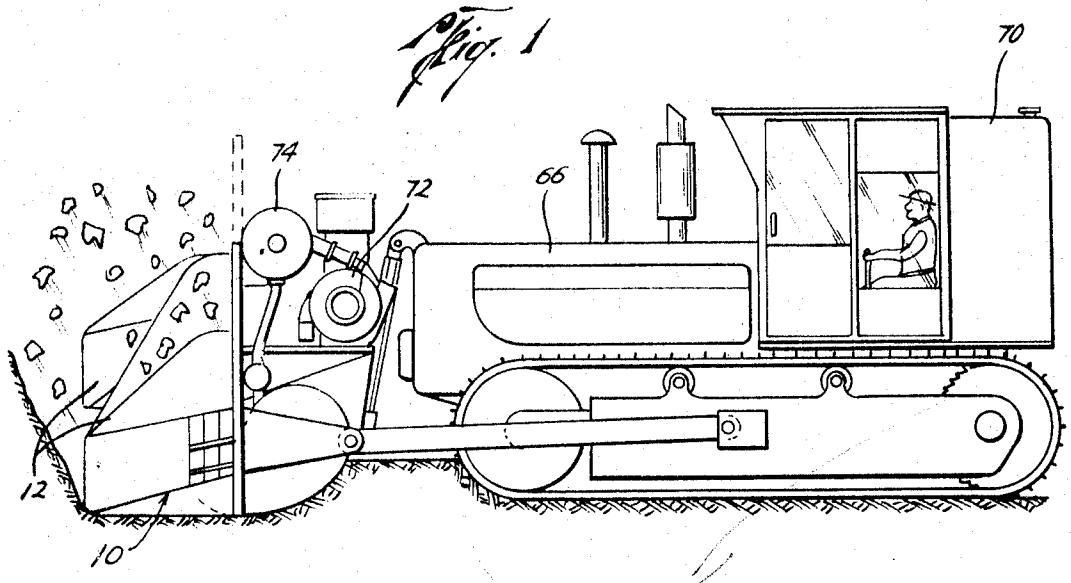
Aug. 19, 1969 J. M. CLARK, JR., ET AL 3,461,577

METHOD OF AND AN APPARATUS FOR DISPLACING MATERIALS

Filed Dec. 15, 1965 3 Sheets-Sheet 1

Fig. 1



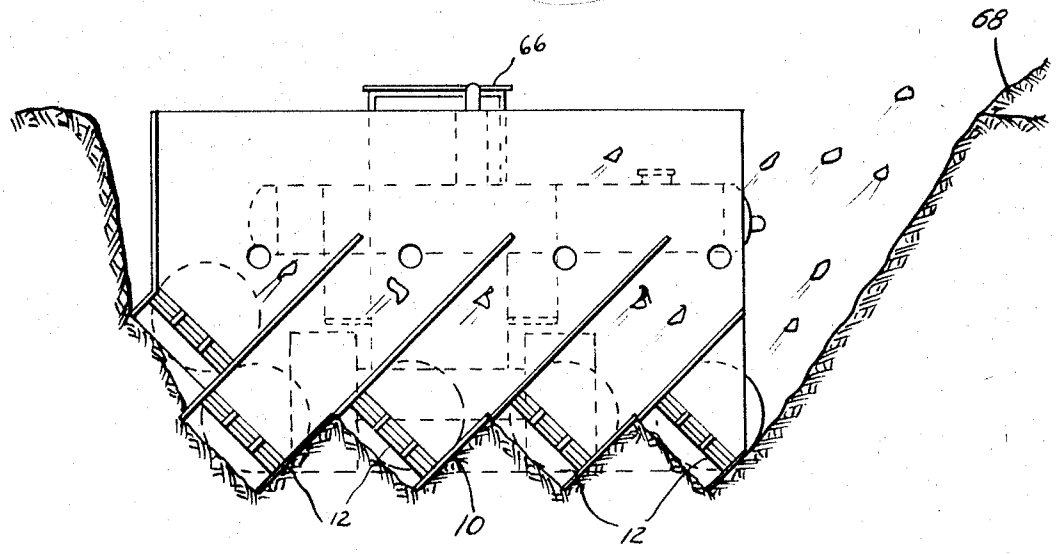


Fig. 2

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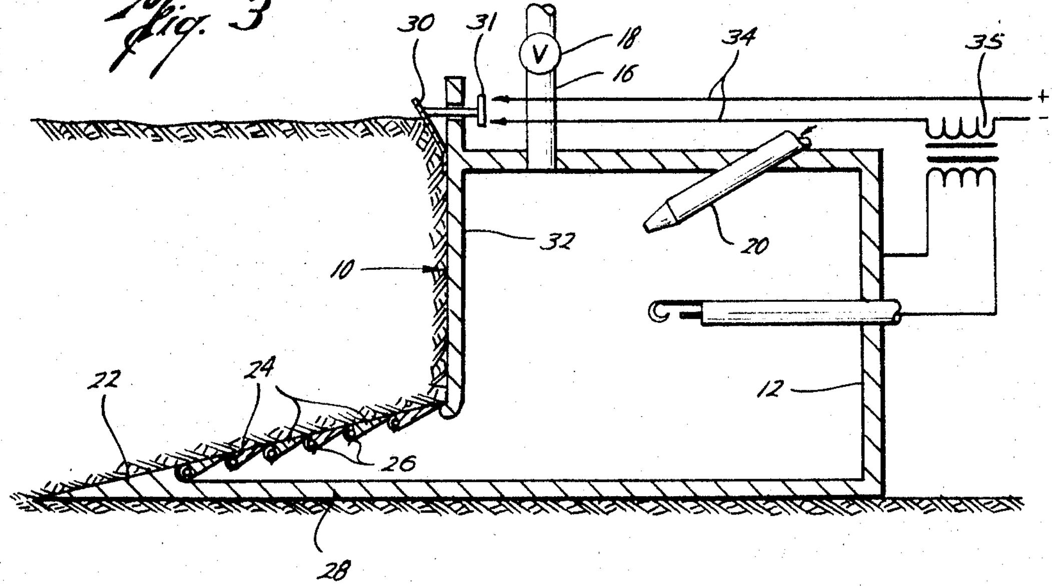
METHOD OF AND AN APPARATUS FOR DISPLACING MATERIALS

Filed Dec. 15, 1965 3 Sheets-Sheet 2

Fig. 3



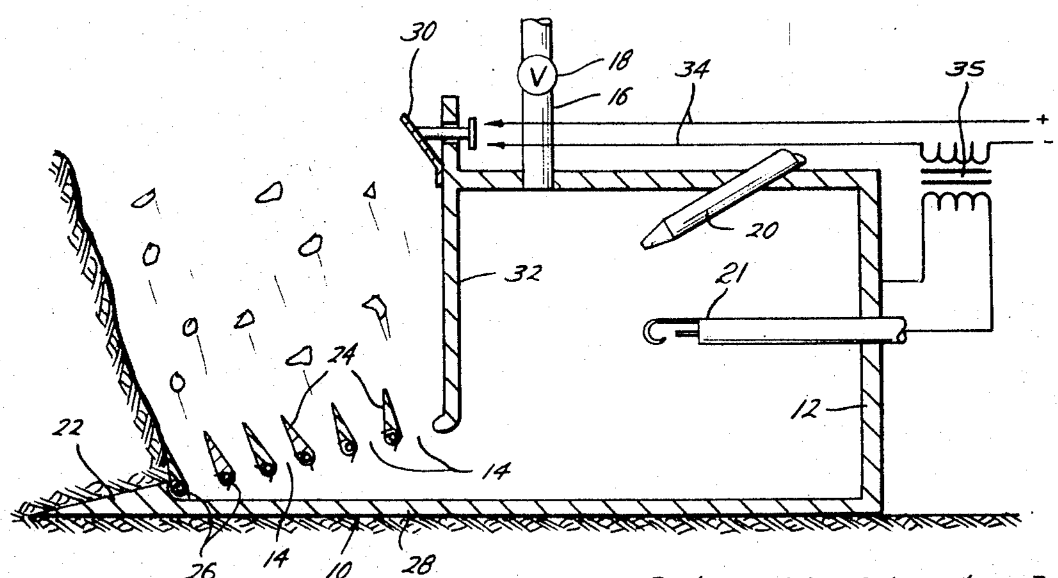


Fig. 4

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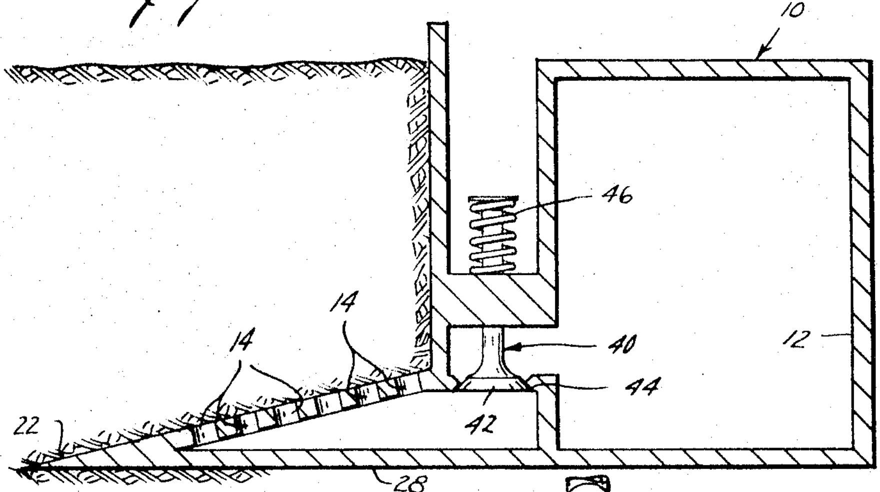
METHOD OF AND AN APPARATUS FOR DISPLACING MATERIALS

Filed Dec. 15, 1965 3 Sheets-Sheet 3

Fig. 5



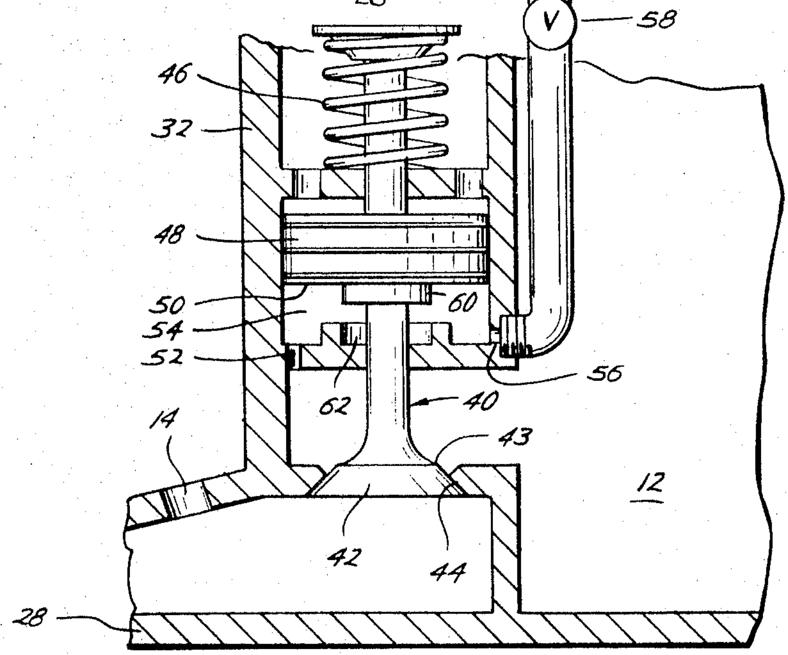


Fig. 6

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METHOD OF AND AN APPARATUS FOR DISPLACING MATERIALS

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U.S. Cl. 37—1 11 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for repetitively displacing material by placing a closed combustion chamber adjacent the material and providing an explosion in the chamber for creating high pressure gases therein and opening the chamber to direct the gases against and fragment and move the material, and repeating the cycle. A combustion chamber having a pointed portion adapted to be pushed into the material to be displaced and which includes a plurality of openings in communication with the combustion chamber, and providing valve means for sealing off the combustion chamber until a predetermined pressure buildup and explosive force occurs in the chamber, and thereafter opening the valve means so that the high pressure and temperature gases created by the explosion flow through the openings and rupture the soil into fragments. The combustion chamber openings normally including louvers covering the openings for preventing the openings from being blocked by the material, but opening upon an increase in pressure in the combustion chamber.

The present invention relates to a method of and an apparatus for displacing materials, and more particularly, relates to a method and an apparatus for providing a repetitive explosion for material displacement and movement.

Generally, the movement of material, for example soil, by mechanical equipment such as draglines and bulldozers is slow, expensive, and in some cases, such as in handling high cohesion soils in the 40 percent moisture content range, is virtually impossible because of the adhesion or stickiness of the soil. The present invention is generally directed to a material movement method and apparatus which will disaggregate and displace high cohesion materials as well as being more than adequate for materials of lower cohesion.

It is the general object of the present invention to provide a method and an apparatus for displacing material by explosive means which utilizes an explosive force to disaggregate and displace the material, and providing repetitive explosions to provide high capacity moving capabilities.

It is still a further object of the present invention to provide a method of and an apparatus for mass movement and displacement of materials by providing a combustion chamber which is periodically charged with a combustive mixture and ignited to form pressure and heat within the chamber which is directed against the materials to fragment, and displace them.

Still a further object of the present invention is the method of and an apparatus for displacing material by placing a combustion chamber adjacent to the material to be moved, providing an explosion in the chamber, opening the chamber and directing the heat and pressure from the explosion against the material thereby moving the material, closing the combustion chamber, and again moving the chamber against the material whereby the cycle may be repeated.

Preferably, for convenience, it is a further object to provide a method of and an apparatus for moving material by providing an explosion or combustion cell which is charged with compressed air and a hydrocarbon fuel to form a combustible mixture which is ignited to form a high pressure within the explosion cell wherein the expanding gas from the combustion cell is directed against the material to disaggregate and displace the material.

A still further object of the present invention is the provision of a method and an apparatus for moving material comprising placing a combustion chamber adjacent and at least partially under the material, introducing air into the chamber, introducing fuel into the chamber, igniting the mixture in the chamber to provide an explosion, opening the chamber, directing the heat and pressure from the explosion upwardly and against the material thereby displacing the material, closing the chamber, and moving the chamber against the unmoved material whereby the cycle may be repeated.

A still further object of the present invention is the provision of a method and an apparatus for displacing material, for example soil, by providing a combustion chamber which includes a pointed portion adapted to be pushed into and under a portion of the soil to be displaced and which includes a plurality of openings in communication with the combustion chamber and directed upwardly, and providing valve means for sealing off the combustion pressure in the combustion chamber until a predetermined pressure build up in the explosive force occurs in the chamber, and thereafter opening the valve means so that the high pressure and temperature gases created by the explosion flow through the openings and rupture the soil into fragments, moving the soil to a new position, and causing some secondary rupturing effect by flashing to steam some of the moisture contained in the soil.

A still further object of the present invention is the provision of a rapidly cycling method of and an apparatus for displacing material by providing a pressure generating combustion chamber which can be charged and ignited within a short period of time to provide a repetitive force for displacing the material as the cell is moved into the undisplaced material.

Still a further object of the present invention is the provision of a combustion chamber for providing an explosion and directing the products of combustion through a plurality of openings adjacent the material to be moved and in which valve means are provided between the combustion chamber and openings therefrom, for example, a valve and valve seat having a spring normally closing the valve and a piston connected to the valve having a greater cross-sectional area than the valve seat and acting to normally close said valve by the action of pressure in the combustion chamber, and an orifice restricting the flow of pressure between the combustion chamber and the piston whereby on increase of pressure on the piston and valve the valve will open after a buildup of the combustion pressure in the combustion chamber to allow the high pressures and high temperatures created to pass through the openings and break up and move the material.

Other and further objects, features and advantages will be apparent in the following description of presently preferred embodiments of the invention, taken in conjunction with the accompanying drawings, where like character references designate like parts throughout the several views, and where,

FIGURE 1 is an elevational view showing a gang of combustion chambers of the present invention being carried by a tractor and in use for displacing soil,

FIGURE 2, is a front elevational view of the apparatus of FIGURE 1,

FIGURE 3 is an enlarged cross-sectional elevational view, partly schematic, illustrating one embodiment of the present invention in contact with the material to be moved,

FIGURE 4 is a cross-sectional view, similar to FIGURE 1 illustrating the present invention in the step of displacing the material,

FIGURE 5 is a cross-sectional elevational view, illustrating another embodiment of the present invention, and

FIGURE 6 is an enlarged fragmentary elevational view in cross-section, illustrating the valve structure shown in FIGURE 5.

By way of example only, the present invention will be described in use for displacing earth and soil, but it is to be understood that the present apparatus and method may conveniently be used for displacing many and various other types of material.

Referring now to the drawings, and particularly to FIGURES, 1, 2, and 3, the numeral **10** generally indicates the apparatus of the present invention in use for earth moving and generally includes an explosion cell or combustion chamber **12** which may be periodically moved into the soil to be displaced by a suitable vehicle such as a tractor **66** to provide an explosive force which is directed through openings **14** and against the soil to displace and move the soil.

The combustion chamber **12** is charged with a suitable combustion mixture for creating an explosion therein, preferably the chamber **12** is charged with an air/fuel mixture, the air being provided by any suitable and conventional means such as a compressor **72** (FIGURE 1) through an air inlet **16** and valve **18**, and the fuel being provided by a suitable and conventional fuel injection nozzle **20** to provide an air/fuel mixture at the desired pressure and air/fuel mixture ratio. Combustion is initiated in the mixture by a suitable ignition source **21** which is preferably located adjacent the center of the combustion chamber **12** to provide the shortest possible flame travel and thus the maximum rate of pressure rise in the combustion chamber **12**.

Preferably, the combustion chamber **12** includes a lip or pointed blade portion **22** for penetrating into and under a portion of the soil, and includes openings **14** whereby the explosive force from the combustion chamber **12** may be directed upwardly for more easily dislodging and breaking up the soil. Therefore, it is preferable that the lip or pointed blade portion **22** be positioned at the bottom and at the forward edge of the combustion chamber **12** and adjacent the bottom **28**.

The combustion chamber **12** is preferably closed while it is being charged with fuel and air to the desired initial pressure prior to ignition. One type of structure that may be provided to close the chamber **12** so that the fuel mixture in the chamber may be compressed to the selected value is a plurality of pivoting louvers **24** which normally are held in a closed position covering the openings **14** as shown in FIGURE 3 by springs **26** such as conventional torsion springs so as to provide an essentially airtight seal to retain the charging pressure in the chamber **12** until combustion of the air/fuel mixture is relatively well advanced. However, upon the rapid rise of pressure within the chamber **12**, as a result of combustion, the louvers **24** will open (FIGURE 4) and release the hot gases at high pressures and high temperatures. The explosion of the high pressure and temperature gases will rupture the soil into fragments, dislocate the fragments to a new position and cause some secondary rupturing effect by flashing to steam some of the moisture contained by the soil. In addition, the hot gases will also move cohesive soils having a high moisture content which at the present time are very difficult to move because of adhesion of these soils to conventional equipment.

After the flow of explosive gases through openings **14** cease, the louvers **24** will snap shut rapidly enough to prevent the entry of any dirt or water into the combustion chamber **12** and the lip **22** of the explosion chamber **12** may be moved into the soil bank by any suitable vehicle such as tractor **66**. The weight of the soil pressing down upon the top of the louvers **24** will aid in keeping them closed tight as the combustion chamber **12** is again charged with high pressure air for repeating the cycle.

The pressure generating chamber **12** can be charged and ignited within a short period of time, generally faster than is possible for the vehicle **66** to move the chamber **12** forward into a new position after each explosion. If desired, an ignition switch **30** may be provided on a forward wall **32** of the pressure chamber **12** so as to contact and be actuated by the soil to close contacts **31** in an ignition circuit **34** thereby igniting the combustive charge in the chamber **12** as soon as the chamber **12** is moved into position against the soil to be moved. Of course, the switch **30** may be omitted, and any suitable manually operated or automatic ignition timing means may be utilized.

By varying the pressure of initial charge, the terminal combustion pressure can also be varied. For example, with an air/fuel mixture of 12.5 to 1, an initial air pressure charge of 200 p.s.i. will result in combustion that produces a peak pressure of approximately 1,000 p.s.i. and a temperature of approximately 4,660° F. By increasing the initial air pressure charge to 425 p.s.i. the resulting combustion from the explosive mixture would produce a pressure of approximately 1,625 p.s.i. and a temperature of approximately 4,790° F. In order to seal off higher combustion pressures in the combustion chamber until a predetermined buildup in the explosive force occurs, valve means in addition to or as a substitute for the spring loaded louvers **24** shown in FIGURES 3 and 4 are provided. Thus, suitable valve means **40** (FIGURES 5 and 6) may be provided having a valve **42** and a valve seat **44** for closing the combustion chamber. A light spring **46** is provided normally keeping the valve **42** seated on the valve seat **44**. A piston **48** is provided in a chamber **54** having a first side **50** exposed to pressure in the combustion chamber **12** through an orifice **52**. It is noted that the cross-sectional area of the piston **50** that is exposed to the pressure in chamber **12** is larger than the cross-sectional area of the valve **42** that is exposed to pressure in the combustion chamber **12**. The orifice **52** is sized such that there will be a sufficient flow through the orifice during the time that the fuel-air mixture is being charged in the combustion chamber **12** so that the pressure drops across the orifice will be sufficiently low so that the net force acting on the piston side **50** to close valve **42** will be greater than the net force acting in an opposite direction on the back of the valve **42** tending to open the valve **42**. This keeps the valve **42** seated during the buildup of charging pressure in the combustion chamber **12**. However, during the combustion process there is a rapid rise of pressure within the combustion chamber **12**, and the restricting effect of the orifice **52** will cause a sufficiently large pressure drop across that orifice on a rapid rate of pressure rise in the combustion chamber to cause the pressure rise on the side **50** of the piston **48** to lag thereby allowing the net force acting on the back area **43** of the valve **42** to overcome the combined opposing force of the larger closing piston **48** and the light spring **46** to allow the valve **42** to open and release the explosive gases from the combustion chamber **12** through the openings **14** to break up and move the soil.

In addition, a bleed off outlet **56** may be provided in fluid communication to the side **50** of the piston **48** to bleed pressure from the closing piston chamber **54** more rapidly than pressure from the combustion chamber can be bled into the chamber **54** through the restricting orifice **52**. This is used to cause a more rapid reduction of the closing force acting on valve **42** and a sudden opening of

the valve **42** to quickly release the combustion pressure from the combustion chamber **12**. Thus release means such as an air valve **58** is provided and suitably actuated to open the bleed off outlet **56** to atmospheric pressure to decrease pressure within the piston chamber **54** so that the valve **42** would open rapidly.

Thus, the valve **42** will provide a rapid release of the hot gases in the combustion chamber, but only after they have reached high terminal pressures and temperatures. With rapid actuation of the valve it may be desirable to provide some deceleration of the valve **42**. Thus, a dashpot piston **60** could be provided to travel into the dashpot cylinder **62** to decelerate the valve **42** to a stop at the end of its travel. It is to be noted that the valve mechanism **40** may be used exclusively to control the buildup and release of pressures in the combustion chamber **12**, and as shown in FIGURE 5 the spring loaded louvers may be omitted. However, the spring loaded louvers **24**, closed by a light spring, may be used in combination with the valve means **40** and their use may be desirable in high moisture content soils, sands, and other materials where water on the soil might tend to find its way through the openings **14** of the lip **22**.

Referring now to FIGURES 1 and 2 a gang of combustion chambers **12** are provided connected to a suitable vehicle such as a tractor **66** for supporting the apparatus **10** and moving it into or against a soil bank. It is noted in FIGURES 1 and 2 that the apparatus **10** may be positioned at approximately 45° to the horizontal to displace the soil **68** to the side of the ditch which is being dug. In addition, the tractor **66** carries a tank **70** containing what may be the common fuel supply for the prime mover and the combustion chambers as well as for an air compressor such as a gas turbine eompressor **72** which may be provided connected to a common reservoir tank **74** for providing air pressure to each of the combustion chambers **12**. Of course, the ignition and other suitable controls could be manipulated from the tractor, and all are conventional and no further description is believed to be necessary. A control (not shown) may be provided for the operator to permit his selection of the charging pressure to be used in the combustion chamber. The terminal pressure developed within the combustion chamber **12** is dependent upon the air charging pressure with its corresponding fuel charge to provide the correct stoichiometric mixture. As the charging pressure is increased then more fuel (with an increased level of energy release) must be added to maintain the correct stoichiometric mixture. The increase of energy release, with a higher terminal pressure, will displace a given quantity of soil through a greater distance or higher in the air. Thus by providing the operator with a control of the combustion chamber charging pressure it will be possible for him to control the distance through which the soil **68** is displaced. As the depth of the soil overlay over the lip **22** changes or the cohesive strength or density of the soil changes, the operator will be able to make suitable corrections to control the displacement distance of the soil **68**.

In operation the material displacing apparatus **10** is placed into position against the material such as soil to be moved by any suitable vehicle such as a tractor **66** shown in FIGURES 1 and 2, preferably so that the lip **22** (FIGURES 3 and 4) is pushed under the bank of soil with the openings **14** directed into the soil to be moved. High pressure air is supplied to the combustion chamber **12** by any suitable means such as a compressor **72** supplying a common manifold pressure tank **74** which in turn is connected by a valve **18** to the air supply inlet **16**. Fuel is injected into the combustion chamber through fuel injection means **20** and of course the amount of fuel injected will be modulated as a function of the air charging pressure and weight of charging air to provide the correct stoichiometric air/fuel ratio in the combustion chamber. Assuming that the ignition switch **30** (FIGURE 3) is to be used, the soil will contact switch **30** closing its electrical contacts **31**, closing electrical ignition circuit **34**, such as an ignition transformer **35**, to provide a continuous spark to be discharged across the spark ignition means **21** located preferably in the center of the combustion chamber **12**. As the flame front propagates through the air/fuel mixture charge, pressure is rapidly developed within the combustion chamber and builds up causing the spring loaded louvers **24** in FIGURES 3 and 4 to open. The force of the explosion is expelled through the openings **14** and displaces the soil above the lip **22**. After the combustion gases are exhausted from the chamber the louvers **24** are closed to reseal the chamber and the soil displacing apparatus **12** is again moved into the soil bank by tractor **66** to repeat the cycle.

And as previously mentioned the greater the initial charging pressures, the greater will be the fuel charge and the force of the resulting explosion. In order to obtain higher pressures in the combustion chamber **12**, the valve means **40** shown in FIGURES 5 and 6 may be used in conjunction with the spring louvers **24** of FIGURES 3 and 4, or as an alternate thereto. Thus, referring to FIGURE 6, since the buildup of charging air in the combustion chamber **12** is relatively slower than the buildup in the combustion pressure, the pressure across the orifice **52** is sufficiently low so that the force acting on the side **50** of the piston **48** will be greater than the force acting on the back **43** of the valve **42** tending to open the valve, and therefore the valve **42** will remain closed. When combustion occurs within the chamber **12**, however, there will be a sufficiently large pressure drop across the orifice **52** preventing the transfer of the rapid rate of pressure rise in the combustion chamber from passing to piston chamber **54** and this lag will allow the high pressure force acting on the back **43** of the valve **42** to open the valve and releease the combustion pressures from within chamber **12**. In addition, a bleed off outlet **56** may be provided controlled by a valve **58** to provide for quick opening of the valve **42** by relieving the pressure in chamber **54** which tends to keep the valve **42** closed. The closing spring **46** will seat the valve **42** after each explosion to allow a buildup of the charging pressure within the combustion chamber **12**.

It is believed that the method of the invention is apparent in the foregoing description of the apparatus of the invention. The method, however, comprises the steps of placing a combustion chamber adjacent to the material to be displaced, providing an explosion in the chamber, opening the chamber, and directing the heat and pressure from the explosion against the material thereby fragmenting and moving the material, closing the chamber, and again moving the chamber against the material whereby the cycle may be repeated. The method further comprehends the steps of introducing a fuel into the chamber, and introducing air into the chamber and igniting the air/fuel mixture in the chamber to provide the explosion. The method further comprehends placing the combustion chamber adjacent and at least partially under the material and directing the heat and pressure from the explosion upwardly and against the material.

What is claimed is:

1. A method of displacing soil comprising,
placing a closed combustion chamber adjacent the soil,
introducing hydrocarbon fuel under pressure into the closed chamber,
introducing air under pressure into the closed chamber,
igniting the mixture of pressurized air and fuel in the closed chamber to provide an explosion,
opening the chamber when the explosion generates high pressure gases and directing the high pressure gases from the explosion against the soil thereby displacing the soil,
closing the chamber, and
moving the chamber against the unmoved soil whereby the cycle may be repeated.

2. The method of claim **1** including,
igniting the mixture adjacent the center of the chamber.

3. A method of displacing material comprising,

placing a closed combustion chamber adjacent and at least partially under the material,
introducing a hydrocarbon fuel under pressure into the closed chamber,
introducing air under pressure into the closed chamber,
igniting the pressurized air and fuel mixture in the closed chamber to provide an explosion creating high pressure gases,
opening the chamber by the force of the explosion but only after the exploded high pressure gases in the chamber have reached a predetermined terminal pressure,
directing the heat and pressure from the explosion upwardly and against the material thereby displacing the material,
closing the chamber, and
moving the chamber against the material whereby the cycle may be repeated.

4. An apparatus for displacing material,
a combustion chamber,
means connected to the chamber for admitting hydrocarbon fuel under pressure into the chamber,
means connected to the chamber for admitting air under pressure into the chamber,
spark igniting means in said chamber for igniting said pressurized mixture of air and fuel,
said combustion chamber including a pointed portion for penetrating into the material, said portion including a plurality of openings in communication with the combustion chamber and directed upwardly, and
valve means normally closing said openings and the combustion chamber for containing the pressurized mixture in the chamber prior to ignition, but opening said openings upon combustion of the mixture and upon a predetermined pressure buildup in said chamber.

5. An apparatus for displacing soil comprising,
a combustion chamber, said combustion chamber including a pointed portion adapted to be pushed into the soil, said portion including a plurality of openings in communication with the combustion chamber and directed upwardly,
means connected to the chamber for admitting hydrocarbon fuel under pressure into the chamber,
means connected to the chamber for admitting air under pressure into the chamber,
spark igniting means in said chamber for igniting the pressurized mixture of air and fuel, and
valve means for closing said chamber to allow a pressure buildup in the chamber prior to ignition and for sealing off the combustion pressure in the combustion chamber from flowing through said openings until a predetermined buildup in the explosive force in the chamber.

6. The apparatus of claim **5** wherein said valve means includes,
spring loaded louvers covering said openings.

7. The apparatus of claim **5** wherein said valve means includes,
a valve and valve seat between the openings and said igniting means,
a spring acting to normally close said valve on said seat,
a piston connected to said valve and having a greater cross-sectional area than said valve seat, and
an orifice restricting the flow of fluid between said combustion chamber and the side of said piston acting to close said valve.

8. The apparatus of claim **5** including,
means normally closing said openings and the combustion chamber, but opening said openings upon combustion of the mixture in the chamber.

9. The apparatus of claim **7** including,
a dashpot piston and cylinder, one of which is connected to the valve and the other of which is connected to the valve seat, said piston traveling into said cylinder as said valve is opened thereby decelerating said valve.

10. The apparatus of claim **7** including,
a bleed off outlet in communication between the atmosphere and said one side of the piston, and
means opening said passageway for relieving the pressure acting on said piston thereby quickly opening said valve.

11. The apparatus of claim **7** including,
means normally closing said openings and the combustion chamber, but opening said openings upon combustion of the mixture in the chamber.

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U.S. Cl. X.R.

37—18, 80, 195; 102—23; 137—512.1, 514; 175—14; 299—13, 14, 36