ABSTRACT
A method and apparatus particularly suited for underwater dredging, trenching and the like. An explosion chamber is provided with a fuel source, a fuel ignitor and an exhaust outlet. A drag intake conduit having a check valve communicates with the explosion chamber as does a drag exhaust chamber. Material to be dredged enters the drag intake and fills the explosion chamber to a certain level while fuel is admitted to the explosion chamber. The fuel is burned or exploded which closes the check valve in the drag intake and forces the drag material out through the exhaust conduit.

9 Claims, 12 Drawing Figures
EXPLOSIVE PUMPING AND DREDGING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

The method and apparatus of the present invention make use of an internal combustion or explosive pumping technique. Internal combustion pumps and related propulsion devices are known in the art as illustrated by U.S. Pat. Nos. 368,678, 1,093,669, 1,152,394, 1,157,071, 1,158,303, 1,257,217, 2,272,477, 3,202,108, 2,885,988, and 3,494,317.

Prior internal combustion type pumps or propulsion devices have had numerous drawbacks. For example, internal combustion pumps have suffered the disadvantage of interrupted flow due in large part to reciprocating type operation involving a plurality of cycles. In addition, certain of the prior art devices have been operable only by balancing columns of water in a U-shaped configuration pump inherently involving delicate operation.

By and large, prior internal combustion type pumps and related devices have been able to pump or function only with respect to liquids due in large part to the use of check valves requiring positive closure in order to operate properly. Consequently, such devices are not suitable for pumping solid-liquid slurries since solid materials tend to clog the moving parts of the pump resulting in malfunction of the system.

It would, therefore, be advantageous to provide an improved internal combustion type pump that provides uninterrupted flow without the use of a check valve on the discharge side of the pump and which is capable of pumping even solid-liquid slurries such as material dredged from lake beds, sea beds and the like. The present invention is directed to such a device uniquely adapted to function as a dredge as will be explained.

SUMMARY OF THE INVENTION

The present invention relates to a method and apparatus for underwater dredging and particularly the preparation of trenches in river beds, lake beds, sea beds, or the like. An explosion chamber is provided to which is attached a drop intake conduit and a drop exhaust conduit. A check valve is located within the drop intake conduit for limiting flow of fluid or drop slurry unidirectionally to the explosion chamber. The system of apparatus functions by admitting drops to the explosion chamber by way of the drop intake conduit. Dregs rise to a certain level within the explosion chamber while fuel is being admitted into the chamber. At a predetermined time, the fuel is ignited and the force of the combustion thrusts the dreg material or slurry through the drop exhaust conduit. The same force momentarily closes the check valve in the drop intake conduit so that the dreg material is forced through the exhaust conduit. The exhaust gases from the combustion reaction pass through the exhaust outlet in the combustion chamber and the cycle is repeated. It should be noted that the inertia of the liquid in the exhaust conduit produced by the gas pressure is sufficient to maintain the flow of liquid throughout the cycle.

It is, therefore, an object of the present invention to provide a unique internal combustion or explosion type apparatus useful as a pump for solid-liquid slurries.

Another object of the present invention is the provision of such apparatus for dredging underwater beds and particularly for forming trenches in underwater beds.

It is a further object of the present invention to provide a method for explosively pumping fluids without interruption of flow, the process being uniquely adapted to pump or move solid-liquid mixtures or slurries such as dredged materials.

Yet another object of the present invention is the provision of a dredging apparatus having an explosion chamber with a fuel inlet, ignition means and an exhaust outlet as well as a drop intake conduit provided with a check valve and a drop exhaust conduit.

Other and further objects, features and advantages will be apparent from the following description of the presently preferred embodiment of the invention given for the purpose of disclosure and taken in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

In the drawings forming a part of the disclosure herein, like character references designate like parts throughout the several views, wherein,

FIG. 1 is a side elevational view, partly in cross section, of an internal combustion device according to the present invention,

FIG. 2 is a similar view showing the combustion chamber of the device containing dregs or material to be pumped at the time fuel within the combustion chamber is ignited,

FIG. 3 is a similar view wherein the dreg material has been forced out the dreg exhaust conduit after ignition and exhaust gases are passing out the exhaust outlet means while a fuel mixture is entering the combustion chamber,

FIG. 4 is a similar view showing the dreg material again rising within the combustion chamber for repetition of the cycle,

FIG. 5 is a side elevational view of the dredging apparatus according to the present invention,

FIG. 6 is a plan view taken along the line 6—6 of FIG. 5,

FIG. 7 is a partial side elevational view, partly in cross section, of a further embodiment of the dredging apparatus according to the present invention uniquely suited for preparing an underwater trench,

FIG. 8 is a front elevational view, taken along the line 8—8 of FIG. 7,

FIG. 9 is a view of the check valve means within the drop intake conduit taken along the line 9—9 of FIG. 7, and

FIGS. 10, 11 and 12 are graphic representations of an example according to the present invention wherein are plotted velocity of fluid, combustion chamber pressure and total flow of fluid versus time.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, an internal combustion system 10 is shown having an explosion chamber 12 generally of an elongated dome configuration oriented in the vertical plane with upper and lower portions. The explosion chamber 12 is provided with a fuel inlet supply means 14 for providing an explosive mixture of fuel to the chamber 12. The chamber is further provided with an ignition means 16 for exploding fuel within the
chamber in timed relation with the fuel inlet supply means 14. An exhaust outlet means 18 removes exhaust gases from the explosion chamber 12 in timed relation with the fuel inlet supply means 14 as well as the ignition means 16.

A drag intake conduit 20 is in fluid communication with the lower interior portion of the explosion chamber 12 and has secured therewithin a check valve means 22 for limiting flow of fluid through the conduit 20 unidirectionally to the explosion chamber 12. Also in fluid communication with the lower interior portion of the explosion chamber 12 is a drag exhaust conduit 24.

As shown in FIGS. 2-4, the fuel inlet supply means 14 preferably comprises a fuel conduit 26 in fluid communication with the upper interior portion of the explosion chamber 12. A check valve 28 is secured within the fuel conduit 26 to limit flow of fuel unidirectionally to the explosion chamber. As will be recognized by those skilled in the art, any suitable form of check valve 28 may be employed, although the drawings illustrate use of a simple ball-type check valve wherein a ball 30 is forced against a seat 32 to close the conduit 26 to further entry of fuel. In the open position, the ball 30 may rest against retention lugs 34 to allow fuel to pass around the ball and into the chamber 12.

The ignition means 16 shown in FIGS. 1-4 may be any suitable means for igniting the fuel mixture within the chamber 12 as may be selected by those skilled in the art. For example, the ignition means 16 may take the form of a high voltage spark plug connected to a suitable electrical source. Preferably, means are provided which coat with the check valve 28 within the fuel conduit 26 to sense closure of the check valve 28 and activate the ignition means 16. Again, such means may be selected by those skilled in the art and may take the form, for example, of an electrical switch which is closed when the ball 30 engages the seat 32 of the check valve 28 to close an electrical circuit thereby providing current to the ignition means 16 or spark plug to arc or spark for purposes of igniting the fuel within the chamber.

With reference to FIG. 1 (and also as shown in FIGS. 2-4) the exhaust outlet means 18 comprises an exhaust gas conduit 36 in fluid communication with the interior portion of the explosion chamber 12 at a point juxtaposed but just above a plane between the intake conduit 20 and the exhaust conduit 24 as shown in the drawings. A float valve means 38 is affixed to the exhaust gas conduit 36 in order that the exhaust conduit 36 may open to the interior of the explosion chamber to remove exhaust gases upon lowering of the level of drag material within the chamber 12 and for closing the exhaust gas conduit 36 upon rising of the level of drag material within the chamber.

While any suitable float valve means 38 may be employed, the preferred arrangement as shown in the drawings includes a ball member 40 having buoyancy relative to the drag material entering the explosion chamber 12. A seat 42 is affixed to the exhaust gas conduit 36 within the exhaust chamber 12. A cage member 44 is secured to the exhaust gas conduit restraining the ball member 40 for releasable engagement with the seat 42. The cage member 44 may be suitable wire mesh or the like of sufficient strength to withstand the force of combustion within the chamber 12 yet having openings therewithin so as to admit the solid-liquid slurry or drag material to cause the ball member 40 to float into engagement with the seat 42.

An advantage of use of the float type valve means 38 is that the valve closes before the drag material being pumped has an opportunity to wedge between the ball 40 and the seat 42 thereby preventing clogging that might otherwise cause a malfunction of the system.

Turning now to the embodiment of FIGS. 5 and 6, the internal combustion apparatus 10 is shown having a drag intake conduit 20 with a flared mouth 20a which is adapted for suction of dregs or other material to be dredged. In addition, the drag exhaust conduit 24 is provided with an upwardly extending portion 24a which in turn divides into a Y shaped configuration with conduit arms 24b and 24c. The upward extending portion 24a adapts the system for dredging while the conduit arms 24b and 24c in the Y shaped configuration further adapts the drag exhaust conduit for digging trenches and the like. Thus, effluent from the dredging operation is moved upward and outward to either side of a trench or channel that is being dug with the apparatus.

Referring now to the embodiment of FIGS. 7, 8 and 9, the internal combustion device 10 of the present invention is illustrated with a modified flared inlet for the drag intake conduit 20, this embodiment being especially preferred for digging large trenches or channels in underwater bodies of earth. Thus, the drag intake conduit 20 is provided with pronounced flared or outwardly tapered walls 46 wherein the opening or leading edge 48 may be of a circumference or periphery approximating the size of the trench to be dredged.

With reference to FIG. 9, there is shown a view of the check valve means 22 secured within the intake conduit 20. The check valve means includes a grid member 52 secured within the drag intake conduit and an openable cover member 54 secured against the side of the grid member 52 facing the explosion chamber 12. While the openable cover member 54 may be formed of any suitable material and in any suitable configuration, one preferred embodiment as shown is a plurality of sectors 56 forming the cover 54, each sector 56 being openable and overlapping another sector on one radial edge if desired. It will be seen that the sectors 56 of the cover 54 rest against the grid 52 when fluid pressure from the explosion chamber 12 is applied against the cover 54. Otherwise, the segments 56 of the cover 54 open to admit drag material from the mouth of the intake conduit 20.

Referring to FIGS. 7 and 8, a grate 50 is secured within the drag intake conduit on the side of the check valve grid member 52 opposed from the explosion chamber 12. The grate 50 is provided with openings smaller than the openings within the grid member 52 of the check valve 22 to act as a filter to screen out or break up agglomerated or larger materials that would otherwise tend to clog or plug the grid member 52 of the check valve 22.

In operation and with reference particularly to FIGS. 2, 3 and 4 of the drawings, the system of the present invention may be partially or totally submerged as required. The depth of submersion, however, must be at least that of the level indicated by the reference numeral 60. In any event, the mouth (20a of FIG. 5 or 48 of FIG. 7) of the intake conduit 20 is submerged to contact the bed of material to be dredged.
At the beginning of a cycle of operation, the fuel mixture inlet valve 14 is closed, the exhaust valve 38 is closed, and the chamber is filled with liquid. The closure of the valve 14 activates the igniter means 16 and the mixture of fuel and air burns within the chamber 12 so that the pressure of the mixture increases preferably about sixfold. This pressure must exceed pressure of the fluid outside of the chamber 12. Since the gas pressure is higher than the outside fluid or liquid pressure, the check valve 22 closes and liquid is forced out the dreg exhaust conduit 24. The expansion of the burnt gas continues pushing liquid out of the pipe 24, the liquid level in the chamber 12 falls, and finally the gas exhaust valve 38 is uncovered. Pressure of the combustion product gases in the chamber at this point should be greater than one atmosphere which is accomplished by regulating the amount of combustible fuel admitted to the chamber 12 just before ignition and by placing outlet 38 preferably within the lower half of the chamber 12 so that the burnt gases do not escape immediately upon ignition. The outlet end of the exhaust pipe 36 should be above water level in the chamber 12. The pressure in the exhaust pipe 36 and the net pressure acts in an upward direction on an area equal in size to the cross-sectional area of the exhaust pipe 36. The weight (w) of the ball 40 acts in a downward direction. The force balance therefore is:

\[
P_s (A) + W - P_x (A) \geq 0
\]

(where A is the area equal to the inside cross-sectional area of the pipe) in order for the valve to open.

Since

\[
W = \frac{1}{2} D^2 h (\rho)
\]

(where D is ball diameter and \(\rho\) is ball density), the equation can be rewritten:

\[
P_s A + \left(\pi D^2 h\right) (\rho) - \rho_s A \geq 0
\]

or

\[
(P_s - \rho_s) (\pi D^2 h) \geq \frac{1}{2} D^2 (\rho)
\]

or

\[
D^2 (\rho) \geq D^2 (\rho)
\]

where D is the inside diameter of the exhaust gas conduit 36.

3. As the burnt gases flow out the pipe 36 to the surface of the body being pumped or dredged, pressure in the chamber 12 decreases. When the chamber pressure decreases to pressure of the fuel/air mixture in the inlet pipe 26, the fuel/air inlet valve 14 opens and fresh fuel mixture flows into the chamber. Since the liquid in the dreg exhaust conduit 24 has been accelerated to a considerable velocity during the fuel expansion, it continues to flow even after the exhaust valve 38 opens. When the exhaust outlet valve 38 opens and reduces the chamber pressure to one atmosphere, the dreg inlet check valve 22 opens due to the outside water or fluid pressure and liquid flows into the chamber 12. The inflow of liquid eventually exceeds the outflow of liquid (since the latter is slowing down) and the level of liquid in the chamber 12 begins to rise. Outflow of liquid continues, however, but at a steadily decreasing rate. When the liquid level reaches the exhaust valve 38, it closes.

To close, buoyancy of the ball must be positive:

\[
(P_s - \rho) \geq 0
\]

(where \(\rho_s = \) liquid density)

This equation, plus the last equation derived above, give the requirements for design of the valve 38 as will be understood by those skilled in the art.

When the exhaust outlet valve 38 closes, pressure in the chamber 12 is one atmosphere. The external water pressure continues to force liquid through the dreg inlet valve 22 and into the chamber 12. Momentum of the column of water in the chamber 12 is sufficient to maintain outward flow in this pipe, albeit at ever-decreasing rates, and the liquid level rises past the valve 38. As it does, pressure in the chamber 12 begins to increase above one atmosphere. The air/fuel mixture pressure should be higher than one atmosphere such as by use of an air compressor forcing air down the fuel mixture inlet pipe 14 so that the fuel/air mixture continues to enter the chamber 12 as the liquid level rises therein. The pressure of the fuel/air mixture is controlled as will now be appreciated such that it is less than the water pressure so that eventually the rising level of liquid in the chamber 12 compresses the mixture to a pressure higher than the supply pressure and the check valve 28 closes. This energizes the ignition circuit and the ignition means 16 to explode the mixture, restarting the cycle.

As an operating example of the system of the present invention, reference is made to FIGS. 10, 11 and 12. Assuming the volume of fuel/air mixture at the time of explosion in the explosion chamber 24 is 124 cu. ft in FIG. 1) to be 22 cubic feet and pressure thereof is 25 psig (pounds per square inch gauge), and assuming the diameter of the dreg exhaust conduit 24 (FIG. 1) to be 16 inches and the length of the dreg exhaust conduit or outlet pipe to be 500 feet, FIG. 10 shows the velocity (in feet per second) of the liquid in the dreg exhaust conduit 24, FIG. 11 shows the pressure (in pounds per square inch absolute) in the explosion or combustion chamber 12, and FIG. 12 shows the cumulative liquid volume pumped for one cycle of the operation. The cycle begins with filling of the chamber 12 with the compressed air/fuel mixture at 25 psig (approximately 40 psia). The filling occurs at a constant pressure and during this period the velocity of the dreg fluid or liquid in the dreg exhaust conduit 24 increases from 5.4 to 9.4 feet per second. After 1.5 seconds, 22 cubic feet of gas have entered the chamber 12 and this gas mixture is exploded which causes a very fast pressure rise to 220 psia. The velocity of the dreg fluid also increases, but less rapidly due to the inertia of the slurry mass and friction of the pipe walls. The gas (exploding fuel mixture) expands as the dreg liquid leaves the chamber 12, until at 25 psia (about 10 psig) the exhaust outlet means 38 (FIG. 3) is opened and the chamber pressure returns to one atmosphere.

Immediately the chamber 12 begins filling with more dreg material under the influence of gravity.

Since the liquid in the dreg exhaust conduit 24 still has a considerable velocity due to the explosive forces earlier applied, the quantity of dreg material entering the system through the check valve 22 is much greater than the volume of the chamber 12.
The filling duration is about 3.8 seconds during which time velocity of the dreg material decays due to the friction forces at the conduit walls. When the chamber 12 is filled with dreg material, the cycle is ready to begin again. It should be noted that the velocity of the dreg material never reaches zero and ranges between the limits of 5.4 feet per second and 26 feet per second. The liquid pressure in the explosion chamber 12 varies from one atmosphere to 220 psia.

FIG. 12 shows the cumulative flow of liquid whereby each cycle pumps about 1,200 gallons of dreg material in 8.8 seconds, or 8,200 gallons per minute.

On the basis of the foregoing example, it is estimated that compressed air requirements are about 342 standard cubic feet per minute at 40 psia which would require about a 35 horsepower compressor drive to meet fuel requirements of 0.34 gallons of gasoline per minute for operation of the system.

It will be recognized that the example set forth above illustrates only one of many possible combinations of gas volume, gas pressure and equipment size. Other parameters and equipment sizes may be employed depending on the nature of the liquid to be pumped or dredged, the distance the material is to be moved and the like.

The present invention, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned as well as others inherent therein. While a presently preferred embodiment of the invention has been given for the purpose of disclosure, numerous changes in the detail of construction and the combination, shape, size and arrangement of parts may be resorted to without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A dredging apparatus, comprising,
   a. an explosion chamber having
      i. a fuel inlet supply means for providing an explosive mixture of air and fuel intermittently to the explosion chamber (a), said fuel inlet supply means (a) (i) comprising,
      1. a fuel conduit in fluid communication with the upper interior portion of the explosion chamber (a),
      2. a check valve within said fuel conduit to limit flow of fuel unidirectionally to the explosion chamber, and
      3. a fuel source means in communication with the fuel conduit for providing an explosive mixture of fuel sequentially to said fuel conduit,
   ii. ignition means for exploding fuel within the explosion chamber (a) in timed relation with the fuel inlet supply means (a) (i), and
   iii. an exhaust outlet means for removal of exhaust gases from the explosion chamber (a),
   b. a dreg intake conduit in fluid communication with the lower interior portion of the explosion chamber (a),
   c. check valve means within the intake conduit (b) for limiting flow of fluid therethrough unidirectionally to the explosion chamber (a),
   d. an unrestricted dreg exhaust conduit in fluid communication with the lower interior portion of the explosion chamber (a), and
   e. means coacting with the check valve (a) (i) (2) within the fuel conduit to sense closure of the check valve (a) (i) (2) and activate the ignition means (a) (ii), closure of said check valve (a) (i) (2) within said fuel conduit caused by pressure within said chamber.

2. The dredging apparatus of claim 1 wherein the exhaust means (a) (ii) comprises,
   an exhaust gas conduit in fluid communication with the interior portion of the explosion chamber (a) at a point juxtaposed and above a plane between the dreg intake conduit (b) and the dreg exhaust conduit (d), and
   a float valve means in said exhaust gas conduit for opening the exhaust conduit to the interior of the explosion chamber (a) to remove exhaust gases upon lowering the level of dregs within the chamber (a) and for closing the exhaust gas conduit upon rising of the level of the dregs within the chamber (a).

3. The apparatus of claim 2 wherein the float valve means comprises,
   a ball member having buoyancy relative to the dregs entering the explosion chamber (a),
   a seat affixed to the end of the exhaust gas conduit within the exhaust chamber (a),
   and a cage member secured to said exhaust gas conduit restraining the ball member for releasable engagement with the seat.

4. The dredging apparatus of claim 1 wherein the check valve means (c) within the intake conduit (b) comprises
   a grid member having openings therein and secured within the dreg intake conduit (b), and
   an openable cover member secured against the side of the grid member facing the explosion chamber (a).

5. The dredging apparatus of claim 4 including, additionally,
   a grate secured within the dreg intake conduit (b) on the side of the grid member opposed from the explosion chamber (a), said grate having openings smaller than the openings within the grid member.

6. The dredging apparatus of claim 1 wherein the dreg exhaust conduit (d) is Y-shaped in configuration.

7. A dredging apparatus, comprising
   a. an explosion chamber having
      i. a fuel inlet supply means including a fuel conduit in fluid communication with the upper interior portion of the explosion chamber (a), a check valve within said fuel conduit to limit flow of fuel unidirectionally to the explosion chamber, and a fuel source means in communication with the fuel conduit for providing an explosive mixture of air and fuel sequentially to said conduit, and
      ii. ignition means for exploding fuel within the explosion chamber (a) in relation to pressure in said chamber,
      iii. means coacting with the check valve within the fuel conduit to sense closure of the check valve and activate the ignition means (a) (ii), and
      iv. an exhaust outlet means including an exhaust conduit in fluid communication with the interior portion of the explosion chamber (a), and a float valve means in said exhaust gas conduit for opening the exhaust gas conduit to the interior of the explosion chamber (a) to remove exhaust gases upon lowering the level of dregs within the
3,787,144

9 chamber (a) and for closing the exhaust gas conduit upon rising of the level of drags within the chamber (a).

b. a dred intake conduit in fluid communication with the lower interior portion of the explosion chamber (a),

c. check valve means within the intake conduit (b) for limiting flow of fluid therethrough unidirectionally to the explosion chamber (a), said check valve means including

i. a grid member secured within the dred intake conduit (b), and

ii. an openable cover member secured against the side of the grid member facing the explosion chamber (a), and

d. a dred exhaust conduit in fluid communication with the lower interior portion of the explosion chamber (a), the dred exhaust conduit (d) and the dred intake conduit (b) defining a plane above which is juxtaposed the exhaust outlet means (a) (iv).

10 8. The dredging apparatus of claim 7 wherein the float valve means of the exhaust outlet means (a) (iv) comprises,

a ball member having buoyancy relative to the drags entering the explosion chamber (a), a seat affixed to the exhaust gas conduit within the explosion chamber (a), and a cage member secured to said exhaust gas conduit restraining the ball member for releasable engagement with the seat.

9. The dredging apparatus of claim 7 including, additionally,

a grate secured within the dred intake conduit (b) on the side of the grid member (c) (i) opposed from the explosion chamber (a), said grate having openings smaller than the openings within the grid member (c) (i).
C. MARSHALL DANN  
Commissioner of Patents
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,787,144 Dated January 22, 1974

Inventor(s) Charles D. Wood

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Change the address of the assignee from "Bexar, Tex." to --San Antonio, Tex.--

Column 1, line 10, cancel "U.S. Pat." and insert --the following United States Letters Patent:--

Column 2, line 40, cancel "thee" and insert --the--

Column 4, lines 15 and 18, cancel "Y" and insert --"Y"--

Column 5, line 45, cancel "(\PiD^{3}16)" and insert -- \frac{\Pi D^{3}}{6} --

Column 5, line 47, cancel the equation shown and insert --
\[(P_a - P_g) \frac{d^2}{4} + \frac{D^3}{6} (\rho) > 0 --\]

Column 5, line 49, cancel the equation shown and insert --
\[\frac{D^3}{6} (\rho) > \frac{d^2}{4} (P_g - P_a) --\]

Signed and sealed this 17th day of September 1974.

(SEAL)
Attest:

McCoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents