United States Patent

[11] 3,588,801

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[54] **IMPULSE GENERATOR**
20 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **340/12, 181/.5**
[51] **Int. Cl.** **H04r 23/00**
[50] **Field of Search** ..... 340/12, 12 (ARC); 181/.5 (C)

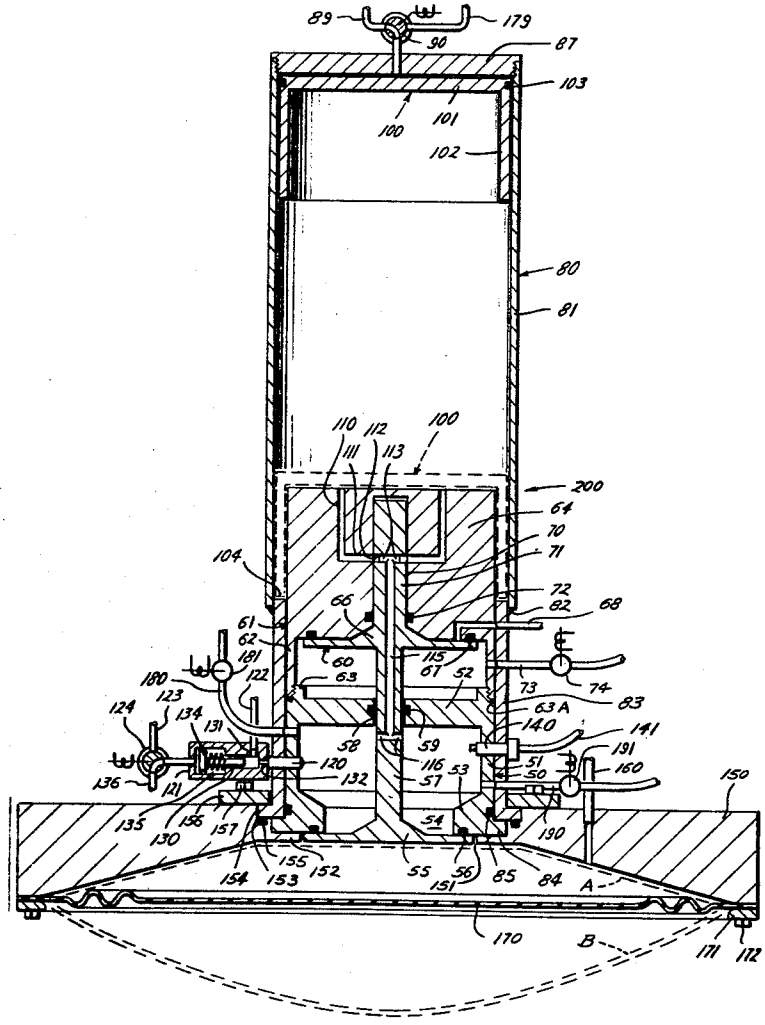
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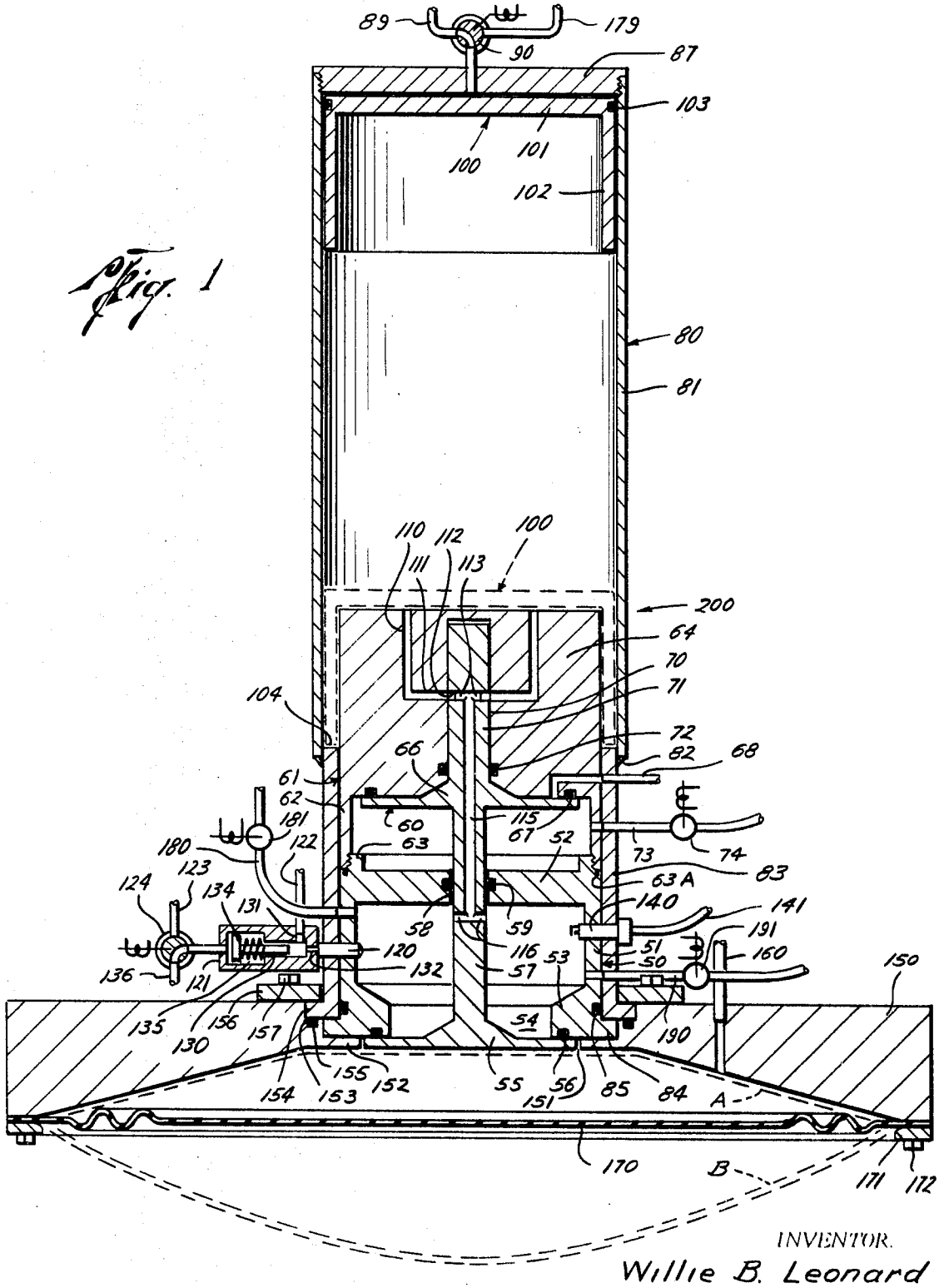
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ABSTRACT: Hydrocarbon fuel is exploded in a container causing the closure to pop open, generating an impulse in the surrounding medium, for example, water. Combustion air in container is heated by compression prior to explosion of fuel. Closure is biased to closed position by air pressure differential which is overcome by pressure of explosion. Initial movement of closure removes bias air pressure differential. A variety of means are shown for receiving the explosion gases to prevent oscillation thereof.



2 Sheets-Sheet 1

Fig. 1



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Fig. 2

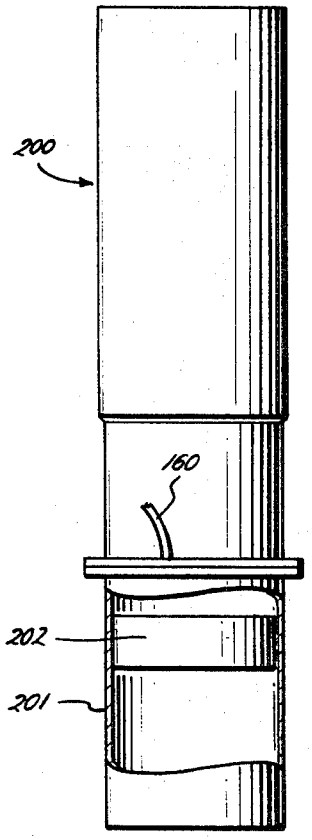


Fig. 3

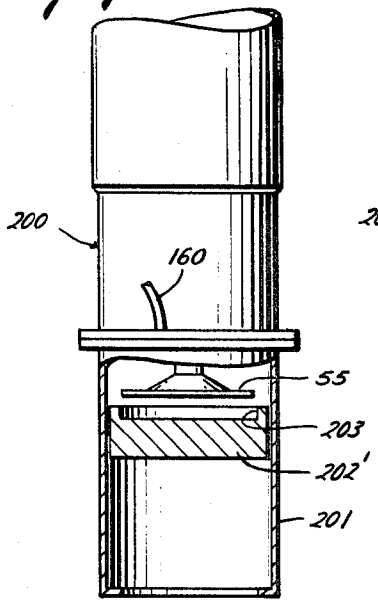
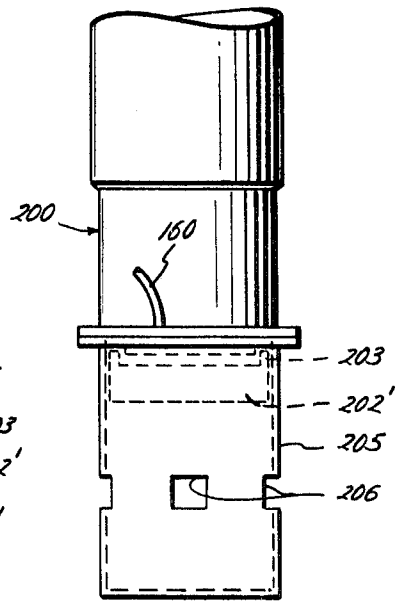


Fig. 4



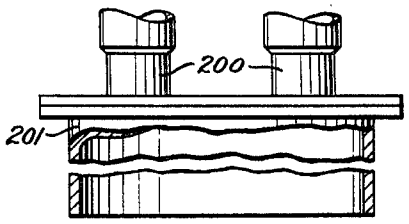


Fig. 7

Fig. 5

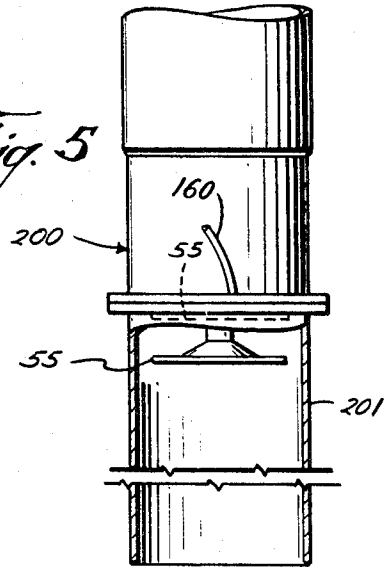
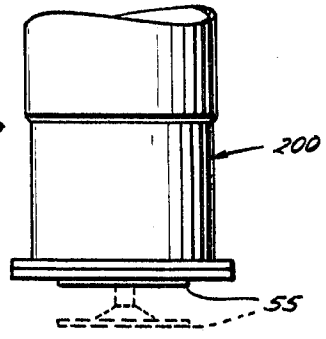


Fig. 6



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IMPULSE GENERATOR

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to impulse generators, especially useful for generating artificial seismic waves in the earth's crust to explore for oil and other minerals. The invention is especially adapted for use under water.

2. Discussion of the Prior Art

It is known that an impulse can be created by the explosion of a mixture of pressurized oxygen and hydrocarbon fuel, e.g. as disclosed in U.S. Pat. No. 1,627,991 issued May 10, 1927, on the application of W. O. Owen, which teaches that such explosion may be effected underground in a bore hole in order to break up an earth formation, the explosion being initiated by a spark plug, the gas being confined by a packer in the hole above the gas.

Merten's U.S. Pat. No. 2,772,746 issued Dec. 4, 1956, notes that in seismic prospecting it is customary to study the records of artificially produced seismic waves, e.g. as created by exploding dynamite positioned in shot holes in the earth or positioned in the atmosphere a fixed height above the earth's surface; or as created by dropping a heavy weight on the earth's surface. Merten discloses apparatus for creating artificial seismic waves by exploding with a spark plug a mixture of pressurized air and hydrocarbon gases inside a bell whose mouth is positioned at the earth's surface, the bell being vented through a check valve to relieve the pressure of the explosion. If desired, a thin flexible diaphragm may be placed over the mouth of the bell to seal in the gas prior to explosion thereof.

Instead of blasting directly on the earth's surface or on a flexible sheet placed thereover as disclosed by Merten, it has been proposed to transmit the force of an explosion to the ground by means of a rigid body, namely, a piston reciprocatably mounted in the lower end of a cylinder, the piston and cylinder forming the explosion chamber, as disclosed, for example, in U.S. Pat. No. 3,215,223, issued Nov. 2, 1965, on the application of Kirby et al.

Another approach to the production of artificial seismic waves is based on the principle of the popgun or champagne cork according to which gas under pressure in a container creates an impulse in the adjacent medium when the closure for the container is suddenly released.

Examples of such popgun-type seismic generators are disclosed in U.S. Pat. Nos. 3,249,177 and 3,310,128 issued May 3, 1966 and Mar. 21, 1967 on the applications of Chelminski. Compressed air in a container, wherein the pressure may be enhanced by burning fuel therein, is released (by opening the container closure) into the medium adjacent the container. The high-pressure gas may be released directly into the water in the case of a submarine seismic generator. For land use, the generator may be placed in a water tank having a flexible bottom adapted to rest on the ground.

According to the Chelminski patents, the closure for the container is held in closed position by a rod connected to a piston subject to the air pressure in the container presses on one side of the piston. Release of the closure is effected by opening a valve to admit balancing air pressure to the other side of the piston.

SUMMARY OF THE INVENTION

According to the present invention an impulse in the adjacent medium is created by release of gas from a container in which fuel is exploded. The explosion of fuel creates a high pressure so that dangerous high-pressure compressed air, e.g. 2000 p.s.i., as used in prior act popgun-type generators, is not required.

When the container pressure builds up high enough it overcomes the pressure holding the container closure in place. The opening of the closure is therefore effected very quickly. Since the explosion is initiated by an electric spark, the timing is more precise than can be effected by opening a valve as was done in prior act popgun generators.

Since the pressure in the container is due to the explosion of fuel rather than precompression or slow combustion, the pressure impulse continues at a high level for a period after the closure has opened rather than immediately dropping off.

Further, in accordance with the invention the oxidizing material (e.g. air or oxygen) used to combine with the fuel for creating the explosion is preheated so that an explosion can be effected with liquid fuels such as diesel oil or the like. To this end means is provided for compressing air fed to the container, the work of compression heating the air. The ability to operate with diesel fuel is a great advantage since such fuel is already available on board the exploration ship in conjunction with which submarine seismic generators are frequently used. Furthermore, such fuel is relatively inexpensive compared with gasoline and liquified petroleum gases which might be exploded without preheating the air. Diesel fuel is also safer to handle.

In accordance with a further feature of the invention, additional fuel can be admitted to the container after initiation of the explosion in order to prolong the impulse or to change its wave shape.

In accordance with the invention the time duration of the pulse is long enough so that the pulse shape can be modified by firing several adjacent generators successively but close enough together in time so that their impulses overlap. The desired pulse shape is created by superposition of the several impulses.

Further in accordance with the invention the exhaust gases from the explosion are contained or controlled by a receiver connected at the mouth of the container over the area of the closure.

The impulse generator of the invention is especially adapted for underwater use, for example 30 to 50 feet below the surface, suspended off bottom from a structure or vessel at the surface. By suitable modification as required to couple the impulse to the ground, the generator may be used on dry land.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical section through an impulse generator in accordance with a preferred embodiment of the invention.

FIGS. 2 through 7 are elevations, partially in section, showing modified forms of impulse generators embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown an impulse generator including a container 50 having cylindrical sidewalls 51 and plane end walls 52, 53. There is an opening 54 in end wall 53. A closure 55 is adapted to cover opening 54 in fluidtight relationship, there being an O-ring 56 disposed in an annular groove around the mouth of the opening to insure a seal with closure 55. The closure is a circular plate carried by a rod 57 that is reciprocatably mounted in a bearing opening 58 in the upper wall 52 of the container. There is an O-ring seal 59 disposed in an annular groove in opening 58 to seal between the rod 57 and bearing opening 58.

Pneumatic bias means is provided to normally urge the rod 57 upwardly, thereby tending to move closure 55 against the lower wall 53 of the container to close opening 54. The pneumatic bias means includes a pressure chamber 60 adapted to hold compressed air or other gas. The chamber is defined by the upper side of container wall 52 and a cylinder 61. The cylinder has sidewalls 62 internally threaded at the lower end and screwed to externally threaded upstanding annular flange 63 on the upper side of wall 52. An annular O-ring 63A seals between walls 52 and walls 62. The upper end of the cylinder is closed by a thick wall or block 64.

Within chamber 60 there is a plate 66, rigidly secured to rod 57, the rod extending through bearing opening 58 from container 50 into chamber 60. The plate 66 normally lies against top wall 64 of the chamber so that it is exposed to chamber pressure only on its bottom side, thereby urging the rod 57 upwardly to position closure 55 in closed position. To restrict

chamber pressure from getting to the top side of plate 66, there is provided an O-ring seal 67 in an annular groove in wall 64 adjacent the outer periphery of plate 66. To prevent pressure buildup on top of plate 66 due to leakage past O-ring seal 67, a slow vent 68 is provided within the area bounded by the O-ring seal.

A deep socket 70 in wall 64 provides a long bearing to support guide stem 71 extending upwardly from plate 66. An O-ring seal 72, disposed in an annular groove in the sidewall of socket 70, seals stem 71 to socket 70.

Compressed air or other gas is supplied to chamber 60 through pipe 73 and solenoid valve 74 from a suitable source (not shown). A pressure of 200 p.s.i., for example, would be suitable.

Conveniently mounted above block 64 is provided compressor means for supplying heated compressed air to container 50. Such compressor means includes a cylinder 80 having sidewalls 81 of larger inner diameter than the outer diameter of block 64. The lower end of walls 81 is welded at 82 to a cylindrical jacket 83 fitted closely about cylinder 61 and container 50 and secured at its lower end to a flange 84 at the base of container 50. An O-ring 85 seals between container 50 and jacket 83.

The upper end of cylinder 80 is closed by a circular plate 87 having a rabbeted and threaded outer periphery screwed into the internally threaded upper end of the cylinder walls 81: Compressed air or other gas under pressure, e.g. at 200 p.s.i., is supplied from a source (not shown) through a pipe 89 and three-way solenoid valve 90 to the upper end of cylinder 80. The source of air or gas pressure for pipe 89 may be the same as that for pipe 73. Alternatively, a hydraulic fluid could be supplied to the upper end of cylinder 80.

Within cylinder 80 is reciprocatably disposed a free piston 100 including a circular top plate 101 and a cylindrical guide skirt 102. An O-ring 102 in an annular groove in the outer periphery of the top plate provides a sliding seal with the inner periphery of the cylinder sidewalls. The skirt 102 is of such thickness as to be receivable within the annular space 104 between the walls 81 and block 64, when the piston is in its lowermost position (as shown in broken lines in FIG. 1). In the lowermost position of piston 100, its top plate 101 is closely adjacent to block 64.

Block 64 contains a plurality of vertical and radial passages 110, 111 which connect the interior of cylinder 100 with socket 70. The radial passages are at a level such that they terminate at their inner ends opposite an annular groove 112 around guide stem 71 when the latter is in its uppermost position. Radial passages 113 in stem 71 connect groove 112 to groove 115 extending axially of stem 71 to radial passages 116 that communicate with the inside of container 50.

When piston 100 is pushed down under the force of compressed air or gas or hydraulic fluid thereabove, the air therebelow in cylinder 80 is compressed into container 50, thereby providing heated pressurized air in container 50. There being no mechanical advantage employed, the maximum pressure thus attainable in container 50 is the same as the pressure of the source to which pipe 89 is connected; the primary purpose of the compressor means is to heat the air, for if cool compressed air were all that were desired it could be supplied direct from the source to which pipe 89 is connected. It should be added, however, that should such source be one of a fluid other than air, then the compressor means serves the further essential function of providing compressed air, for an oxygen containing gas is needed to create an explosion in the container 50.

Diesel fuel, or the like, is injected into the container 50 through a nozzle 120 by a fuel pump 121 fed by fuel line 122 from a suitable source (not shown). The fuel pump may be activated by compressed air or gas fed by pipe 123 through solenoid activated valve 124 from a suitable source (not shown). If desired, the same source used to supply pipe 89 or pipe 73 may be used. Alternatively, hydraulic fluid may be used to drive pump 121 or it could be driven by an electric motor. Although diesel fuel has been mentioned as preferred, other liquid hydrocarbon such as kerosene or gasoline could be used.

The fuel pump may include a small diameter piston 130 operating in a small diameter bore or cylinder fed by fuel line 122 through a check valve 131 and exhausting to nozzle 120 through a check valve 132, the piston 132 being connected to a large diameter piston 134 moving in a large diameter bore or cylinder, piston 134 being urged to the left for pump intake by spring 135 and moved to the right for the injection stroke of the pump whenever valve 124 is activated to admit compressed air. When three-way valve 124 is returned to its original position, the large cylinder is connected to vent pipe 136 to allow the compressed air to escape, the spring 137 returning the piston to the previous position and drawing fuel into the small cylinder.

The fuel pump 121 and nozzle 120 form a fuel injection means. Although only one such means is shown, additional fuel injection means may be provided for the container 50.

To explode the gas-oil mixture in container 50, one or more spark plugs, such as that shown at 104, are provided, extending through the sidewall of container 50, connected to electric power supply cable 141.

Upon explosion of the mixture in container 50, the pressure builds up rapidly. As soon as the pressure exerts enough force on closure 55 to overcome the force on plate 66, the closure opens and the pressurized mixture in container 50 is released. The slightest downward movement of closure 55 also moves plate 66 away from seal 67. This allows air in chamber 60 to get above plate 66 and balance the pressure thereon and allows closure 55 to open more quickly.

To the lower end of container 50 and jacket 83 is connected an inverted dish-shaped receiver 150. The receiver has a central opening 151 large enough to pass closure 55. A lip 152 around the opening 151 extends beneath the lower wall 53 of the container. A shoulder 153 on the receiver extends beneath the flange 154 at the lower end of jacket 83. An O-ring seal 155 is disposed in an annular groove in shoulder 154 to seal the receiver to jacket 83. A plurality of lugs 156 held to the receiver by screws 157 overlie the flange 154, thereby clamping the receiver to the lower end of jacket 83, with the lower end of the container clamped between the receiver and the jacket.

A vent pipe 160 extends through the receiver and upwardly to the atmosphere above the surface of the water in which the generator is disposed.

A flexible diaphragm 170, made of rubber, thin or corrugated metal, extends over the lower end of the receiver and is secured in fluidtight relationship to the outer periphery of the receiver by a clamping ring 171 and a plurality of screws 172.

Normally the diaphragm 170 is held against the lower face of the receiver by hydrostatic pressure, as shown at A in broken lines. Upon opening of the closure 55, the high pressure gas from the container enters the receiver and causes the diaphragm to move down to the position shown at B in broken lines. This acts against the water in which the generator is immersed, creating a seismic wave therein which progresses down through the water into the earth beneath the water. Meanwhile, the high pressure gas is also vented through pipe 160, which prevents bursting of diaphragm 170. The receiver prevents the escape of gas into the water where it might compress and expand repeatedly, such oscillations being undesirable in that they might disturb the hydrophones or geophones of the underwater seismic receiver system used in conjunction with the generator.

When the pressure in the receiver has been fully relieved through vent pipe 160, hydrostatic pressure forces the diaphragm back to position A, returning the closure 55 to its original position. The return of closure 55 is also effected independently by plate 66, for the diameter of stem 71 is slightly larger than the diameter of rod 57, creating a net upwardly acting area subject to the pressure in cylinder 61. It is to be observed that at this time the pressure at the upper end of stem

71 is fully relieved through vent pipe 160 in the receiver, the upper end of the stem being sealed from cylinder 61 by O-ring 72. Once the closure 55 returns to closed position, it remains there until the next explosion, for simultaneously the plate 66 moves against O-ring 67 and the full area at the bottom of the plate then acts to hold the plate against block 64.

To prepare the generator for refiring, valve 90 is moved to connect the upper end of cylinder 80 to atmospheric vent pipe 179 which extends to the surface of the water. This releases the pressure which held down piston 100 during the explosion. If desired, cylinder 80 could be vented prior to the explosion, the passages from container 50 to cylinder 80 being small. Next, fresh air is admitted to container 50 through pipe 180 and solenoid activated valve 181 from a source (not shown) of air under pressure. If desired, the source may be the same source as that connected to pipes 123, 89, and 73. However, the pressure is throttled or otherwise reduced so as to be just enough to raise piston 100 to the top of cylinder 80. If full pressure were admitted below piston 100, the same pressure admitted above the piston would be unable to move the piston down. After air has thus been admitted to container 50 and cylinder 80, valve 181 is closed and valve 90 moved to admit compressed air above piston 100. This moves the piston down, compressing the air in cylinder 80 into container 50, and the generator is ready to be fired again.

Depending upon the dimensions of the container 50 and the cylinder 80, it may be desirable to purge the container 50 of products of the explosion prior to refiring. This can be done in a variety of ways. As shown, a vent pipe 190 is connected to the container and the vent pipe connected through a valve 191 to a vacuum line. Opening the valve in the vent pipe would cause the container to vent to the vacuum line. Alternatively, the vent pipe could be connected through the valve to discharge into the water. Then by actuating the piston up and down one or more times with air from pipes 180 and 89, fresh air could be drawn in and discharged several times through the vent pipe to purge the container; or with piston 100 held in its lowermost position by air pressure thereabove, air under more than the pressure used to raise piston 100 could be alternately admitted to container 50 and exhausted therefrom by means of valve 181, which in this case would be a three-way valve for alternately connecting the container to the compressed air line or to a vent pipe. After purging container 50, the generator would then be prepared for refiring in the manner previously explained.

The generator shown in FIG. 1 may be said to comprise receiver 150 and a power unit 200 thereabove, the power unit including the container, the pneumatic chamber, and the compressor. Other forms of receivers can be used in conjunction with the power unit 200.

Referring to FIG. 2, the power unit 200 is connected at its lower end to a long cylinder 201 within which is disposed a free piston 282. The bottom of the cylinder is open although an internal rim or the like is provided to prevent the piston from being pushed out of the cylinder by the explosion. A vent pipe 160, analogous to vent pipe 160, is provided in the closed upper end of cylinder 201.

Referring to FIG. 3, the construction is the same as in FIG. 2 except that the piston 202 is provided with an upstanding annular flange 203 at its upper end. The flange is of larger inner diameter than the outer diameter of closure 55. The piston is thus spaced from the closure to prevent impact of the closure on the piston at the moment of opening of the container upon explosion of the gas-oil mixture therein. As soon as the closure opens enough to release the high-pressure gas from the container, the gas forces the piston down away from the path of travel of the closure.

Referring to FIG. 4, the construction is the same as in FIG. 3 except that the cylinder 205 is closed at its bottom, so there is no water flow passage through the closed lower end of the cylinder. Instead, vent ports 206 are provided in the sides of the cylinder to vent same until free piston 207 passes the ports. The water in the bottom of the cylinder 205 cushions the stop of the piston at the lower end of its stroke.

Referring to FIG. 5, there is shown a further modification which is the same as the FIG. 3 construction except that the piston 202 is completely omitted. If desired, the cylinder 201 could be made long enough so that all the exhaust gases from the container explosion are retained therein. However, to prepare the receiver cylinder for the next firing, there is still need for vent pipe 160. Vent pipe 160 in all embodiments preferably should extend to the surface so as to be at atmospheric pressure.

FIG. 6 shows a further modification wherein the receiver is omitted altogether, the power unit 200 alone constituting the impulse generator. This construction is suitable for use where free gas exhaust creates no problem.

Comparing the various forms of receiver means shown in FIGS. 1 through 5, it will be seen that in every case there is an inverted cup structure opening at its lower end to the liquid in which the generator is submerged, and if, as in FIGS. 1 through 4, there is included a partition means, e.g. a flexible diaphragm or free piston, to separate the exploding gas from the liquid and to prevent its escape except through designated vents, such partition means is mounted so as to be closely adjacent to or contiguous with the closure just prior to the explosion, i.e. in the normal or prefiring position of the generator. The volume of the receiver cup is thus initially occupied almost 100 percent by water and upon the explosion of the material in the container, the products of the explosion quickly displace the water in the receiver cup, moving the water downwardly in the direction of the bottom of the body of water in which the generator is immersed. Even in the case of the FIG. 4 structure wherein there are side openings to prevent the reaction of the water and exhaust gas from lifting the generator, the upper part of cylinder 205 forms an inverted cup which opens into ports 206, and the water below piston 202 moves down before it is expelled laterally from the ports.

Although in describing the invention, reference has been made to air as the gas supplied to the container for reacting with the fuel to create an explosion, other sources of oxygen may be used, and if desired, pure oxygen can be used. A variety of fuels could be substituted for the previously suggested diesel oil. The most important point is that an explosion is used to create the high pressure in the container of a pop-gun-type generator. Although the piston in the compressor cylinder has been described as being driven by air, it could be driven hydraulically or mechanically, the essential feature being that the air fed to the container be compressed and thereby heated.

The operation of the generator has been described as though each valve were separately actuated. However, all of the valves will normally be actuated electrically and a single controller may be provided to actuate them automatically in the desired sequence. The controller would be located at the surface along with the various sources of compressed air, hydraulic fluid fuel, and electric power, the various electric cables, fuel pipes, air and hydraulic lines extending from the generator up through the water in which the generator is immersed to the vessel or structure at the surface.

It is to be understood that any conventional or other desired spread or disposition of generators and geophone receivers may be used in conjunction with the present invention. However, as previously mentioned, pulse shape can be controlled by overlapping in time the pulses generated by adjacent generators. Pulse shape can also be controlled by continuing fuel injection during the course of the explosion, either by repeated operation of the same fuel injector or by operation of additional fuel injectors in the same container. Finally, it is to be noted that in the embodiment of FIG. 5, the water column in the receiver cylinder may be made long enough to have high inertia, thereby to promote the transmission of low frequency waves to the adjacent water, such low frequency waves better penetrating the earth of the water-earth interface. If desired, a plurality of power units may be mounted to exhaust into a single receiver in order to better integrate the overlapping pulses from the plurality of units. Other modifications may be made

within the spirit of the invention. For example, instead of using a pneumatic chamber to bias the closure to closed position, a spring or other resilient means could be employed.

I claim:

1. An impulse generator comprising a container having an opening and a closure for the opening,
biasing means urging the closure to closed position,
means to supply explosive material to the container, and
means to initiate an explosion of said material in the container sufficient to overcome said biasing means and open said closure.

2. An impulse generator comprising a container having an opening and a closure for the opening,
biasing means urging the closure to closed position,
means to supply explosive material to the container,
means to initiate an explosion of said material in the container and open said closure to release the exhaust gas from said container to flow out of said opening past said closure,
receiver means connected over said container opening to control the exhaust gas from the explosion,
said receiver means comprising an inverted cup open at its lower end to the surrounding medium, and
vent means communicating with the upper end of the cup.

3. Combination according to claim 2 wherein said receiver means further includes separator means normally lying adjacent said closure and adapted to move down in said receiver upon release of products of explosion into the receiver.

4. Combination according to claim 3 wherein said inverted cup is of greater maximum diameter than depth giving it a dish shape, and said separator means includes a flexible diaphragm adapted normally to lie against the dish shape sides and top of the cup.

5. Combination according to claim 2 wherein said cup is of cylindrical shape and said separator means includes a free piston in said cylindrically shaped cup adapted normally to lie against the upper end of the cup.

6. Combination of claim 5 including means on the upper end of said piston to engage the upper end of said cup around the outer periphery of said closure to space said piston from said closure.

7. Combination of claim 2 wherein said inverted cup is of cylindrical shape and including a vertically downward extension of the cylindrical walls of said cup, said extension being closed at its bottom, the junction of the lower end of said cup and the upper end of said extension being provided with laterally opening ports, said separator means including a free piston adapted to travel vertically up and down in said cup and extension.

8. Combination including a plurality of adjacent generators adapted to be fired with their explosion times overlapping, each generator including:
an impulse generator comprising a container having an opening and a closure for the opening;
biasing means urging the closure to closed position;
means to supply explosive material to the container;
means to initiate an explosion of said material in the container and open said closure; and
common receiver means to control the products of the explosions of all the generators.

9. An impulse generator comprising a container having an opening and a closure for the opening,
biasing means urging the closure to closed position,
means to supply explosive material to the container, and
means to initiate an explosion of said material in the container and open said closure,
said means to supply explosive material to the container including:
means to inject fuel into the container and
compressor means in direct communication with the container to compress directly into the container a volume of an oxygen furnishing gas which volume is initially at the same pressure as the gas in the container and thereby increase the temperature and pressure and quantity of gas in the container.

10. An impulse generator comprising a container having an opening and a closure for the opening,
biasing means urging the closure to closed position,
means to supply explosive material to the container,
means to initiate an explosion of said material in the container and open said closure, and
vacuum means to purge said container of the products of explosion.

11. An impulse generator comprising a container having an opening and a closure for the opening,
biasing means urging the closure to closed position,
means to supply explosive material to the container,
means to initiate an explosion of said material in the container and open said closure, and
means to inject fuel into said container after the explosion has been initiated to prolong the time of explosion and thereby shape the energy pulse created by the explosion.

12. An impulse generator comprising a container including wall means having an opening and a closure for the opening,
biasing means urging the closure to closed position,
means to supply explosive material to the container, and
means to initiate an explosion of said material in the container sufficient to overcome said biasing means and open said closure,
said biasing means comprising:
a pneumatic chamber isolated by being sealed apart from the container,
plate means in and surrounded by said chamber and subjected to pressure therein to urge the plate in one direction, and
means passing through said wall means of the container connecting the plate to the closure.

13. Combination of claim 12 wherein said pressure in said chamber urges said plate means against a wall of said isolated chamber with a force independent of the pressure in said container, and including means to seal between said wall of said isolated chamber and said plate means around an area of said plate means, and means to vent the space between said wall of said isolated chamber and said area of the plate means to a space separate from said container.

14. Combination of claim 13 wherein said container and chamber are cylindrical and disposed adjacent each other end to end with one end of the container adjacent one end of the chamber and with said container and chamber each extending axially away from said adjacent ends in opposite directions, said means connecting said plate and closure comprising a rod reciprocatably passing through a bearing in the adjacent ends of said container and chamber, said opening in said container being at the end of said container opposite from said bearing, said chamber wall against which said plate is urged being at the end of said chamber opposite from said bearing.

15. Combination of claim 14 including a block forming the upper end of said chamber, a bearing socket in the lower side of said block, and a guide stem on the upper side of said plate, said stem being received in said socket.

16. Combination according to claim 15 wherein said means to supply explosive material to the container includes means to inject fuel into the container and compressor means in communication with the container to heat and compress on oxygen furnishing gas into the container, said compressor means comprising a cylinder surmounting said block, a free piston in said chamber, means to admit pressure fluid to said cylinder above said piston, and fluid passage means placing the container in communication with the interior of said cylinder below said piston.

17. Combination of claim 15 wherein said fluid passage means comprises a passage extending inside said rod and stem communicating at its lower end with said container and at its upper end with said socket and a passage extending inside said block from said cylinder to said socket, and means sealing between said stem and socket at a point nearer said plate than

the point of communication of the last said passage with said socket.

18. Combination according to claim 17 wherein the diameter of said stem is greater than the diameter of said rod.

19. Combination according to claim 18 including means to admit oxygen furnishing gas into said container and thence into said compressor means in communication therewith.

20. Combination according to claim 19 including a vacuum line means connectable to said container to purge said container of the products of explosion.