United States Patent [19]

Sugden

[11] **3,830,545**

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[54] **SHIELD TUNNELING MACHINE WITH ORBITING CUTTERHEAD**

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[52] **U.S. Cl.** **299/33,** 61/85, 175/62, 175/106, 175/343, 299/56, 299/90

[51] **Int. Cl.** **E01g 3/03**

[58] **Field of Search** 299/31, 33, 56, 58, 90; 61/84, 85; 175/62, 106, 343

[56] **References Cited**

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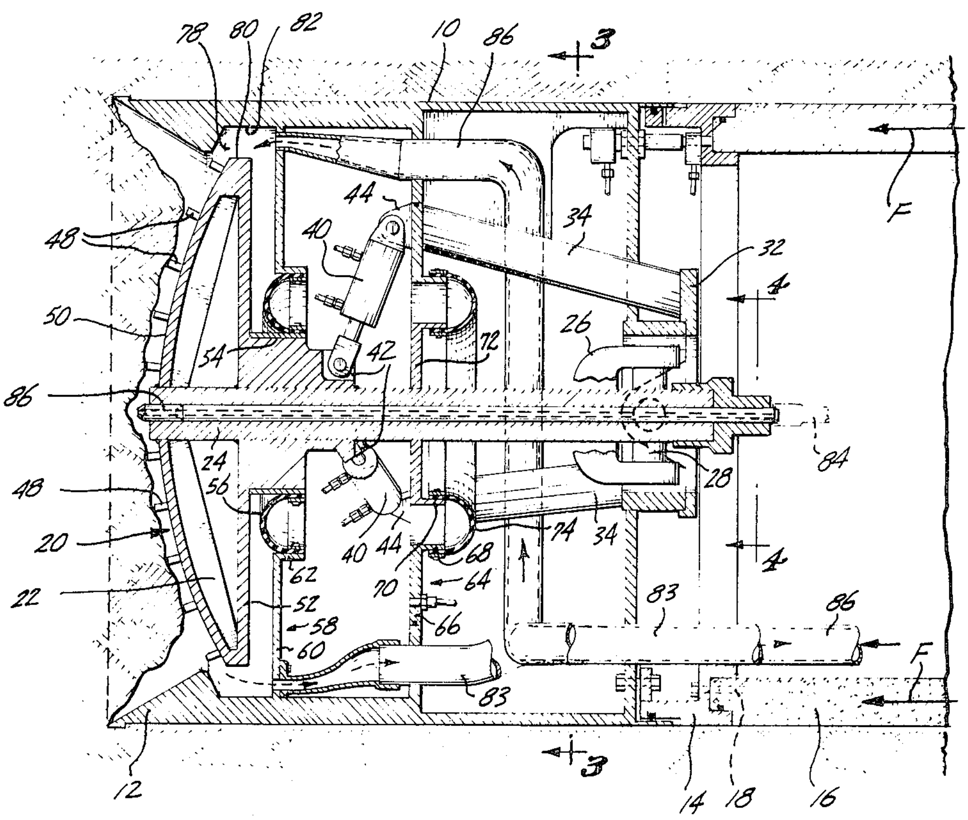
Attorney, Agent, or Firm—Graybeal, Barnard, Uhlir & Hughes

[57] **ABSTRACT**

The cutterhead and cutter elements thereon undergo an orbiting radial shifting movement as the shield is advanced. Water is delivered to the cutterhead region forwardly of a water tight bulkhead for admixture with the material being excavated from the tunnel face. The resulting mixture is pumped away from the tunnel face through a removal pipe which extends rearwardly through the bulkhead. The bulkhead includes a fixed outer portion and a flexible diaphragm type seal which closes the space between the cutterhead and said fixed outer portion.

12 Claims, 5 Drawing Figures



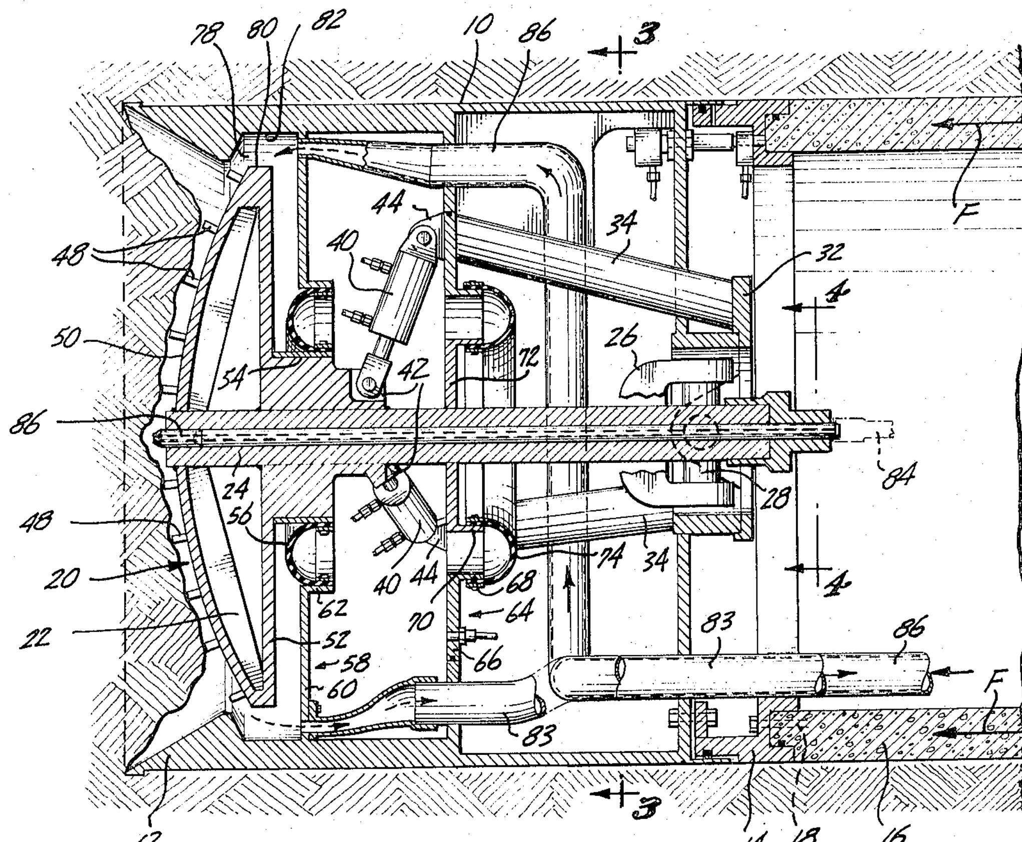

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Fig. 1.

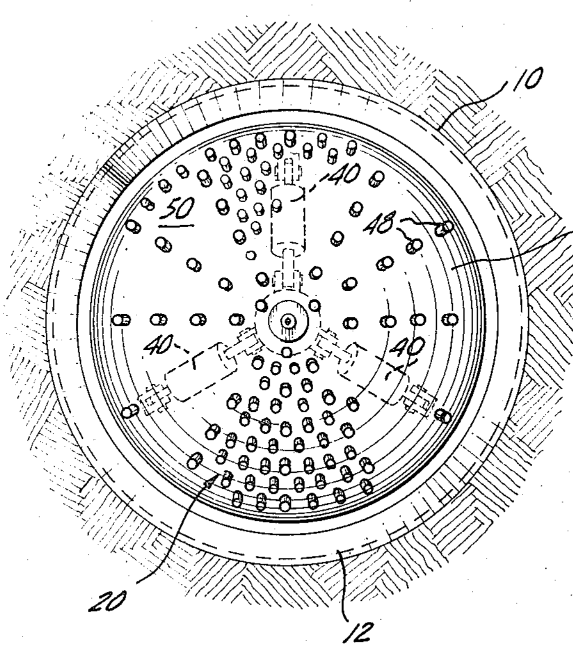
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Fig. 2.

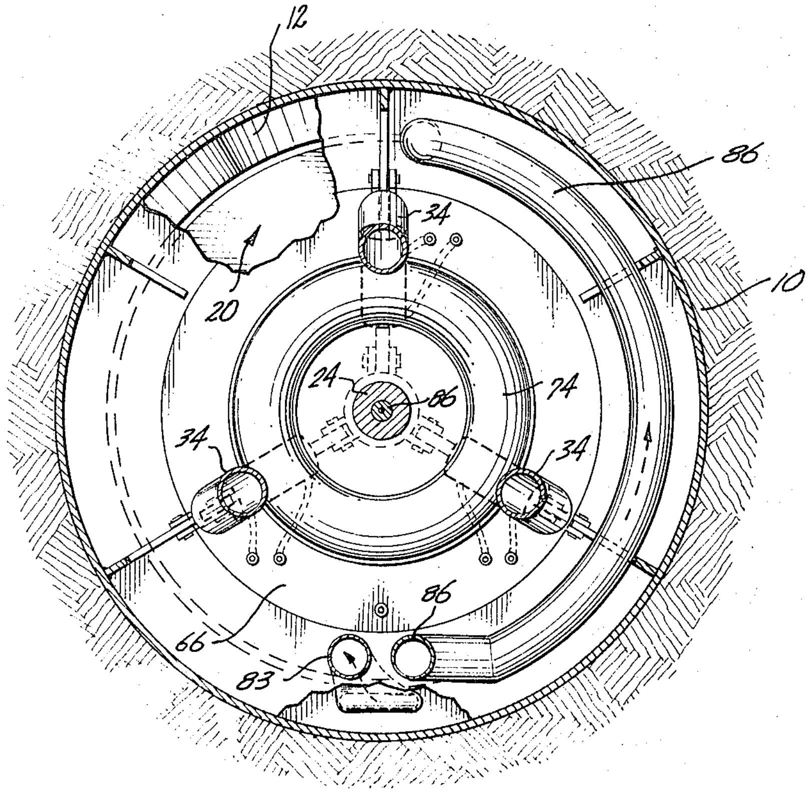

Fig. 3.

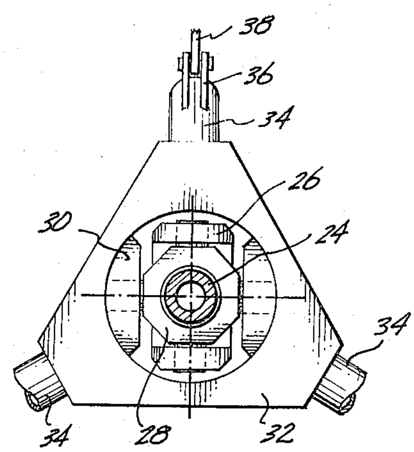

Fig. 4.

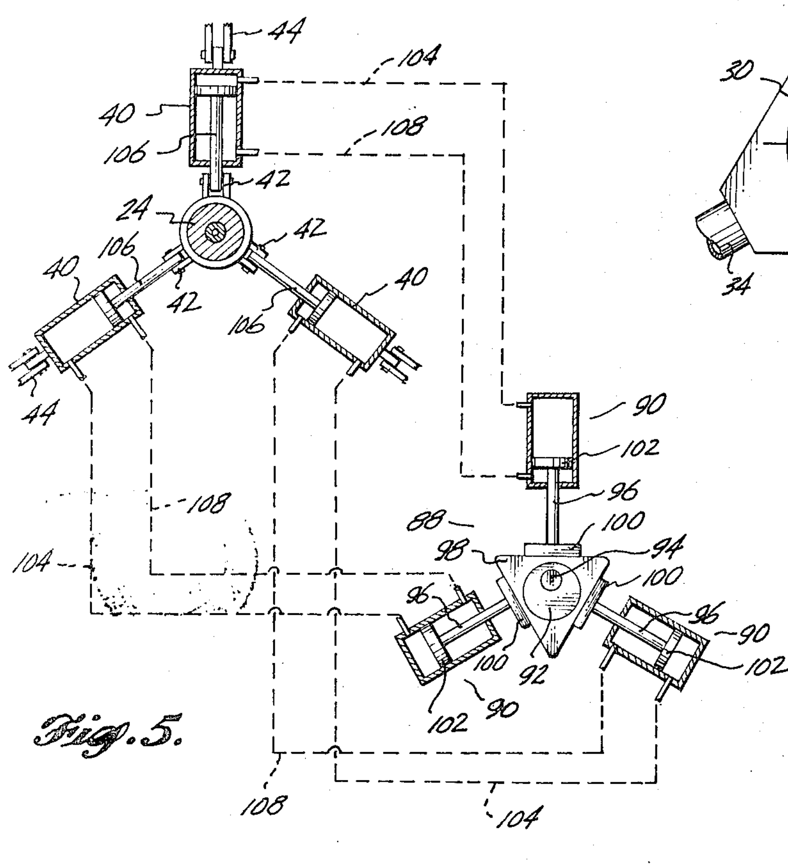

Fig. 5.

SHIELD TUNNELING MACHINE WITH ORBITING CUTTERHEAD

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to tunneling machines and more particularly to shield type tunneling machines operable for excavating tunnels in soft ground.

2. Description of the Prior Art

It is known to excavate tunnels in relatively soft ground by the use of "bulkhead" tunneling machines. This type of tunneling machine comprises a tubular caisson, termed a "shield," which is advanced axially through the ground. A transverse bulkhead divides the shield axially. Water or some other liquid is pumped into the region forwardly of the bulkhead to mix with the excavated ground material. The resulting mixture is removed from the region forwardly of the bulkhead via a conduit extending rearwardly through an opening in the bulkhead. Examples of this type of tunneling machine are shown by U.S. Pat. No. 360,959 granted Apr. 12, 1887 to James H. Greathead; by U.S. Pat. No. 3,260,054 granted July 12, 1966 to Hans Lorenz; by U.S. Pat. No. 3,334,945 granted Aug. 8, 1967 to John V. Bartlett; and by U.S. Pat. No. 3,360,061 granted Dec. 26, 1967 to Carlos R. Canalizo.

It is common in tunneling machines of this type to locate a rotating cutterhead or some other type of cutter element forwardly of the bulkhead for mechanical excavating the tunnel face. Each of the foregoing patents discloses some form of a mechanical excavator.

SUMMARY OF THE INVENTION

The present invention relates to the provision of a bulkhead shield type tunneling machine having a cutterhead which undergoes an orbiting radial shifting movement rather than rotation. The orbiting head is easily supported and driven and no rotating-to-stationary parts seal is required. Rather, the bulkhead is provided with a flexible wall section which is connected to a portion of the cutterhead and is sufficiently distortable to permit the orbiting movement of the cutterhead.

Preferably, the cutterhead includes an elongated drive shaft which projects through an opening in a rigid portion of the bulkhead and which is mounted at its rear end onto the shield by means of a universal joint. Preferably, such cutterhead is driven by a ring of radially disposed piston-cylinder linear motors which are interconnected between the shield and a portion of the cutterhead at locations rearwardly of the bulkhead. A fluid pressure generator distributes fluid pressure pulses from each said linear motor to the next in repetitive cyclic fashion around said ring for in this manner producing the orbiting radial shifting movement of the cutterhead and the cutter elements carried thereby. An important advantage of this type of drive system is that it will not stall out in the event the cutterhead encounters hard material which restrains its movement. Instead the input energy is absorbed by the elasticity of the drive fluid.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an axial sectional view of an embodiment of the invention;

FIG. 2 is a front elevational view, looking towards the face of the cutterhead shown in FIG. 1, showing a representative number of cutter elements which in actuality are substantially evenly spaced over the entire face of the cutterhead;

FIG. 3 is a cross sectional view of the machine shown by FIG. 1, taken substantially along line 3—3 of FIG. 1;

FIG. 4 is a cross sectional view taken along line 4—4 of FIG. 1; and

FIG. 5 is a diagrammatical view of a fluid drive system for the cutterhead.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In preferred form, the tunneling machine of this invention comprises a cylindrical shield **10** having an open forward end bordered by a leading cutting edge **12.** Shield **10** may comprise a separate tail ring **14** with respect to which the shield proper may be adjustable for steering purposes. The tail ring **14** may be firmly secured to a forward cylindrical tunnel lining section **16,** such as by a plurality of bolts **18.** An endwise force (indicated by force arrows F) may be directed against the lining section **16** to move both it and the shield **10** forwardly (not shown) may be added to the lining in succession behind section **16,** and each pushed forwardly tommove the shield **10** and the lining segments ahead of it forwardly together. Of course, other techniques of advancing the machine may be employed.

According to the invention, an orbiting type cutterhead **20** is supported within the shield **10** forwardly of bulkhead means which divides the shield **10** axially into a forward wet compartment and a rearward dry compartment. Preferably, cutterhead **20** comprises a radial, generally disc shaped cutter carrier **22** attached to the forward end of an elongated tubular shaft **24.** Shaft **24** extends rearwardly through the shield **10** and at its rear end is connected to the first yoke **26** of a universal joint. From yoke **26** shaft **24** extends rearwardly through a trunnion member **28.** The second yoke **30** of the universal joint is attached to a support plate **32** which may be rigidly connected to the shield **10** by a plurality of support legs **34** and mounting plates **36, 38** (FIG. 4).

A ring (e.g., three) of equally spaced, radially disposes piston-cylinder linear motors **40** are interconnected between connector plate portions **42** of the cutterhead **20** and anchor plates **44** secured to the shield **10.** The respective ends of the motors **40** are connected by pivotal joints to the supports **42, 44.** A pressure generator PG (FIG. 5) is provided for distributing fluid pressure pulses from each linear motor **40** to the next in repetitive cyclic fashion around said ring, for producing the orbiting radial shifting movement of the cutterhead **20** and the cutter elements **48** thereon, as will hereinafter be described in greater detail.

The cutter carrier **22** may comprise a spherical forward wall **50** and a planar rear wall **52,** both of which are welded or otherwise firmly secured at their centers to the forward portion of the shaft **24.** Walls **50** and **52** come together and are secured together at their peripheries. A cylindrical section **54** may project rearwardly from wall **52** to serve as both a reinforcement for the mounting plates **42** and a mounting member for a flexible wall section **56** of a bulkhead **58.** In addition to flexible wall section **56** the bulkhead **58** comprises an annular fixed wall **60** which is firmly secured at its outer periphery to the shield **10.** A central opening is formed in wall **60** about which a cylindrical mounting ring **62** is secured. The flexible wall **56** is annular in form and has a radial dimension which is substantially larger than the radial space which exists between the two support rings **54, 62** when the shaft **26** is centered within the shield **10.** As a result, flexible wall **56** is distortable enough so that it does not interfere with the orbiting movement of the cutterhead **20** while it forms its sealing or closure function.

A second bulkhead **64** may be provided rearwardly of the linear motors **40.** The secondary bulkhead **64** may comprise a rigid annular outer portion **66** secured to the shield **10,** a fixed annular outer mounting ring **68,** an inner movalbe mounting ring **70** which is attached to a radial plate **72** which in turn surrounds the tubular shaft **24,** and a second flexible wall section **74.** The secondary bulkhead **64** serves as a backup for the primary bulkhead **58** in the event that something happens to the latter.

Flexible wall sections **56, 74** may be made from truck innertubes which are not inflated.

Preferably, compressed air is delivered into the space between the two bulkheads **58, 64.** In the event one of the bulkhead seals **56, 74** breaks or a leak otherwise develops in one of the bulkheads **58, 64,** the loss of air pressure within the compartment between the two bulkheads **58, 64** may be sensed (by means not shown) and used to produce a signal to the operator that a leak has developed.

The cutter elements **48,** which may be short chisel-like elements, are on the cutter carrier **22** in sufficient numbers so that during orbiting movement of the cutterhead **20** a large part of the tunnel face is swept by an orbiting cutter element **48.** In FIG. **2** only a representative portion of the cutter elements **48** are shown.

An annular space or gap **78** is formed between the outer periphery **80** of the cutter carrier **72** and the adjacent ring portion **82** of the shield **10.** This annular space **78** serves to meter the flow of ground material rearwardly when freely flowing ground material is encountered.

A material removal pipe **83** is provided to pick up the mined material from the annular region immediately surrounding and trailing the peripheral portion **80** of the cutter carrier **22.** Such pipe may be a part of a material removal system of the general type disclosed by the aforementioned U.S. Pat. No. 3,334,945.

Under certain ground conditions a cutting fluid (e.g., water, mud, etc.) is delivered to the face region of the tunnel forwardly of the cutter carrier **22.** It may be delivered to the face region by way of a delivery conduit **84** which is supported within the hollow shaft **24** and has a discharge nozzle **86** at its forward end. Alternatively, or additionally, the water, mud, etc. may be delivered into the region **78** by a conduit **86.** The water, mud, etc., delivered through conduit **84** (and/or conduit **86**) serves to fluidize the ground material. Cutter carrier **22** and the cutter elements **48** serve to agitate and mix together the earth material and the water, mud, etc., so as to form a slurry which is easily pumpable rearwardly through the conduit **83.** Of course, when wet ground is encountered it is not necessary to deliver a cutting fluid through the conduit **84** (and/or conduit **86**). When extremely wet ground is encountered the cutter carrier **22** and the cutter elements **48** will primarily function as a slurrying implement and will not be needed for mechanically breaking the ground material loose from the tunnel face.

The conduits **83, 84, 86** are of sectional construction so that additional sections can be added to them as the shield **10** is moved forwardly through the ground.

Referring now to FIG. **5,** a pressure pulse generator **88** is shown connected to the drive motors **40** for the cutterhead **20.** The generator **88** may be mounted on a sled (not shown) located in the tunnel rearwardly of the shield **10.** Generator **88** is shown to comprise three piston cylinder units **90,** each of which is associated with one of the drive motors **40.** A crank shaft **92** having a center of rotation **94** provides an eccentric drive for the pistons **96.** The cylindrical drive lobe of the crank shaft **92** turns within a central opening formed in a triangular member **98.** The inner ends of the pistons **96** include flat portions **100** which make sliding contact with the three bases of member **28** as the crank shaft **92** turns about axis **94.** Rotation of shaft **92** about axis **94** drives the member **98** along an orbital path. As it so moves the member **98** changes the position of the pistons **96** relative to their respective cylinders. When a piston **96** is forced radially outwardly the fluid within the chamber outwardly of its head **102** is forced through a conduit **104** into the radially outer chamber within the associated fluid motor **40.** Such fluid pushes the piston **106** of the motor **40** radially inwardly to drive the shaft **24** and also forces the fluid which is in the radially inner chamber of the motor **40** to flow from such chamber through a conduit **108** into the radially inner chamber of the associated generator cylinder **90.** This type of hydraulic drive system is basically similar to the hydraulic drive system disclosed by my U.S. Pat. No. 3,544,075, granted on Dec. 1, 1970. Of course, it is to be understood that the cutterhead **20** may be driven throughout its orbital path of travel by any suitable drive mechanism.

The tunneling machine of this invention possesses many important advantageous over known prior machines provided for the same purpose. It utilizes a fixed bulkhead. No pressurization is required in the tunnel behind the shield. The pressurization that is done forwardly of the bulkhead is done by the same fluid which is supplied for the purpose of fluidizing the cut ground material. All of the machinery is located in dry areas within the shield or within the tunnel rearwardly of the shield. Since an orbital rather than a rotary motion is employed, no rotary seals or packings are needed. The orbital motion requires only a relatively small amount of movement for any given part on the cutterhead (e.g., a maximum movement of only about 3 inches). Therefore, a diaphragm type seal can be employed between the moving and stationary parts. The machine provides good control of progress because the amount of material being removed can be easily controlled by varying the cutterhead speed and the flow rate of fluid through the cutterhead region. Also, it is believed that deformation of the diaphragm **56** which occurs during orbiting of the cutterhead **20** may produce a peristaltic pumping effect forwardly of the bulkhead **58,** to aid movement of the water, mud, etc., and the cuttings picked up thereby, from the cutterhead region back through the removal pipe **33.**

The direction of cutterhead drive should be reversible so that any counter torque problems which are incurred can be readily resolved by merely reversing the direction of orbit. In some installations the front wall **50** of the cutter carrier **22** may be flat rather than spherical. Also, in some installations the seal sections **56, 74** may be omitted and the orbiting drive motors **40** operated in the wet rather than in the dry.

It is believed that it will always be necessary to supply water or mud to the face of the tunnel. If an attempt were to be made to use only ground water to form a slurry, it would probably lead to a cave in of the ground material in front of the machine. The circulation of water or mud at a controlled pressure can maintain a hydrostatic balance at the tunnel face, (i.e., the ground water pressure can be opposed by an equal pressure) to prevent a collapse of face and an over amount of excavation attended by ground caving and/or systems. Also, the almost complete closure at the face afforded by the orbiting cutterhead with its small amount of movement (compared with a rotating cutterhead), and its metering action, help prevent over excavation of the face.

Another advantage of the tunneling system of this invention is that the density of the circulating fluid can be monitored to provide a means of equating the amount of solid material excavated to the forward advance of the shield. The presence of one or more bulkheads, sealed by flexible diaphragms, permits pressurization of the face by a liquid without having to pressurize the tunnel rearwardly of the bulkhead, thus allowing personnel to work in the tunnel behind the machine under normal atmospheric pressure.

Having thus described the invention, it will be understood that various changes and modifications may be made in the specific form and construction of the various components thereof, without departing from the scope of the appended claims which define the scope of protection.

What is claimed is:

1. A machine for tunneling through earth formations, comprising:

a tubular shield having side wall means and an open forward end;

a cutterhead at the forward end of said shield including a plurality of forwardly directed cutter elements;

means for causing an orbiting radial shifting movement of said cutterhead and the cutter elements thereon;

a radial bulkhead in said shield adjacent said cutterhead, said bulkhead including a fixed portion secured to said shield and a flexible radial closure wall means interconnected between said support and said cutterhead, said flexible wall means being sufficiently distortable to permit such orbiting radial shifting movement of the cutterhead relative to said support; and

material removal conduit means extending rearwardly from the cutterhead region forwardly of said bulkhead.

2. The machine of claim **1**, further comprising means for delivering a cutting fluid under pressure to the cutterhead region forwardly of said radial bulkhead, for admixture with the earth material being removed from the tunnel face.

3. The machine of claim **1**, wherein said cutterhead comprises a generally radial cutter carrier on which the cutter elements are located, an elongated shaft connected at its forward end to said cutter carrier and extending rearwardly therefrom within said shield, said shield comprises a support for the rear end of said shaft and a universal joint interconnected between said support and the rear end of said shaft, and said means for causing an orbiting radial shifting movement of said cutterhead and the cutter elements thereon comprises a ring of radially disposed piston-cylinder linear motors interconnected between said cuterhead and said shield at a location rearwardly of said radial bulkhead, and means for distributing fluid pressure pulses from each said linear motor to the next in repetitive cyclic fashion around said ring, for producing said orbiting radial shifting movement of the cutterhead and the cutter elements thereon.

4. The machine of claim **3**, further comprising means for delivering a fluid under pressure to the cutterhead region forwardly of said radial bulkhead, for mixture with the earth material being removed from the tunnel face.

5. The machine of claim **3**, wherein the means for delivering a fluid under pressure to the cutterhead region forwardly of said radial bulkhead comprises a conduit extending axially through said elongated shaft.

6. The machine of claim **3**, wherein the fixed portion of the bulkhead comprises an annular wall fixed at its outer periphery to said shield and having an open center through which said elongated shaft extends, and said flexible radial closure wall means is attached to said fixed portion of said bulkhead.

7. The machine of claim **6**, wherein said flexible radial closure wall means is annular and radially is substantially larger in dimension than the radial clearance which exists between the cutterhead and the radial inner extent of said fixed wall when said elongated shaft is substantially coincident with the center axis of the shield.

8. The machine of claim **1**, wherein said cutterhead comprises a generally radial cutter carrier having an outer periphery spaced relatively close to the side wall means of said shield, with a radial gap being formed about said cutter carrier between its outer periphery and the side wall means of said shield in which said cutter carrier moves during the orbiting radial shifting movement of the cutterhead, with said forwardly directed cutter elements being mounted on said cutter carrier.

9. The machine of claim **8**, wherein said means for causing an orbiting radial shifting movement of said cutterhead and the cutter elements thereon comprises a ring of radially disposed piston-cylinder linear motors interconnected between said cutterhead and said shield at a location rearwardly of said radial bulkhead, and means for distributing fluid pressure pulses from each said linear motor to the next in repetitive cyclic fashion around said ring, for producing said orbiting radial shifting movement of the cutterhead and the cutter elements thereon.

10. The machine of claim **8**, wherein the fixed portion of the bulkhead comprises an annular wall fixed at its outer periphery to said shield and having an open center through which a portion of the cutterhead extends, and said flexible radial closure wall means is interconnected between said portion of the cutterhead and said fixed wall.

11. The machine of claim **3**, further comprising a second radial bulkhead in said shield spaced rearwardly of said piston-cylinder linear motors and forwardly of said universal joint, said second bulkhead also comprising an annular wall portion fixed at its outer periphery to said shield and having an open center through which said elongated shaft extends, and a second flexible radial closure wall means interconnected between a portion of said cutterhead and said fixed wall portion of the bulkhead.

12. The machine of claim **11**, further comprising means for delivering compressed air into the space between the two bulkheads for pressurizing such space.

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