

PATENT SPECIFICATION

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(54) IMPROVED ACOUSTIC SOURCE FOR SUBSEA EXPLORATION

- (71) We, MOBIL OIL CORPORATION, a corporation organised under the laws of the State of New York, United States of America, of 150 East 42nd Street, New York, New York 10017, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to marine acoustic sources.
- In recent developments in marine seismic surveying, pneumatic acoustic sources have been employed to generate acoustic signals in water by the rapid release of pressurized gas from a chamber. These sources generally employ spool-shaped valves, one rim of which opens and closes an outlet port through which the pressurized gas is released and the other rim of which is used for control purposes employing pressurized gas.
- In one known source, the control rim is supported for movement within the chamber of the source. In the closed position of the valve, gas pressure in the chamber acts on the control rim to maintain the valve closed. In addition the control rim cooperates with a seal to form a control region sealed from the high gas pressure in the main chamber. Actuation of the valve is accomplished by increasing the pressure in the control region to move the valve to a position to disengage the seal. At this point, the high gas pressure in the main chamber acts on an increased area of the valve to move the valve rapidly to an open position to release the high gas pressure into the water for generating an acoustic pulse.
- In accordance with the present invention, an acoustic source comprises a chamber having an inlet port for gas admission, an outlet port for gas release, the outlet port being valve controlled, and the source is characterized in that the valve comprises a closure member of magnetizable material, and that magnetic means is employed for holding the valve in the closed position, said closure member being movable to an open position for release of the gas through said outlet port. More particularly, the source includes a chamber formed of rigid wall structure having a first end and an outlet port spaced from the first end to be coupled to water. Movable valve means comprising magnetic material is supported for movement between a closed position and an open position for closing and opening the outlet port. When the valve is in its closed position, supply means introduces a fluid into the chamber to form a high gas pressure therein. Means is provided for applying a magnetic field to the valve's magnetic material for forming a magnetic force for holding the valve in its closed position against the force of the high gas pressure within the chamber. In addition, means is employed for reducing the effect of the magnetic force on the valve for rendering the magnetic force ineffective to hold the valve in its closed position to allow the high gas pressure in the chamber to move the valve to its open position to release the gas rapidly into the water to generate an acoustic pulse.
- In one embodiment disclosed, an electrical coil is supported to surround the outlet port. The valve is moved adjacent to the electrical coil when moved to its closed position. The coil is energized to form the magnetic field which is applied to the valve to form the magnetic holding force. When it is desired to actuate the valve to generate an acoustic pulse, current to the coil is controlled by a switching arrangement to reduce the magnetic holding force thereby allowing the high gas pressure to move the valve rapidly

to its open position for release of the high pressure gas into the water.

Figure 1 illustrates the pneumatic acoustic source of the present invention in the environment in which it is to be used;

Figure 2 is an enlarged cross-sectional view of the acoustic source with its quick-acting valve in a closed position;

Figure 3 illustrates one type of switch used to control the operation of the acoustic source;

Figure 4 is a partial cross-sectional view of another embodiment of the acoustic source showing its valve in a partial open position;

Figures 5 and 6 illustrate alternative switches for controlling the acoustic source;

Figure 7 is a cross-sectional view of a portion of the source illustrating laminated members forming the electromagnetic assembly of the source and its fast acting valve;

Figure 8 illustrates a modified arrangement for providing oscillation and reversal of the magnetic flux to assure rapid release of the fast acting valve;

Figure 9 illustrates detailed circuitry of a timing and switching arrangement which may be employed to operate the source;

Figure 10 illustrates a portion of a preferred seal arrangement employed at the lower end of the source;

Figure 10a illustrates a modification of Figure 4;

Figure 11 illustrates the interior of the source of Figure 10 looking downwardly from the top of the source; and

Figure 12 is an enlarged view of Figure 11 taken along the lines 12-12 thereof.

Referring now to Figure 1, the acoustic source 20 of the present invention is shown supported in water from a boat 21 by a cable arrangement 22. As can be seen from Figure 2, the acoustic source comprises enclosing wall structure 24 forming a pressure chamber 25 and which has an outlet port 26 at the lower end to be coupled to water. A quick-opening valve 27 is provided for opening and closing the outlet port. When the valve is in a closed position, the chamber is pressurized with high gas pressure. Ring-shaped seal 28, comprising a resilient member and located in slot 29, seals the outlet port. At a desired time, the valve 27 is actuated for sudden downward movement, as illustrated in Figures 1 and 4, to allow the high pressure gas to escape rapidly into the water by way of the outlet port 26 to generate an acoustic pulse.

The quick-acting valve 27 is made of magnetic material, such as mild steel. It is supported by a retract system 31, including cylinder 32 and piston 33, for movement to a closed position adjacent structure 34 forming the outlet port 26. Structure 34 is constructed of magnetic material, preferably mild steel. Positioned within ring-shaped slot 35, formed

in structure 34, and surrounding the outlet port is an electrical coil 36. This coil, along with structure or core 34, forms an electromagnet. In the operation of the source, coil 36 normally is energized by current applied thereto from DC source 37, leads 38, normally closed switch 39, and leads 40 of cable 41. This current produces a magnetic field as illustrated at 42. This field in turn produces or develops a magnetic force which is applied to and acts on the valve when it is in its closed position to hold the valve closed against the gas pressure within the chamber 25. When it is desired to actuate or trigger the valve 27 to generate an acoustic pulse, switch 39 is actuated, for example merely to interrupt the flow of current to the coil, to allow the magnetic field and resulting force to decay to a level insufficient to hold the valve in its closed position against the pressure in the chamber 25. At this point the high gas pressure in the chamber then moves the valve 27 rapidly downward to its open position for release into the water to generate an acoustic pulse. Water in container 43 slows the valve 27 at the end of its opening movement. Following the generation of an acoustic pulse, retract mechanism 31 moves the valve 27 to its closed position for a repeat cycle.

As now can be understood, the present source with its magnetic valve control system has advantages due to its simplicity. By applying the magnetic field and hence the magnetic holding force directly to the valve, for control purposes, the number of mechanical working parts is reduced and the inertia of moving parts is minimized.

The chamber pressurizing system, power supplies, and control instrumentation are located on the tow boat and are illustrated in the dashed box 44. The chamber pressurizing system, in one embodiment, may comprise an air compressor only, illustrated at 45 in Figure 2 or, in another embodiment, an arrangement for forming a combustible mixture of diesel fuel and air which is ignited and burned in the chamber. The first embodiment is illustrated in Figure 2. In this embodiment, air compressor 45 is coupled to the chamber 25 by way of conduit 46, valve 47, and conduit 48, including check valve 49. The air compressor 45 also is coupled to the retract cylinder 32 by way of conduit 46, conduit 50, three-way valve 51, and conduit 52. Valve 47 is a normally closed solenoid controlled valve while valve 51 is a solenoid controlled valve which normally vents retract cylinder 32 to the atmosphere by way of conduit 52 and vent 53. A timer 54 controls both valves 47 and 51 and, in addition, switch 39 which in its simplest form comprises a movable arm 55 normally biased, by spring 56, to contact terminal 57 as illustrated by the switch 39a in Figure 3.

The sequence of operation during one

cycle will now be described in the embodiment employing only compressed air and the switch of Figure 3. In the beginning of this cycle, it is assumed that an acoustic pulse has been generated and the valve 27 has been moved to its closed position. At this time both valves 47 and 51 are in their normal states whereby the flow of air to chamber 25 and to cylinder 32 is blocked and, in addition, cylinder 32 is vented to the atmosphere. In addition, arm 55 of switch 39a is in normal position and contacts terminal 57 whereby DC current is applied to the coil 36 to produce the magnetic holding force for holding the valve 27 closed. Timer 54 first causes valve 47 to open to allow air to flow into the chamber 25. After the chamber 25 has been pressurized to the desired value, timer 54 allows the valve 47 to close to block the flow of air into the chamber 25. Next, timer 54 causes arm 55 of switch 39a to move to a position away from terminal 57 to interrupt the flow of current to the coil 36 and thereby de-energize the coil. This allows the magnetic field to decay whereby the pressure in the chamber 25 may move the valve to its open position for release of the air into the water. After the valve 27 has opened and the gas pressure in chamber 25 released, timer 54 allows arm 55 of switch 39a to be moved to its normal position contacting terminal 57 to create again the electromagnetic holding force. At about the same time, timer 54 controls valve 51 to block vent 53 and allow air to flow into retract cylinder 32 by way of conduits 50 and 52. The pressurized air in cylinder 32 acts on piston 33 to move the piston and hence the valve 27 upward to its closed position where the magnetic holding force holds it closed. Timer 54 then causes valve 51 to block the flow of air through conduit 50 and to vent cylinder 32 to the atmosphere by way of conduit 52 and vent 53.

The source 20 and valve assembly may be constructed to withstand and hold various chamber pressures. In one embodiment, the chamber 25 has a volume of 1.3 cubic feet. Chamber structure 24 is of soft iron while core 34 and valve 27 each is of solid mild steel as indicated above. Core 34 and valve 27 are circular in shape and have exterior diameters of about ten inches, respectively. The maximum thickness of these members is about three inches and $1\frac{3}{4}$ inches, respectively. The port 26 at its lower end has a diameter of three inches. Slot 35 is about one inch square in cross section spaced about $1\frac{3}{4}$ inches from the port 26. Coil 36 has 200 turns of 16 gauge copper wire and draws 4 amps at about 8 volts DC from source 37. The force developed by this coil is sufficient to hold the valve 27 closed against gas pressures up to about 500-650 psi for the source having the dimensions mentioned

above. Coils of different ampere-turns may be employed in sources of different sizes and configurations to hold pressures at different values.

Coil 36 may be secured within the slot 35 by an encapsulating epoxy or by a thin nonmagnetic holding ring, illustrated in Figure 4 at 60, and secured to structure 34 by bolts 61. In addition, vents 62 extending from slot 35 to the outside environment may be employed to release air trapped within the slot 35. In the sources disclosed in Figures 2 and 4, core 34 is secured to chamber structure 24 by way of rim 63 welded to chamber structure 24 and a plurality of bolts 64 threaded through rim 63 and into core 34. A seal, not shown, may be provided between rim 63 and core 34 to assure adequate sealing.

Although shown only in the embodiment of Figure 4, an arrangement is provided for preventing gas pressure leaking past the seal 28 from prematurely causing the valve 27 to open. This arrangement comprises an annular slot 65 and a plurality of apertures 66 extending from the slot 65 through the valve 27 to its back side. Slot 65 is formed in the top surface of the valve 27 and surrounds but is spaced from the area of the valve's top surface which contacts the seal 28. Gas, which leaks past the seal 28 when the valve is closed and the chamber pressurized, flows into slot 65 and through apertures 66 and hence is channeled away from the valve's outer surface area outside the circumference of the seal and the slot. This prevents the formation of additional downward force on the valve's outer surface which may otherwise cause it to open prematurely.

In the embodiment described above, there is a delay in the release of the valve 27 from the electromagnet after it is turned off. This delay is believed to be caused primarily by remanent magnetism in the iron and in addition by eddy currents. Both of these phenomena delay the time when the magnetization or magnetic field reduces to a value where the gas pressure forces the valve open. Hence the time of opening varies with the gas pressure in the chamber. This does not affect the output from the source, but does require compensation either in the recording of the processing of the seismic data.

The delay in opening due to the remanent magnetism may be reduced by reversing the connection of the coil 36 to the DC source 37 or by reversing the connection to a voltage source of increased but opposite polarity upon switching. As can be understood, the magnetization of the iron lags the change in current in the circuit. Thus, when the arm 55 of switch 39a is opened to interrupt the flow of current to coil 36, remanent magnetism exists in the iron. The switching alternatives

illustrated in Figures 5 and 6, however, remove the remanent magnetism thereby affording more prompt release of the valve. In the switch 39b of Figure 5, the leads 38 of DC power supply 37 are connected to terminals 70 which in turn are connected to terminals 71 by leads 72. Normally arms 73 are biased by springs 74 to contact terminals 70 whereby current of one polarity is applied to the coil 36. When it is desired to release the valve 27 to generate an acoustic pulse, timer 54 causes arms 73 to disengage terminals 70 to interrupt the flow of current and then to rapidly engage terminals 71 to apply a current of opposite polarity to the coil 36. After release of the gas pressure, timer 54 then allows arms 73 to be biased back to their normal positions, contacting terminals 70.

In the alternative switch 39b of Figure 6, arms 73 also normally are biased by springs 74 to contact terminals 70 whereby the output from supply 37 is applied to the coil 36 in a first direction. When it is desired to release the valve 27 to generate an acoustic pulse, timer 54 causes arms 73 to contact terminals 75 whereby the output from DC source 76 is applied in a reverse direction to the coil 36. The source 75, however, is a larger source which may supply, for example, 48 volts at 30 amps to the coil 36 for decreasing the remanent magnetism at an even higher rate.

In the embodiments described above, wherein the electromagnetic core 34 and the valve 27 are of solid mild steel, the collapsing magnetic field, which occurs when the switch is opened or reversed, creates eddy currents in the steel which oppose and delay the moment when the field reduces to a point that the gas pressure forces the valve open. In order to reduce this delay even more, the electromagnetic core 34 and the valve 27 may be laminated, as shown in Figure 7. In this embodiment, the generation of eddy currents is greatly deduced by the laminations when the current to the coil is turned off or reversed, allowing the flux, and therefore the holding force, to change rapidly and to reduce the delay time.

One method of laminating members 34 and 27 is to spirally wind flat steel ribbons and machine the members from the wound steel coils. The layers are insulated from each other, for example, by normal oxide coating, and are assembled to avoid external connections between the inner and outer ends of the ribbon to avoid the flow of eddy currents. A suitable clamping arrangement may be employed to hold the laminated structure together.

In the embodiment employing a laminated core 34 and valve 27, the circuit of Figure 6, rather than a reversing switch, may be employed to reduce the remanent magnetism. In this circuit, capacitor 77 is connected

in parallel across the coil 36 and forms a resonating circuit with the inductance L of the coil. In the operation of this embodiment, arm 55 of switch 39 normally is closed to form the magnetic holding force for holding the valve 27 closed. When arm 55 opens to disengage terminal 57, current in the coil 36 oscillates in the circuit comprising the L and C. The current quickly decays through zero and reverses, thereby removing remanent magnetism and allowing a quick release of the valve 27. The embodiment of Figure 8 is employed preferably only with the source having the laminated core 34 and laminated valve 27 so that the resonant action of the coil and capacitor is not over-damped by eddy currents in the steel.

In one embodiment, the timer 54 employed for controlling the operation of the instrumentation may be a mechanical type of timer comprising a rotating shaft for driving a plurality of cams for controlling various switching operations. In the preferred embodiment, however, the timer is an electronic timer, one type of which is illustrated in Figure 9. Thus timer is a ring counter comprising a plurality of silicon controlled rectifiers illustrated at 80-85 and controlled by pulser 86. The silicon controlled rectifiers produce on-off signals for controlling relay control circuits, three of which are illustrated at 87-89. Circuit 87 controls an intermediate relay 90 which in turn controls the solenoid operated valve 47. Circuit 88 controls an intermediate relay 91 which controls the switch 39. In addition, circuit 89 controls intermediate relay 92 which in turn controls the three-way valve 51. Intermediate relays 90-92 are employed to protect the small relays of circuits 87-89 from the larger currents and voltages drawn by the larger coils which are employed to actuate valves 47, switch 39, and valve 51, respectively.

In the operation of the system, the silicon controlled rectifiers (SCRs) 80-85 normally are off. In addition, transistor 93, which is a driver stage, normally is nonconducting. The Start button first is momentarily closed to apply current from the B+ conductor to SCR 80. This causes the SCR to conduct. Pulser 86, which may be a unijunction transistor, produces output pulses which are applied to transistor 93. Choke 94 has a high impedance to a pulse but low impedance to DC. Thus, when any one SCR is conducting DC, there is very little voltage drop across the choke and the voltage on common lead 95 is near that of B+. When a pulse from the pulser 86 is applied to the transistor 93 it conducts for the duration of the pulse with current flowing through the choke. As the choke impedance is high for a short pulse, the voltage on lead 95 drops to a low value. This causes the voltage at all SCR anodes to drop

70

75

80

85

90

95

100

105

110

115

120

125

130

very low since they are all connected to lead 95. The SCR, which is conducting at the time, turns off since it has lost its anode voltage. The voltage on lead 95 quickly rises back to B+ as the pulse terminates, but the SCR does not turn back on. However, the next adjacent SCR on the right does turn on because its gate is driven positive by the capacitor which connects it to the anode of the previous SCR. Thus each pulse from pulser 86 turns the conducting SCR off which results in the next adjacent SCR being turned on, whereby SCRs 80-85 are turned on and off in succession to produce a series of control outputs which are applied to circuits 87-89 by way of conductors 102-103, 104-105, and 106-107, respectively. The output at the juncture of resistor 108 and capacitor 109 is applied back to SCR 80 to recycle the timer.

Referring to the relay control circuits 87-89, since all of these circuits are similar, only circuit 87 will be described. This circuit comprises a transistor 110 which is normally off and a transistor 111 which is normally in a state whereby it is capable of conducting. The output pulse from conductor 102 causes transistor 110 to conduct thereby energizing solenoid coil 112. This causes ganged switches 113 and 114 to be moved downward to contact terminals 115 and 116, respectively. Current then flows through solenoid 112 from B+ by way of conductor 117, terminal 115, and switch 113 to hold the solenoid in its energized position. Movement of switch 114 to contact terminal 116 causes intermediate relay 90 to be energized which in turn moves switch 118 to contact terminal 119, thereby energizing the solenoid of control valve 47 to allow air from compressor 45 to flow to the pressure chamber 25.

The output from conductor 103 next turns transistor 111 off, thereby interrupting the current flow through solenoid 112. Switches 113 and 114 are then returned to their normal states by springs 113a and 114a, thereby de-energizing solenoid 90. Switch 118 then is allowed to return to its normal open position by spring 118a thereby causing valve 47 to be de-energized to block the flow of air to the chamber 25.

In circuit 87 diodes 120 are Zener diodes which are biased by resistor 121 so that they break down and conduct with low impedance and about three volts drop across each. They serve to assure that transistors 110 and 111 are in the off condition when their base leads, 102-103, are properly biased by the SCRs 80-81, respectively.

The next output from conductor 104 causes circuit 88 to actuate relay 91 to close normally open switch 122. This allows capacitor 123, charged from power supply 124, to discharge through the coil of relay 125 and to energize the coil rapidly and at

a precise time, thereby opening arm 55 of switch 39a or reversing arms 73 of switches 39b or 39c quickly and precisely at the desired moment.

The next output from conductor 105 causes circuit 88 to de-energize solenoid 91, thereby allowing spring 126 to open switch 122 which in turn allows the arms of switches 39a, 39b, or 39c to be moved to their normal positions.

The output from conductor 106 causes relay 92 to be energized thereby closing switch 131. This allows current to be applied to the coil of valve 51 to block vent 53 and allow air from the air compressor to pass to the cylinder 32 by way of conduit 50 and conduit 52. The last output from conductor 107, as can be understood, causes relay 92 to be de-energized whereby spring 133 opens switch 131. This allows current to be applied condition, venting the retract cylinder 32.

Although only six silicon controlled rectifiers have been illustrated, in practice there are twenty which are turned on in succession during each cycle by the operation of the pulser 86. While conductors 102-107 are shown with fixed connection to the anodes of SCRs 80-85, respectively, in reality, by means of selector switches the conductors which operate the on and off states of the relay control circuits may be connected to any chosen anode of any SCR so as to afford great flexibility in choosing the actuating times of the various valves and switches. In addition, the pulser 86 can be adjusted to produce output pulses at different repetition rates to vary the cycle of operation. In one embodiment the timer is adjusted to operate the acoustic source 20 to produce acoustic pulses at a repetition rate of one pulse every six seconds.

Although the timer described in the system of Figure 10 employed silicon controlled rectifiers, it is to be understood that a similar type of ring counter could be employed utilizing multivibrators.

Referring again to Figure 4, there will be described briefly the embodiment wherein the source is pressurized by the ignition of a diesel fuel mixture injected into or formed in the chamber 25. This arrangement comprises a diesel fuel nozzle 140 for spraying diesel fuel into the chamber 25 and a glow plug 141 which is continuously energized by current applied thereto by conductor 142 extending from step down transformer 143, coupled to AC supply source 144. Diesel fuel is applied to nozzle 140 from source 145, solenoid controlled valve 146, conduit 147, and check valve 148. Valve 146 normally is maintained in a closed position to block the flow of fuel to nozzle 140. In a cycle of operation, air is injected into the chamber 25 as described above for pressurizing the chamber. After the chamber has been pressurized with air, timer

54 opens valve 146 for a short period of time whereby diesel fuel is sprayed into the chamber toward glow plug 141. The diesel fuel mixes with the pressurized air and is ignited by the glow plug. After a short period of time, the timer 54 next allows valve 146 to close to block the flow of diesel fuel to the nozzle 140. The remaining sequence of operation is the same as that described in connection with the embodiment of Figure 2.

Referring again to Figure 2, there will be described other structural features of the source. Deceleration container 43 is a cylindrical member having an interior diameter slightly larger than the exterior diameter of valve 27. The cylindrical walls of container 43 are welded to circular bottom plate 150 which, in turn, is supported by a plurality of spaced rods 151, coupled to rim 63 and to plate 150 by way of bolts illustrated at 152. As the valve 27 moves downward the water within the container 43 is squeezed upward between the exterior diameter of the valve 27 and the interior diameter of the container to decelerate the valve.

The cylindrical wall structure of retract cylinder 32 is welded to the bottom surface of plate 150 and to the top surface of plate 153. Plate 153, in turn, is supported by a plurality of spaced rods 154, coupled to plate 150 and to plate 153 by way of bolts illustrated at 155.

Valve 27 is coupled to retract piston 33 by way of coupling rod 160. The lower end of rod 160 is welded to piston 33 while its upper end is secured to valve 27 with a flexible coupling arrangement to provide a cushioning effect and to avoid the necessity of high precision of alignment of parts. The flexible coupling arrangement comprises a circular plate 161 threaded to the upper end of rod 160 and which also is coupled to valve structure 27 by way of bolts 162. The apertures in plate 161 through which the bolts 162 extend are larger than the stems thereof whereby the plate 161 can move relative to the bolts 162. A resilient member 163 is inserted between the plate 161 and the valve 27. The upper end of rod 160 pivots in a rounded aperture formed in the lower surface of the valve 27. Cup-shaped member 164 is threaded to the upper end of rod 160 and is provided to prevent excessive angular movement between the rod 160 and the valve 27.

The seal 28 for the source in one embodiment comprises a stainless steel ring 170 and a resilient elastomer O-ring 171 (see Figure 10) located in the slot 29. This slot is formed by metal holding rings 172 and 173 secured to the magnetic core structure 34 by bolts illustrated at 174. A plurality of spaced radially extending channels 175 extends from the pressure chamber region to the slot 29 whereby pressurized gas is applied to the slot 29 for effecting a seal between the elastomer

O-ring 171, the walls of the slot 29, and the metal seal ring 170 and between the metal ring 170 and the top surface of valve 27. Resilient O-ring 176 located in slot 177 provides a seal between ring 172 and structure 34.

In the preferred embodiment, the elastomer O-ring 171 is of the heat resistant type. In the source employing diesel fuel increased protection for the elastomer O-ring, from the hot gases formed in the chamber can be obtained by providing a labyrinth for cooling the hot gases before application to the slot 29.

In the operation of a pneumatic acoustic source employing diesel fuel, it has been found desirable to employ a shield to protect the igniter or glow plug from the direct air injected into the chamber to reduce cooling of the glow plug and hence to avoid erratic firing which might otherwise occur. For example, if the glow plug is not shielded, the cooler air injected for mixing purposes may cool the glow plug to a temperature whereby ignition of the air-diesel fuel mixture may be sporadic or prevented if the temperature is lower than that necessary for ignition to take place.

Figures 10a-12 show an arrangement for shielding the glow plug from the direct air. The shield is illustrated at 180 in Figure 10a. It is a half cylinder welded to the chamber wall and located to one side of the glow plug as shown in Figures 11 and 12. The air conduit 48 has an interior extension 181 with a curved end pointing to the side of the chamber interior and downwardly whereby the air injected is deflected around the chamber in a clockwise direction and downwardly in a swirling motion. As seen in Figures 11 and 12, the shield 180 is located between the glow plug and the air flowing to the glow plug in a clockwise direction. With this arrangement, diesel fuel may be sprayed from nozzle 140 toward the glow plug 141 unobstructed by the shield.

WHAT WE CLAIM IS:—

1. An acoustic source comprising a chamber having an inlet port for gas admission, an outlet port for gas release, the outlet port being valve controlled, characterized in that the valve comprises a closure member of magnetizable material, and that magnetic means is employed for holding the valve in the closed position, said closure member being movable to an open position for release of the gas through said outlet port.

2. The source according to claim 1 wherein said magnetic means comprises a solenoid surrounding said outlet port.

3. A source according to claim 1 or 2, wherein the valve is reciprocable and a valve member remote from a closure member cooperates with means for returning the opened valve to the closed position.



54 opens valve 146 for a short period of time whereby diesel fuel is sprayed into the chamber toward glow plug 141. The diesel fuel mixes with the pressurized air and is ignited by the glow plug. After a short period of time, the timer 54 next allows valve 146 to close to block the flow of diesel fuel to the nozzle 140. The remaining sequence of operation is the same as that described in connection with the embodiment of Figure 2.

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Valve 27 is coupled to retract piston 33 by way of coupling rod 160. The lower end of rod 160 is welded to piston 33 while its upper end is secured to valve 27 with a flexible coupling arrangement to provide a cushioning effect and to avoid the necessity of high precision of alignment of parts. The flexible coupling arrangement comprises a circular plate 161 threaded to the upper end of rod 160 and which also is coupled to valve structure 27 by way of bolts 162. The apertures in plate 161 through which the bolts 162 extend are larger than the stems thereof whereby the plate 161 can move relative to the bolts 162. A resilient member 163 is inserted between the plate 161 and the valve 27. The upper end of rod 160 pivots in a rounded aperture formed in the lower surface of the valve 27. Cup-shaped member 164 is threaded to the upper end of rod 160 and is provided to prevent excessive angular movement between the rod 160 and the valve 27.

The seal 28 for the source in one embodiment comprises a stainless steel ring 170 and a resilient elastomer O-ring 171 (see Figure 10) located in the slot 29. This slot is formed by metal holding rings 172 and 173 secured to the magnetic core structure 34 by bolts illustrated at 174. A plurality of spaced radially extending channels 175 extends from the pressure chamber region to the slot 29 whereby pressurized gas is applied to the slot 29 for effecting a seal between the elastomer

O-ring 171, the walls of the slot 29, and the metal seal ring 170 and between the metal ring 170 and the top surface of valve 27. Resilient O-ring 176 located in slot 177 provides a seal between ring 172 and structure 34.

In the preferred embodiment, the elastomer O-ring 171 is of the heat resistant type. In the source employing diesel fuel increased protection for the elastomer O-ring, from the hot gases formed in the chamber can be obtained by providing a labyrinth for cooling the hot gases before application to the slot 29.

In the operation of a pneumatic acoustic source employing diesel fuel, it has been found desirable to employ a shield to protect the igniter or glow plug from the direct air injected into the chamber to reduce cooling of the glow plug and hence to avoid erratic firing which might otherwise occur. For example, if the glow plug is not shielded, the cooler air injected for mixing purposes may cool the glow plug to a temperature whereby ignition of the air-diesel fuel mixture may be sporadic or prevented if the temperature is lower than that necessary for ignition to take place.

Figures 10a-12 show an arrangement for shielding the glow plug from the direct air. The shield is illustrated at 180 in Figure 10a. It is a half cylinder welded to the chamber wall and located to one side of the glow plug as shown in Figures 11 and 12. The air conduit 48 has an interior extension 181 with a curved end pointing to the side of the chamber interior and downwardly whereby the air injected is deflected around the chamber in a clockwise direction and downwardly in a swirling motion. As seen in Figures 11 and 12, the shield 180 is located between the glow plug and the air flowing to the glow plug in a clockwise direction. With this arrangement, diesel fuel may be sprayed from nozzle 140 toward the glow plug 141 unobstructed by the shield.

WHAT WE CLAIM IS:—

1. An acoustic source comprising a chamber having an inlet port for gas admission, an outlet port for gas release, the outlet port being valve controlled, characterized in that the valve comprises a closure member of magnetizable material, and that magnetic means is employed for holding the valve in the closed position, said closure member being movable to an open position for release of the gas through said outlet port.

2. The source according to claim 1 wherein said magnetic means comprises a solenoid surrounding said outlet port.

3. A source according to claim 1 or 2, wherein the valve is reciprocable and a valve member remote from a closure member cooperates with means for returning the opened valve to the closed position.

4. A source according to claim 3, wherein said returning means comprises a source of pressurized air.
- 5 5. A source according to claim 4, wherein said source of pressurized air also supplies the inlet port with the gas to be admitted.
- 10 6. A source according to claim 5 which also includes a timing system which synchronizes gas admission with solenoid de-energization so that the valve is permitted to open when the gas pressure in the chamber has reached a predetermined value.
- 15 7. A source according to any preceding claim which further comprises a dashpot arrangement acting upon the valve closure member.
- 20 8. A source according to any preceding claim wherein the chamber contains a diesel injector and igniter, for generating high gas pressure by explosion.
- 25 9. A source according to claim 8, wherein a shield is interposed in the gas flow path between the igniter and the inlet port.
- 30 10. A source according to claim 9, wherein the inlet port bears an extension internal to the chamber and shaped to create a generally helical gas flow path within the chamber.
11. A source according to claim 9 or claim 10, wherein the shield is a semicylindrical baffle.
12. A source according to any preceding claim in which there is formed in the outlet port valve seating an annular groove containing a resilient O-ring supporting a metal seal ring.
- 35 13. A source according to claim 12, wherein that part of the groove occupied by the O-ring communicates with the interior of the chamber.
- 40 14. A source according to any preceding claim wherein the valve closure member and that part of the chamber which defines the outlet port are of laminated metal.
- 45 15. A source according to any of claims 2 to 14 which further comprises means for accelerating de-energization of the solenoid.
- 50 16. A source according to claim 15, wherein said accelerating means comprises circuitry for effecting current reversal at the time of de-energization.
- 55 17. An acoustic source for subsea exploration constructed and arranged to operate substantially as described with reference to, and as illustrated in, Figures 1 to 12 of the accompanying drawings.

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