United States Patent [19]

Myers

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[54] **COMPOUND HYDRAULIC SEISMIC SOURCE VIBRATOR**

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[51] **Int. Cl.**[4] **H04R 23/00**

[52] **U.S. Cl.** **367/142**; 367/143; 367/174; 181/120

[58] **Field of Search** .... 367/143, 174, 142; 181/110, 120, 402; 91/530, 167 R; 92/65

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,653,298 4/1972 Bilodeau 92/65

3,676,840 7/1972 Bays 340/12

4,139,733 2/1979 Falkenberg 381/202

4,741,246 5/1988 Padarev 91/530

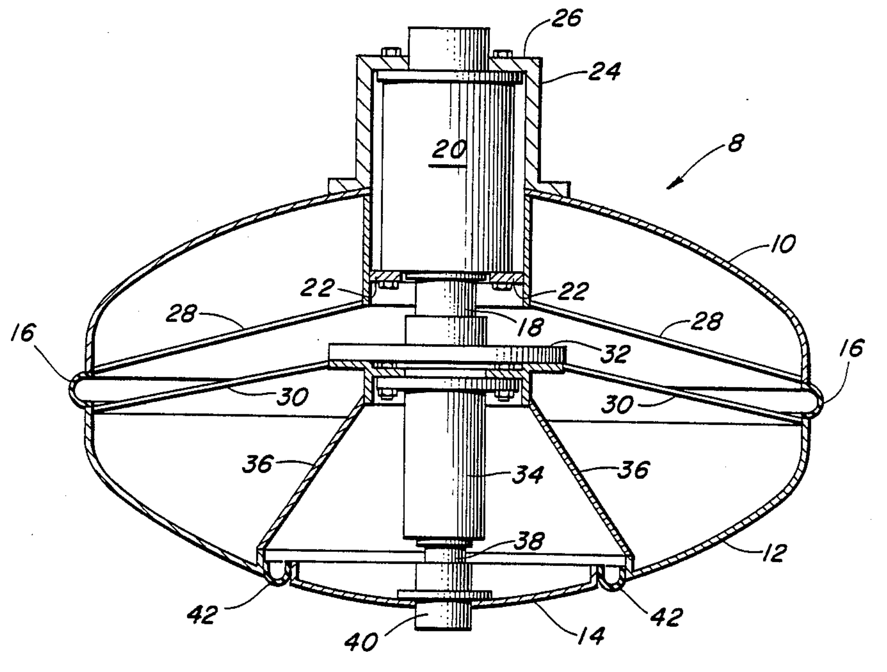
Primary Examiner—Deborah L. Kyle

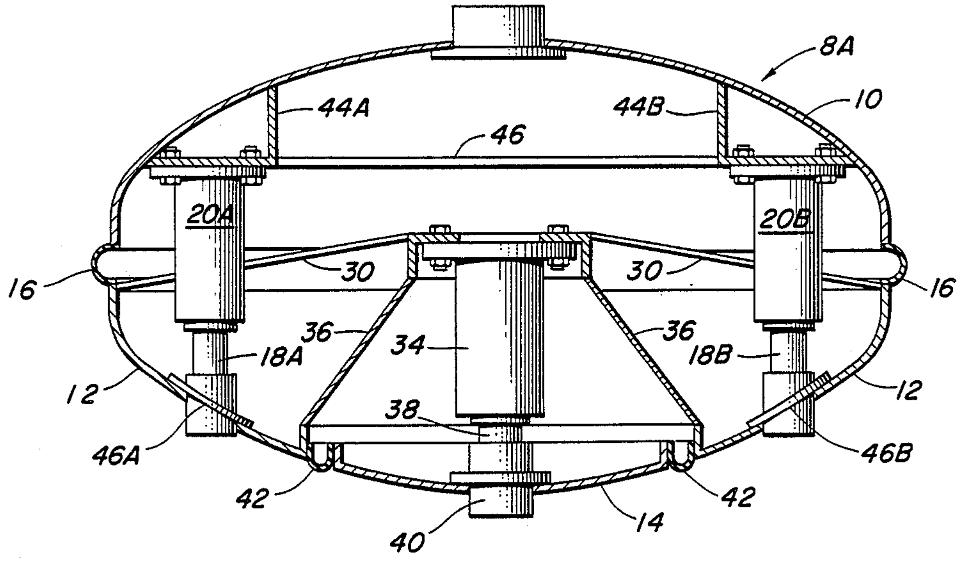
Assistant Examiner—J. Woodrow Eldred

[57] **ABSTRACT**

A seismic source marine vibrator having compound hydraulic cylinders for high and low frequencies is used to generate both low frequency and high frequency acoustic pulses. Low frequency pulses are generated by operating a low frequency radiating surface and a high frequency radiating surface simultaneously. High frequency pulses are generated by operating the high frequency radiating surface alone.

22 Claims, 2 Drawing Sheets

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10
44A
44B
46
20A
20B
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FIG. 2

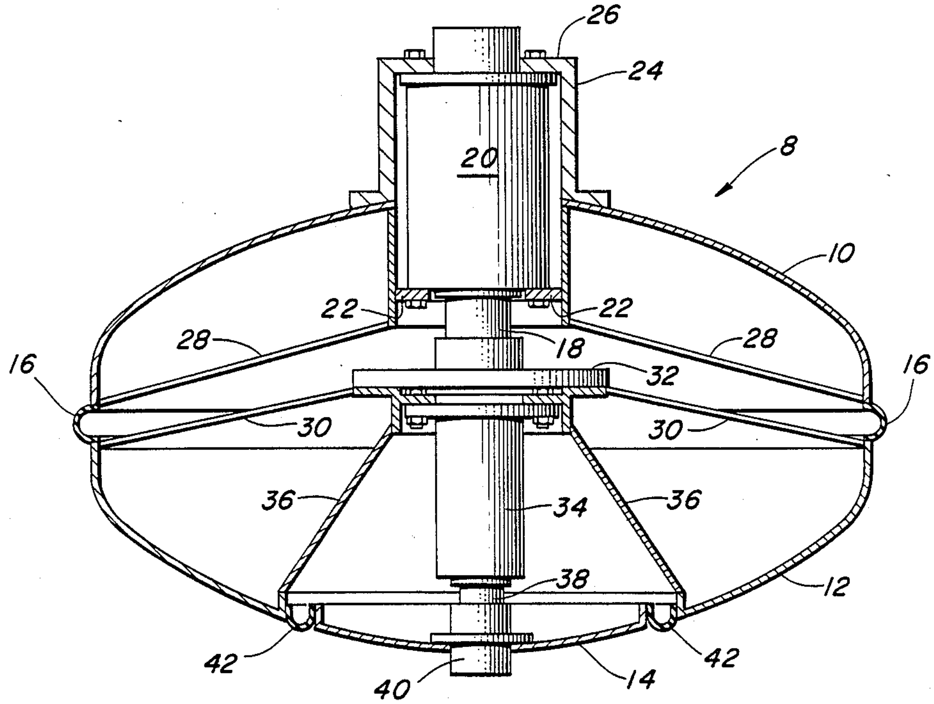
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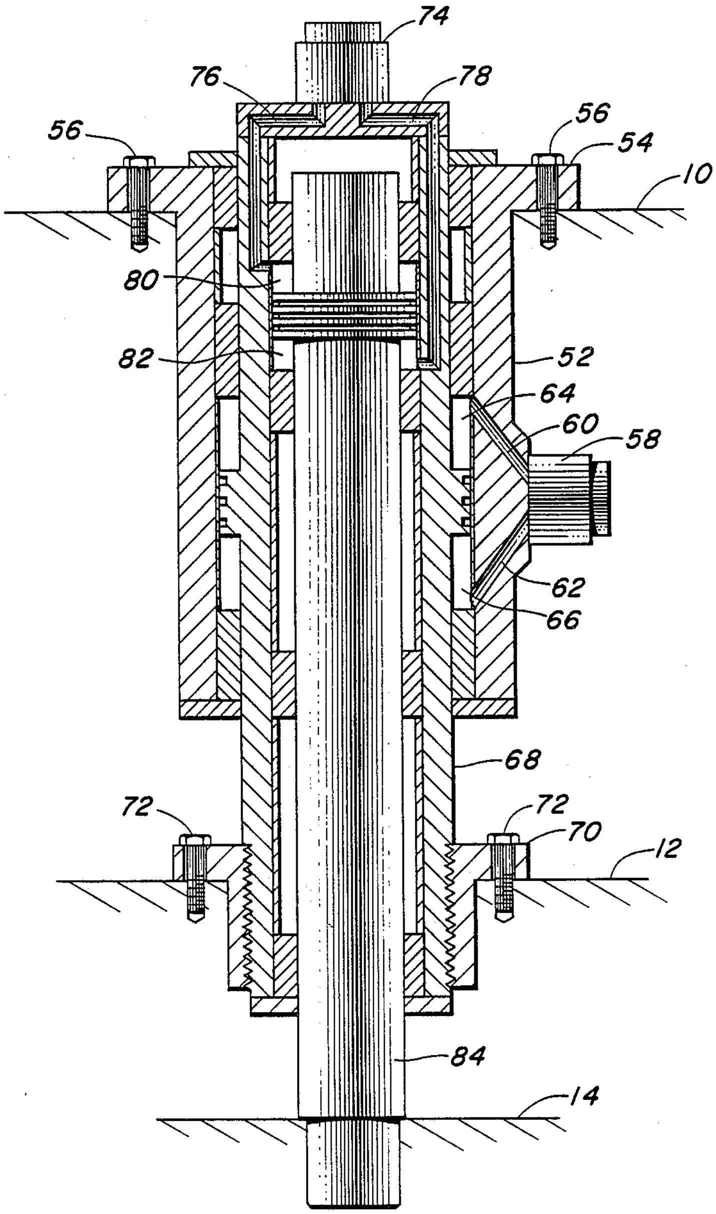
FIG. 1



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COMPOUND HYDRAULIC SEISMIC SOURCE VIBRATOR

CROSS REFERENCE TO RELATED APPLICATION

This application is related to co-pending U.S. patent application Ser. No. 265,601 entitled "Multiple Frequency Range Hydraulic Actuator" (ICR 8139) filed concurrently herewith.

BACKGROUND OF THE INVENTION AND RELATED ART

The present invention relates to marine seismic exploration, and more particularly to marine seismic exploration in which a seismic source is coupled to the ocean floor to generate acoustic pulses.

In present seismic exploration, acoustic pulses are generated by seismic sources, propagate through the earths crust, are reflected by subsurface interfaces and detected upon the return to the surface. In marine exploration, seismic sources have taken the form of explosive charges and airguns. However, both of these types of seismic sources have had deleterious effects on marine life. As a result, a hydraulic vibrator had been developed. The hydraulic vibrator used in marine exploration is similar to that used in land based seismic exploration. This type of seismic source has been found to have less deleterious effects on marine ecosystems.

In seismic pulse generation, it is beneficial to be able to generate pulses over a wide frequency range. In this regard, the use of hydraulic vibrators includes a problem in the range of frequencies generated. In general, a hydraulic vibrator system includes a hydraulic power plant, a hydraulic cylinder, hydraulic circuitry and structural members designed to operate over a range of frequencies. Stroke and flow requirements for low frequency operation necessarily are exclusive of high frequency operation due to their size and mass. Similarly, stroke and flow design requirements concommitant with high frequency propagation exclude the applicability of these vibrator systems from use in low frequency systems.

PRIOR ART

An example of an early type hydraulic vibrator system is described in U.S. Pat. No. 3,392,369 titled "Fluid-Actuated Dual Piston Underwater Sound Generator" issued to J. A. Dickie et al. In the patent, two similarly sized sound radiating pistons are driven by hydraulic actuators in unison. The pistons are arranged as a pair of oppositely outwardly facing elements on opposite sides of the stationary housing and are sealed to the housing by flexible rubber gaskets. The actuator is adapted to move each piston in the direction opposite to that of the other at any particular time. As the pistons move out changing the external volume of the transducer, the internal space is filled with a gas under pressure. The apparatus described in this patent is designed to operate at low frequencies so that the sound waves which are generated under water have low attenuation.

U.S. Pat. Nos. 3,329,930 and 3,394,775, both entitled "Marine Vibration Transducer" issued to J. R. Cole et al. also describe hydraulic seismic source generators. U.S. Pat. No. 3,329,930 relates to a vibrational transducer that is driven at a controlled rate, two-part vibration by driving a piston vertically, reciprocally against the water medium. In this patent, a single piston is used in conjunction with a single actuator. U.S. Pat. No. 3,394,775, which is a continuation in part of U.S. Pat. No. 3,329,930, introduces a vibrational transducer unit which consists of two pistons attached to a cylinder and a piston rod. A flexible rubber cylinder or boot is slipped over these two pistons and securely fastened to each so that air which is trapped between the pistons cannot escape into the water nor can water flow into the air chamber. The reciprocating piston imparts a pressure wave into the water while the innerhousing areas within the rubber enclosure are isolated and maintained at a predetermined air pressure such that maximum coupling of vibrational energy into the water medium is provided.

U.S. Pat. No. 3,482,646 titled "Marine Vibrator Devices" issued to G. L. Brown et al. is a single piston, single actuator type of assembly similar to that of the U. S. Pat. No. 3,392,369. A pair of shell-like housing members are disposed generally in parallel and are flexibly sealed between the respective outer peripheries to define an interior air space. A drive means is contained within the air space and connected to the respective housing members to impart reciprocal movement to one housing member with respect to the other.

Additional hydraulic seismic source generating systems are described in U.S. Pat. No. 4,103,280, titled "Device for Emitting Acoustic Waves in a Liquid Medium" issued to Jacques Cholet et al., U.S. Pat. No. 4,211,301 titled "Marine Seismic Transducer" issued to J. F. Mifsud, U.S. Pat. No. 4,294,328 titled "Device for Emitting Acoustic Waves in a Liquid Medium by Implosion" issued to Jacques Cholet et al. and U.S. Pat. No. 4,578,784 titled "Tunable Marine Seismic Source" issued to J. F. Mifsud.

However, as stated previously, all of the foregoing hydraulic vibrator systems share a common problem. That is, none of the foregoing systems are capable of operating over a wide range of frequencies but in general, are limited to acoustic pulse generation in the low frequency range.

SUMMARY OF THE INVENTION

The present invention provides a hydraulic seismic source vibrator which is directed to solving the problems presented by prior art hydraulic seismic source vibrators. The present invention consists basically of an upper housing, a low frequency radiating surface, a low frequency hydraulic cylinder, a high frequency radiating surface, and a high frequency hydraulic cylinder. In operation, the low frequency pulses are generated through the operation of the low frequency radiating surface to which the high frequency radiating surface is connected. When low frequencies are to be generated, both the low frequency surface and the high frequency surface are operated in conjunction to provide the effect of one large low frequency radiating surface. The physical combination of the low frequency radiating surface with the high frequency radiating surface generates acoustic pulses having a frequency range from low frequencies to a mid range. For the operation in the higher frequency range, the high frequency radiating surface operates alone. In doing so, the high frequency radiating surface can provide acoustic pulses having frequencies from the mid range to high frequencies, which have not been attained by hydraulic vibrator systems previously.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial sectional side view of a first embodiment of a compound hydraulic seismic source vibrator.

FIG. **2** is an alternative embodiment of a compound hydraulic seismic source vibrator which utilizes two low frequency hydraulic cylinders and one high frequency hydraulic cylinder.

FIG. **3** is a variation of the compound hydraulic seismic source vibrator of FIG. **1** in which the low frequency and the high frequency hydraulic cylinders are combined into a single cylinder.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The following description identifies an apparatus by which both low frequency and high frequency acoustic pulses may be generated in subsurface environments. A compound marine vibrator is described in which a woofer/tweeter type of arrangement is configured to permit generation of both low frequency and high frequency acoustic pulses.

Referring now to FIG. **1**, a first embodiment of the present invention is illustrated as hydraulic vibrator **8** which includes an upper housing **10**, a low frequency radiating surface **12**, and a high frequency radiating surface **14**. Low frequency radiating surface **12** is connected to upper housing portion **10** through flexible gasket **16** and low frequency piston rod **18**. Low frequency piston rod **18** is connected to low frequency piston (not shown) within low frequency hydraulic cylinder **20**. Low frequency hydraulic cylinder **20** is mounted to upper housing **10** on a cross piece **22** and on a cap **24** at its top ledge **26**. Cap **24** is mounted on upper housing **10** at its central uppermost portion. Support brackets **28** are provided connecting upper housing **10** with cross pieces **22** to provide stability for low frequency hydraulic cylinder **20**. Additional support brackets **30** are connected to a support disk **32** which is mounted on low frequency piston rod **18**. Support brackets **30** are connected to low frequency radiating surface **12** to transmit the force generated through low frequency piston rod **18** directly to low frequency radiating surface **12**.

High frequency hydraulic cylinder **34** is mounted on support disk **32** which has additional support members **36** mounted to low frequency radiating surface **12**. High frequency piston rod **38** is connected directly to high frequency radiating surface **14** through mounting disk **40**. High frequency radiating surface **14** is connected to low frequency radiating surface **12** through flexible gasket **42**.

In operation, when low frequency acoustic pulses are to be generated, hydraulic cylinder **20** is actuated which drives low frequency piston rod **18**. Movement of low frequency piston rod **18** forces low frequency radiating surface **12** along with support disk **32**, high frequency hydraulic cylinder **34**, mounting disk **40**, and high frequency radiating surface **14** to move in unison to generate low frequency acoustic pulses. During high frequency operation, low frequency piston rod **18** is maintained in a stable position, holding support disk **32** fixed. Accordingly, high frequency hydraulic cylinder **34** is also held fixed allowing high frequency piston rod **38** to move independent of support disk **32** and low frequency radiating surface **12**. In operation, high frequency piston rod **38** moves, moving mounting disk **40** which is connected to high frequency radiating surface **14** causing the generation of high frequency acoustic pulses. Low frequency radiating surface **12**, due to its connection to support disk **32**, high frequency hydraulic cylinder **34**, and high frequency radiating surface **14**, is only capable of generating low frequency acoustic pulses due to the mass involved. On the other hand, high frequency radiating surface can be moved rapidly to generate high frequency acoustic pulses by the action of high frequency piston rod **38** due to its size and its construction for movement independent of the operation of low frequency radiating surface **12**.

In this regard, hydraulic vibrator **8** provides an acoustic pulse generator capable of generating both low frequency acoustic pulses and, because of its unique configuration, high frequency acoustic pulses also.

Referring now to FIG. **2**, a second embodiment of the present invention is illustrated having similar components identified with the same numerals as those in FIG. **1**. In the embodiment of FIG. **2**, two low frequency hydraulic cylinders **20A** and **20B** are illustrated as individually being connected to low frequency radiating surface **12**. Cylinders **20A** and **20B** are mounted to upper housing **10** through brackets **44A** and **44B**, respectively. Brackets **44A** and **44B** are further supported by cross piece **46**. In operation, low frequency hydraulic cylinders **20A** and **20B** are actuated simultaneously causing low frequency piston rods **18A** and **18B** to move low frequency radiating surface **12** in unison. Low frequency piston rods **18A** and **18B** are connected directly to low frequency radiating surface **12** through mounting disks **46A** and **46B**. When low frequency hydraulic cylinders **20A** and **20B** are not actuated, they maintain the position of low frequency radiating surface **12** in a fixed position with respect to upper housing **10**. Accordingly, high frequency radiating surface **14** may be moved by high frequency piston rod **38** through the actuation of high frequency hydraulic cylinder **34** independently of low frequency radiating surface **12**. This is due to the fact that high frequency hydraulic cylinder **34** is mounted on support members **36** and support brackets **30**, both of which are secured to low frequency radiating surface **12**.

As with the operation of the embodiment illustrated in FIG. **1**, hydraulic vibrator **8A** as illustrated in FIG. **2** may generate low frequency acoustic pulses through the operation of low frequency hydraulic cylinders **20A** and **20B** in unison, forcing the motion of low frequency radiating surface **12**, support brackets **30**, support members **36**, high frequency hydraulic cylinder **34**, high frequency radiating surface **14** and mounting disk **40**. When high frequency acoustic pulses are desired, actuation of high frequency hydraulic cylinder **34** permits motion of high frequency radiating surface **14** independent of low frequency radiating surface **12**.

In operation, for both the embodiments of FIG. **1** and FIG. **2**, any movement of the low frequency hydraulic cylinder piston rod **18** in FIG. **1** or **18A** and **18B** in FIG. **2** is transmitted directly to the low frequency radiating surface **12**, the high frequency hydraulic cylinder **34** and the high frequency radiating surface **14** only. Any movement of the high frequency hydraulic cylinder piston rod **38** is transmitted directly to the high frequency radiating surface **14**. Thus, the low frequency hydraulic system is optimized to drive the low frequency hydraulic cylinder over a range of frequencies from very low frequency, long stroke, up to intermediate frequencies. The high frequency hydraulic system is

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