Dec. 6, 1966 R. O. BREDTHAUER 3,290,095

MINING MACHINE WITH PIVOTALLY MOUNTED AND OPPOSED ELONGATED CUTTERS

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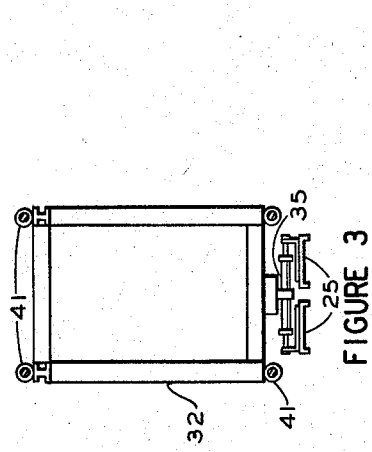


FIGURE 3

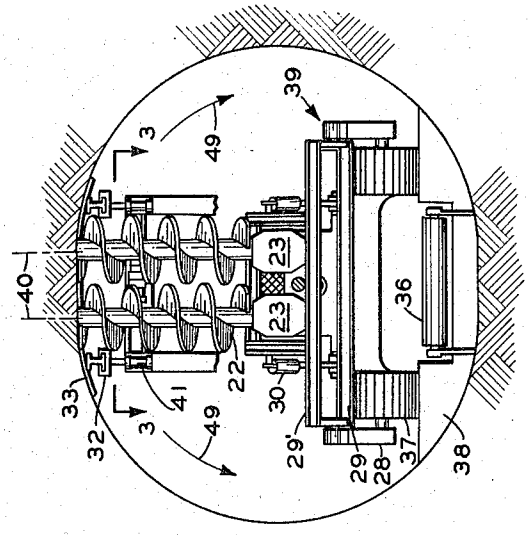


FIGURE 2

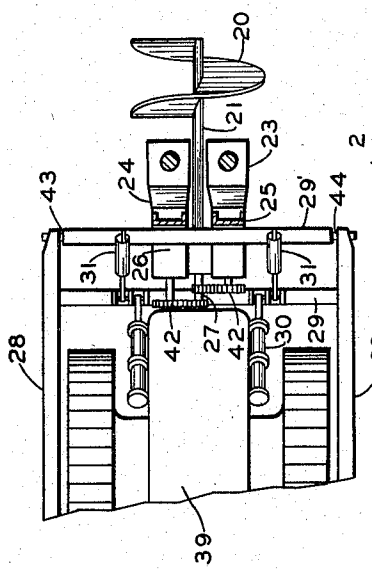


FIGURE 4

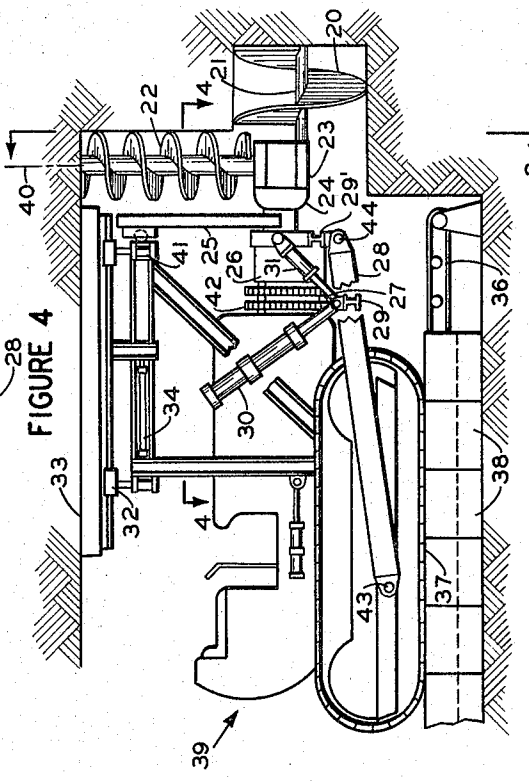


FIGURE 1

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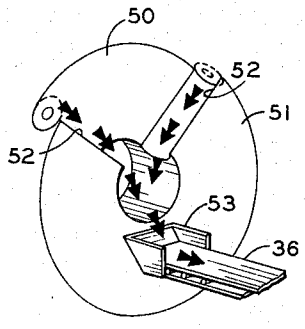


FIGURE 5-A

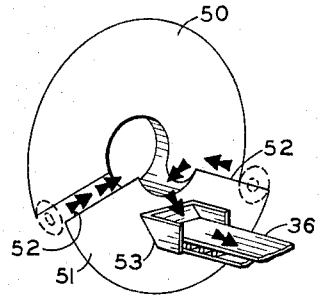


FIGURE 5-B

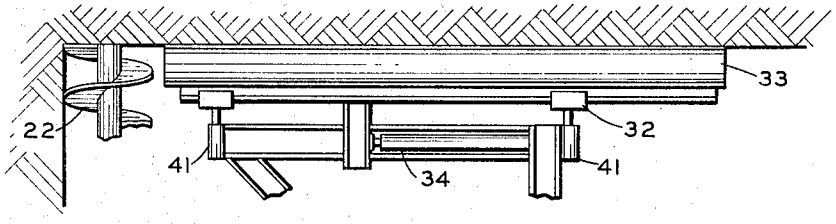


FIGURE 6-A

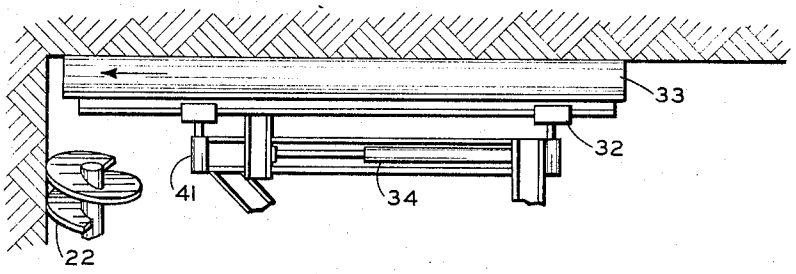


FIGURE 6-B

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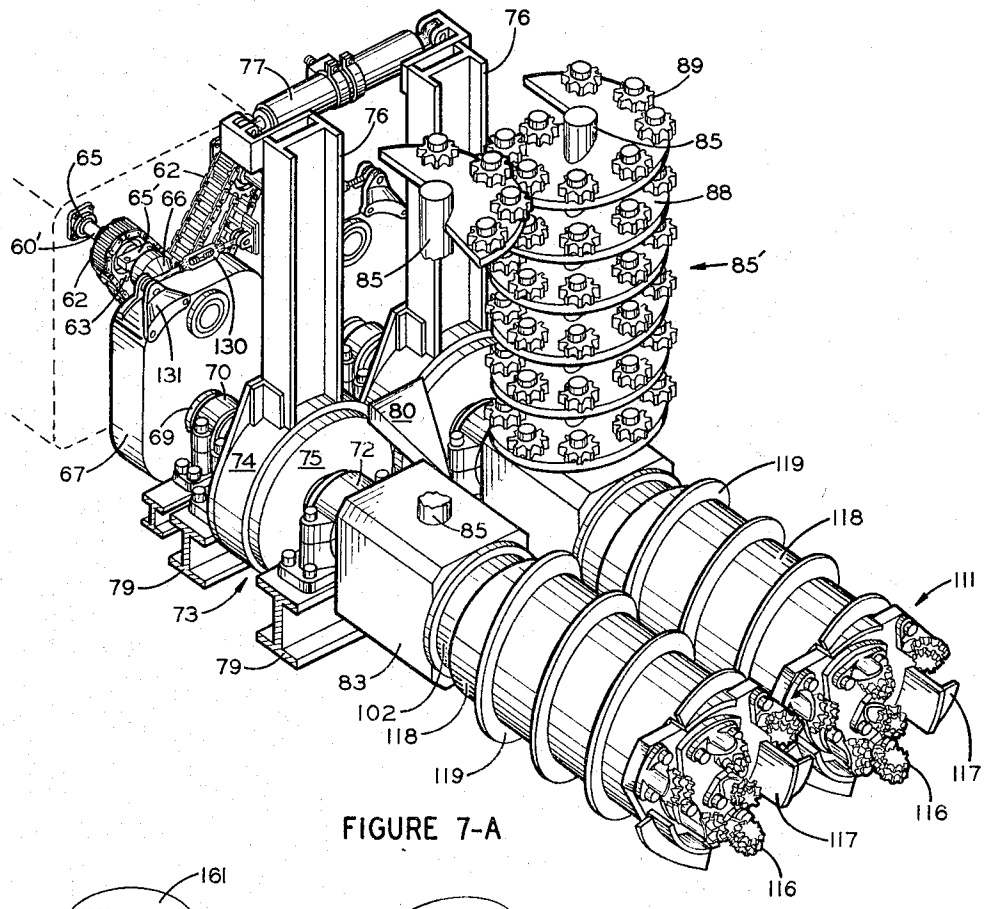


FIGURE 7-A

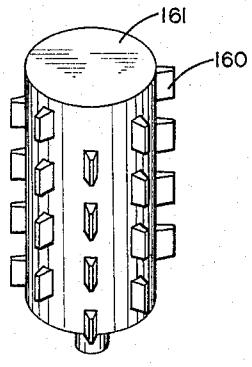


FIGURE 7-B

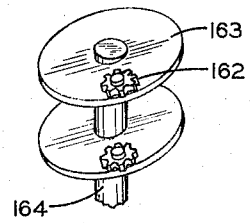


FIGURE 7-C

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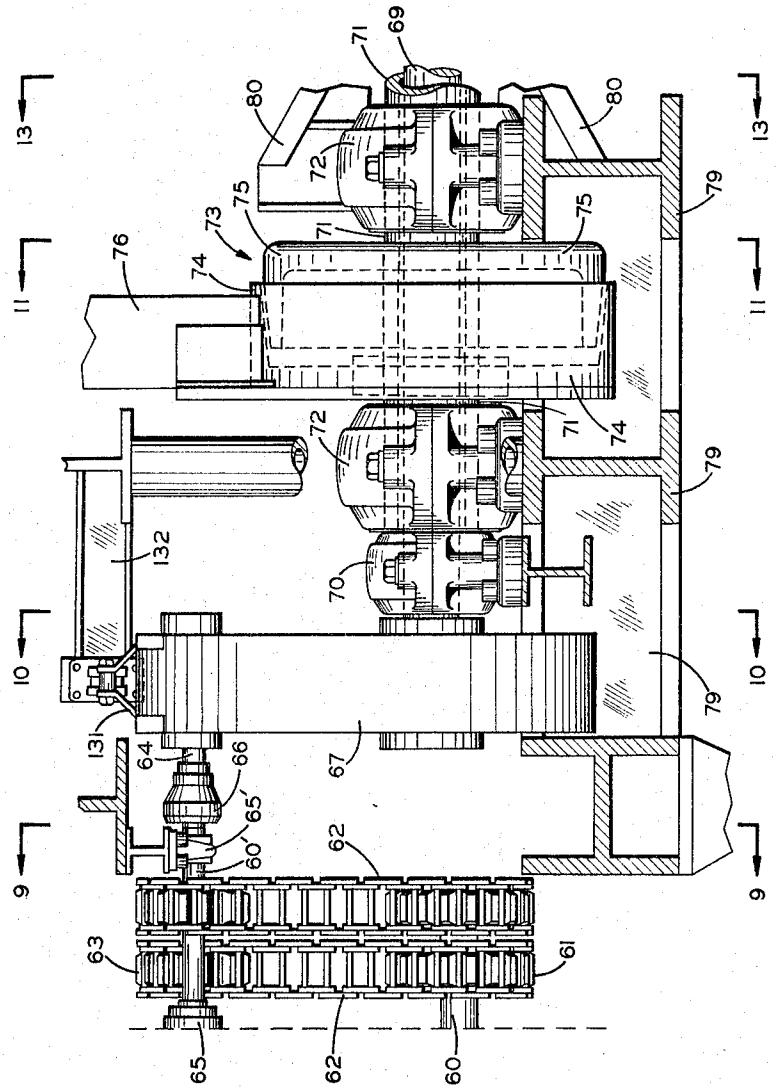


FIGURE 8-A

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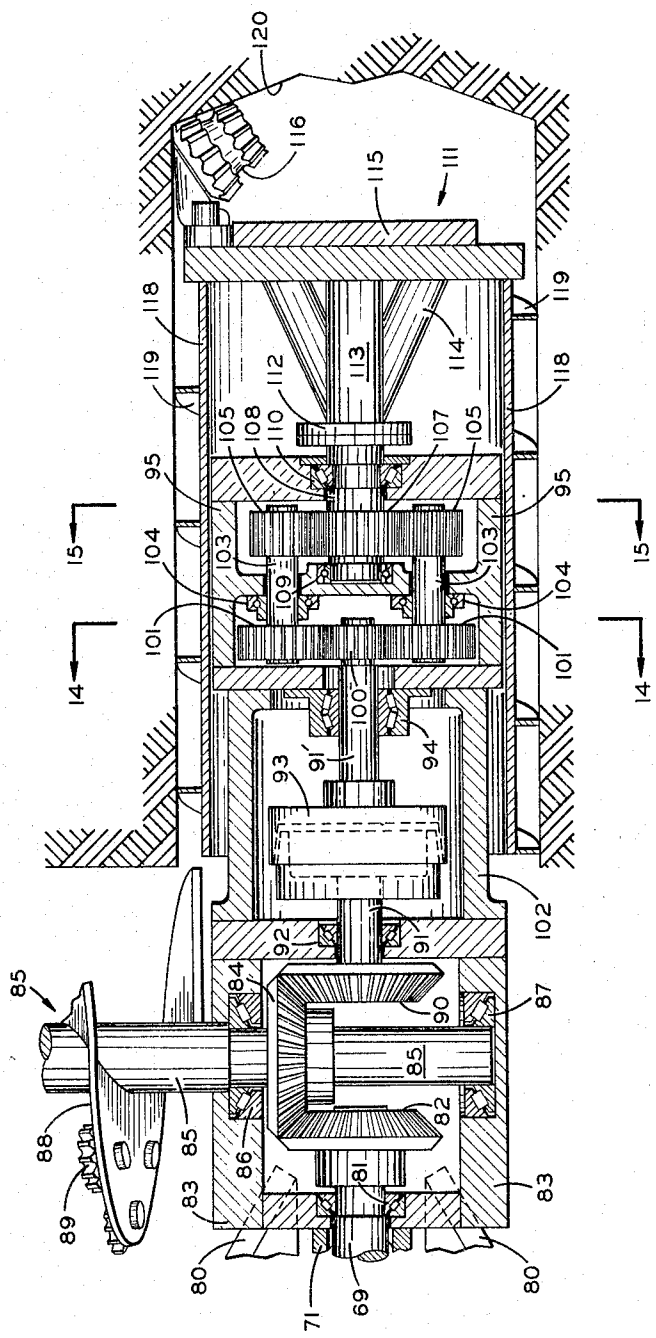


FIGURE 8-B

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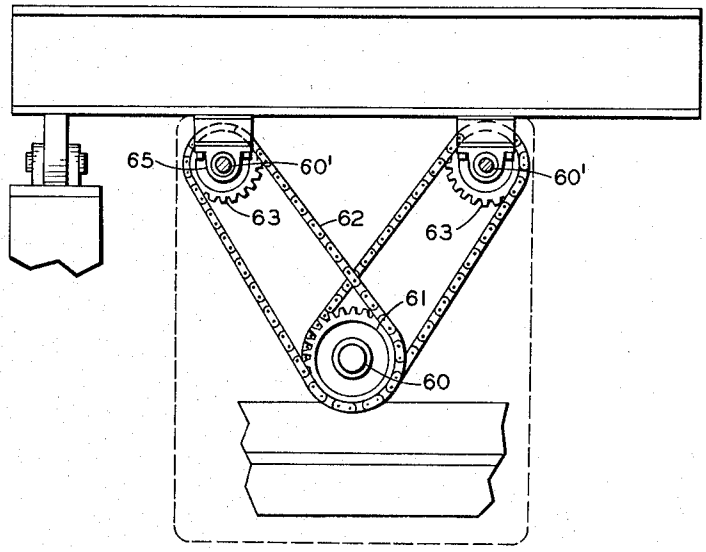


FIGURE 9

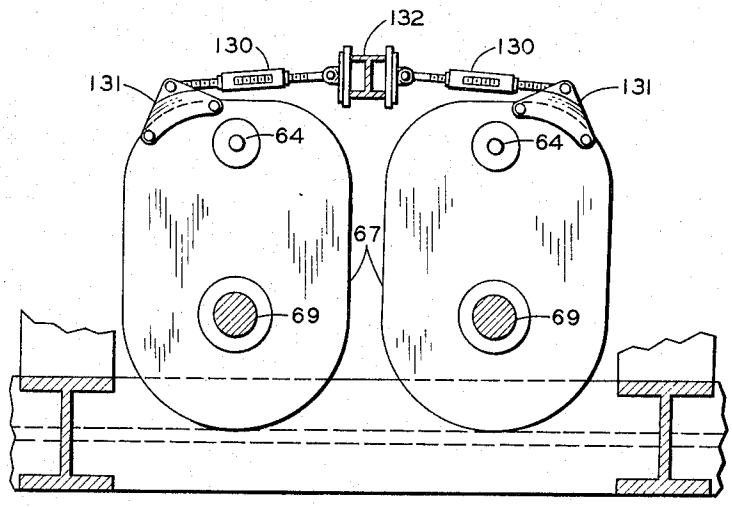


FIGURE 10

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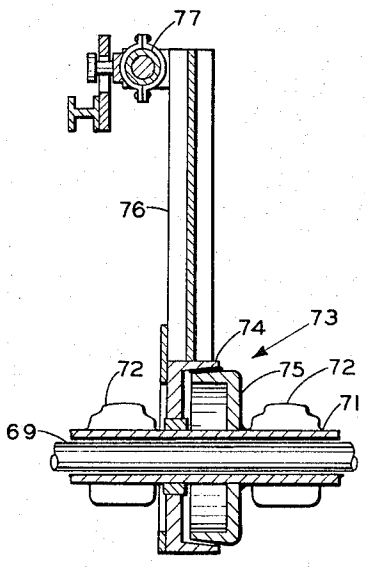


FIGURE 12

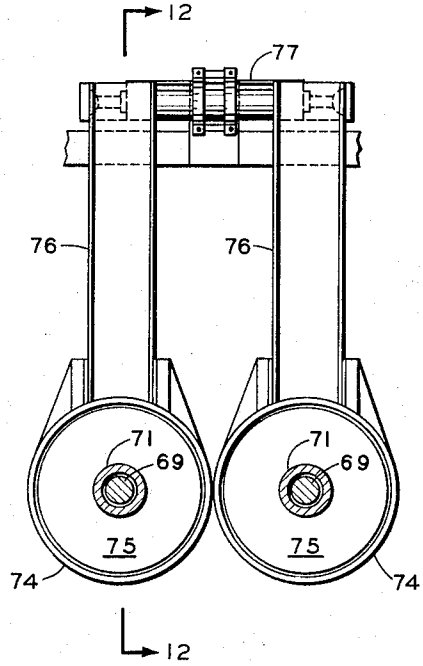


FIGURE 11

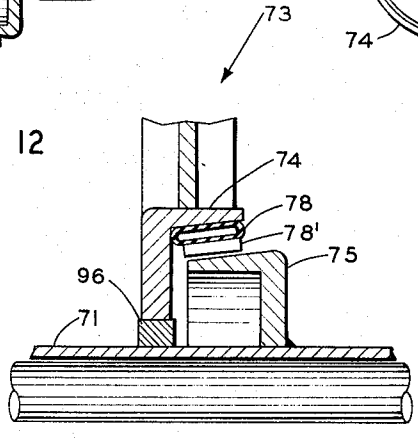


FIGURE 12-A

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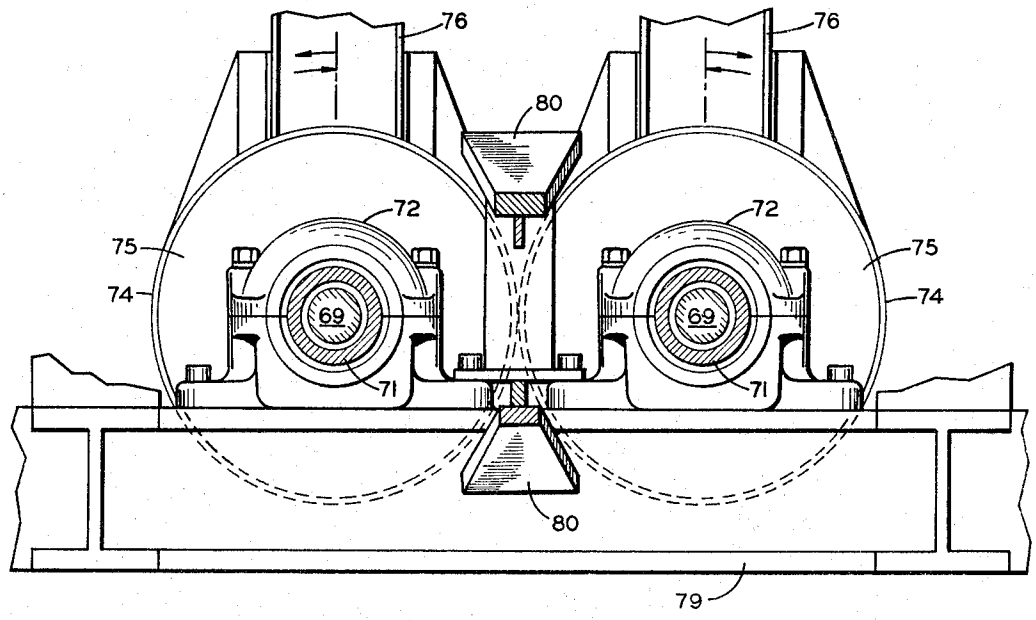


FIGURE 13

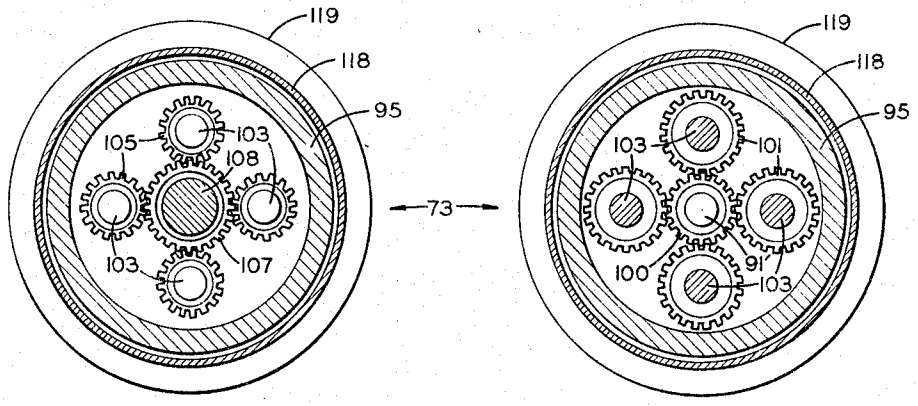


FIGURE 15

FIGURE 14

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MINING MACHINE WITH PIVOTALLY MOUNTED AND OPPOSED ELONGATED CUTTERS

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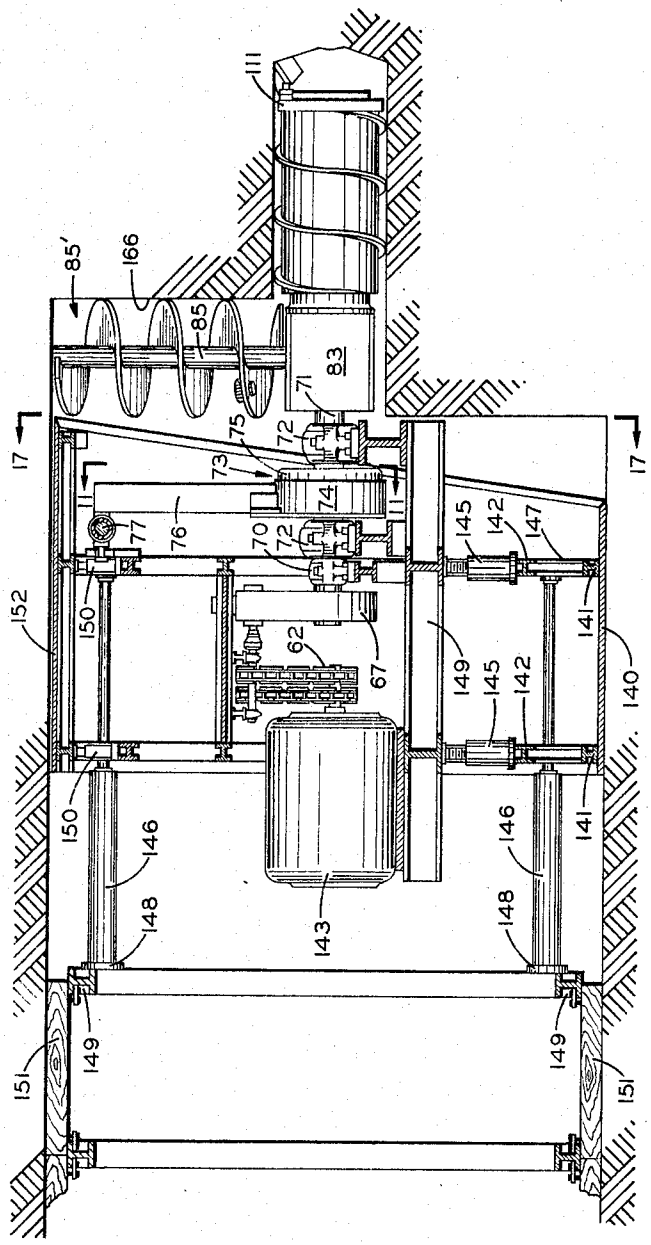


FIGURE 16

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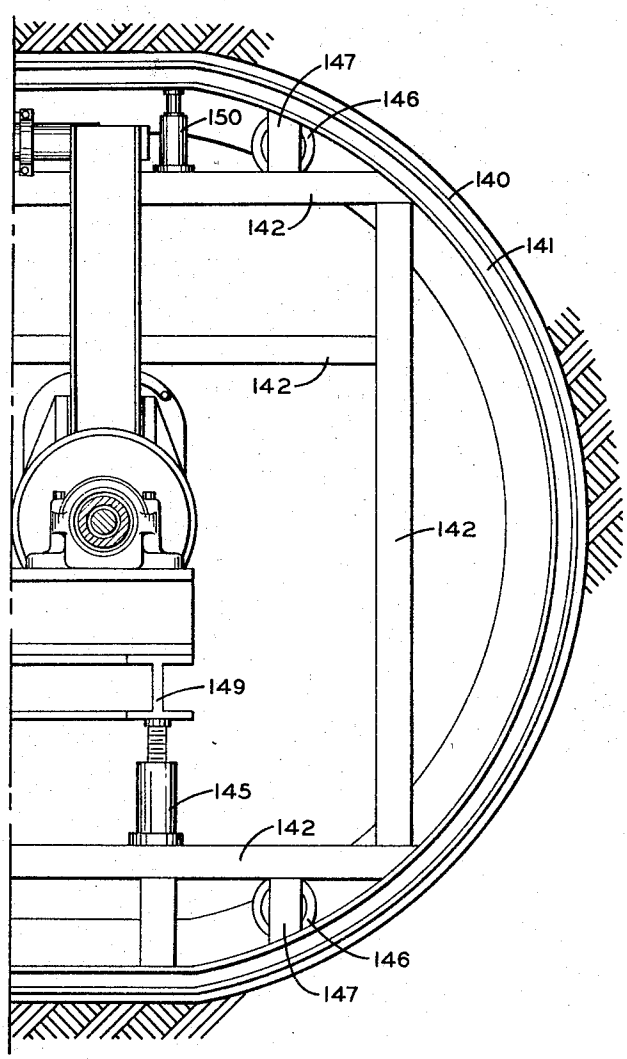


FIGURE 17

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United States Patent Office 3,290,095 Patented Dec. 6, 1966

3,290,095

MINING MACHINE WITH PIVOTALLY MOUNTED AND OPPOSED ELONGATED CUTTERS

Raymond O. Bredthauer, Houston, Tex., assignor to Hughes Tool Company, Houston, Tex., a corporation of Delaware

Filed May 28, 1964, Ser. No. 370,802
7 Claims. (Cl. 299—57)

This invention relates generally to mining or tunneling machines and more particularly concerns a machine having cutters which operate in a novel and advantageous manner.

Many prior art mining machines have the cutters arranged to frontally attack the tunnel face in a manner causing large longitudinal reactive forces to bear against the machine. To resist these forces and to prevent slippage between the machine and the tunnel floor, it is frequently necessary to insert wall jacks between the machine and the tunnel walls, floor and/or ceiling. Or it is sometimes necessary to use more complex apparatus and techniques to prevent slippage, which if not prevented can drastically decrease the drilling rate of the machine.

Other prior art machines use elongated cutters pivotally mounted to operate in a substantially horizontal plane. One example of this type machine may be seen in the U.S. Patent of Gonski et al., No. 3,121,558. While such machines have been successful to a large degree and represent valuable contributions to the earth boring art, they nonetheless have some of the disadvantages of other prior art machines. For example, large longitudinal reactive forces are imposed on such machines because of their mode of operation. Consider the fact, for illustration of this point, that the elongated cutters of such machines must be thrust longitudinally a large distance into the tunnel face before they are rotated pivotally. During the initial longitudinal thrust stage, large longitudinal reactive forces are imposed on the machine, as is common in other prior art machines. This is a disadvantage which limits the efficiency and thus the effectiveness of these machines.

It is an object of this invention to overcome to a large degree the disadvantage explained above of prior art machines. More specifically, it is an object of this invention to provide a tunneling or mining machine which reduces the longitudinal reactive forces imposed on the machine by using a novel cutting arrangement and mode of operation, which reduces the longitudinal thrust stage. Another object is to provide a machine having elongated cutters which move through the tunnel face in a direction substantially perpendicular to the tunnel and on a ledge formed therein by an initial longitudinal thrust of the cutters while simultaneously rotating them about their longitudinal axes. This results in a cutting motion which produces the majority of reactive forces in a substantially vertical plane, thus reducing the longitudinal reactive forces.

In accordance with the foregoing objects the invention may be broadly described as a tunneling or mining machine having frontally mounted elongated and opposed cutters which rotate pivotally in a substantially vertical plane and which simultaneously rotate about their longitudinal axes. After an initial thrust into the tunnel face, the pivotal rotation in a substantially vertical plane reduces significantly the longitudinal reactive forces imposed against the machine. When rotated pivotally in opposite directions, the transverse reactive forces on the machine are also reduced. To accomplish this result a strong and reliable mechanism is required to provide sufficient torque to rotate the elongated cutters pivotally. Similarly, a strong mechanism is required to rotate the cutters about their longitudinal axes.

The invention will be more readily understood with reference to the following detailed description and the accompanying drawing, in which:

FIGURE 1 is a partially schematic side elevational view showing the elongated cutters of the present invention frontally mounted on a commercially available tractor,

FIGURE 2 is a sectional end view of the invention as seen looking in the direction of the lines and arrows **2—2** of FIGURE 1, showing more clearly the initial disposition of the elongated cutters,

FIGURE 3 is a partial sectional view as seen looking along the lines and arrows **3—3** of FIGURE 2, showing a hydraulic cylinder and lever arms mechanism for pivotally moving the elongated cutters,

FIGURE 4 is a fragmentary sectional view taken as indicated by the lines and arrows **4—4** of FIGURE 1, showing a lower supporting framework and more details of the initial disposition of the elongated cutters and their driving mechanisms,

FIGURES 5–A and 5–B are perspective views of a tunnel face, illustrating in schematic form the paths the elongated cutters follow as they rotate pivotally, and the paths the cuttings from the tunnel face follow as they progress toward and through a horizontal conveyor,

FIGURES 6-A and 6–B show a roof support and its movable upper member which adds operational stability to the tunneling machine,

FIGURE 7–A is a perspective view of an embodiment of the present invention having two pilot bits, two elongated cutters in the form of augers, and mechanisms for rotating them pivotally and about their longitudinal axes,

FIGURES 7–B and 7–C show alternate embodiments of the elongated cutters, illustrating that the invention is not limited to cutters having the auger design of FIGURE 7–A,

FIGURES 8–A and 8–B are fragmentary sections taken longitudinally through one side of the FIGURE 7–A embodiment to show a preferred power train that may be used in practicing the invention,

FIGURE 9 is a sectional view as seen looking along the lines and arrows **9—9** of FIGURE 8–A. This figure shows the sprocket and chain drive which is attached to a tractor power take-off shaft to divide the power train into two components,

FIGURE 10 is a sectional view taken as looking along the lines and arrows **10—10** of FIGURE 8–A. This view shows the configuration of the shaft mounted speed reducers,

FIGURE 11 is a sectional view, taken as seen looking along the lines and arrows **11—11** of FIGURE 8–A, and this view shows the clutch mounted lever arms and the hydraulic cylinder disposed therebetween which cooperate to pivotally rotate the elongated cutters,

FIGURE 12 is a sectional view as seen looking along the lines and arrows **12—12** of FIGURE 11,

FIGURE 12–A is a fragmentary sectional view which shows in greater detail the clutch configuration of FIGURE 12,

FIGURE 13 is a sectional view taken as seen along the lines and arrows **13—13** of FIGURE 8–A, showing the disposition and configuration of the cusp breakers,

FIGURES 14 and 15 are sectional views as seen looking in the direction of the lines and arrows **14—14** and **15—15** of FIGURES 8–B. These views show the speed reduction unit which is adjacent to the pilot bit,

FIGURE 16 is another side elevational view, partly in section, which shows the invention mounted in a shield propulsion unit, and

FIGURE 17 is a sectional view as seen as looking in the direction of the lines and arrows **17—17** of FIGURE 16 to show in greater detail the configuration of the shield

and the disposition of the various mechanisms supported therein.

Referring to FIGURES 1 through 4 of the drawing to explain first the salient features of the invention, notice that there are three separate cutters frontally mounted on the tractor 39. The foremost cutter 20 is a pilot bit which rotates about shaft 21. In addition to pilot bit 20 there are a pair of elongated cutters 22 which rotate about their longitudinal axes 40 and which also rotate pivotally, as may be seen in the sectional end view illustrated in FIGURE 2. Arrows 49 indicate the pivoting of cutters 22 in a vertical plane.

Before proceeding further with a detailed structural description, reference is made to FIGURES 5–A and 5–B, which when considered in conjunction with FIGURES 1 through 4 and the brief explanation above will simplify further study of the invention. Notice that the elongated cutters 22 shown in FIGURES 1 and 2, when rotated pivotally and oppositely after an initial incremental forward thrust of tractor 39, form two shelves 52 in the tunnel face 51. The cutters 22 continue to pivot downwardly until they reach a vertical position 180 degrees removed from their initial position shown in FIGURE 2. Then they are retracted, thrust another increment into the tunnel face (now designated by numeral 50 in FIGURES 5–A and 5–B), and the operation is repeated. A more detailed explanation of the operation of the invention and the advantages to be gained by its use will be given later. This initial explanation is given merely to provide a basis for a more thorough initial understanding of various mechanisms used to accomplish the desired results.

Referring once again to FIGURES 1 through 4, where the mechanism for rotating both the pilot bit 20 and the elongated cutters 22 are shown, the detailed description is continued. Notice that the pilot bit 20 and its shaft 21 are connected to a speed reducer 26, which in turn is connected to the tractor power take-off shaft 27 via a chain or belt drive mechanism 42, the function of which is to divide the power available from the tractor 39 into three components. Thus, the speed reducer 26 (actually three speed reducers, one for each power component), in addition to providing the proper rotational speed to pilot bit 20, rotates at the proper speed the elongated cutters 22 about their longitudinal axes 40 with the aid of clutches 24 and gear boxes 23.

To rotate pivotally the elongated cutters 22, there are a pair of lever arms 25, which are initially disposed vertically and parallel to cutters 22. In this embodiment the cutters actually have an intermittent pivotal movement rather than a continuous movement. This action results from the use of a hydraulic cylinder 35 interposed between lever arms 25, as is clearly illustrated in FIGURE 3. The clutch 24 at the lower end of the lever arms 25 functions as a ratchet mechanism which disengagedly connects the lever arms 25 to the cutters 22. Assuming that each lever arm 25 and each cutter 22 is vertically disposed and rigidly connected by means of clutch 24, the extension of hydraulic cylinder 35 forces both of them to pivot a predetermined distance toward the horizontal. Then the clutch 24 is disengaged and hydraulic cylinder 35 is retracted, drawing lever arms 25 (but not the cutters 22) back to the initial vertical position. Then the clutch 24 is thrown to engage lever arms 25 and cutters 22 once again, so that the step above may be repeated. Thus, the cutters 22 intermittently rotate across the entire tunnel face.

The elongated cutters 22, the pilot bit 20, and all the above described mechanisms used to operate them, are supported primarily by the main support bars 28, which extend longitudinally along the sides of the tractor. A plurality of transverse support bars 29 and 29′ are connected to main support bars 28, and it is these bars that contact and directly support the various power train mechanisms described above. A hydraulic cylinder 30 is connected to main support bar 28 to provide vertical adjustment of the pilot bit 20 and the elongated cutters 22 with respect to the tractor 39. Main support bars 28 are mounted pivotally as is designated by numeral 43 to permit such vertical adjustment. Furthermore, angular adjustment of the pilot bit 20 and elongated cutters 22 is accomplished by the use of hydraulic cylinders 31, which connect the transverse support bar 29 and the speed reducer 26. Notice that the forward transverse support bar 29′ has on each end a pivotal mounting 44, enabling angular movements with respect to the tractor 39 of the pilot bit 20, the elongated cutters 22, and the various power train mechanisms in response to the action of hydraulic cylinders 31. This facet of the invention enables the machine to alter its vertical direction of travel during the tunneling or mining operation in a convenient and simple manner. Changes in the direction the machine travels during the tunneling operation are controlled by the conventional operation of the tractor 39 and are not described for that reason.

Disposed above the tractor 39 is a roof support 32, which in this embodiment supports an axially movable roof 33, which is adjusted forwardly and rearwardly by hydraulic cylinders 34, and adjusted vertically by hydraulic cylinders 41. The purpose of the roof support 32 and axially movable roof 33 is to provide better support for the machine, especially while the cutters 22 move through the cutting cycle described briefly above. To illustrate this function of the axially movable roof 33, FIGURE 6–A shows the cutters 22 in their initial vertical disposition. As the cutters 22 pivot toward a horizontal position, as is shown in FIGURE 6–B, the movable roof 33 is thrust forward by the action of hydraulic cylinders 34 to a position between the cutters 22, thereby furnishing support to the tunnel roof over the cutters. Since many of the reactive forces imposed on the machine act in a vertical plane defined by the longitudinal axes 40 of the cutters 22, the provision of a movable roof 33 greatly increases the operational stability of the machine.

A conventional cuttings conveyor 36 is disposed below the tractor and between tracks 37 to remove the cuttings. A runway fabricated of sections 38 is provided to support the tracks 37 and is extended as the tunnel progresses to keep the tractor 39 level.

When cutters 22 of the opposed auger type are used, as are shown in FIGURES 1 and 2, the cuttings from the face of the tunnel are removed as described previously and as may be seen in FIGURES 5–A and 5–B. The cutters 22 move the cuttings toward conveyor 36 and cuttings chute 53 and therefore away from the machine. This action of the cutters is achieved even after the cutters 22 move below the horizontal plane, as is shown in FIGURE 5–B, and this is one of the advantages of using elongated cutters 22 having an auger configuration.

To explain in more detail a practical power train mechanism that may be used to rotate the elongated cutters both pivotally and about their longitudinal axes, reference is made in FIGURES 7–A, 8–A and 8–B. This embodiment is similar to that shown in FIGURES 1 through 4 except it has two pilot bits instead of one. As illustrated, a power take-off shaft 60 on the front of a tractor drives a sprocket 61 which is connected by means of chains 62 to jack shafts 60′ by means of sprockets 63, as may be seen more clearly in FIGURE 9. The purpose of this mechanism is to divide the power train into two components, each of which ultimately rotates an elongated cutter 85′ and a pilot bit 111 as is shown in FIGURE 7. Jack shaft 60 (referring now to only one side of the power train as is illustrated sectionally in FIGURES 8–A and 8–B) is connected to a support bearing 61′ and then to a universal joint 66. A shaft 64 extends from universal joint 66 into the shaft mounted speed reducer 67.

As is shown more clearly in FIGURE 10, the speed reducer 67 drives an inner drive shaft 69 by means of a series of gears (not shown). There are many types of speed reducers and the commercially available shaft

mounted type is shown merely because it is a great weight saver. Notice that shafts **64** and **69** are the only support needed for both speed reducers **67**. Since the torques imposed on these members must be counteracted, turnbuckles **130** are attached to support frame **132** and to ears **131** which protrude from the speed reducer **67**.

Referring again to FIGURE 8–A, the inner drive shaft **69** is supported by pillow block **70**. In front of pillow block **70** is a second pillow block **72** which supports an outer, independently rotatable shaft **71** that surrounds inner drive shaft **69**. Outer shaft **71** is connected to a clutch **73**, or more specifically, to the inner member **75** of clutch **73**. The outer member **74** of the clutch **73** is relatively rotatably supported on outer shaft **71** through bearing **96**, and does not pivot with **71** until the clutch is engaged. This may be seen more clearly in FIGURES 11, 12, and 12–A where it may be seen that lever arms **76** are connected to the outer members **74** of clutch **73**. At the upper end of lever arms **76** is a hydraulic cylinder **77** which pivots the lever arms **76** to a predetermined angular position. With clutch members **74** and **75** engaged, the elongated cutters **85'** of FIGURE 7–A pivot with lever arms **76**. Then the members **74** and **75** of clutch **73** are disengaged while lever arms **76** are retracted for another cycle, as has been described in connection with FIGURES 1 through 4. To eliminate the need for axial movements in the clutch **75**, a commercial pneumatic clutch is clearly illustrated in FIGURE 12–A. There, an inflatable rubber tube **78** is secured to outer member **74** and has on its innermost surface shoes **78'**. When air is forced into rubber tube **78**, the shoes **78'** are forced against inner member **75**, thus securing shaft **71** and cutters **85'** to lever arms **76**.

Supported by frame support **79**, as are the outer members, is a cusp breaker **80**. As is apparent in FIGURE 13, a wedge of formation will be left between the two pilot bits **111** of FIGURE 7–A. When one pilot bit is used, as is shown in the FIGURE 1 embodiment, it is not necessary to use a cusp breaker **80**, but it is beneficial in embodiments having two pilot bits in order to prevent a formation build-up that would impede forward progress of the machine.

Referring again to FIGURE 8–B, a thrust bearing **81** is disposed in gear box **83** and around the inner drive shaft **69** to take the axial loads transmitted through the first bevel gear **82** inside gear box **83**. A second bevel gear **84** is secured to elongated cutter shaft **85** and engages the first bevel gear **82**. Shaft **85** is supported by an upper tapered roller bearing **86** and a lower tapered roller bearing **87**, both of which are disposed in gear box **83**. These bearings resist forces which are transmitted through the rotatable cutters **89**, auger flights **88**, and elongated cutter shaft **85**. A third bevel gear **90** is connected to gear reduction shaft **91**, which is supportd by a tapered roller bearing **92**. Shaft **91** is connected to a clutch **93** inside housing **102** to control the rotational movement of the forward end **91'** of the shaft **91**. A spherical roller bearing **94** supports shaft **91'** and prevents axial movement of the pinion **100** of the first spur gear set, which is shown in FIGURE 8–B but more clearly in FIGURE 14. Spur gears **101** engage pinion **100** and are supported by gear shafts **103**. Bearings **104** support gear shafts **103**, which have on their opposite ends a set of pinion gears **105** in a second gear set (shown more clearly in FIGURE 15). Spur gear **107** is connected to pilot bit drive shaft **108**, which in turn is supported by bearing **110**.

Connected to drive shaft **108** through flange **112** is a pilot bit **111**. Although the particular type pilot bit is immaterial in practicing the invention, FIGURE 8–B illustrates a bit having a central shaft **113** which connects flange **112** to at least one but usually a series of plates **115**. For structural strength there are a plurality of struts **114** which connects central shaft **113** to the plates **115**. Disposed on the plates **115** are a number of cutter assemblies **116**, the function of which is to remove formation from the face of the pilot hole **120**.

To remove the cuttings from the pilot hole there are a series of fragmentary auger flights **117** (see FIG. 7–A) disposed between the cutter assemblies **116** as is taught in the application of Warren T. Jones, Serial Number 325,095, filed November 20, 1963, and now Patent No. 3,172,489. Extending rearwardly from the plates **115** is a cylindrical support **118** that protects the various drive train mechanisms from the abrasive or otherwise detrimental action of the cuttings. Auger flights **119** are wrapped around shield **118** to move the cuttings rearwardly along the pilot hole and into a conveyor, such as the conveyor **36** of FIGURE 1.

It is apparent that the overall operation of the elongated cutters **85'** and the pilot bits **111** of FIGURE 7–A is basically similar to the previously described operation of the embodiment illustrated in FIGURES 1 through 4. To enable a better understanding of the various mechanisms described in connection with FIGURE 7–A, however, an explanation of the operation of that embodiment will be given.

Therefore, notice that the pilot bits **111** of FIGURE 7 are driven by the gear reduction unit enclosed in housing **95**, which may be seen in FIGURE 8–B. The clutches **93** that joins the gear reduction drive shaft **91** at its forward end **91'** is provided to disengage the pilot bit **111** while the elongated cutters **85'** are being rotated through their vertical paths. This is beneficial from an efficiency point of view since forward longitudinal motion is halted while the elongated cutters **85'** are being pivoted in the vertical plane. Rotational movemnt of pilot bits **111** is ineffectual and should be ceased for this reason.

The pivotal movement of the auger central shaft **85** is accomplished by the rigid engagement of gear box **83** to outer rotatable shaft **71**, which is connected to the inner member **75** of clutch **73**. When the inner member **75** of clutch **73** is engaged with the outer member **74**, then any pivotal movement of lever arms **76** will cause a similar pivotal movement of the auger central shaft **85**. Consequently, when clutch members **74** and **75** are disengaged the lever arms **76** may be returned to their initial vertical position (shown in FIGURE 7), but the auger central shafts **85** will be left at the angular disposition to which they were carried by the pivotal movement of lever arms **76**. Thus it may be seen that the auger central shafts **85** are ultimately indexed from the upward vertical position (as seen in FIGURE 7) 180 degrees to a downward vertical position (not shown). Consequently, successive or incremental sections of the tunnel face may be removed with minimum longitudinal reactive forces bearing against the machine.

The only large longitudinal reaction forces are created during the initial step when the elongated cutters **85'** and pilot bits **111** are being thrust against and buried into the tunnel face. During this step the pilot bits **111** are rotating as are the auger central shafts **85** to achieve maximum cutting efficiency. After the initial step, the rotation of pilot bits **111** is ceased by disengaging clutch **93**, and then the indexing of the elongated cutters **85'** is accomplished through the cooperation of hydraulic cylinder **77**, lever arms **76**, and clutch **73**.

Since it is now apparent that the invention relates primarily to a novel arrangement and configuration of elongated cutters, there are obviously a wide variety of suitable mobile carriages. The tractor **39** of FIGURE 1 is a convenient carriage but it has disadvantages, principally its lack of rigidity and the fact that the tracks are far removed from the center of gravity of the power train mechanisms, the elongated cutters **22**, and the pilot bit **20**.

A much more rigid carriage and one having better overall weight distribution is designated by the numeral **140** in FIGURES 16 and 17. Actually, carriage **140** is commonly called a shield and is already known generally in the tunneling art. The shield **140** slides along the tunnel

floor, being pushed forward when desired by the action of plural hydraulic propulsion jacks **146**. External framework **141** is jointed to internal framework **142** as is shown more clearly in FIGURE 17. The propulsion jacks **146** engage transverse members **147** that span the external framework **141** and the internal framework **142**. The base **148** of the propulsion jacks **146** are thrust against ring beams **149**, which are added periodically together with additional support bars **151**.

Lower portions of the internal framework **142** support the vertical adjustment jacks **145**, which control the vertical placement of platform **149**. The drive train mechanisms and electric motor **143** are supported by the platform **149**.

Roof adjustment jacks **150** are supported by portions of the internal framework **142** and change when desired the vertical placement of roof **152**.

The power train mechanisms are identical to those described in connection with FIGURES 1 through 4. Briefly, the motor **143** is connected to chains or belts **62**, which in turn are connected to the shaft mounted speed reducers **67**. Internal shafts (not shown) rotate the elongated cutters **85'** about their longitudinal axes and also rotate pilot bits **111**. An external shaft **71** connects lever arms **76** and elongated cutters **85'** through clutches **73** to provide an intermittent pivotal movement to the elongated cutters **85'** upon the actuation of hydraulic cylinder **77**. The operation of this part of the invention has been previously described.

The carriage or shield **140** is propelled by actuating propulsion jacks **146**, which forces the elongated cutters **85'** and pilot bits **111** into the tunnel face **166**. When the propulsion jacks reach their maximum extension, another ring beam **149** is installed with additional support bars **151**. Then the bases **148** of the jacks are moved up to another ring beam and thus the cycle is repeated. Of course, while the shield **140** is being thrust forward, roof support jacks **150** are retracted to lower the adjustable roof **152**. This prevents interference with forward movement of the shield **140**, but when the elongated cutters **85'** are being pivoted, roof **152** is thrust against the tunnel roof to eliminate vibrations of the machine, to counteract the reactive forces and to support the roof over the augers.

Thus it may be seen that the construction and operation of shield **140** and its cooperation with elongated cutters **85'** and the pilot bits **111** produce advantageous results due to the increase of rigidity and improved weight distribution.

The elongated cutters **85'** are not limited to the auger configuration of FIGURE 7–A. In FIGURE 7–B, for example, a multiplicity of drag-type cutters **160** are illustrated as being supported on a cylindrical drum **161**. In the very loose, unconsolidated formations of the earth such cutters are highly practicable, especially since they have little tendency to clog when moisture is present.

FIGURE 7–C illustrates a multiplicity of rotatable cutters **162** disposed on a series of plates **163** which in turn are aligned in an oblique fashion with respect to the central shaft **164**, only one cutter per plate being illustrated although a multiplicity would usually be employed. The placement of the plates **163** is such that the rotatable cutters **162** cover during rotation of central shaft **164** substantially the vertical extent of the shaft **164**. Scraper blades are used on this embodiment to wipe cuttings from the path of succeeding cutters.

It is readily apparent that the pilot bits may have many forms and thus the type illustrated as having rotatable cutters is not essential. Drag type or disc cutters are within the scope of the invention. The resulting core merely breaks before forward progress of the machine is impeded due to the natural vibrations of the machine.

The advantages of the invention are readily apparent in view of the above description of its structure and its mode of operation. The use of elongated cutters which rotate about their own longitudinal axes and simultaneously pivot in a plane transverse the tunnel axis, a plane which is substantially vertical when the tunnel is horizontal, overcomes to a great extent the disadvantages of prior art machines. More specifically, the removal of the tunnel face by cutters which move through a vertical plane reduces substantially the longitudinal reactive forces acting against the machine. It will be recalled that after the initial forward thrust, the reactive forces are primarily transverse. The vertical disposition of the elongated cutters reduces the distance traveled by the machine during the initial forward thrust when compared with prior art tunneling machines having horizontally disposed elongated cutters. Moreover, the creating of ledges in the tunnel face by the elongated cutters decreases further the longitudinal reactive forces. In addition, the use of a pair of oppositely pivoting elongated cutters reduces the net transverse force exerted on the machine.

Although specific terminology has been used to add clarity to the description, it is apparent that the invention is not limited to any specific terms but encompasses all equivalent devices which operate in a similar manner to accomplish a similar result.

It will be apparent that a horizontal frame of reference has been chosen largely for the convenience it offers in discussing relationships between parts of the specific embodiments discussed throughout the foregoing, and that the tunnel or shaft in which the invention operates may have a grade or inclination departing widely from the horizontal. With such grades, parts described above as being vertical will generally no longer be vertical, but will usually be normal to the longitudinal axis of the tunnel, normal to the tunnel roof, or the like.

I claim:

1. A mining or tunneling machine for removing incremental layers of rock from a working face of a tunnel or the like, said machine comprising:
   (a) a mobile carriage,
   (b) means for propelling the carriage along the tunnel axis into the tunnel face,
   (c) a pair of elongated cutters rotatable about their longitudinal axes and mounted upon the forward end of the carriage to pivot about axes substantially parallel to one another and to the tunnel axis, said elongated cutters being disposed with their longitudinal axes transverse the tunnel axis and being provided with peripheral cutting structure over substantially their full axial lengths, and
   (d) drive means supported by the carriage and connected to the elongated cutters for rotating them about their longitudinal axes and also for pivoting them in opposite directions about said substantially parallel axes which are parallel to the tunnel axis.

2. A tunneling or mining machine which attacks a tunnel face or the like in a manner to reduce the longitudinal reactive forces that are transmitted from the tunnel face to the machine, said machine comprising:
   (a) a carriage with propulsion means for moving the machine incrementally along the tunnel axis into the tunnel face,
   (b) a pilot bit rotatably mounted on the end of the carriage to form a pilot hole in the tunnel face,
   (c) means supported by the carriage for rotating the pilot bit,
   (d) a pair of elongated cutters mounted intermediate the pilot bit and the carriage, said elongated cutters being rotatable about their longitudinal axes and pivotable about adjacent axes substantially parallel to one another and to the tunnel axis, said elongated cutters being disposed with their longitudinal axes transverse the tunnel axis and being provided with peripheral cutting structure over substantially their full axial lengths, and
   (e) drive means connecting the elongated cutters and the carriage for rotating said cutters about their own

axes and for pivoting them in opposite directions to cut successive layers from the tunnel face.

3. The machine of claim 2 in which each elongated cutter comprises an auger which in rotation moves the cuttings from the tunnel face toward the pivot point of the cutter, and in which there is a conveyor disposed to receive the cuttings from each auger to move them away from the tunnel face.

4. A tunneling machine which attacks a tunnel face in a manner to reduce the longitudinal reactive forces acting against the machine, which comprises:

(a) a carriage having propulsion means for moving the machine incrementally along the axis of the tunnel into the tunnel face,

(b) at least one pilot bit rotatably mounted at the forward end of the machine,

(c) means supported by the carriage for rotating the pilot bit,

(d) a pair of elongated cutters mounted intermediate the pilot bit and the carriage, said cutters being oppositely pivotable about adjacent axes substantially parallel to one another and to the tunnel axis, said elongated cutters being disposed with their longitudinal axes transverse to the tunnel axis and being provided with peripheral cutting structure over substantially their full axial length,

(e) means for rotating the elongated cutters about their longitudinal axes, and

(f) a pair of lever arms, each of which is pivotally and coaxially mounted behind one of the elongated cutters and disengagedly connected thereto,

(g) means connected to the lever arms for indexing them and the engaged elongated cutters apart to a predetermined angular disposition and for returning the lever arms to an initial position so that indexing may be repeated.

5. The machine of claim 4 in which the means for indexing the lever arms comprises:

(a) a hydraulic cylinder spanning the lever arms to first spread them apart a predetermined distance from an initial position and then to retract them to the initial position, and

(b) a pair of shafts, each of which connects one elongated cutter to one lever arm, and

(c) a clutch interposed in each shaft to engage the elongated cutters to the lever arms while the hydraulic cylinder spreads the lever arms apart, said clutch then disengaging the elongated cutter from the lever arm while the lever arm is returned to the initial position.

6. In a mining or tunneling machine having propulsion means and means for moving cuttings rearwardly from the face of a horizontal tunnel, the improvement being a novel cutter arrangement which removes successive vertical sections of earth from the tunnel face, said improvement comprising:

(a) a pair of elongated cutters rotatable about their longitudinal axes and mounted on the forward end of the machine with their longitudinal axes transverse the axis of the tunnel, each said cutter being provided with peripheral cutting structure over substantially its full axial length,

(b) a pair of shafts substantially parallel to each other and to the axis of the tunnel, each of which pivotally connects one of the elongated cutters to the machine,

(c) drive means connected to the shaft for rotating the cutters about their longitudinal axes, and

(d) means for rotating the elongated cutters pivotally in opposite directions in a substantially vertical plane so that the cutters remove successive sections of earth from the tunnel face.

7. The machine of claim 6 in which the means for rotating the elongated cutters pivotally comprises:

(a) a pair of lever arms mounted in a substantially vertical plane behind the elongated cutters,

(b) a pair of shafts, each of which connects one lever arm to one elongated cutter,

(c) a ratchet mechanism in each of said shafts to release the elongated cutters from the lever arms, and

(d) means spanning the lever arms to pivot them and the engaged elongated cutters a predetermined amount from an initial vertical position and for returning the lever arms to the initial position while the ratchet mechanism disengages said lever arms from the elongated cutters so that the operation may be repeated to move the elongated cutters successively across the entire tunnel face.

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