

[54] **ACOUSTICAL VIBRATION GENERATION CONTROL APPARATUS**

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[51] Int. Cl. **B06b 3/00**

[58] Field of Search 116/137 A; 166/249, 312; 175/56, 55; 340/5 R, 15.5 BH, 18 R, 18 HC; 181/5 DG, .5 J

[56] **References Cited**

UNITED STATES PATENTS

3,405,770	10/1968	Galle et al.	175/56
3,441,094	4/1969	Galle et al.	175/56

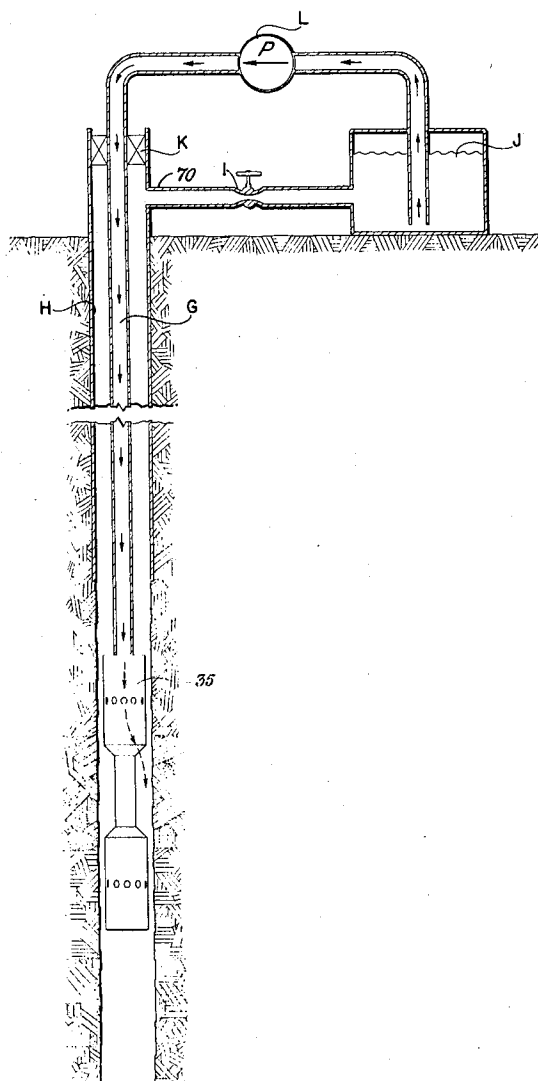
3,520,362	7/1970	Galle.....	166/249
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[57] **ABSTRACT**

Following is disclosed acoustical apparatus whereby pressure fluctuations of large magnitude may be generated by pumping fluid through a first conduit to drive an acoustical oscillator coupled with an acoustical compliance that transmits the pressure fluctuations to an adjoining medium. A second conduit, containing the first conduit and the oscillator, returns fluid flow back toward a pump means. A variable restriction means such as a valve is used to control the back pressure in the system to prevent cavitation and increase the efficiency.

12 Claims, 5 Drawing Figures



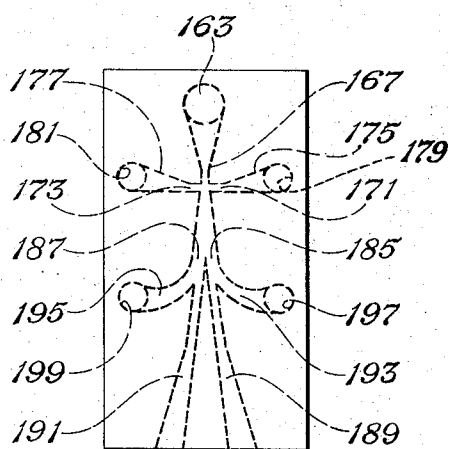
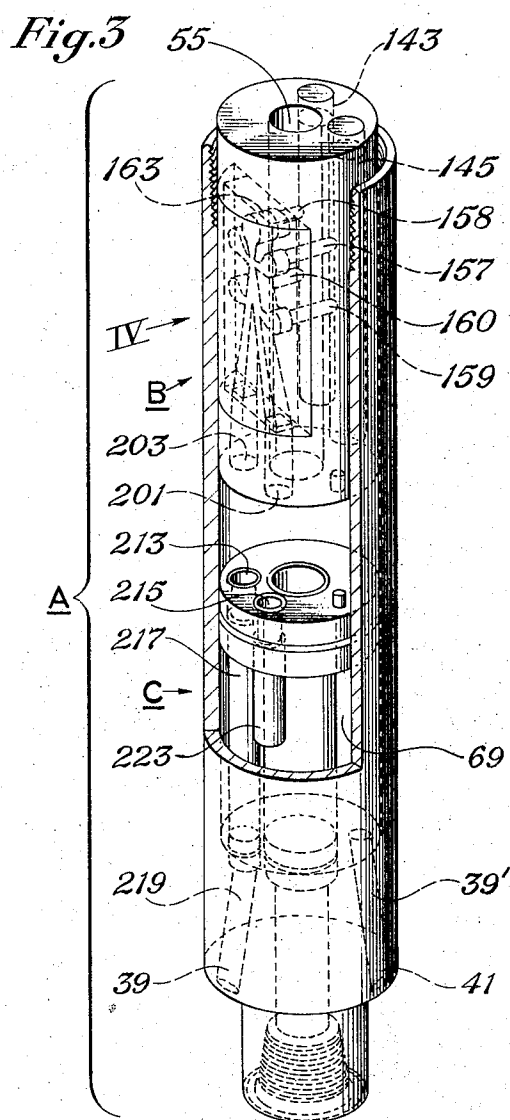


Fig. 4

ACOUSTICAL VIBRATION GENERATION CONTROL APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to the field of acoustics, and in particular to the generation of acoustical pressure fluctuations in a fluid medium through utilization of control means that prevents cavitation and improves efficiency.

2. Description of the Prior Art

The prior art includes fluidic oscillators connected remotely if desired with the output of a fluid pump to generate pressure fluctuations that are acoustically coupled to a fluid around the exterior of the apparatus. In U.S. Pat. No. 3,405,770, "Drilling Method and Apparatus Employing Pressure Variations in a Drilling Fluid," issued on Oct. 15, 1968, are disclosed drilling methods and apparatus that successfully utilizes such a system for improving the penetration rate of an earth boring drill bit. Other related apparatus and methods are shown in U.S. Pat. No. 3,441,094, "Drilling Methods and Apparatus Employing Out-of-Phase Pressure Variations by a Drilling Fluid," which issued on Apr. 29, 1969. In U.S. Pat. No. 3,520,362, "Well Stimulation Method," are disclosed methods and apparatus for using a related acoustical system as a well stimulation method and means to improve the efficiency of the recovery of minerals from the earth.

SUMMARY OF THE INVENTION

The efficiency of generation of acoustical pressure fluctuations in the above discussed prior art apparatus is improved by the present invention through utilization of means to control the back pressure of the fluid in the acoustical components. That is, in the instance wherein an acoustical system driven by an oscillator is operated by fluid pumped through a first conduit and back toward the pump in a second conduit, cavitation is minimized and efficiency increased with a flow restriction means to selectively control fluid back pressure. This is especially advantageous when fluidic acoustical components are used.

My invention therefore provides improved means and methods for more efficiently generating acoustical pressure fluctuations in a region or zone of a conduit that may be remotely located from an energy supplying pump means. This object is accomplished through utilization of an acoustical oscillator connected with and driven by a pump means, and a region or zone in a conduit coupled with the output of the acoustical oscillator. A fluid return line is connected with the region or zone, and flow restriction means selectively control the average pressure therein. The disclosed oscillator is of the fluidic type, having two output legs and means for switching the flow between the legs. An acoustical coupler is utilized to invert the phase relationship of one leg such that the output of the oscillator is effectively connected in one embodiment with an acoustical compliance formed in a selected region of the conduit. To minimize energy dissipation in the return line, acoustical energy isolation means may be used to avoid the transmission of acoustical energy through the fluid return line. Seal means are utilized to direct fluid flow through a flow restriction means, which may for example be a manually or automatically controlled valve

that selectively varies back pressure in the system. From the flow restriction means, fluid may be returned to a fluid reservoir or sump and re-introduced to the pump means.

Additional objects, features and advantages of the invention will become apparent in the following description of the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1A is a side elevation view illustrating schematically acoustical vibration generation and control apparatus constructed in accordance with the principles of the invention;

FIG. 1B is a fragmentary schematic side elevation view of the acoustical vibration generation portion of the apparatus shown in FIG. 1A;

FIG. 2 is a side elevation view in longitudinal section showing a portion of the apparatus shown in FIG. 1;

FIG. 3 is a perspective view of the acoustic vibration generator assembly, with a portion thereof broken away to expose its interior. The oscillator unit B is shown lifted from the normal operating position to add clarity to the drawing;

FIG. 4 is a plan view of a portion of the fluidic oscillator unit shown in perspective in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference initially to FIG. 2 of the drawing, the letter A designates an acoustic vibration generator assembly which includes an oscillator unit B and a coupling device C. The coupling device C communicates with fluid adjacent an adjoining medium or region designated by the letter F (see FIG. 1B) which in this instance is representative of a mineral producing region in a well bore. An upper resonator or acoustical filter D (see FIG. 2) is disposed above the generator assembly, and a lower resonator or acoustical filter E is disposed beneath the generator assembly. The apparatus described thus far is supported by a first conduit G (see FIG. 1A) disposed inside a second conduit H forming a portion of a fluid flow return line containing a variable flow restriction means such as the valve I which returns fluid to a fluid reservoir J. Seal means K between the first and second conduits prevents loss of fluid from the pump means L which supplies the first conduit G, the fluid oscillator unit B and coupling device C.

Describing the above components in greater detail, beginning from the top of FIG. 2, the numeral 11 designates a threaded coupling of a tubing member, which is received by a mating threaded portion 13 of a housing 15 which contains a resonator D having a cavity 17 defined by an interior cylindrical surface 19 of the housing 15, an exterior cylindrical surface 21 of an insert 23, a flange 25 on an upper region of the insert 23 and a radial shoulder 27 on a sub 29 secured by threads 31 to housing 15 and by threads 33 to an upper portion of a housing 35 of the acoustic vibration generator assembly A. Since the insert 23 is removable in this instance, suitable seal means are used, as indicated in FIG. 2, to prevent fluid flow to or from cavity 17 except through apertures 37 extending obliquely through the sub 29. The word "tubing" is used broadly to encompass any conduit, usually an elongated tubular member.

Housing 35 of the generator assembly A contains the acoustic coupling device C and the oscillator unit B, both of which may be of the type described in Pat. No. 3,405,770, "Drilling Methods and Apparatus Employing Pressure Variations in a Drilling Fluid," issued Oct. 15, 1968. As described in that patent, the coupling device C is tuned to the operating frequency of the oscillator unit B, and has one or more exit ports 39 extending through exterior surface 41 of the housing into communication with the fluid surrounding a small diameter sub 47. The invention is not limited to the specific forms of oscillators and coupling devices described in the above mentioned patent, but encompasses, at least in its broadest aspects, other suitable forms of oscillator units and coupling devices, although the above fluidic, i.e., containing no moving mechanical components, devices appear to be most advantageous since they eliminate moving mechanical parts.

The lower region of the housing 35 of the generator assembly A has a small diameter region 43 connected by threads 45 to a similarly small diameter sub 47 which has its lower region secured by threads 49 to the housing 51 which contains lower resonator or filter E, which is one form of acoustic vibration isolator means. An axial bore 53 extends downward through the upper resonator D, sub 29, generator assembly A, coupling device C and sub 47. Bore 53 terminates in this instance at the top of housing 51. However, in other embodiments, this bore can communicate with passages for the flow of fluid therethrough.

As shown in FIG. 2, one or more apertures 55 are formed obliquely in housing 51 to communicate with the annulus (that space between the housing and the wall of the borehole) and a cavity 57 formed on a lower region of the housing by a sleeve 59 secured by threads 61 to the housing and by a plug 63 secured by threads 65 to the sleeve 59. The relative sizes of the apertures 55 and cavity 57 are selected such that the resonator is tuned substantially to the operating frequency of the oscillator unit B.

The volume of fluid between the wall of the bore hole and the exterior surface of sub 47 and the small diameter regions of housing 35 and 51 defines an exterior acoustic tank or compliance 66 opposite the region, medium or zone to receive acoustic vibrations, said compliance having dimensions correlated with the dimensions of the apertures 39 and cavity 69 of the coupling device C to couple the oscillator unit with the acoustic load.

The axial bore 53 is an extension of the first conduit G shown in FIG. 1B which receives fluid from the pump means L connected with the fluid reservoir J. The first conduit G extends inside a second conduit H, which is sealed from the first conduit by the seal means G. The fluid line 70 extends from the second conduit H and forms a part of a fluid flow return line that includes a variable flow restriction means I, which in this instance is a valve that may be opened or closed to control the static pressure in the system. Thus, by opening or closing the valve, selective control is maintained over the average pressure in the fluid return line, over the average pressure in the acoustical compliance, and over the pressure drop across the acoustical oscillator.

Referring now to FIGS. 3 and 4, the acoustic vibration generator assembly A includes a "fluidic" oscillator in that it has no moving mechanical components. It is a high gain, bi-stable fluidic amplifier with positive

feedback to cause oscillation of the bi-stable unit. The coupling device B couples the output of the acoustic vibration oscillator with the drilling fluid located in the acoustic compliance, cavity or tank 66 as shown in FIG. 2.

The preferred oscillator configuration is shown in FIGS. 3 and 4, wherein the oscillator is designated by the letter B. Fluid flowing through the first conduit G and the associated passage 53 shown in FIG. 2 is diverted through a supply port or inlet passage 163 of the oscillator. From input 163, the fluid flows from a power nozzle 167 and alternatively flows into receiver channels 185 and 187. This alternating flow results from the positive feedback effected by feedback channels 193, 195; feedback ports 197, 199; apertures 159, 160; cavities formed in the axial bores 143, 145; apertures 157, 158; control ports 179, 181; passages 175, 177; and control nozzles 171, 173. During each half cycle of oscillation, a majority of the fluid entering the receiver channels 185 or 187 flows into either diffuser channel 189 or 191 and to the outlet 201 or 203 of the acoustic vibration oscillator. The output of the diffuser channel 191 feeds aperture 213, tube 217 and aperture 39, which together with the fluid therein constitute an acoustic inertance. Aperture or passage 39 communicates with the fluid in the acoustic tank or compliance. The output of the diffuser channel 189 feeds aperture 215 and tube 223, which constitute another acoustic inertance. Tube 223 terminates within annular cavity 69, which constitutes another acoustic compliance. Passage or aperture 39' is an acoustic inertance communicating between annular cavity 69 and the acoustic tank or compliance. To improve the reliability of oscillation on-set under high back pressure conditions, it is advantageous to insert flow restrictions in diffuser channels 189 and 191. However, the openings of the restrictions should be made as large as possible to minimize power loss. Suitable dimensioning of all the acoustical elements within the acoustical coupling circuitry accomplishes three objectives: (1) proper matching of the output impedance of the oscillator A with the dissipative load on the circuit; (2) effective phase inversion of the vibrations in one of the output legs of the oscillator A; and (3) the provision of a high Q system. Hence, the acoustic generator means may be utilized to effect large pressure variations at selected frequencies in the acoustic compliance or tank 66.

In operation pump L is activated to draw fluid from the fluid reservoir J and force it under pressure through the first conduit G, located partially inside the second conduit H, which contains at a selected location the acoustic vibration generator assembly A and acoustic compliance 66 opposite some medium such as a formation of the earth in a region F to be stimulated acoustically. Fluid therefore flows from the first conduit G into the axial opening 53 (see FIG. 2) to feed the oscillator unit B which generates acoustic energy. This acoustic energy is transmitted by acoustic coupling device C and the exit ports 39 and 39' into the acoustic tank or compliance 66. Fluid then returns to the surface of the well bore in the annulus defined by the exterior of the apparatus and first conduit G and the interior of the second conduit H. Consequently, acoustic energy is transmitted to the earth. The previously described acoustic energy isolation means or acoustic filters or resonators D and E prevent the dissipation of substantial quantities of acoustic energy upward or downward in the annulus.

The length of zone F in FIG. 1 may be varied by inserting different lengths of subs between the housing 35 of the generator assembly A and the housing 51 of the lower resonator E to vary the length of the acoustically treated zone. Acoustic energy will normally travel both upward and downward through the well bore but is effectively prevented from doing so in this instance by the use of the isolator means. The resonators D and E are used as side branches with inlets at points one quarter wave length above and below the acoustic tank 66. This effectively causes the acoustic impedance looking into the annulus from acoustic tank 66 to be very high, thus preventing substantial loss of acoustical power either up or down the annulus.

Fluid flow returns in the annulus between the first and second conduits G and H toward the pump L. A seal means K, which may be in the form of a conventional blow-out preventer pipe ram, is inserted between the first and second conduits G and H to cause fluid to return to the variable flow restriction means, in this instance valve I located in the return line 70. By varying the setting of this valve, the back pressure in the acoustic circuit may be maintained at a selected average pressure. The flow restriction and back pressure control are beneficial in preventing cavitation in the oscillator; otherwise substantial damage to the system may result. In addition, efficient operation of the oscillator is not achieved unless cavitation is prevented. Further, if peak-to-peak pressure amplitudes of 1500 psi are to be utilized, for example, the average static back pressure in the vicinity of the oscillator should be at least 1500 psi and preferably somewhat above this figure or otherwise the desired peak-to-peak pressure variations cannot be obtained.

It should be apparent from the foregoing that an invention has been provided having significant advantages. The acoustical power output of an acoustic vibration generator may be conveniently enhanced through utilization of the flow restriction means described above. That is, by altering the average static pressure in the system to a selected value and superimposing thereon acoustic vibrations, the maximum or peak pressures may be conveniently enhanced. Since the flow restriction means and the pump means may be remotely located from the acoustic oscillator and coupling means, control over the apparatus is thus made easier. Further, the possibility of cavitation in the oscillator unit itself may be essentially eliminated by use of the restriction means such that maximum efficiency may be derived from the system with minimum possibility of damage to the system components.

While the invention has been described only in one of its forms, it should be apparent to those skilled in the art that it is not so limited but is susceptible to various changes and modifications without departing from the spirit thereof. The specific form of for example, the oscillator, the coupling device, the first and second conduits, the flow restriction means and the pump means may be varied widely by those of average skill in the art to accomplish the objects and advantages of the invention.

I claim:

1. Acoustical vibration generation and control apparatus comprising:
 - pump means;
 - an acoustical oscillator connected with and driven by the pump means;

an acoustical load means to receive the fluid output of the acoustical oscillator;

a coupling means connecting the oscillator output with the acoustical load means;

a fluid return line connected with the acoustical load means;

control means to selectively control the average pressure in said apparatus.

2. The apparatus of claim 1 wherein said acoustical oscillator is fluidic.

3. The apparatus of claim 1 which further comprises acoustical isolation means to confine acoustical oscillations to a selected portion of the apparatus.

4. Acoustical vibration generation and control apparatus comprising:

pump means;

a fluidic acoustical oscillator driven by the pump means;

an acoustical coupler adapted to receive the output of said oscillator;

an acoustical compliance adapted to receive output of said oscillator and said coupler;

a fluid return line connected with the acoustical compliance; and

a flow restriction connected with the fluid return line to selectively control the average pressure in said apparatus.

5. The apparatus of claim 4 which further comprises acoustical isolation means to confine acoustical oscillations substantially to said acoustical compliance.

6. The apparatus of claim 5 wherein said acoustical isolation means are Helmholtz resonators spaced one quarter wave length or an odd multiple thereof above and below said compliance.

7. Acoustical vibration generation and control apparatus comprising:

pump means;

a fluidic acoustical oscillator driven by the pump means and including two outputs, each with vibrations out-of-phase with respect to the other;

phase inversion means connected to one of said oscillator outputs;

an acoustical compliance to receive in phase outputs of said phase inversion means and oscillator;

a fluid return line connected with the acoustical compliance;

a flow restriction connected with the fluid return line to selectively control the average pressure in said apparatus.

8. The apparatus of claim 7 wherein said flow restriction is a variable valve.

9. Acoustical vibration generation and control means comprising:

pump means having a fluid input and a fluid output;

a first conduit connected with the output of said pump;

an acoustical, fluid driven oscillator adapted for fluid communication with and to be driven by fluid flow in said first conduit;

a second conduit to receive the output of said oscillator;

flow restriction to control the back pressure in the second conduit; and

acoustical isolation means in said second conduit to isolate the acoustical energy to a selected zone.

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10. The apparatus of claim 9 wherein said flow restriction is a variable valve and the first conduit is seal-
ingly disposed interior of the second conduit.

11. The apparatus of claim 10 which further includes
a fluid reservoir to receive the fluid from said second
conduit, and to supply fluid to said pump means.

12. Acoustical vibration generation and control ap-
paratus comprising:

pump means having a fluid input and a fluid output;

a first conduit connected with the output of said
pump;

a fluidic acoustical oscillator driven by the pump

means and including two outputs, each with vibra-
tions out-of-phase with respect to the other;
phase inversion means connected to one of said oscil-
lator outputs;

an acoustical compliance to receive in phase outputs
of said phase inversion means and oscillator;

a second conduit connected with said acoustical
compliance;

a flow restriction to control the back pressure in the
second conduit; and

acoustical isolation means in said second conduit to
isolate the acoustical energy to a selected zone.

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