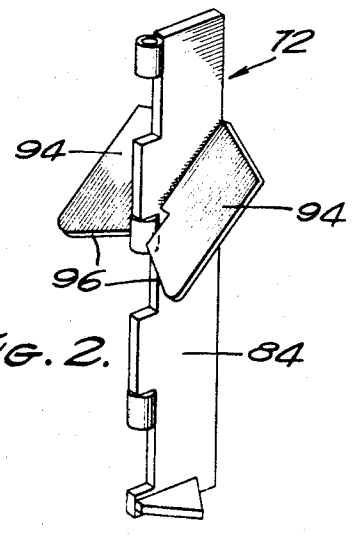


FIG. 2.

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ROTARY TUNNELING MACHINE HAVING IMPROVED DEBRIS DISPOSAL MEANS

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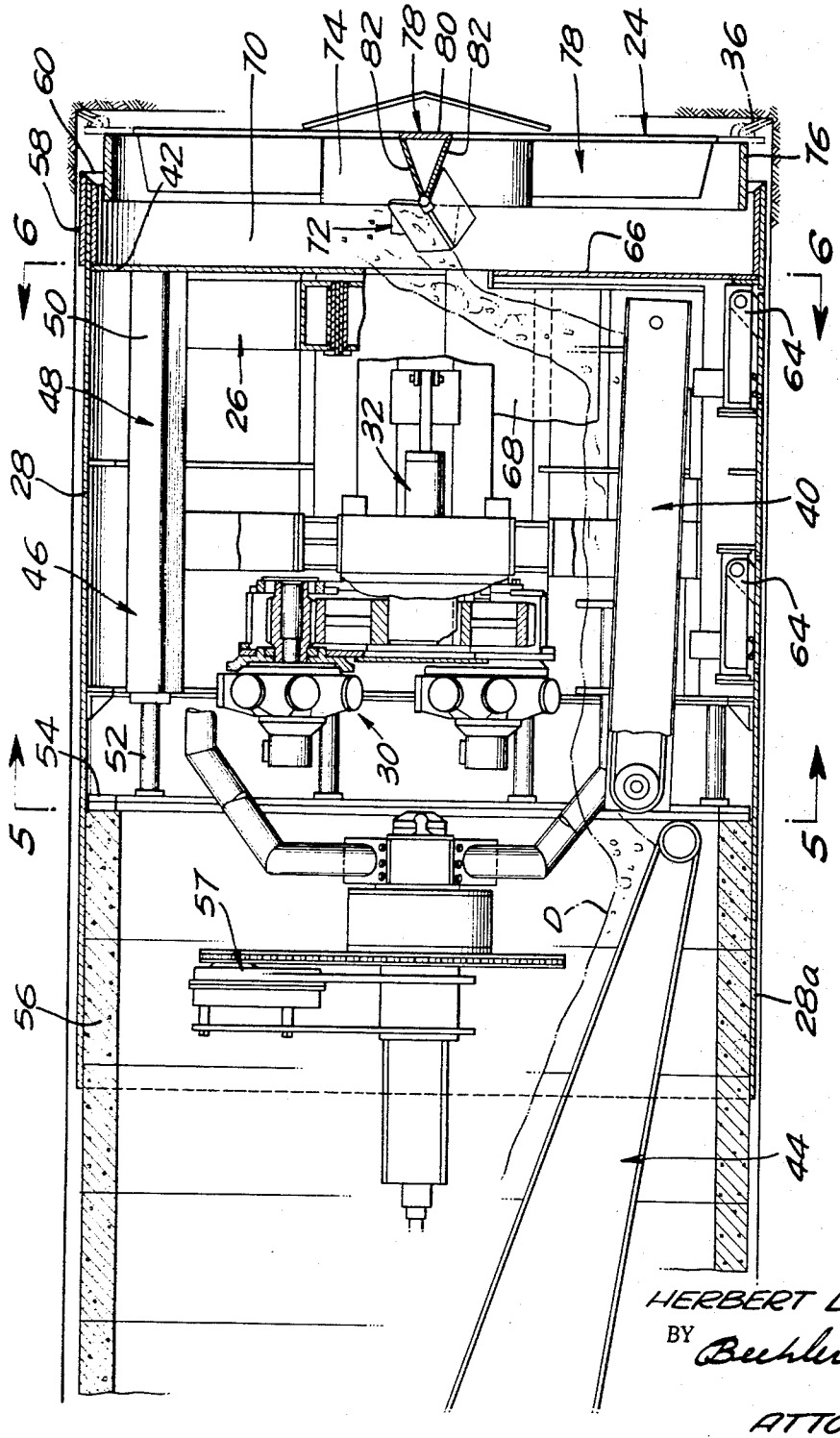


FIG. 4.

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ROTARY TUNNELING MACHINE HAVING IMPROVED DEBRIS DISPOSAL MEANS

Filed Sept. 9, 1966 5 Sheets-Sheet 3

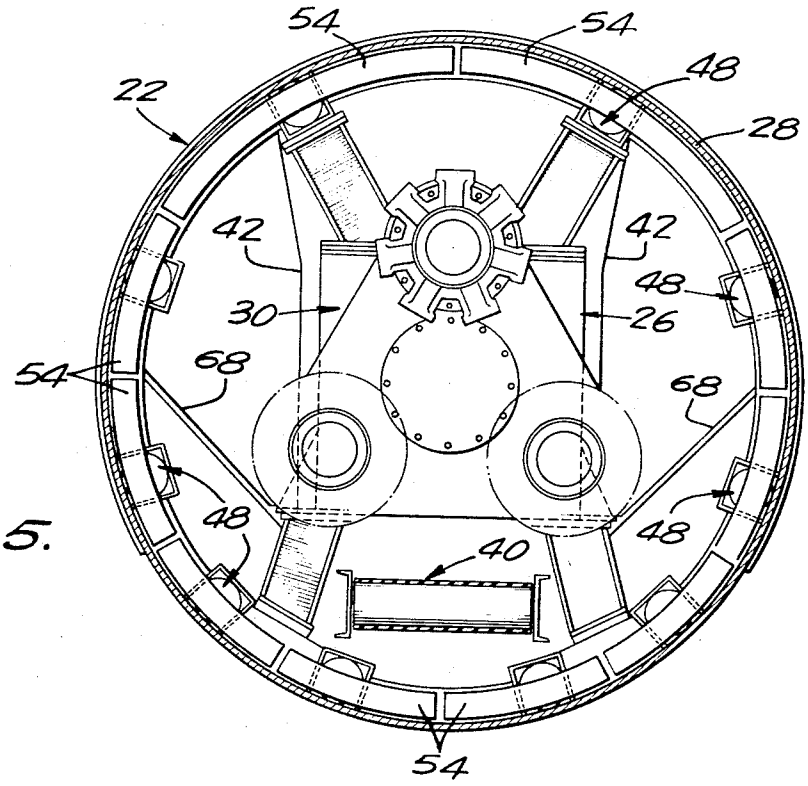


FIG. 5.

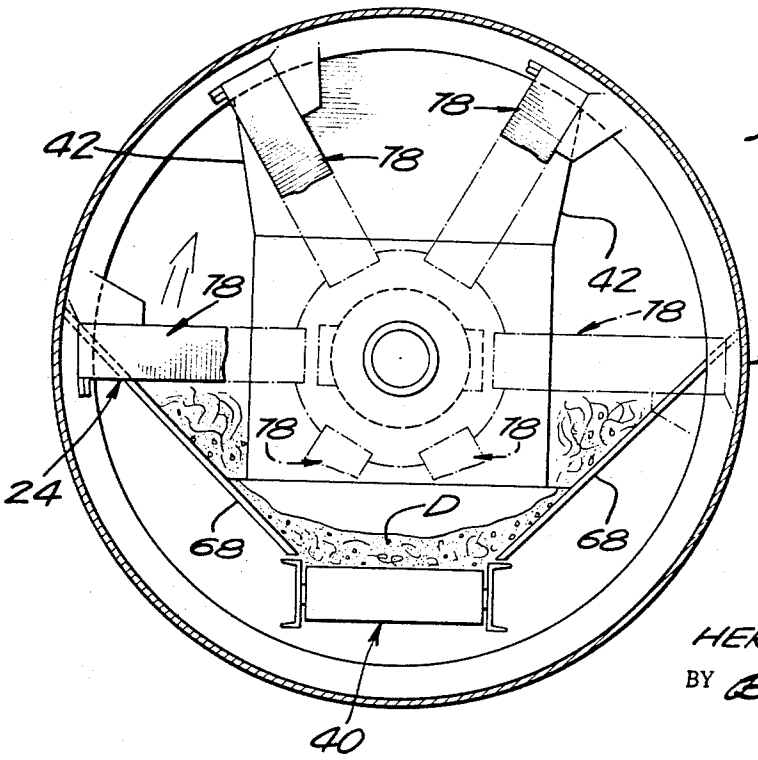


FIG. 6.

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ROTARY TUNNELING MACHINE HAVING IMPROVED DEBRIS DISPOSAL MEANS

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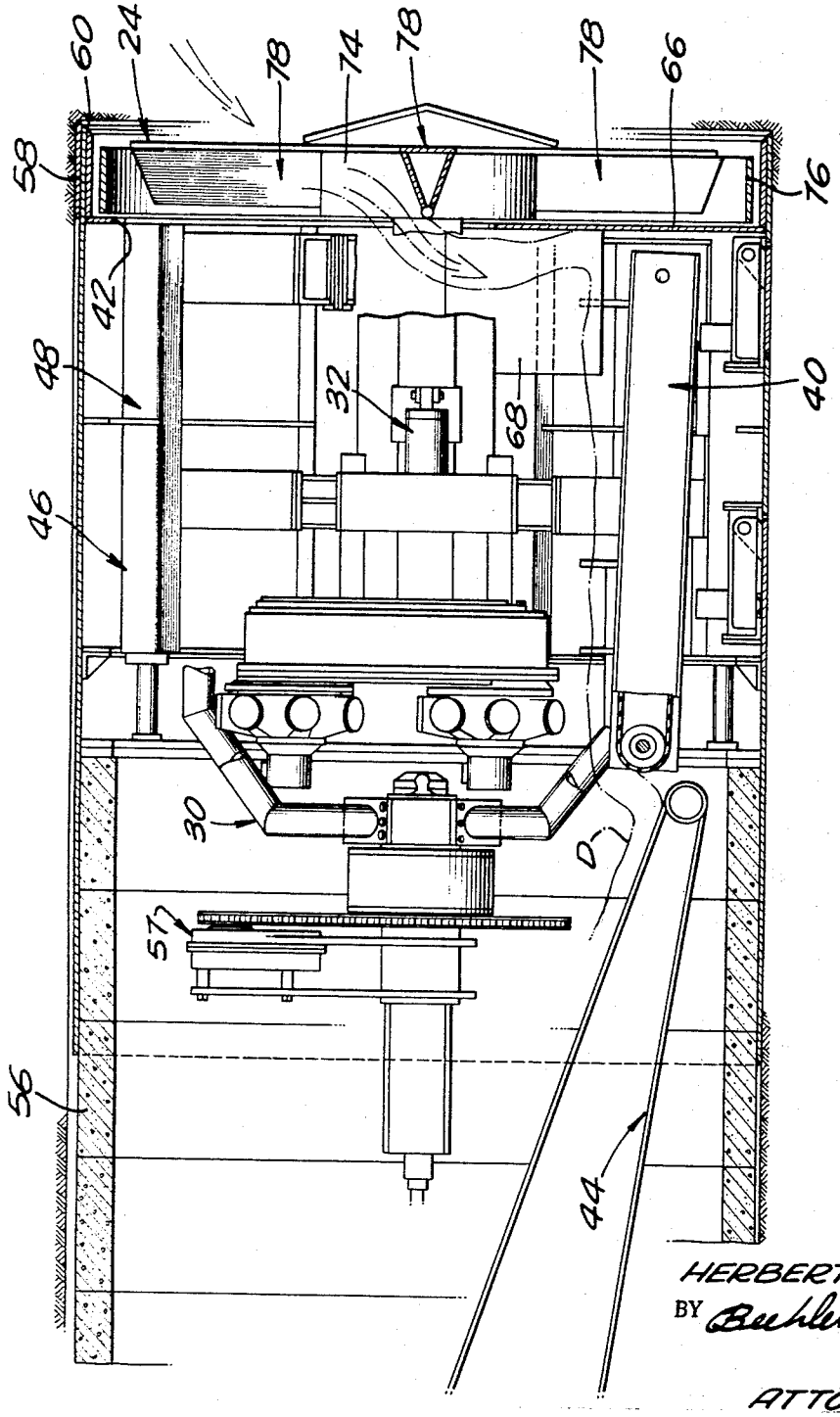


FIG. 1.

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Filed Sept. 9, 1966 5 Sheets-Sheet 5

FIG. 8.

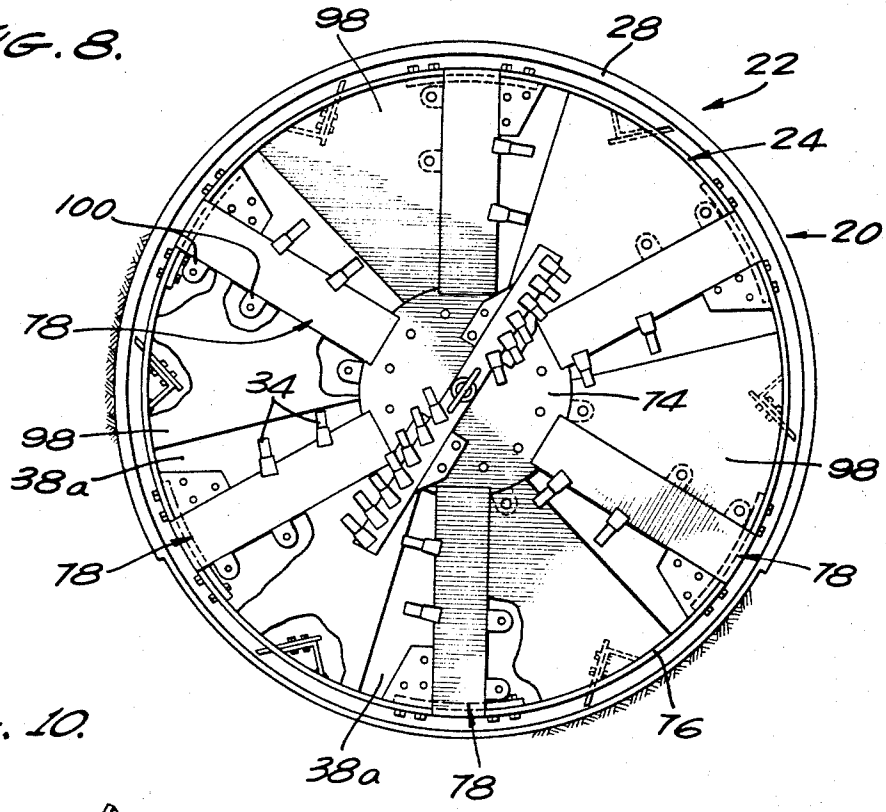


FIG. 10.

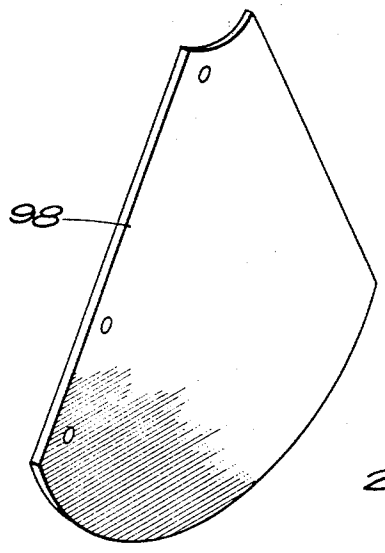
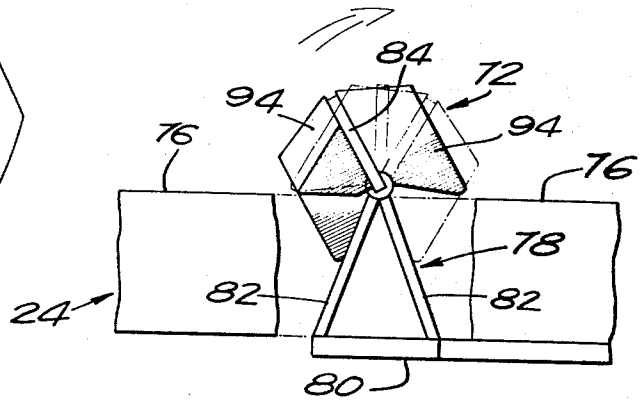


FIG. 9.



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3,413,033

ROTARY TUNNELING MACHINE HAVING IMPROVED DEBRIS DISPOSAL MEANS

Herbert L. Clark, Arcadia, Calif., assignor to Smith Industries International, Inc., Los Angeles, Calif., a corporation of California

Filed Sept. 9, 1966, Ser. No. 578,287
16 Claims. (Cl. 299—33)

ABSTRACT OF THE DISCLOSURE

A rotary tunneling machine as provided with a front shearing edge surrounding a rotary cutting wheel which is axially adjustable to a rear cutting position wherein the shearing edge is conditioned to shear the tunnel wall in advance of the wheel and a forward cutting position wherein the cutting wheel is conditioned to cut the tunnel wall in advance of the shearing edge. The cutting wheel has relatively wide radial spokes for sweeping debris upwardly from the bottom of the cut and deflecting debris rearwardly to a conveyor as the cutting wheel advances into the tunnel face, and removable baffle plates along the rear sides of the spokes for deflecting debris from the spokes to the conveyor when the cutting wheel occupies its forward cutting position.

This invention relates generally to earth boring machines. More particularly, the invention relates to an improved tunneling machine with novel cutting debris disposal means.

As will appear from the ensuing description, the improved cutting debris disposal means of the present invention may be utilized to advantage in various types of tunneling machines. However, the disposal means are intended primarily for use on one particular type of tunneling machine and, for this reason, will be disclosed in connection with this particular machine.

The tunneling machine referred to is equipped with a frame including an outer generally cylindrical shell, and a rotary cutting wheel mounted on the front end of the frame. Secured to the front side of the cutting wheel are a number of face cutters. A number of gauge cutters are removably mounted about the perimeter of the wheel. Extending axially through the wheel are openings through which debris, produced by operation of the cutting wheel, may pass from the front side to the rear side of the wheel. A conveyor is mounted on the machine frame, within its outer shell, for receiving this debris through one or more entrance openings in the front end of the frame and transporting the debris to the rear end of the frame, where the debris is discharged into hopper cars, or the like, for removal from the tunnel.

The tunneling machine under consideration is designed for operation in both relatively hard and relative soft earth formations. To this end, the cutting wheel is mounted on the machine frame for axial movement relative to the frame between a forward or extended cutting position and a rear or retracted cutting position. In its forward cutting position, the cutting wheel projects forwardly a distance beyond the front edge of the frame shell. In its rear cutting position, the cutting wheel is retracted within the front end of the shell. Extending about the front edge of the shell is a relatively sharp earth shearing edge. When tunneling through relatively hard earth formations, the cutting wheel is extended to its forward cutting position and the gauge cutters are mounted about the perimeter of the wheel. In this operating mode of the machine, the frame and cutting wheel are driven forwardly in unison to cause the wheel to penetrate the earth formation in such a way that the face cutters on the wheel cut the tunnel face and the gauge cutters cut the tunnel wall. When tunneling through relatively soft earth formations, the gauge cutters are removed from the cutting wheel and the latter is retracted to its rear cutting position within the front end of the frame shell. The frame and cutting wheel are again driven forwardly in unison to cause the cutting wheel to penetrate the earth formation in such a way that the face cutters on the wheel cut the tunnel face, as before. In this case, however, the tunnel wall is sheared by the front shearing edge on the frame shell.

The existing tunneling machines of the kind under discussion have an inherent deficiency which the present invention seeks to overcome. This deficiency resides in the fact that when the cutting wheel occupies its forward cutting position, a relatively wide gap exists between the rear side of the wheel and the front end of the machine frame. As a consequence, during operation of an existing tunneling machine with the cutting wheel in its forward cutting position, much of the debris removed by the wheel drops to the bottom of the gap between the wheel and frame and is thereafter raised by the wheel to the front debris entrance opening in the machine frame through which the debris passes to the conveyor. This method of debris disposal is quite unsatisfactory. Thus, permitting the debris to drop to the bottom of the gap between the cutting wheel and the frame and then utilizing the cutting wheel to raise the debris to the higher level of the front debris entrance opening in the machine frame is obviously a very inefficient method of effecting movement of the debris from the cutting wheel to the conveyor. Moreover, the weight of the debris which is raised from the bottom of the gap by the rotating cutting wheel and the drag exerted on the cutting wheel by the mass of debris which collects at the bottom of the gap impose a continuous increased loading on the cutting wheel, thus necessitating increase driving torque for the wheel.

According to the present invention, the above deficiency of the existing tunneling machines is avoided by providing the cutting wheel with deflectors which are effective to deflect a major portion of the debris from the wheel directly into the debris entrance opening in the machine frame. Accordingly, the amount of debris which falls to the bottom of the gap between the cutting wheel and the frame is greatly reduced and the operating efficiency of the machine is correspondingly increased. Moreover, the loading on the cutting wheel, and hence the required driving torque for the wheel, are reduced. According to a further feature of the invention, the debris deflectors on the cutting wheel are pivotally mounted in such a way that each deflector is positioned at an optimum angle to deflect debris from the cutting wheel to the front debris entrance opening in the machine frame throughout a major portion of each complete revolution of the wheel. As the deflectors rotate through their top and bottom dead-center positions with the rotating cutting wheel, the positions of the deflectors are abruptly reversed in such a way that each deflector receives an impact or jar. This periodic jarring of the deflectors aids in removing any debris which tends to adhere to the deflectors. A further feature of the invention resides in the fact that the debris deflectors are removable from the cutting wheel to permit retraction of the wheel to its rear cutting position, wherein the rear side of the wheel is situated in close proximity to the front end of the machine frame.

Another deficiency of the existing tunneling machines of the kind under discussion which the present invention seeks to overcome is encountered when the machines are employed for tunneling through relatively soft earth formations. Thus, the cutting wheel openings through which debris passes from the front side to the rear side of the cutting wheel of the existing machines are generally

so large as to provide inadequate tunnel face support in many soft earth formations. In many cases, for example, the tunnel face collapses through the cutting wheel openings, resulting in an inrush of debris which either overloads the conveyor or completely engulfs the interior of the machine.

According to the present invention, this latter deficiency of the existing tunneling machines is avoided by providing the cutting wheel with removable bulkheads or breast boards. These breast boards provide sufficient support for the tunnel face to prevent collapse of the face, when tunneling through relatively soft earth formations. Moreover, the breast boards restrict the flow of debris through the cutting wheel to a rate which is sufficiently low to prevent overloading of the conveyor. The breast boards are removed from the cutting wheel when the latter is extended to its forward cutting position for tunneling through hard earth formations.

It is a general object of the invention, therefore, to provide a tunneling machine of the character described having improved debris disposal means.

Another object of the invention is to provide an improved tunneling machine including a rotary cutting wheel having a forward cutting position in which the wheel is spaced from the frame, thus defining a gap between the wheel and frame across which debris must pass to a conveyor on the frame, and wherein the cutting wheel is equipped with novel deflectors for deflecting debris from the cutting wheel to the conveyor, thus to materially reduce the quantity of debris which drops to the bottom of the gap and thereby substantially increase the operating efficiency of the machine.

A related object of the invention is to provide a tunneling machine of the character described wherein the debris deflectors are pivotally mounted on the cutting wheel in such a way that each deflector assumes an optimum debris deflection position throughout a major portion of each full revolution of the cutting wheel.

Another related object of the invention is to provide a tunneling machine of the character described wherein the debris deflectors undergo rotation with the cutting wheel through top and bottom dead-center positions at which the angular positions of the deflectors are reversed in such a way that each deflector receives an impact for breaking loose any debris which tends to adhere to the deflector.

Yet another related object to the invention is to provide a tunneling machine of the character described wherein the cutting wheel is axially movable relative to the machine frame between its forward cutting position to condition the machine for tunneling through relatively hard earth formations and a rear retracted cutting position closely adjacent the frame to condition the machine for tunneling through relatively soft earth formations, and wherein further the deflectors are removable from the cutting wheel to permit retraction of the wheel to its rear cutting position.

A further object of the invention is to provide a tunneling machine of the character described wherein the cutting wheel is equipped with removable breast boards for supporting the tunnel face, thus to prevent collapse of the face, and restricting flow of debris through the cutting wheel to the debris conveyor on the machine frame when tunneling through relatively soft earth formations.

Other objects, advantages, and features of the invention will become readily evident as the description proceeds.

With these and such other objects in view, the invention consists in the construction, arrangement, and combination of the various parts of the invention, whereby the objects contemplated are attained, as hereinafter set forth, pointed out in the appended claims, and illustrated in the accompanying drawings.

In these drawings:

FIGURE 1 is a perspective view of a tunneling machine having a rotary cutting wheel equipped with novel debris deflectors according to the invention;

FIGURE 2 is an enlarged perspective of one of the debris deflectors;

FIGURE 3 is an enlarged fragmentary perspective view illustrating the manner of attachment of the debris deflectors to the cutting wheel;

FIGURE 4 is an axial section through the tunneling machine illustrating the operation of the debris deflectors on the cutting wheel;

FIGURE 5 is a section taken on line **5—5** in FIGURE 4;

FIGURE 6 is a section taken on line **6—6** in FIGURE 4;

FIGURE 7 is a section similar to FIGURE 4 with the debris deflectors removed from the cutting wheel and showing the wheel retracted to its rear cutting position and mounting the removable breast boards of the invention for conditioning the tunneling machine for tunneling through relatively soft earth formations;

FIGURE 8 is a front end view of the tunneling machine in FIGURE 7;

FIGURE 9 is an enlarged fragmentary section through the cutting wheel of the present tunneling machine illustrating the manner in which the debris deflectors of the invention, when installed on the cutting wheel, reverse their positions during rotation with the wheel through top and bottom dead-center positions; and

FIGURE 10 is a perspective view of one of the removable breast boards which are installed in the tunneling machine in FIGURES 7 and 8.

In general terms, the tunneling machine **20** of the invention which has been selected for illustration in these drawings comprises a frame **22** and a rotary cutting wheel **24** at the front end of the frame. Frame **22** includes an inner supporting frame structure **26** and an outer cylindrical shell **28** surrounding the frame structure. Mounted on the frame structure **26** are drive means **30** for driving the cutter in rotation on the central axis of the shell **28**. As mentioned earlier and hereinafter explained in greater detail, the rotary cutting wheel **24** is movable axially of the frame **22** between a forward extended cutting position, illustrated in FIGURE 4, and a rear retracted cutting position, illustrated in FIGURE 7. In its forward cutting position, the cutting wheel projects a distance forwardly of the front end of the frame shell **28**, as shown in FIGURE 4. As shown in FIGURE 7, in its rear cutting position, the cutting wheel is retracted substantially completely within the front end of the shell. Operatively connected between the machine frame **22** and the cutting wheel **24** are means **32** for driving the cutting wheel axially between its forward and rear cutting positions.

Mounted on the front cutting face of the rotary cutting wheel **24** are a number of face cutters **34**. These cutters are conventional and are mounted in the usual way for effecting a cutting action against the tunnel face during rotation of the cutting wheel in the clockwise direction, as viewed in FIGURE 1. As will appear presently, the face cutters **34** are utilized when tunneling through both hard and soft earth formation. About the perimeter of the cutting wheel **24** are a number of guage cutters **36**. As mentioned earlier, and hereinafter explained in greater detail, guage cutters **36** are removably attached to the cutting wheel and are employed only when cutting through relatively hard earth formations.

Extending axially through the cutting wheel **24** are a number of openings **38** through which the debris produced by cutting operation of the wheel may pass from the front side of the wheel to the rear side of the wheel. Mounted on the supporting frame structure **26** of the tunneling machine frame **22**, within the frame shell **28**, is a conveyor **40**. During operation of the tunneling machine **20**, this conveyor receives debris D from the cutting wheel **24** through a pair of debris entrance openings **42** in the front

end of the frame **22** and conveys the debris to the rear end of the frame. The debris discharges from the rear end of the conveyor **40** onto a second conveyor **44** which then carries the debris to a waiting hopper car (not shown) in which the debris is transported from the tunnel.

Rigidly mounted on the inner frame structure **26** of the machine frame **22**, within the frame shell **28**, are means **46** for driving or propelling the tunneling machine forwardly to urge or feed the cutting wheel **24** against the tunnel face. Feed means **46** comprise a number of hydraulic actuators or push rams **48** extending axially of and circumferentially spaced about the interior of the frame shell. Each push ram has a cylinder **50** rigidly attached to the frame structure **26** and a ram rod **52** extending rearwardly from the cylinder. Mounted on the rear end of each ram rod is a segmental thrust shoe **54**. These thrust shoes are engageable with the leading end of the tunnel liner **56**, successive sections of which are installed within the rear tail shield **28***a* of the frame shell **28** as the tunneling machine advances. An erector means **57** is mounted at the rear end of the machine to aid installation of these liner sections. Associated with the hydraulic push rams **48** is a hydraulic system (not shown) for pressurizing the ram cylinders **50** to selectively extend and retract the ram rods **52**. As is well understood in the art, the rams are periodically extended to drive or propel the tunneling machine forwardly in a cutting stroke, during which the cutting wheel **24** is fed against the tunnel face to affect a cutting action. The rams are then retracted, a new liner section is added, and the rams are again extended to drive the machine forwardly in a cutting stroke.

Welded to the outer surface of the frame shell **28**, at the front end of the shell, is a hardened metal band **58**. This band extends about the upper half of the frame shell between positions slightly below the level of the tunnel spring line. The front edge of the shell and band are beveled or sharpened, as shown best in FIGURE 4, to define an earth shearing edge **60** about the front end of the shell.

During operation of the tunneling machine, the cutting effort exerted by the cutting wheel **24** on the tunnel face produces a reaction torque on the machine frame **22** which tends to rotate the frame on its longitudinal axis. Rotation of the frame under the thrust of this reaction torque is prevented by torque fins **62**. These torque fins are hydraulically extended against or into the tunnel wall to restrain the frame against rotation, in the well known way. Mounted within the frame shell **28** are hydraulic thrust units **64** having thrust shoes which may be selectively extended into and retracted from thrusting engagement with the wall of the tunnel to effectively steer the tunneling machine as the latter progresses through the earth formation.

The tunneling machine **20**, as it is thus far described, is conventional. Briefly, in operation of the machine, the cutting wheel **24** is extended to its forward cutting position of FIGURE 4 or retracted to its rear cutting position of FIGURE 7, and the gauge cutters **36** are installed on or removed from the wheel, depending on the nature of the earth formation at the tunnel face, i.e., depending upon whether the formation is hard or soft. In either case, the hydraulic push rams **52** are alternately extended to drive the tunneling machine forwardly in a cutting stroke and retracted to permit installation of a new tunnel liner section **56**. During each cutting stroke, the cutting wheel **24** is driven in rotation by the cutting wheel drive means **30** and is fed forwardly against the tunnel face. When tunneling through hard formations with the cutting wheel in its forward cutting position, the face cutters **34** on the wheel cut the tunnel face and the gauge cutters **36** cut the tunnel wall. When tunneling through soft formations with the cutting wheel in its rear cutting position, the face cutters **34** again cut the tunnel face, while the tunnel wall is sheared by the front earth shearing edge **58** on the frame shell **28**. The debris D removed by the cutting wheel passes rearwardly through the cutting wheel openings **38** and the front debris entrance openings **42** in the machine frame **22** to the conveyor **40**. The debris is then carried rearwardly by the conveyor **40** to the conveyor **44** which discharges the debris into a waiting dump car (not shown), or the like, situated behind the machine.

In a typical tunneling machine of the kind under discussion, the front debris entrance openings **42** are formed in a transverse bulkhead **66** which is welded or otherwise rigidly fixed to the front end of the inner machine frame structure **26**, within and a distance rearwardly of the front end of the frame shell **28**. It should be noted here that the illustrated machine has two debris entrance openings which are located at opposite sides of the shaft of the cutting wheel **24**. Within the frame shell **28**, directly behind these openings, are inclined chutes or ramps **68** (FIGURE 6) for receiving the debris entering through the openings and conveying the debris to the conveyor **40** which is situated between the inner lower ends of the ramps. Other tunneling machines of this general type have a single debris entrance opening in the bulkhead **66** which is located directly below the cutting wheel shaft, a distance above the bottom of the frame shell **28**.

As noted earlier, the existing tunneling machines of this kind have an inherent deficiency which the present invention shares. Thus, when the cutting wheel **24** is extended to its forward cutting position of FIGURE 4, a relatively wide gap **70** exists between the rear side or face of the cutting wheel and the frame bulkhead **66**. Much of the debris D removed by the cutting wheel during each forward cutting stroke of the machine drops to the bottom of this gap after passing rearwardly through the cutting wheel openings **38**. The rotating cutting wheel continuously raises the debris from the bottom of the gap to the debris entrance openings **42**. However, the bottom of the gap remains constantly filled with a large amount of debris. This method of debris disposal is quite unsatisfactory for the reasons mentioned earlier.

According to the present invention, the cutting wheel **24** is provided with debris deflectors or baffles **72** for deflecting or conveying, across the gap **70** directly into the front debris entrance openings **42** of the machine, a major portion of the debris D removed by the cutting wheel. These deflectors, which constitute the major contribution of the present invention, appreciably enhance the operating efficiency of the tunneling machine and effect a reduction of the drag force or torque imposed on the cutting wheel by the debris that does collect in the gap **70**. As shown in the drawings, cutting wheel **24** comprises a hub **74**, a cylindrical band-like rim **76**, and a number of uniformly angularly spaced spokes **78** which extend radially between and are rigidly joined at their ends to the hub and rim. Each spoke has a generally triangular shape in transverse cross section, as may be best observed in FIGURE 4, and comprises a front wall **80** parallel to the plane of the wheel and rearwardly convergent side walls **82** which are joined along their rear edges. The present debris deflectors **72** are attached to the rear apex edges of the cutting wheel spokes **78**, respectively, and extend rearwardly from the cutting wheel **24**, across the gap **70**, to positions closely adjacent the front frame bulkhead **66**.

Referring to FIGURES 2 and 3, it will be observed that each deflector **72** comprises a generally rectangular baffle plate **84** having notches **86** cut in one longitudinal edge thereof. Welded or otherwise securely fixed to the plate within and at one end of the notches **86**, respectively, are coaxial bearing sleeves **88**. A corresponding number of bearing sleeves **90** are welded or otherwise rigidly joined to the rear edge of each cutting wheel spoke **78**. The bearing sleeves on each wheel spoke and the bearing sleeves on the respective deflector baffle plate are axially spaced to mate coaxially in the manner illustrated in broken lines in FIGURE 3. Each baffle plate is releasably pivotally secured to its respective cutting wheel spoke by removable hinge pins **92**. It is evident at this point, there-

fore, that the present debris deflectors **72** are removably mounted on the cutting wheel **24**. It is further evident that each deflector is swingable relative to the cutting wheel about a pivot axis located along the front longitudinal edge of the respective baffle plate **84** and extending radially of the cutting wheel along the rear edge of the corresponding wheel spoke **78**. The debris deflectors are substantially coextensive with their respective cutting wheel spokes.

Welded to opposite sides of each deflector baffle plate **84**, intermediate the ends of the plate, are flanges **94** which serve the dual function of gussets and limit stops. To these ends, the flanges **94** extend laterally across the baffle plates so as to reinforce these plates against bowing, and the flanges have front edges **96** disposed for seating engagement with the inclined side faces of the adjacent cutting wheel spokes **78** to limit swinging movement of the plates relative to the cutting wheel. With regard to this latter function of the flanges **94**, attention is directed to FIGURE 9, wherein it will be observed that the flanges **94** on each baffle plate **84** limit swinging movement of the plate relative to its respective cutting wheel spoke **78** between a first (full line) position, wherein the plate is disposed in generally coplanar relation to one inclined side face of the spoke, and a second (broken line) position, wherein the plate is disposed in generally coplanar relation to the opposite inclined face of the spoke.

The debris deflectors **72** are mounted on the cutting wheel **24** only during operation of the tunneling machine **20** with the cutting wheel in its forward cutting position of FIGURE 4. The deflectors, when thus installed, extend across the gap **70** between the cutting wheel and the front frame bulkhead **66** in the manner illustrated. It is evident that during operation of the tunneling machine in this latter mode, each deflector **72** alternately undergoes upward rotation with the cutting wheel from a bottom dead-center position to a top dead-center position during one-half of each revolution of the wheel and subsequent downward rotation with the cutting wheel from the top dead-center position to the bottom dead-center position during the other half of each revolution. It is further evident that during each upward travel of each deflector, the latter is retained in one of its limiting positions of FIGURE 9 relative to the cutting wheel and during each downward travel of the deflector, the latter is retained in its other limiting position relative to the wheel, in such a way that each deflector baffle plate **84** is disposed in generally coplanar relation with the currently uppermost inclined face of its respective cutting wheel spoke **78** through virtually each full revolution of the cutting wheel. As a consequence, in any given angular position of the cutting wheel, some or all of the debris deflectors **72** currently located at either side of a vertical plane containing the rotation axis of the wheel, and the currently upper faces of the corresponding cutting wheel spokes **78**, slope downwardly toward the frame bulkhead **66** and are thus effective to convey the debris D entering through the adjacent cutting wheel openings **38** across the gap **70** between the wheel and the bulkhead into the debris entrance openings **42** in the bulkhead, in the manner shown in FIGURE 4. The quantity of debris which drops to the bottom of the gap is thus greatly reduced and the operating efficiency of the machine is correspondingly increased.

A unique feature of the present debris deflectors **72** resides in the fact that as each deflector rotates through each of its top and bottom dead-center positions with the cutting wheel **24**, the deflector abruptly swings or flips from its current limiting position to the other limiting position in such a way that the deflector receives a jar or impact. These periodic impacts on the deflectors knock loose any debris which tends to adhere to the deflectors or their adjacent cutting wheel spokes **78**, thereby preventing debris from collecting on the deflectors and spokes.

As noted earlier, the gauge cutters **36** are removed and the cutting wheel **24** is retracted to its rear cutting position of FIGURE 7 when tunneling through relatively soft formations. In this latter position of the cutting wheel its rear side or face is situated in close proximity to the front frame bulkhead **66** so that the debris deflectors **72** are unnecessary. Accordingly, deflectors are removed from the cutting wheel prior to retraction of the wheel. It will be recalled that the deflectors are released for removal from the cutting wheel by extracting the deflector hinge pins **92**. During operation of the tunneling machine with the cutting wheel in its rear cutting position, the currently upper inclined faces of the wheel spokes **78** convey the debris D into the debris entrance openings **42** in the frame bulkhead **66**.

It was mentioned earlier that some earth formations, notably sand and mud, are so soft or fluid that the tunnel face tends to collapse through the openings **38** in the cutting wheel **24**. The inrush of debris caused by such collapse would either overload the conveyor **40** or engulf the entire interior of the tunneling machine. According to a further feature of the present invention, collapse of the tunnel face when tunneling through such soft earth formations is prevented by mounting sector-shaped bulkheads or breast boards **98** on the cutting wheel **24**, within its debris entrance openings **38**, in the manner shown in FIGURE 8. To this end, the cutting wheel spokes **78** are provided with apertured lugs **100** and the breast boards **98** are provided with openings **102** to receive mounting bolts for removably attaching the breast boards to the spokes. The breast boards **98**, when installed on the cutting wheel **24**, are located in the plane of the wheel and restrict the wheel openings **38** to relatively narrow radial slits **38a** (FIGURE 8). These slits restrict the flow of debris to the cutting wheel sufficiently to permit proper disposal of the debris. The breast boards themselves, of course, provide increased support for the tunnel face to resist its collapse.

It is now obvious, therefore, that the invention herein described and illustrated is fully capable of attaining the several objects and advantages preliminarily set forth.

The invention has been described in considerable detail in order to comply with the patent laws by providing a full public disclosure of at least one of its forms. However, such detailed description is not intended in any way to limit the broad features or principles of the invention, or the scope of patent monopoly to be granted.

Having described the invention, what is claimed as new in support of Letters Patent is:

1. A tunneling machine comprising:

a frame having front and rear ends,

a rotary cutter mounted on the front end of said frame having openings through which debris removed by said cutter passes from the front side to the rear side of said cutter,

a conveyor on said frame for transporting said debris from the front end to the rear end of said frame,

said frame including a front transverse bulkhead behind said cutter having a debris entrance opening through which said debris passes from said cutter to said conveyor,

the rear side of said cutter being spaced forwardly from said bulkhead, whereby a gap exists between the rear side of said cutter and said bulkhead,

deflectors mounted on said cutter and extending rearwardly from said cutter across said gap for conveying debris entering through said cutter openings across said gap into said debris entrance opening,

said frame including an outer generally cylindrical shell having a front end defining an earth shearing edge disposed forwardly of said bulkhead,

said cutter being mounted on said frame for axial movement relative to said frame between a forward cutting position, wherein said cutter projects forwardly of said shearing edge and said gap exists between said bulkhead and the rear side of said cutter, and a rear cutting position, wherein said cutter is retracted into

the front end of said shell and the rear side of said cutter is located in close proximity to said bulkhead,

means removably mounting said deflectors on said cutter, whereby said deflectors may be removed from said cutter to permit retraction of said cutter to its rear cutting position, and

gauge cutters removably mounted about the perimeter of said cutter for providing said cutter with a cutting radius at least equal to the cutting radius of said shearing edge when said cutter occupies its forward cutting position, said gauge cutters being removable from said cutter to permit reaction of said cutter to its rear cutting position.

2. A tunneling machine comprising:

a frame having front and rear ends,

a rotary cutter mounted on the front end of said frame having openings through which debris removed by said cutter passes from the front side to the rear side of said cutter,

a conveyor on said frame for transporting said debris from the front end to the rear end of said frame,

said frame including a front transverse bulkhead behind said cutter having a debris entrance opening through which said debris passes from said cutter to said conveyor,

the rear side of said cutter being spaced forwardly from said bulkhead, whereby a gap exists between the rear side of said cutter and said bulkhead,

deflectors mounted on said cutter and extending rearwardly from said cutter across said gap for conveying debris entering through said cutter openings across said gap into said debris entrance opening,

said deflectors comprising generally flat baffle plates extending radially of said cutter along the edges of said cutter openings, respectively, and pivotally mounted along their forward edges on said cutter for swinging of each baffle plate about a radial axis of said cutter, whereby each baffle plate undergoes upward rotation with said cutter and is urged downwardly in one direction about its pivot axis during one-half of each revolution of said cutter and each baffle plate undergoes downward rotation of said cutter and is urged downwardly in the opposite direction about its pivot axis during the other half of each cutter revolution, and

coacting stop means on said cutter and each baffle plate for limiting swinging movement of the respective plate relative to said cutter between a first limiting position, wherein the respective baffle plate slopes downwardly in the direction of said bulkhead during its upward travel with said cutter, and a second limiting position, where in the respective plate slopes downwardly in the direction of said bulkhead during its downward travel with said cutter.

3. A tunneling machine according to claim 2 wherein:

said cutter comprises radial spokes defining therebetween said cutter openings, and

said baffle plates are pivotally mounted along the rear sides of said cutter spokes, respectively.

4. A tunneling machine according to claim 3 wherein:

each said cutter spoke has rearwardly convergent side faces, and

each said baffle plate is disposed in generally coplanar relation with one face of the adjacent cutter spoke in one limiting position of the respective baffle plate and in generally coplanar relation with the other face of the adjacent spoke in the other limiting position of the respective baffle plate.

5. A tunneling machine comprising:

a frame having front and rear ends,

a rotary cutter mounted on the front end of said frame having openings through which debris removed by said cutter passes from the front side to the rear side of said cutter,

a conveyor on said frame for transporting said debris from the front end to the rear end of said frame,

said frame including a front transverse bulkhead behind said cutter having a debris entrance opening through which said debris passes from said cutter to said conveyor,

the rear side of said cutter being spaced forwardly from said bulkhead, whereby a gap exists between the rear side of said cutter and said bulkhead,

deflectors mounted on said cutter and extending rearwardly from said cutter across said gap for conveying debris entering through said cutter openings across said gap into said debris entrance opening,

said frame including an outer generally cylindrical shell having a front end defining an earth shearing edge about said shell and disposed forwardly of said bulkhead,

said cutter being mounted on said frame for axial movement relative to said frame between a forward cutting position, wherein said cutter projects forwardly of said shearing edge and said gap exists between said bulkhead and the rear side of said cutter, and a rear cutting position, wherein said cutter is retracted into the front end of said shell and the rear side of said cutter is disposed in close proximity to said bulkhead,

said cutter comprising a cutting wheel having radial spokes defining therebetween said cutter openings,

said deflectors extending lengthwise of and are substantially coextensive with said spokes,

means removably mounting said deflectors on their respective adjacent spokes, thereby to permit removal of said spokes from said cutter for retraction of said cutter to its rear cutting position, and

gauge cutters removably mounted about the perimeter of said cutter for providing said cutter with a cutting radius at least equal to the cutting radius of said shearing edge when said cutter occupies its forward cutting position, said gauge cutters being removable from said cutter to permit retraction of said cutter to its rear cutting position.

6. A tunneling machine according to claim 5 wherein:

each said deflector comprises a generally flat baffle plate disposed rearwardly of and generally coextensive with the adjacent cutter spoke, whereby each baffle plate undergoes upward rotation with said cutter during one-half of each cutter revolution and downward rotation with said cutter during the other half of each cutter revolution,

said deflector mounting means comprise hinge means pivotally mounting each baffle plate on the adjacent cutter spoke for swinging about a pivot axis extending lengthwise of the adjacent spoke, whereby each baffle plate is urged downwardly in one direction about its pivot axis during upward travel with said cutter and in the opposite direction about its pivot axis during downward travel with said cutter, and

coacting stop means on each baffle plate and the adjacent cutter spoke for limiting swinging movement of the respective baffle plate relative to said cutter between a first limiting position, wherein the respective baffle plate slopes downwardly in the direction of said bulkhead during upward travel with said cutter, and a second limiting position, wherein the respective baffle plate slopes downwardly in the direction of said bulkhead during downward travel with said cutter.

7. A tunneling machine according to claim 6 wherein:

each said cutter spoke has rearwardly convergent side faces,

one side face of each spoke is uppermost during one-half of each revolution of said cutter and the other side face of each spoke is uppermost during the other half of each cutter revolution, and

each said baffle plate is disposed in co-planar relation

with the currently uppermost face of the adjacent cutter spoke during upward travel of the respective baffle plate of said cutter and each baffle plate is disposed in generally coplanar relation with the currently uppermost face of the adjacent cutter spoke during downward travel of the respective baffle plate with said cutter.

8. A tunneling machine according to claim 7 wherein:

said coacting means comprise flanges welded to opposite sides of said baffle plates, respectively, for reinforcing said baffle plates, and

said flanges on each baffle plate have edges disposed for seating engagement with said faces of the adjacent cutter spoke for limiting swinging movement of the respective baffle plate relative to said cutter.

9. In a rotary tunneling machine, the combination comprising:

a rotary cutting wheel including a hub, a plurality of spokes having their inner ends rigidly secured to said hub and extending radially outwardly therefrom, and a cylindrical rim rigidly secured to the outer ends of said spokes, said spokes having a substantial width in a direction perpendicular to the plane of said wheel whereby they provide a sweeping action for pushing debris upward from the bottom of the cut as said wheel advances into the tunnel face,

a plurality of elongated baffle plates disposed behind respective ones of said spokes to provide rearward extensions thereof,

means pivotally securing the forward edge of each of said baffle plates to the rearward edge of the corresponding spoke,

and stop means associated with each of said baffle plates and cooperating with said baffle plate and its associated spoke so that said baffle plate may pivot between two limit positions,

the operation during rotation of said rotary cutting wheel being such that when a particular spoke is moving upward its associated baffle plate is inclined downwardly in one of its limit positions, and when the particular spoke is moving downwardly its associated baffle plate is inclined downwardly in its other limit position.

10. The combination claimed in claim 9 wherein the outer end of each of said baffle plates is coextensive with the outer end of its associated cutting wheel spoke, whereby the spoke end and the baffle plate end together sweep debris in an upwardly direction from the lower portion of the tunnel.

11. The combination claimed in claim 9 wherein each said cutter spoke has rearwardly convergent side faces, one side face of each spoke being uppermost during one half of each revolution of said cutting wheel and the other side face of each spoke being uppermost during the other half of each revolution of said cutting wheel, said stop means providing limit positions such that each said baffle plate is disposed in substantially coplanar relationship with the currently uppermost face of its associated spoke.

12. The combination claimed in claim 9 wherein said stop means comprises a pair of flanges welded to respective sides of each said baffle plate, said flanges being adapted to seat against the respectively associated faces of the associated cutting wheel spoke.

13. The combination claimed in claim 9 wherein said baffle plates are removably secured to said spokes.

14. In a rotary tunneling machine, the combination comprising:

a frame having front and rear ends,

a rotary cutting wheel at the front end of said frame,

a shearing edge on the front end of said frame extending concentrically about said cutting wheel,

means supporting said cutting wheel on said frame for

rotation on the axis of said wheel and adjustment along said axis between a rear cutting position wherein said shearing edge projects forwardly of said cutting wheel to shear the tunnel wall and a forward cutting position wherein said cutting wheel projects forwardly of said shearing edge,

gauge cutters releasably secured to said cutting wheel about the perimeter thereof to cut the tunnel wall in advance of said shearing edge when said wheel occupies said forward cutting position,

a conveyor on said frame behind said cutting wheel for receiving debris removed by said wheel as the latter advances into the tunnel face,

said cutting wheel including radial spokes having a substantial width in a direction perpendicular to the plane of said wheel for sweeping debris upwardly from the bottom of the cut and deflecting debris rearwardly toward said conveyor,

baffle plates to be disposed in operative positions along the rear sides of said spokes, respectively, wherein said plates project rearwardly from said spokes to provide rearward extensions thereof for sweeping debris upwardly from the bottom of said cut and deflecting debris rearwardly from said spokes toward said conveyor when said cutting wheel occupies said forward cutting position, and

means for releasably securing said baffle plates to their respective spokes to permit retraction of said cutting wheel to its rear cutting position.

15. In a rotary tunneling machine, the combination comprising:

a rotary cutting wheel including a number of radial spokes having a substantial width in a direction perpendicular to the plane of said wheel for sweeping debris upwardly from the bottom of the cut and deflecting debris rearwardly to the rear side of said wheel as said wheel advances into the tunnel face,

baffle plates disposed in operative positions along the rear sides of said spokes, respectively, wherein said plates project rearwardly of said spokes to provide rearward extensions thereof for sweeping debris upwardly from the bottom of said cut and deflecting debris rearwardly from said spokes, and

means releasably securing said plates to their respective spokes.

16. In a rotary tunneling machine, the combination comprising:

a rotary cutting wheel including a number of radial spokes defining intervening generally sector-shaped openings for passing debris through said wheel as the latter advances into the tunnel face,

generally sector-shaped breast boards disposed within said openings, respectively, and having a circumferential dimension less than the circumferential dimension of their respective openings, and

means releasably securing said breast boards to said cutting wheel in such manner that said breast boards restrict said openings to condition said cutting wheel for cutting through relatively soft earth formations and said breast boards are removable to condition said cutting wheel for cutting through relatively hard earth formations.

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