# United States Patent [19]

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[54] **METHOD FOR MECHANIZED SEAM MINING**


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[21] Appl. No.: **219,218**

**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 873,344, Nov. 3, 1969, abandoned.

[52] **U.S. Cl.** .......... **299/18,** 37/195, 299/19, 299/34, 299/37

[51] **Int. Cl.** .......... **E21c 27/34**

[58] **Field of Search** .......... 37/54, 80 R, 195; 299/9, 10, 16, 17, 18, 19, 34, 37, 38



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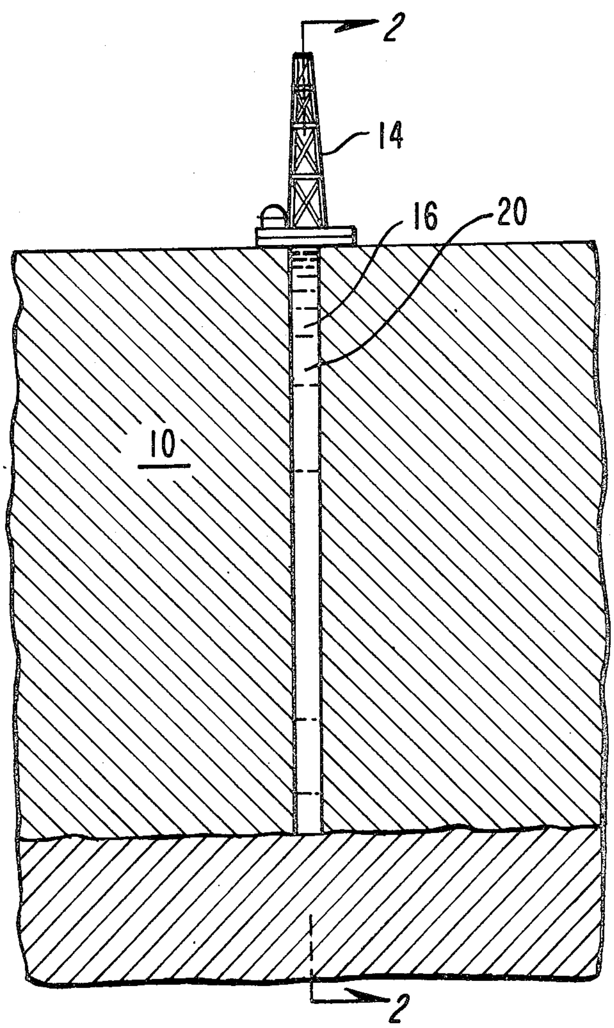
[57] **ABSTRACT**

An ore seam or vein is mined by robbing ore from the side of a pilot hole using a gravity force broach to form a trench. The operators and most of the equipment, except for the broach, are located outside the trench. In weak formations the trench is filled with drilling fluid which lends mechanical support to its walls, and the drilling fluid may also be utilized in collecting the ore or mineral from the trench.

Apparatus is disclosed for adjusting a parasite weight load on the broach to a desired value, and for providing a progressively advancing reciprocating drive for the broach.


**20 Claims, 22 Drawing Figures**



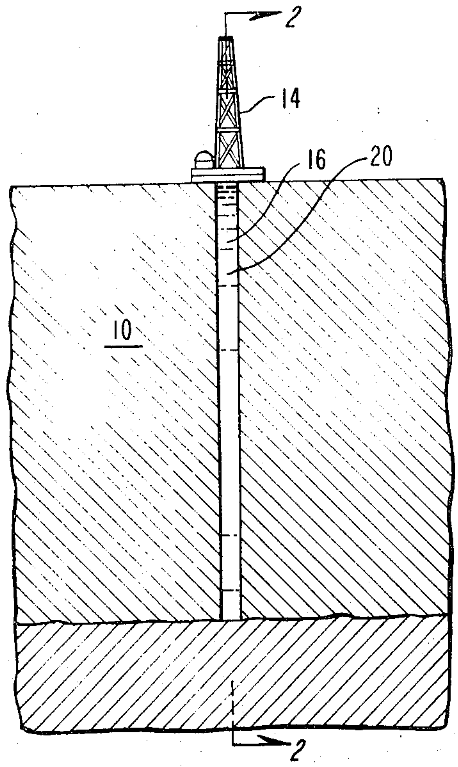



FIG.—1

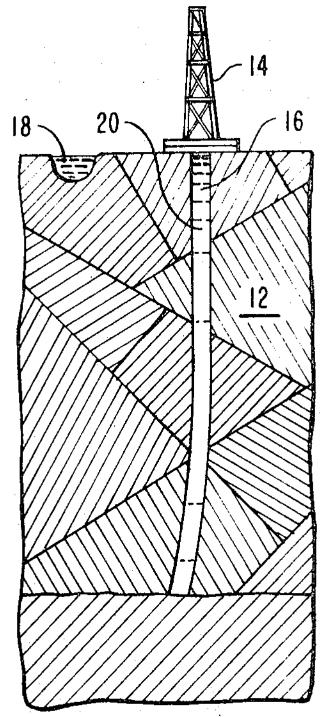



FIG.—2

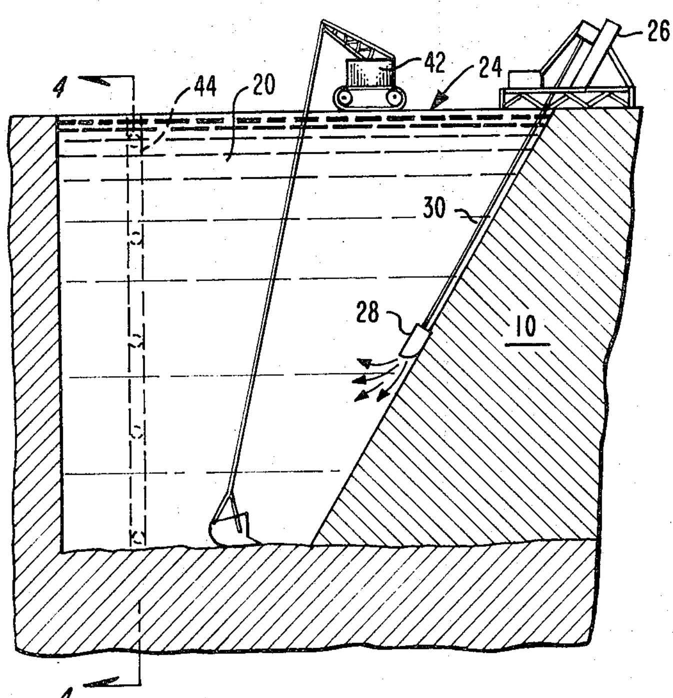



FIG.—3

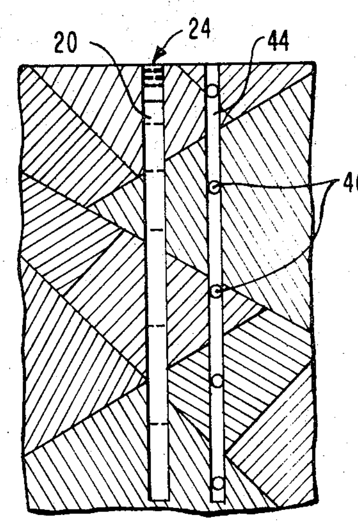



FIG.—4

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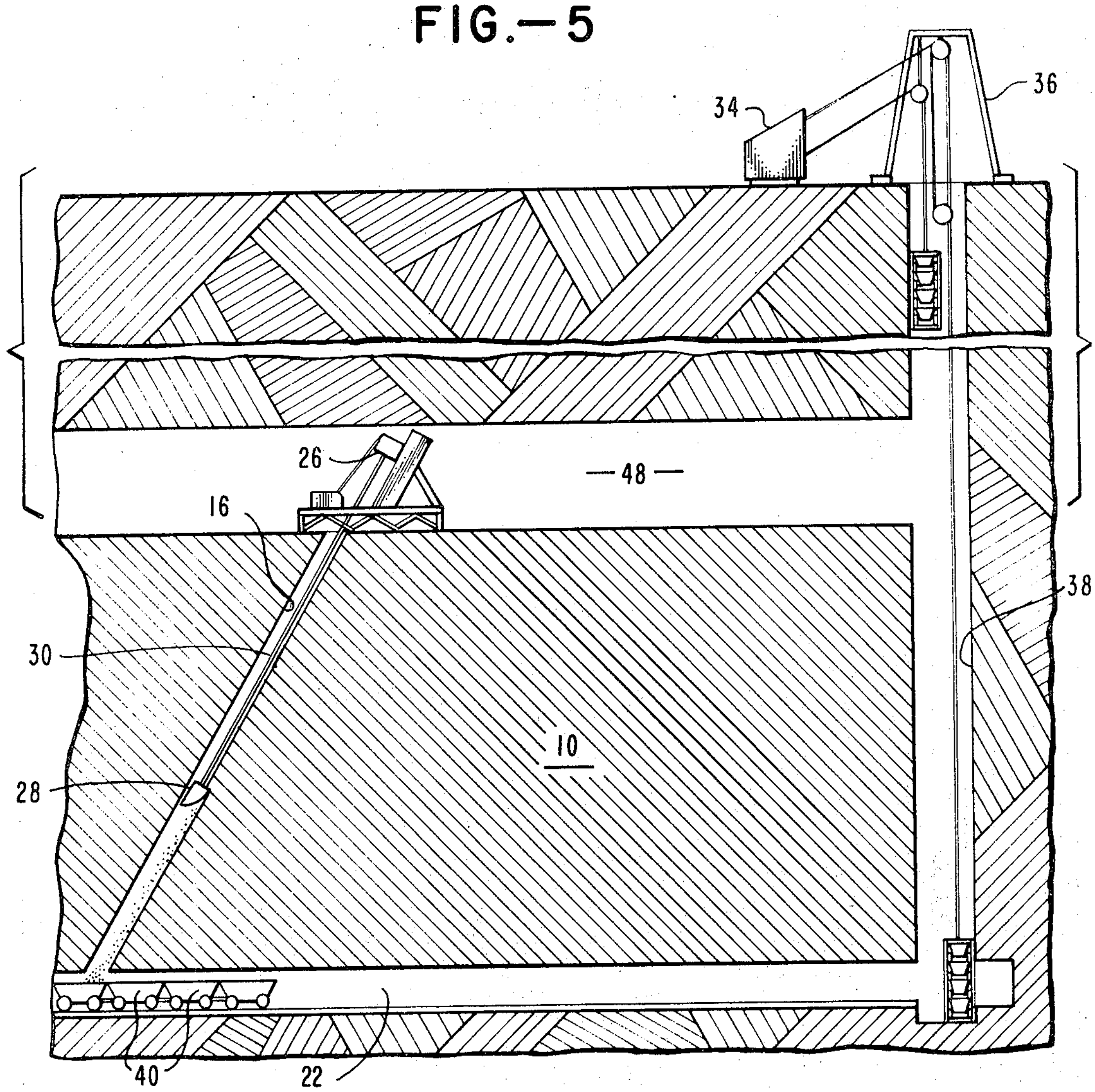
FIG.—5



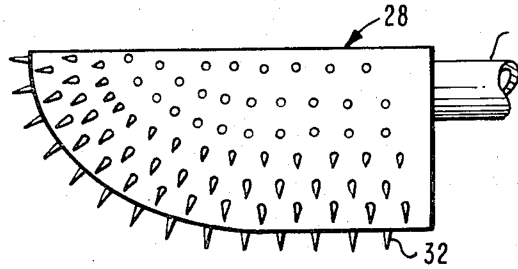




FIG.—6

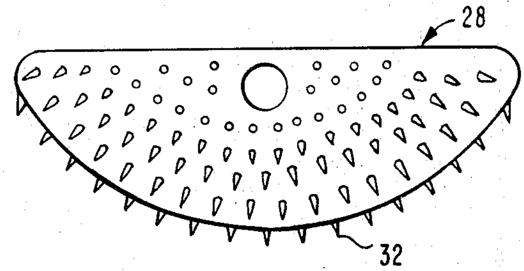



FIG.—7

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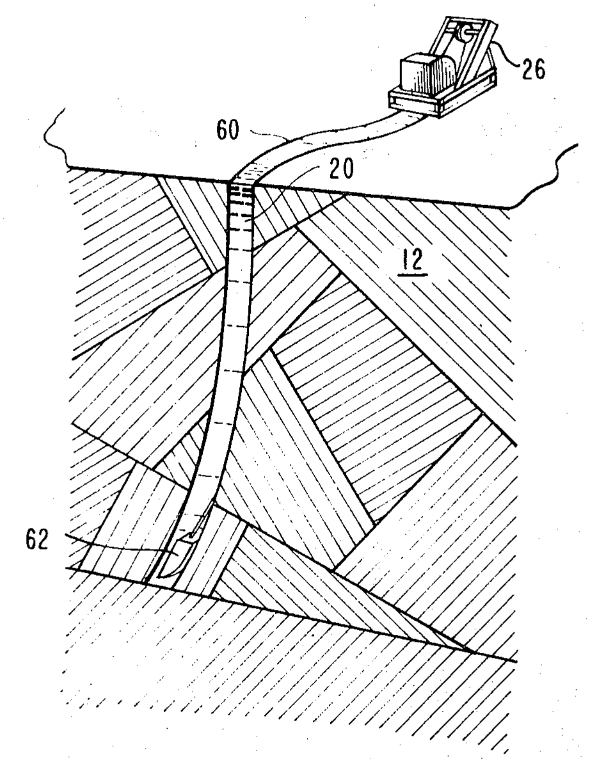
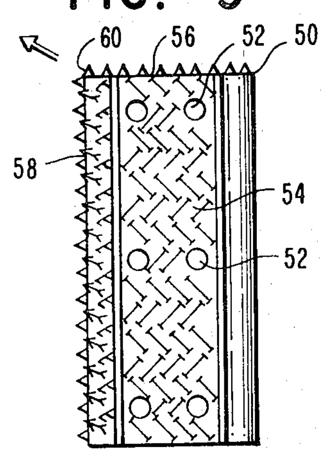



FIG.—10

FIG.—9



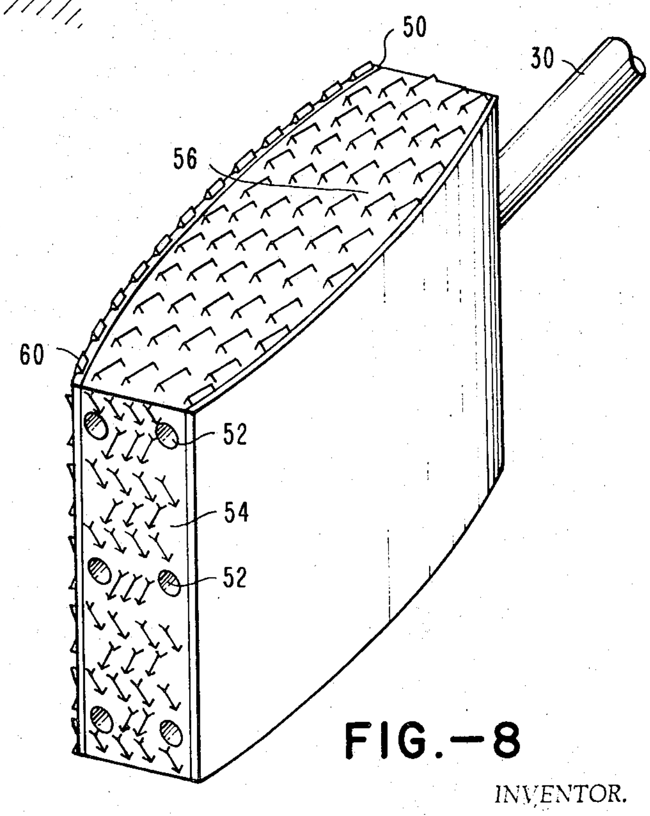




FIG.—8

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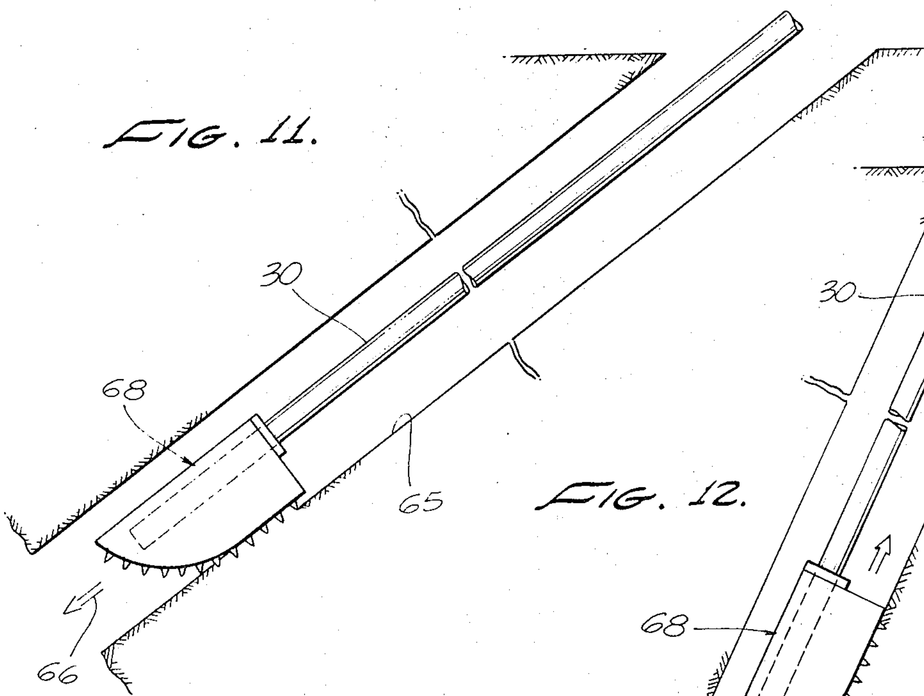



FIG. 11.

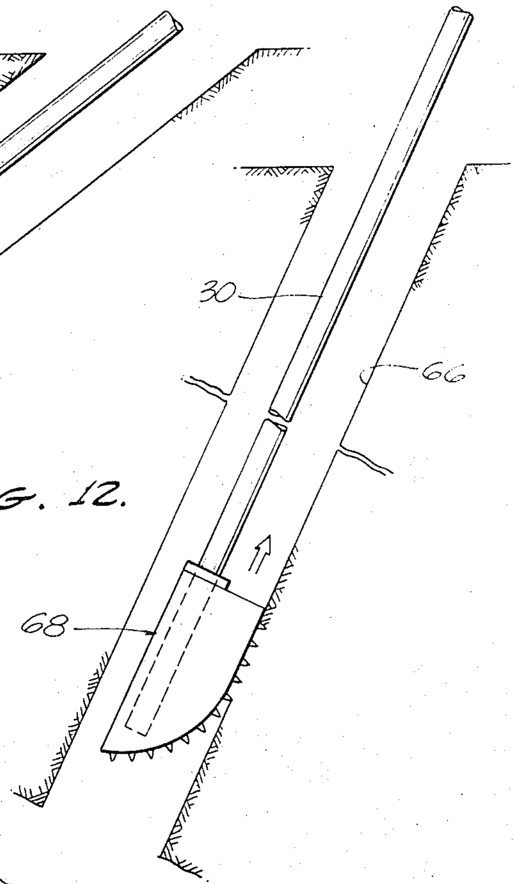



FIG. 12.

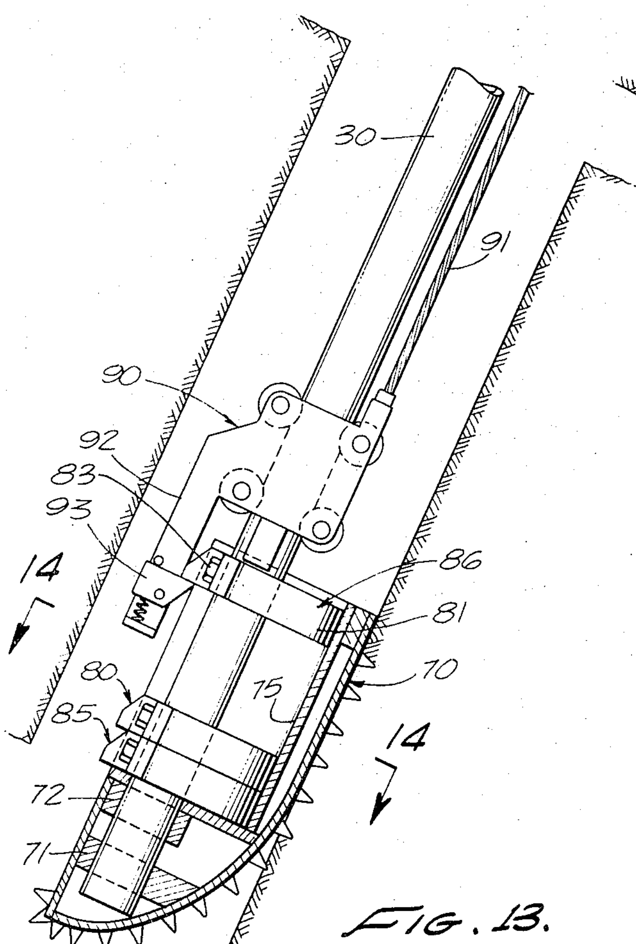
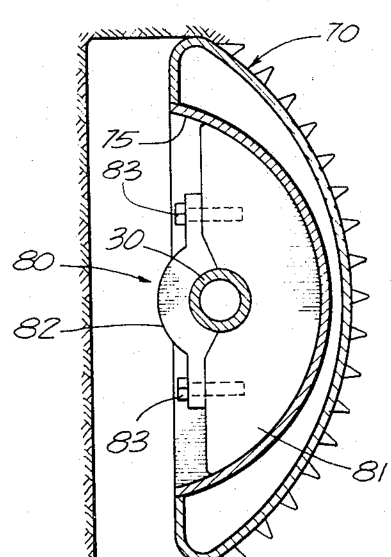



FIG. 13.

FIG. 14



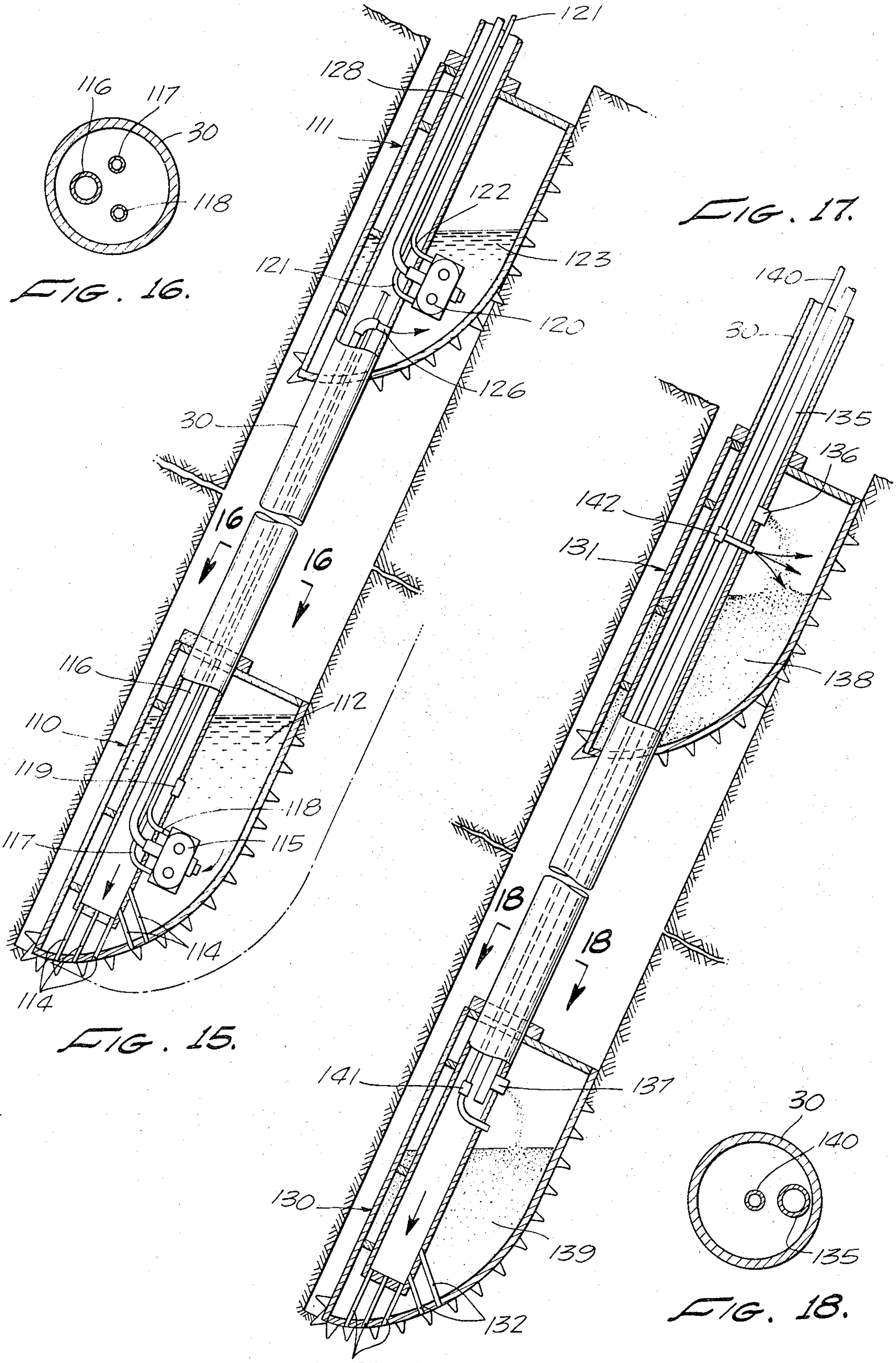



FIG. 16.

FIG. 15.

FIG. 17.

FIG. 18.

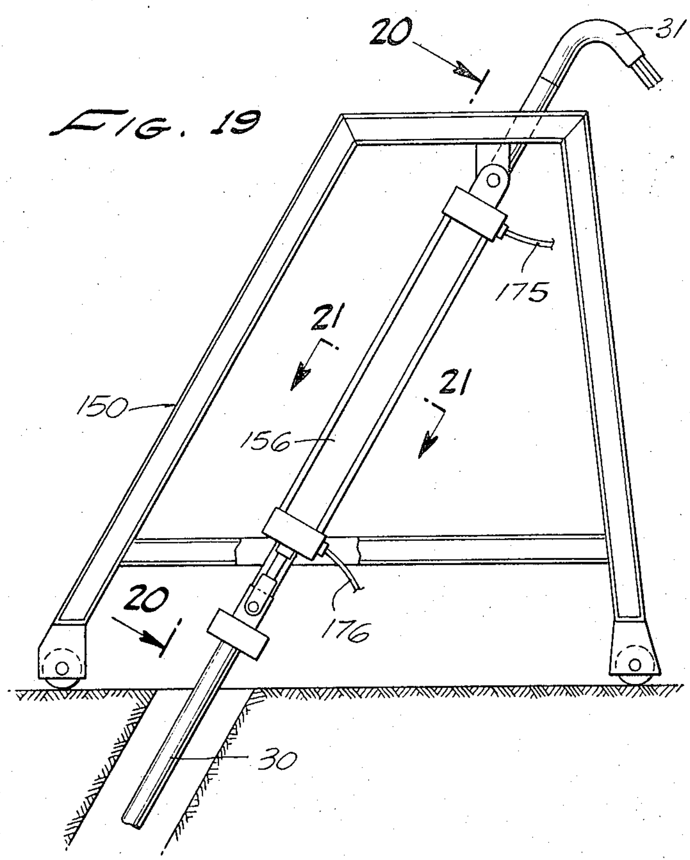



FIG. 19

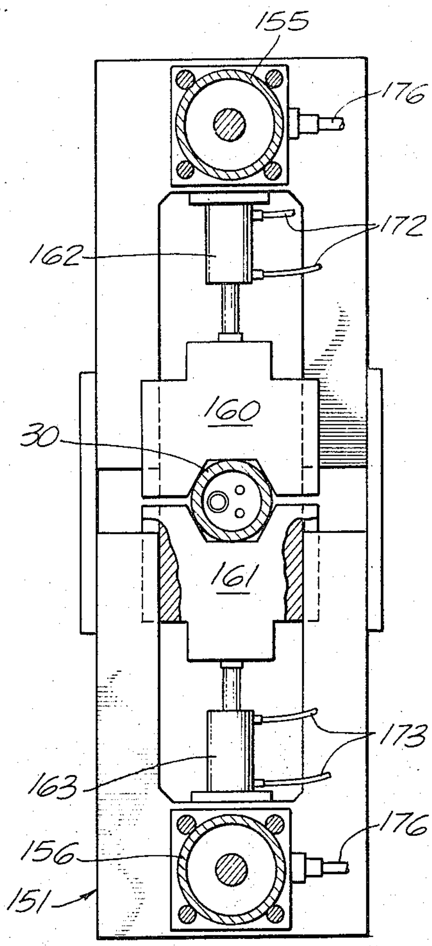



FIG. 21.

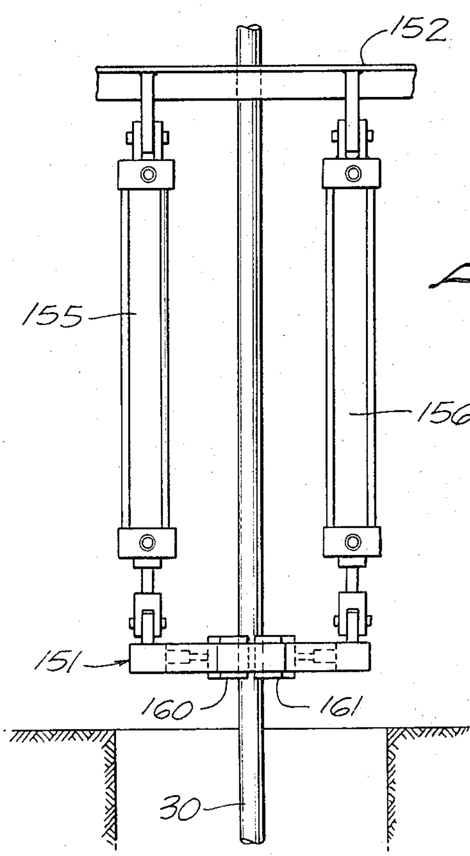



FIG. 20.

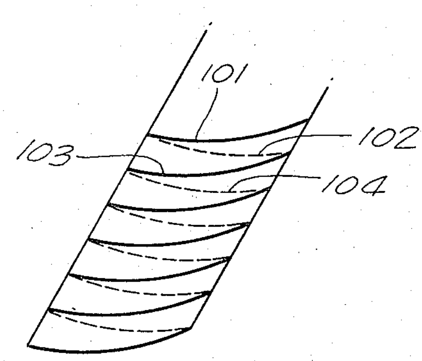



FIG. 22.

## METHOD FOR MECHANIZED SEAM MINING

The present application is a continuation-in-part of my copending application Ser. No. 873,344 filed Nov. 3, 1969 and now abandoned.

This invention relates to mechanized mining procedures. More particularly, this invention relates to forming a trench in an ore or mineral seam or vein by mechanically robbing organic or inorganic ore value from the side of a pilot hole.

Previously, it had generally been considered necessary to have men working in the area of the working face from which ore is being mined. This necessitates shoring the walls to protect the safety of the persons in the mining area.

These and other disadvantages of the prior art have been overcome according to the present invention. A mining operation is commenced, according to the present invention, by sinking a pilot hole into an ore or mineral seam or vein, hereinafter referred to as a "seam." The seam is then mined by robbing the ore from one side of the pilot hole using a heavily weighted broaching tool. The side of the pilot hole, which is being broached, elongates until eventually a trench is formed.

The side of the pilot hole which is being broached, that is, the working face of the trench, extends to such an angle to the horizontal that the force of gravity drives the broach against the working face. The only power required is that necessary to move the broaching tool in a reciprocating motion along the working face of the trench.

It is not necessary for men to enter the trench at any time.

The ore or mineral, which is robbed from the working face of the trench, is collected in one of several ways. The trench may be filled with a fluid, such as drilling mud, which has a specific gravity greater than that of the ore. The ore rises to the top of the fluid in the trench and is skimmed off. This technique is particularly suited to ores that have a low specific gravity, such as, for example, coal and oil shale.

The presence of the heavy drilling fluid in the trench tends to prevent the walls from caving into the trench. This feature is particularly important where the formation surrounding the ore seam is relatively weak. Using this technique, it is possible to mine ore seams that are relatively narrow and are located in weak surrounding formations.

The ore seams, which are mined according to this invention, extend at such a dip angle that the force of gravity drives the broaching tool toward the working face of the trench with sufficient force to dislodge the ore.

Where the ore is of such a nature that it has a specific gravity greater than that of any available fluid, the loosened ore may be dredged from the bottom of the trench using conventional dredging techniques.

When the surrounding formation is structurally strong and the walls of the trench do not need the support of a heavy fluid, the ore may be collected by driving a drift below and intersecting with the trench. As the ore is robbed from the working face of the trench, it falls down through the trench into the drift and is collected and removed from that point. The drift forms the bottom of the trench. No fluid is used in this trench.

This invention permits the economical mining of very narrow seams of ore and is also applicable to large ore seams where the seam is wide enough so that several parallel trenches can be made in it. When the ore seam is covered by a considerable thickness of overburden, it is convenient to mine the ore seam by driving two drifts, one above the other, in generally parallel relationship with a pilot hole extending between them. Broaching operations are conducted from the upper drift, and the ore is collected in the lower drift. When a number of trenches have been prepared extending parallel to one another in a large ore seam, very efficient mining can be accomplished by blasting down the walls between the trenches.



According to another aspect of the invention the trench may be filled with relatively pure water which is circulated by forceful means, and the circulation velocity of the water is effective to retrieve the ore or mineral at a satisfactory rate even through its specific gravity may be greater than that of the water. This method of retrieval is particularly adaptable in mining a seam of coal at a considerable depth below ground surface.

According to the invention the reciprocating broach is preferably driven by means of a relatively rigid elongated member, having a certain amount of lateral bending flexibility, and for this purpose there is preferably used a drill pipe or drill stem of the type which is conventional in the drilling of oil wells. Due to the bending capability of the elongated member the broach performs its cutting action primarily under the influence of gravity.

According to another feature of the invention the elongated rigid member which provides a reciprocating drive action for the broach is itself preferably driven in a progressively advancing movement. Thus, the broach is able to both widen and deepen the hole in which it is working. The amount of progressive advancement imparted to the broach may be selected relative to the amount of reciprocating action, in order to control the rate at which the hole is deepened relative to the rate at which it is widened. It is therefore possible for a single broach, with a relatively short reciprocating drive action, to mine a hole of great depth.

Yet another feature of the invention is the use of a progressively advancing reciprocating drive action for a broach to first cut a pathway downward into a seam of mineral or ore that is to be mined and then to cut a similar pathway back up towards the surface, thereby widening the hole in which it is operating.

Yet another preferred feature of the invention is the use of a reciprocating drive mechanism that is powered by means of one or more hydraulic cylinders, for imparting a reciprocating drive movement to the elongated rigid member or drill pipe which is in turn connected to the broach. The drive mechanism preferably also includes a holding jaw which is hydraulically operated, and is periodically released for a brief interval of time in order to advance the drill stem in a longitudinal direction.

### DRAWING SUMMARY

FIG. 1 is a cross-sectional view of an ore seam having a pilot hole therein;

FIG. 2 is a cross-sectional view taken along line 2—2 in FIG. 1;

FIG. 3 is a cross-sectional view of a partially mined ore seam wherein ore is dredged from a fluid-filled trench;

FIG. 4 is a cross-sectional view taken along line 4—4 in FIG. 3;

FIG. 5 is a cross-sectional view of a partially mined ore seam where ore is collected in a drift below the trench;

FIG. 6 is a side elevation of a typical broach;

FIG. 7 is a front elevational view of a broach shown in FIG. 6;

FIG. 8 is a perspective view of an additional embodiment of a broach which is designed to drift from a straight line as it cuts through a formation;

FIG. 9 is an elevation view of a broach of FIG. 8;

FIG. 10 is a perspective view of a curved trench formed by the use of a broach which is designed to drift from a straight line to follow a curved ore seam;

FIG. 11 is an elevation view showing a relatively flat hole that is cut in accordance with the invention;

FIG. 12 is a view like FIG. 11 but showing a relatively steep hole;

FIG. 13 is an elevation view, partially in cross section, showing a form of broach which is adapted for adding or taking away metallic weights;

FIG. 14 is a cross section taken on the line 14—14 of FIG. 13;

FIG. 15 is an elevation view, partially in cross section, showing a pair of broaches driven in tandem and adapted to be loaded with a weight load of water;

FIG. 16 is a cross-sectional view taken on the line 16—16 of FIG. 15;

FIG. 17 is an elevation view, partially in cross section, showing a pair of broaches driven in tandem and adapted to be loaded with sand;

FIG. 18 is a cross section taken on the line 18—18 of FIG. 17;

FIG. 19 is an elevation view of a power drive mechanism provided in accordance with the invention;

FIG. 20 is an elevation view taken on the line 20—20 of FIG. 19;

FIG. 20 is a cross-sectional view taken on the line 21—21 of FIG. 19; and

FIG. 22 is a typical movement diagram for a broach.

Referring particularly to the drawings, there is illustrated an ore seam 10 located in a soil formation 12. The drilling tower 14 is positioned straddling the ore seam. A pilot hole 16 extends through ore seam 10 following through an angular bend, as shown particularly in FIG. 2. Pilot hole 16 is filled with drilling fluid 20. Drilling fluid 20 is prepared and stored in mud pit 18.

Referring particularly to FIGS. 3 and 4, there is illustrated an ore seam 10 which is partially mined. A trench 24 has been formed by the mining operation. Trench 24 is filled with drilling fluid 20. A movable drilling rig 26 is positioned so as to bring broach 28 into contact with the working face of trench 24. Broach 28 is suspended from drilling rig 26 by means of drill stem 30. Drill stem 30 is hollow and is adapted to conduct drilling fluid from drilling rig 26 and discharge it at the cutting surfaces of broaching tool 28. A dredge 42 is provided adjacent trench 24 and is adapted to collect ore which has been robbed from the working face of trench 24 by broaching tool 28. The ore, dredged from the bottom of trench 24 by means of dredge 42 is transported away from trench 24 for further processing. Blasting shaft 44 is drilled adjacent to trench 24 at the end remote from the working face of the trench. An explosive string 46 is lowered into blasting shaft 44. Setting off explosive string 46 will cause the walls of trench 24 to collapse in the vicinity of blasting shaft 44. This will reduce the volume of drilling fluid required to maintain trench 24 substantially full.

Referring particularly to FIG. 5, there is illustrated an ore seam 10 which is embedded some distance beneath the surface of the earth. In order to effectively mine this ore body or seam, a lower drift 22 and an upper drift 48 are driven along the strike of the ore seam. A haulage shaft 38 is driven at a location intersecting both drifts 22 and 48. The drilling and broaching operations are conducted from upper drift 48, and the dislodged ore is collected in lower drift 22. A string of ore cars 40 are positioned so as to collect ore as it drops to the bottom of the trench. The full ore cars are then hauled to the surface of vertical haulage shaft 38 by means of hoists 34 operating over A-frame 36.

Referring particularly to FIGS. 6 and 7, there is illustrated a broaching tool 28 which depends from a hollow drill stem 30. The cutting surfaces of the broaching tool 28 are provided with cutting teeth of which tooth 32 is typical. The interior of the broaching tool may be filled with lead or other suitable material to provide the broach with sufficient weight to force it against the working face of the trench. The direction of the cutting tool is controlled by the location of the teeth and by preventing the rotation of drill stem 30. The sides of the broaching tool are not provided with cutting teeth, so there is no cutting action at the sides of the tool. This prevents the cutting tool from straying to one side or the other off of the ore seam.

The broach 50, illustrated particularly in FIGS. 8 and 9, is carried by hollow drill stem 30. Drilling fluid is circulated downwardly through drill stem 30, into broach 50 and out through circulation ports 52 at first side 54. Circulation ports 52 are generally disposed so that they open at the lower side of broach 50 when it is in use in a mining operation. First side 54, second side 56, and third side 58 are all provided with cutting teeth of which tooth 60 is typical. The teeth on first side 54 and third side 58 tend to cut the working face of a trench so that broach 50 moves generally in a direction normal to the face of third side 58. Second side 56, however, tends to cut in a direction which moves broach 50 parallel to third side 58 and normal to second side 56. The result of second side 56 cutting in a direction perpendicular to that in which first side 54 and third side 58 are cutting causes broach 50 to drift in a direction which is the resultant of these two cutting actions. The resultant direction is indicated generally by the arrow in FIG. 9. Broach 50 is conveniently used where it is desired to follow an ore seam which curves. The broach 50 does not move towards its bald sides, that is, the sides on which it has no teeth, because it does not cut in those directions. Broach 50 can also be made to move along a compound curved path by locating teeth so that the resultants of the directions in which cutting takes place cause the broach to follow the desired compound curve. A typical trench 60 having a compound curvature produced by broach 62 is shown in FIG. 10.

The flow of drilling fluid through circulation ports 52 in broach 50 cleans the teeth of the broach so that they can take a full cut every time the broach is reciprocated. Uniform cleaning or flushing of the teeth is important because if the teeth on one side of the broach become loaded with ore, that side of the broach ceases cutting and the broach follows the other sides which are still cutting. This will throw the broach off course.

Also, efficiency decreases if the teeth are clogged with ore or gangue.

The gravity forced broaching tool is preferably one which has no moving parts for reasons of simplicity and economy. Where the ore being mined requires it, gravity weighted broaches having moving cutting surfaces (not shown) may be used if desired.

Where drilling fluid is employed, it is preferably forced through the broaching tool so as to wash the chips away from the broaching tool. Drilling fluid circulation and preparation are accomplished using conventional procedures.

The drilling fluid, preferably of the kind commonly known as drilling mud, serves a dual purpose. The drilling mud floats those ores with low specific gravities away from the working face in the trench and brings them to the surface for recovery. In those mining operations where the walls of the trench do not have sufficient strength to stand unsupported during the mining operation the presence of a heavy drilling mud generally prevents the trench walls from collapsing. The density of the drilling mud is adjusted to a value which is sufficient to prevent the trench from caving in. In general, it is necessary to increase the weight of the drilling mud as the strength of the trench wall decreases.

The technique wherein a drift is driven under the ore seam and forms the bottom of the trench as it is developed does not use drilling mud and requires a formation which has sufficient strength to stand up during the mining operation without caving into the lower drift.

The present invention is particularly well suited for use in mining coal, oil shale and other lightweight ore values. When coal is being mined, the drilling fluid preferably has a specific gravity at least about 10 percent above that of the coal. The viscosity of the drilling fluid is such that the coal will rise at suitable rates. As the broach is reciprocated in the mining trench at an angle of from about 20 degrees to 60 degrees from the vertical, the drilling fluid is circulated through the drill stem and out through the broach at a circulation rate which is sufficient to assure movement of the coal after is is robbed from the cutting face of the trench. Additional strings of pipe may be inserted into the slurry filled trench close to the bottom of it if desired. These provide additional drilling fluid circulation in addition to that caused by the drilling fluid being introduced through the broach. The coal is recovered by skimming from the surface of the drilling fluid in the trench. Skimming is accomplished by use of either a controlled overflow of drilling fluid from the mined trench or a mechanical raking device.

Alternatively, the drilling fluid used in mining coal may be relatively pure water, which is then circulated by force so that the velocity of the water is effective to raise the coal.

As the trench develops in length (extending beyond, for example 75 to 100 feet), it tends to become worthless and even a burden, since additional drilling fluid must be added to the trench to keep it full. In order to maintain the drilling fluid requirements within reasonable limits, for example, 500,000 gallons for mining a trench 10 feet wide, 50 feet long, and 1,000 feet deep, it is desirable to backfill the trench constantly, thus moving the column of drilling fluid forward as the trench develops during the mining process. Backfilling the mined trench is accomplished by drilling powder holes perpendicular to the trench's longitudinal line, but at an angle to its vertical line. Explosives from these holes cave the trench walls at selective areas from bottom to top through milli-second controlled shooting. This moves the column of drilling fluid forward along the trench in a controlled manner as mining proceeds along the strike. This method of drilling fluid displacement leaves drilling fluid loss of as little as 15 to 30 percent by volume in the caved-in portions of the trench.

According to the invention the inclined working face will slope at an angle of about 30° from the vertical, or 60 degrees from the horizontal, if a very soft or weak formation is being mined. A trench of this kind is shown in FIG. 11 where the sloped working face is designated as **65.** A broach **68** is driven by a drill stem **30** as in previous illustrations.

If the material being mined is very hard or strong then the slope of the hole is generally about 60° from the vertical, or 30 degrees from the horizontal. A hole of this kind is illustrated in FIG. **12** where the sloped surface is designated as **66.** The broach is again designated as **68** and its driving drill stem as **30.**

Since the mining method of the present invention relies primarily upon the weight of the broach to destroy the structural integrity of the ore or mineral that is being mined, it follows that the weight of the broach per unit of its cutting area is at least comparable to the failure strength of the material being mined. Where the broach is provided with a curved surface which carries the cutters, as is generally the case, the actual amount of such cutting surface that engages the ore or mineral will vary from time to time during the mining operation. When the broach is being pushed downward the driving force from its drill stem is in a direction generally parallel to the working face, as indicated by arrow **67** in FIG. **11.** The effective weight of the broach may then be represented by the algebraic sum of a vertical vector representing the weight of the broach, and the inclined vector **66** representing the driving force of the drill stem.

During the downward stroke of the broach the amount of driving force applied through the drill stem to the broach may be less than the weight of the broach itself. During the upward stroke of the broach the driving force applied through drill stem **30** to lift the broach must be greater than the weight of the broach. Therefore, the lifting force applied to the drill stem when lifting the broach may be significantly greater than the driving force that would ordinarily be applied to the broach when driving downward. However, when cutting a hole in the first instance, the broach, at the end of each of its forward movements, will ram into the bottom of the hole. This ramming action, in order to be effective, may require a driving force that is considerably greater than would otherwise be required simply for cutting material from the sloped surface **65** or **66.** FIGS. **15** and **17** show a broach which is engaged with or rammed into the lower end of the hole being cut.

When the trench is filled with fluid the floatation effect upon the broach may greatly diminish the force required to lift it.

Reference is now made to FIG. **22** which illustrates schmatically a typical movement path for the broach. The lines shown in FIG. **22** are not actual movement lines but are simplified for purpose of ease in illustration. FIG. **22** illustrates the path of movement of a broach as it is being driven progressively downward, in cutting a new hole. Thus the curved line **101** at the top of the diagram indicates that the broach has moved somewhat downward and has also been forced up, away from the working face **65** or **66**, due to the curved nature of the lower front end portion of the broach. Then the broach is retracted and follows a curved path in the opposite direction indicated by dotted lines **102.** However, it is not retracted all the way to its original position. The broach is again driven downward as shown at solid curved line **103.** It is retracted again as shown at **104.** This action is continued, with the broach working itself back and forth, and progressively deeper into the hole.

According to the present invention it is possible to selectively vary the amount by which the broach is driven forward on each reciprocating movement, beyond the distance that it was driven on the previous reciprocating movement. It is also possible to vary the length of each reciprocating movement. By appropriate selection of these values, and the ratio between them, the relative widening and deepening of the hole can be controlled.

According to the invention the broach may be driven downward in a zig-zag pathway, as shown in FIG. **22,** to cut the hole in the first instance. Then it may be pulled back upward toward the surface in a similar pathway, in order to widen the hole that has already been cut. In pulling the broach back up toward the survace the drive mechanism is adjusted so that during each reciprocating movement the broach is raised a little farther than it had been lowered. For example, it may be lowered 9 feet 11 inches and then raised 10 feet 00 inches. A repetition of this movement pattern will eventually result in raising the broach all the way out of the hole.

An important feature of the present invention is the provision of a removable parasite weight load for the broach, which may be loaded on the broach and may then be taken away or its value adjusted. Reference is now made to FIGS. **13** and **14** illustrating one form of broach which is adapted to receive a parasite weight load, with the parasite weight load being adjustable as desired.

As shown in FIGS. **13** and **14** a broach **70** has the hollow drill stem **30** connected thereto for providing the reciprocating driving action. Within the interior of the broach, as shown in FIG. **13,** fixed bulkheads **71** and **72** receive the forward end of the drive stem **30,** in order to provide structural rigidity. The drive stem **30** is welded or otherwise fastened to the bulkheads **71, 72** by means not specifically shown. The rearward end of broach **70** is of a somewhat dish-shaped or semicylindrical configuration, providing a recess **75.** FIG. **13** shows separate metallic weights **85, 80,** and **86** supported on the drill stem **30** within the recess **75.**

As shown in FIG. **14** the weight **80** includes a thick metal plate **81** which has the approximate shape of half a donut, and is received by the curved lower wall of recess **75** with the upper recess of the plate **81** being fitted about the lower side of drive stem **30.** A smaller latch plate **82** passes over the upper surface of the drive stem **30,** and the extending arms of latch plate **82** are fastened to plate **81** by means of bolts **83.** The weights **85** and **86** shown in FIG. **13** may be constructed in a similar manner.

FIG. **13** also illustrates the method of removing a weight while the broach is engaged in a mining operation. A wheeled trolley **90** rides on the drive stem **30,** being supported from a cable **19.** Wheeled carriage **90** has an upper arm **92** which extends forwardly, and carries a spring-loaded latch member **93.** When the trolley is lowered down the drive stem **30** the latch **93** engages latch plate **82** of the uppermost one of the weights. Then the cable **91** is pulled up so as to retrieve the weight. One or all of the weights may be retrieved in this manner.

In accordance with the present invention it is highly advantageous to be able to vary or adjust the parasite weight load on the broach. In some instances the hardness of the seam or vein will change a great deal as the cutting progresses deeper. Optimum mining action will then require that the weight per unit area of the broach be increased or decreased. It is not feasible to retrieve the broach all the way to the surface in order to change the parasite weight load. If the broach is working 2,000 feet below the surface of the ground in a coal mine, for example, then raising the broach to the surface would necessitate disconnecting successively all of the sections of drive stem which make up that 2,000 feet of distance. After the weight of the broach was adjusted it would then be necessary to reverse the operation. If it were desired to adjust the weight load again, the broach would again have to be raised to the surface, all the driven stem disassembled, and the procedure reversed. Utilizing the broach shown in FIGS. **13** and **14,** however, the reciprocating drive action may be briefly interrupted while a single weight is added to or removed from the broach. It may even be desirable to continue the reciprocating drive of the broach while the weight is being added or subtracted.

Upon commencing to dig a hole the angle of the hole or of its sloped surface upon which the broach will ride is a matter to be selected by the operator or operators. However, after the broach has descended to some depth the angle of the sloped surface will be determined by the mining conditions. That is, the hardness of the material being mined, the cutting capability of the broach, and the weight per unit area of the broach, will be the primary factors which determine the angle of the sloped surface. The strength of the driving force imparted on the drill stem will also have some effect on the angle of the sloped surface, particularly since the force driving the broach downwardly and the force raising the broach upwardly will, in general, be individually and separately controlled.

The direction or pathway followed by a seam or vein will generally have been determined before the mining operation is commenced. Various kinds of instrumentation, which are not the subject of the present invention, may be utilized to monitor the mining operation so as to determine whether the broaching tool is following the pathway of the seam or vein. Lightening the weight load on the broach will cause the forward end of the broach to point in a somewhat more upwardly (more nearly horizontal) direction. Conversely, increasing the weight load on the broach will cause it to dig at a steeper angle.

The value of the parasite weight load on the broach also has an effect upon the mining rate. If the material being mined is very hard, and the broach is insufficiently weighted, then the mining rate will be unsatisfactory. A relatively small increase in the weight load on the broach may then produce a corresponding increase in the mining rate, or even a proportionately greater increase in the mining rate. Once the weight load is sufficient to cope with the failure strength of the material, however, further increases in the parasite weight load may be of relatively little benefit. It is also true that the value of the weight load on the broach has an effect upon the horse power consumption for driving the broach. The interdependence of horse power consumption, mining rate, and angle of the sloped surface upon which the mining operation is being performed, make it highly advantageous to be able to adjust the parasite weight load on the broach while the mining operation is in progress.

According to the present invention the collecting of the ore after it has been robbed from the sloped working face of the trench may be accomplished in any one of several different processes, depending upon which is more convenient and economical for the particular job site. The trench may be filled with fluid and the ore dredged from the bottom of the trench, as shown in FIGS. 3 and 4. The trench may be filled with fluid having density greater than the density of the ore, thus floating the ore on the surface of the fluid where it may be skimmed off. A third method is to use the forced circulation of a fluid, which will not necessarily have as high a density as the ore or mineral that is being recovered. In the forced circulation system the fluid may be fed under pressure down the drive stem and thence through the broaching tool into the trench, returning up through the trench to the surface. In some applications it is preferred, however, to supply the water directly into the trench and then pump it back upward through the drive stem. This process is particularly applicable where the mined material is cut into relatively small particles which can easily pass into openings in the broaching tool without creating any problem of clogging the passageways involved. In order to carry out this latter process it is preferred to place a pump to work with the drive stem a few feet below the fluid level in the trench.

Another method of recovering the ore or mineral is through the forced circulation of an air stream. The resulting dust problem would, in many instances, not be tolerable to the operators working at the surface of the ground above the hole. However, in some instances this process may be the best. The method of retrieving the ore by haulage on ore cars or conveyor belts in a lower drift has been illustrated in FIG. 5. Ore haulage by cars is shown.

In FIGS. 11 to 14, inclusive, there is no indication of the use of a drilling fluid being circulated through the broaching tool. The broaching tool illustrated in these drawing figures may be used in a dry mining process, or may, if desired, be provided with suitable passageways for fluid circulation and be used in a wet mining process.

Reference is made to FIGS. 15 and 16 illustrating another form of apparatus provided in accordance with the present invention. Two broaching tools 110, 111 are connected in tandem to a drive stem 30. Broaching tool 110 is the lower one of the two and is shown located at the bottom of a hole being mined. Drill stem 30 extends into and throughout most of the length of the broaching tool 110, where it is rigidly secured to an internal structure of the broach. At the forward or lower end of the drive stem 30 there are a number of passageways 114 provided for the passage of drilling fluid from the drive stem 30 into the area forward of the broaching tool.

A pump 115 is permanently mounted in the lower interior portion of broaching tool 110. Pump 115 is attached underneath the drill stem 30. The output of pump 115 is connected to a tube 116 which extends into drill stem 30 and hence upwardly. A quantity of water 112 is shown substantially filling the interior of the broach 110. Pump 115 is submerged far below the level of this body of water. The purpose of pump 115 is to selectively pump water out of the broach 110, to thereby lighten the broach.

A pair of hydraulic fluid lines 117, 118 are also connected to the pump 115, and extend into the drill stem 30 and thence upward to the surface of the ground. These hydraulic fluid lines circulate hydraulic fluid under pressure to provide a source of driving energy for the pump.

The drive stem 30 extends throughout the length of the broaching tool 111, being rigidly supported from the internal structure of the broaching tool. The interior of broaching tool 111 is shown as being partially filled with a body of water 123. A pump 120 is permanently installed inside the broaching tool 111, being attached to the lower side of drill stem 30. A pair of hydraulic lines 121, 122 are coupled to the pump 120, and these hydraulic lines extend into the interior of drive stem 30 and hence upwardly to the surface of the ground, not shown. The purpose of hydraulic lines 121, 122 is to provide hydraulic fluid under pressure in order to operate the pump 120.

The upper end of hose 116 is connected to a fitting 126 for discharging water into the lower end of broaching tool 111. Thus, when the pump 115 in broaching tool 110 is energized, the level of the water body 112 in the broach 110 is lowered and the water pumped therefrom enters the lower end of broaching tool 111, raising the level of water body 123 therein. The output of pump 120 is coupled to a hose or tube 128 which extends into the drive stem 30 and thence upwardly to the surface of the ground. When pump 120 is operated the level of the water body 123 in broaching tool 111 is lowered.

Within the broaching tool 110 a valve 119 is provided in one portion of the side wall of the drive stem 30. Valve 119 is controlled from the surface of the ground, by means not shown. The purpose of valve 119 is to permit water to flow from the interior of drive stem 30 into the hollow interior portion of the broaching tool 110. In this manner the parasite weight load for broaching tool 110 may be selectively increased, as desired. In order to decrease the parasite weight load for broaching tool 110 it is necessary to operate the pump 115.

In order to increase the parasite weitht load for the broaching tool 111 it is necessary to operate the pump 115, thus pumping water out of the broach 110 and into the broach 111. In order to decrease the parasite weight load for broach 111 it is necessary to operate the pump 120.

One method of determining the proper parasite weight loads for the broaches 110, 111 is by means of instrumentation of any desired kind, but such instrumentation does not form a part of the present invention. Another method of determining the proper parasite weight loads for the broaches is the experimental or empirical method. According to this latter method it is, however, necessary to verify the results achieved in some manner. It is, therefore, desirable to utilize instrumentation of some kind, as a means of determining when the optimum weight loads have been achieved.

Reference is now made to FIGS. **17** and **18** illustrating another broach construction provided in accordance with the present invention. The construction in generally the same as that shown in FIGS. **15** and **16,** but sand is used to provide the parasite weight loads for the broaching tools, instead of water.

More specifically, a broaching tool **130** and a broaching tool **131** are connected in tandem upon a drive stem **30.** Drive stem **30** extends throughout the entire length of broaching tool **131,** and throughout the greater portion of the length of broaching tool **130,** being in each instance rigidly supported from an interior structure of the broaching tool. Broaching tool **130** is the lower one of the two. From the lower end of drive stem **30** a number of passageways **132** extend through the forward end of the broaching tool **130,** for discharging drilling fluid in the area in front of the broaching tool.

A small tube **135** is contained within the drive stem **30** for supplying sand to the broaching tools **130, 131.** A discharge port **136** extends from tube **135** through the wall of drive stem **30** and communicates with the interior of broach **131.** A port **137** attached to tube **135** extends through the wall of drill stem **30** and communicates with the interior of broaching tool **130.** When it is desired to increase the parasite weight load of either one of the broaches, sand is fed down by force of gravity from the surface of the ground through the tube **135.** A body of sand **138** is contained within broach **131** and a body of sand **139** within broach **130.**

Also contained within the drive stem **30** is a smaller tube **140** which acts as a compressed air supply line. Air supply line **140** extends downward into that portion of drill stem **30** which is surrounded by the broaching tool **130.** A control valve **141** is attached to the lower end of the air supply tube **140,** and communicates with the interior of broaching tool **130.** Within the confines of broaching tool **131** a control valve **142** is incorporated in the air line **140,** and communicates through the wall of drive stem **30** with the interior of broaching tool **131.**

The control valves **141, 142** are controlled from above the surface of the ground, by means not shown. Compressed air may be released into the interior of broaching tool **130,** or into the interior of broaching tool **131,** or both, as desired. Release of compressed air inside either of the broaching tools will cause an air turbulence and the flow of air into the sand supply line **135,** which then acts as an air return line. Turbulent air revolving within the broaching tool will progressively pick up the sand from the surface of the sand body, thus reducing the parasite weight load on the broach.

Reference is now made to FIGS. **19** to **21,** inclusive illustrating a suitable drive means for drivingly reciprocating the drive stem **30.**

A frame **150** is supported on wheeled legs and straddles the trench or hole. At about the top of the hole the drive stem **30** is grasped by a pair of jaws **160, 161.** The jaws **160, 161** are driven towards each other by respective hydraulic cylinders **162, 163** which are mounted upon a horizontal beam **151.** Another horizontal beam **152** (FIG. **20**) forms the uppermost portion of the structure of frame **150.** A pair of hydraulic cylinders **155, 156** have their upper ends pivotally coupled to the upper beam **152** while their lower ends are pivotally coupled to the lower beam **151.** The common plane of the cylinders **155, 156** extends into the hole or trench and is occupied by the driven stem **30.**

The cylinder **162** is operated by hydraulic pressure lines **172** while cylinder **163** is operated by pressure lines **173.** Control means, not shown, control the operation of the cylinders **162, 163** and hence of the gripping jaws **160, 161** in the desired manner.

Each of the hydraulic cylinders **155, 156** is controlled by a hydraulic pressure line **175** coupled to its upper end and a hydraulic pressure line **176** coupled to its lower end. The hydraulic pressure lines are, in turn, controlled by means not shown in order to achieve the desired mode of operation.

The upper end of drill stem **30** extends upward through and above the frame **150,** and has an L-shaped fitting **31** connected thereto. The purpose of fitting **31** is to provide convenient access to whatever tubes or cables are contained within the drive stem **30,** such as, for example, hydraulic pressure lines, water evacuation lines, sand supply lines, air pressure lines, or the like.

In one mode of operation of the drive means the broach is reciprocated without progressive advancement, for the purpose of widening the trench or hole. In that mode of operation the gripping jaws **160, 161** are not released from the drive stem, and hence the cylinders **162, 163** are not actuated.

In a second mode of operation the broach is progressively advanced deeper into the hole, which, of course, necessitates periodically stopping the operation in order to add on another section of the drive stem **30.** Whenever a new section of drive stem **30** is added the end fitting or control fitting **31** is simply moved to a higher location. In this progressive advancement of the broaching tool it is necessary to periodically release the gripping jaws **160, 161.** Upon the downward movement of cylinders **155, 156,** the drive stem **30** and its accompanying broach may, for example, be advanced by **20** feet. Then it is retracted, for example, a distance of **19** feet **6** inches. The cylinders **155, 156** must retract the full **20** feet in order to be ready for the next forward driving movement. Therefore, the gripping jaws **160, 161** are released from the drive stem **30** when it arrives at the distance of **19** feet **6** inches. The cylinders **155, 156** travel upward another **6** inches with the jaws in their open position, and then the cylinders **162, 163** are actuated so as to close the jaws **160, 161** and again grip the drive stem **30.**

In a third mode of operation of the drive means the broach is progressively retracted from the hole. The operation is the same as in the second mode except that the lifting distance is greater than the downward driving distance.

As will be understood by those skilled in the art, what has been described are preferred embodiments in which modifications and changes may be made without departing from the spirit and scope of the accompanying claims.

What is claimed in support of Letters Patent is:

**1.** The process of seam mining which comprises:

forming within the seam a trench having a sloped surface which extends at an acute angle to the horizontal;

placing a broaching tool upon said sloped surface;

weighting the broaching tool with a removable parasite load whose weight value is selected with regard to the angle of said sloped surface, the hardness of

the material being mined, and the cutting capability of the broaching tool;
placing a relatively rigid elongated member having some bending flexibility, within the trench in a position above and generally parallel to said sloped surface;
attaching the lower end of said member to said broaching tool;
drivingly reciprocating the upper end of said member in a longitudinal direction so as to reciprocate said broaching tool up and down said sloped surface and thereby rob ore from said sloped surface; and
collecting the robbed ore from said trench.

**2.** The process of claim **1** which includes the additional step of adjusting the weight value of said parasite load while the mining operation is in progress.

**3.** The process of claim **1** which includes the additional step of adjusting the angle of said sloped surface by adjusting the weight value of said parasite load.

**4.** The process of claim **1** which includes the additional step of adjusting the mining rate by adjusting the weight value of said parasite load.

**5.** The process of seam mining which comprises:
forming within the seam a trench having a sloped surface;
placing a broaching tool upon said sloped surface;
weighting said broaching tool with a removable parasite load whose weight value is selected with regard to the angle of said sloped surface, the hardness of the material being mined, and the cutting capability of said broaching tool;
placing a relatively rigid elongated member having some bending flexibility within the trench and disposed above and generally parallel to the slope of said sloped surface;
attaching the lower end of said member to said broaching tool;
placing a reciprocating drive means upon the surface of the ground adjacent the top of said trench;
attaching the upper end of said member of said drive means;
operating said drive means so so to drivingly reciprocate said elongated member in a lengthwise direction and concurrently reciprocate said broaching tool up and down said sloped surface, thereby to rob ore from said sloped surface; and
collecting the robbed ore.

**6.** The process claimed in claim **5** wherein the weight value of said parasite load is adjusted while the mining operation is in progress.

**7.** The process of claim **5** which includes the additional step of adjusting the angle of said sloped surface by adjusting the weight value of said parasite load.

**8.** The process of claim **5** which includes the additional step of adjusting the mining rate by adjusting the weight value of said parasite load.

**9.** The process of seam mining which comprises:
forming within the seam a hole having a sloped surface;
placing a broaching tool upon said sloped surface;
extending a relatively rigid elongated member into the hole and attaching its lower end to said broach;
and drivingly reciprocating the upper end of said member, and at the same time progressively advancing said member in a longitudinal direction;
whereby the reciprocating action of said broach robs ore from said sloped surface, and said broach concurrently advances longitudinally of said hole.

**10.** The process of claim **9** wherein the length of said reciprocating movement is less than the length of said broach.

**11.** The process of claim **9** wherein the length of said reciprocating movement is less than the depth of said hole.

**12.** The process of claim **9** which further includes the step of placing a removable parasite weight load upon said broach, whereby both the mining rate and the ultimate slope of said sloped surface are determined in part by the value of said weight load.

**13.** The process of claim **9** which further includes the step of forcefully circulating a fluid within the hole as a means of collecting the robbed ore.

**14.** The process of claim **9** wherein said broach is progressively advanced in one direction in said hole, and the progressively advancing drive action is then reversed in order to widen said hole.

**15.** The process of seam mining which comprises:
forming within the seam a hole having a sloped surface;
placing upon said sloped surface a broaching tool having cutters adapted for cutting in both directions;
placing a reciprocating drive means above the hole;
extending a relatively rigid elongated member into the hole, attaching its lower end to said broach, and attaching its upper end to said reciprocating drive means; and
operating said reciprocating drive means in such manner as to reciprocate said broaching tool through only a portion of the depth of the hole, applying a greater force when lifting said broach then when driving said broach downwardly, thereby robbing ore from said sloped surface;
said elongated member having lateral bending flexibility, and said broaching tool having a weight per unit of its cutting area which is at least comparable to the failure strength of the material being mined.

**16.** Process of seam mining comprising:
forming a pilot hole in said seam;
mechanically robbing ore from a sloped surface formed in a side of said pilot hole, whereby said pilot hole is enlarged to form a trench;
maintaining said trench substantially full of a fluid which has a specific gravity greater than water; and
collecting said robbed ore from said trench.

**17.** The process of claim **16** wherein said ore is mechanically robbed from said sloped surface by the reciprocating action of a weighed broaching tool.

**18.** The process of claim **16** wherein the specific gravity of said fluid is greater than that of the ore and the ore is collected from the upper surface of said fluid.

**19.** A process of mining comprising:
forming a trench;
maintaining said trench substantially full of drilling fluid;
mechanically robbing ore from a sloping working face of said trench by drawing a weighted broaching tool along said working face, said broaching tool being forced against working face primarily by the force of gravity;

circulating a stream of drilling fluid through said broaching tool to flush chips away from said broaching tool; and

collecting said robbed ore from said trench.



**20.** The process of claim **19** wherein said drilling fluid is also circulated within said trench as a means of collecting the robbed ore.

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