DEEP-WATER LOW-FREQUENCY SOURCES WITH TRANSDUCERS OF THE LINEAR ELECTRIC MOTOR TYPE

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I. INTRODUCTION

For the investigations on long-range reflection sounding, conducted in 1980s at the Pacific Oceanological Institute, sources with center frequencies about 200 Hz were developed. The sources were designed for deriving an acoustic power up to 10 kW at depths up to 2000 m.

2. DESIGN OF THE MOST POWER SOURCE

The appearance of the source with center frequency 223 Hz is shown in Fig.1, the axial section - in Fig.2. The source contains liquid-filled resonant pipe 1 with radiating rigid pistons 2 at end faces. The pistons are fixed on flat springs 3. Axial oscillations of pistons are excited by transducers of the linear electric motor type. The stationary elements (inductors) 4 of transducers are made like cylinders equal with pipe 1 internal diameter and fastened on its ends. The moving elements (armature) 5 fastened on pistons 2. The armature power supply is carried by means of flexible wire. The cavities of the source are filled in dielectric liquid. For compensation of a liquid volume changes, due to temperature and static pressure changes elastic membrane 6 serves. In operating position the pipe axis is oriented vertically. For unloading of springs 3 and membranes 6 from weight of the liquid at staying of the source aboard and dynamic loads, arising at moves of the source on a depth at vessel tossing, there is tight wall 7 on a middle of a length of the pipe 1. The symmetry of a design provides the balance of mass in a source oscillatory system.

Fig.3 shows schematic picture of an axial transducer section. Magnetic core 8 of armature 5 and pole heads 9 of inductor 4 are made of electrical steel laminations. Magnetic core 10 of inductor is solid. The direct current in windings 11 creates a constant magnetic field of radial directions with an induction B, running through the coil 12 of armature. At flowing in the coil 12 alternating current with frequency, close to source resonant frequency f_0 the piston oscillates in axial direction, exciting in the liquid an immobile sound wave. Distributions diagrams of amplitudes of variable pressure P_m and oscillatory speed V_m in the immobile wave along a pipe axis x are shown in Fig.2.b

3. SOME PARAMETERS, EXPERIMENTAL AND CALCULATED RESULTS

Source, shown on Fig.1. is made of following materials: pipe 1 - chromium-nickel steel 12X18H10T; pistons 2 - aluminium alloy AMg5; springs 3 - steel 60C2A; coils 11,12 - cooper; filling dielectric liquid - diesel fuel.

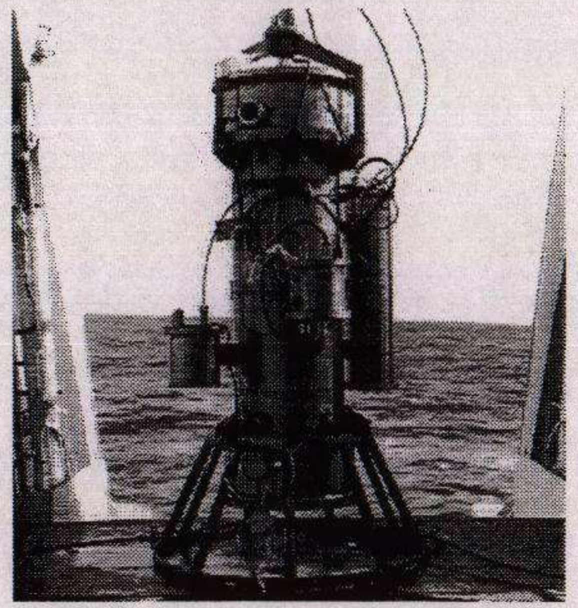

Fig.1. The appearance of the source with center frequency 223 Hz.

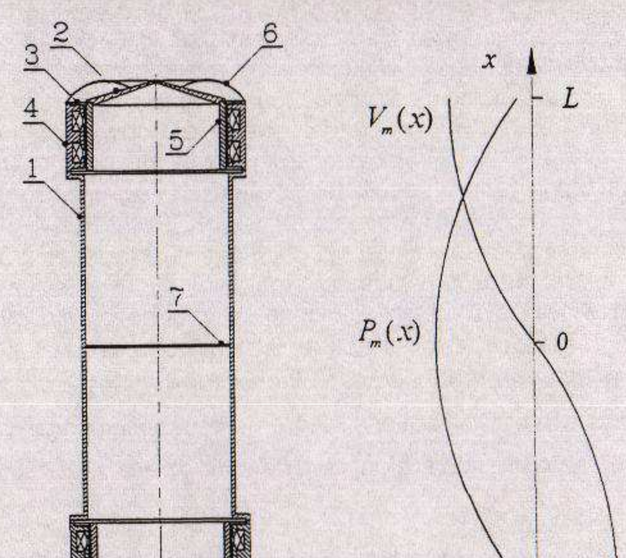

Fig.2. a. Axial section of the source with center frequency 223 Hz
b. Distributions of variable pressure P_m and oscillatory speed V_m along the pipe axis x.

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Own resistance of AC coils connected in series of 6 Ohm; inductance of 10 mHn; constant induction B=1 Tl; length of the source $2L$= 2 m; internal diameter of the pipe of 0.5 m; full mass of about 1000 kg.

Resonance frequency of the source f_0 = 223 Hz. Bandwidth at a level - 3 dB of about 3 Hz. (Q= 80). The calculated characteristic directivity diagram of the source is axial symmetric. Its minima (-5.5 dB) coincide directions of the pipe axis and the maximum is located in a plane perpendicular to axis. The corner at the level -3 dB makes 90°. directivity factor of 2.1. Fig.3 shows frequency dependencies of the impedance $|Z_e|$ and of electric power coefficient $cos\varphi$.

Maximum radiating power W_r is defined by strength of springs. The allowable amplitude of the oscillatory displacement of the pistons makes 1.33 mm, that corresponds W_r of 10 kW. According effective sound pressure in the maximum plane of 50000 Pa (source level 214 dB). Thus the minimum depth of immersing will make 270 m. On smaller depths W_r was limited by cavitation in the filling liquid. Cavitation is accompanied by radiation of signals with frequencies nf_0 multiple of f_0.

4. ANOTHER VARIANTS OF DEEP-WATER SOURCES MANUFACTURING

At early stages of development above described source, transducers sketch of which shown in Fig.5 were investigated. The arrangement of the AC winding in splines of the armature (Fig.5.a) leads to lower necessary DC power in windings of inductor 2. Reduction of spline number up to two and use in inductor of permanent magnets 3 (Fig.5.b) leads to simplification a transducer design and to lower its cost. Helmholtz resonator (Fig.5. c - unbalanced, with one tube, d -counterbalanced, with two tubes) may have very low frequency resonance at small sizes of the source. However the radiation in that case is undirected. If the depth of source immersing will not exceed 500 m, for reduction of its dimensions and mass, for bandwidth expansion as well as for decrease of harmful cavitation influence can be applied acoustical compliance elements, placed in the filling liquid [1].

5. POSSIBILITY OF TRANSDUCER APPLICATION IN SWALLOW SOURCE

The transducer of the linear electric motor type is possible also to applied for example in high-efficiency sources of sweep-signals with power up to 1 kW, in the frequency range 20-160 Hz suitable for sounding of bottom sediments at investigation of a petroleum and gas stocks on a shelf. The high efficiency of such source will be reached by tuning of elasticity of the mechanical oscillatory system of the working source for achievement of the resonance at radiation frequency. The tuning of elasticity will be carried out by change of air volume in the source cavity.

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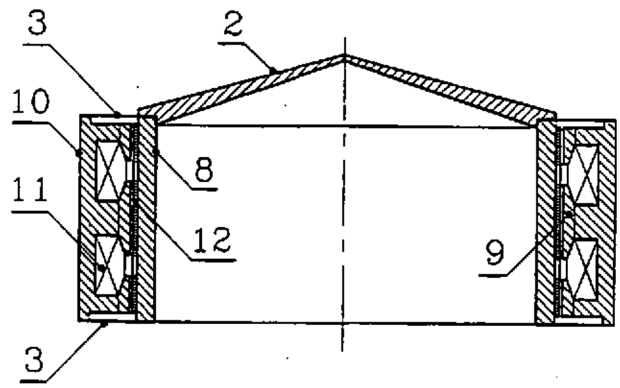

Fig.3. Schematic picture of an axial transducer section.

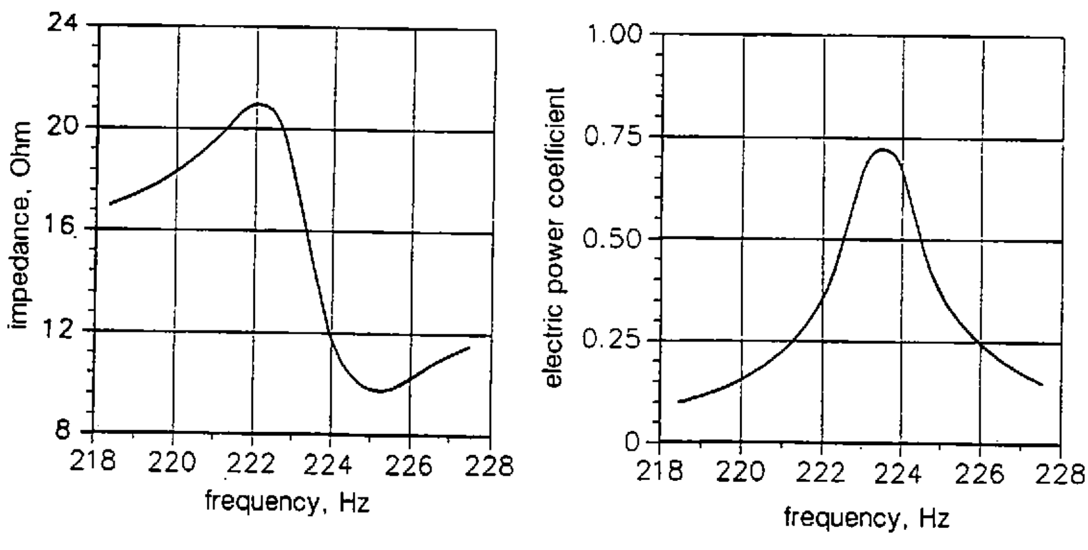

Fig.4. Frequency dependencies of the impedance $|Z_e|$ and electric power coefficient $cos\varphi$.

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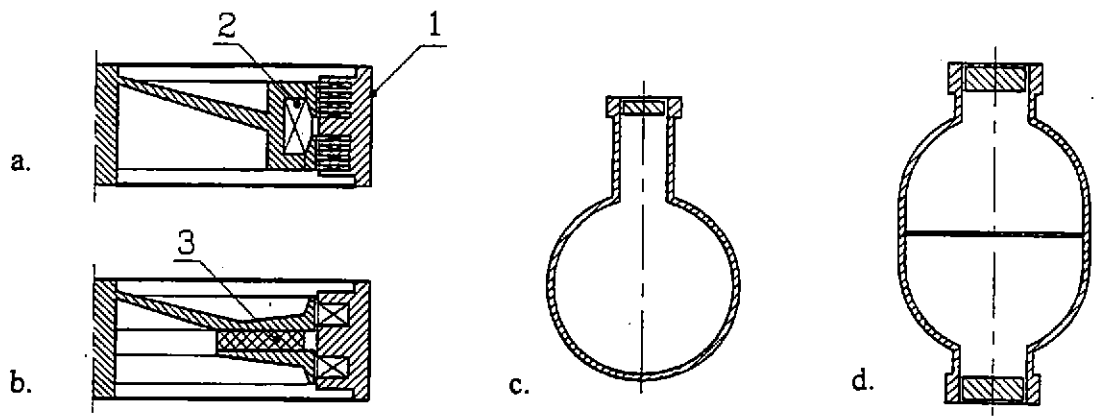

Fig.5. Variants of manufacturing of transducers and deep-water sources.
a. The arrangement of a AC winding in splines of the armature.
b. Two spline. Use in inductor of permanent magnets.
c. Unbalanced Helmholtz resonator.
d. Counterbalanced Helmholtz resonator.

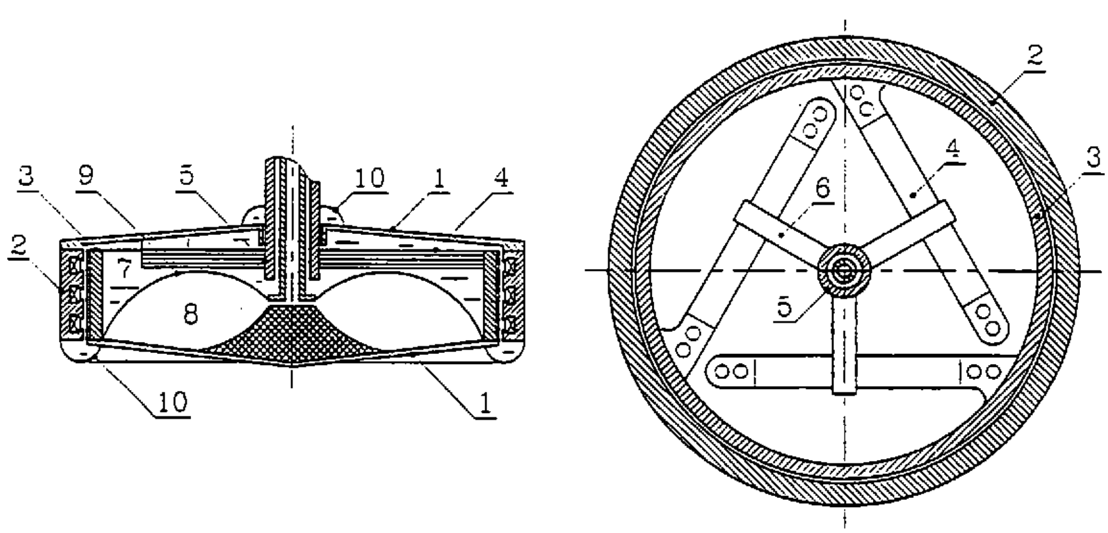

Fig.6. Variant of swallow source design.

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The source can have the appearance, presented in Fig.6. Each of two pistons 1 is rigidly connected to one of ring element of the transducer 2 and 3. Among themselves the pistons are connected by sets of flat springs 4. The source is supported by the cylindrical support 5, connected by arms 6 with zero points of springs 4. The source cavity is partially filled in by dielectric liquid 7, separated from air 8 by elastic membrane 9. Admission and removal of the liquid and air is carried out through the channels of the support 5. The elastic seals 10 keep the liquid 7. The static air pressure is close to the pressure in external environment. Pump 11 (Fig.7,a) pumps liquid in the additional tank 12, containing the separating membrane 13. The inertial element 14 prevents the air from moves in the pipeline 15 with frequency of radiating signal. There is a possibility to use of two sources (Fig. 7,b) for simultaneous radiation of up- and down-sweeps.

Some sizes and parameters: constant induction B=0.32 Tl; inductance of 4 mHn; Own resistance of AC coils connected in series of 0.18 Ohm; piston diameter of 1 m; mass of about 500 kg.

Fig.8 shows calculating frequency dependencies of the air volume in the source cavity (by deep of 20 m), of the electric power coefficient, of the electrical-acoustical efficiency as well as of the amplitude of excitation voltage by radiated power of 1000 W.

a.

b.

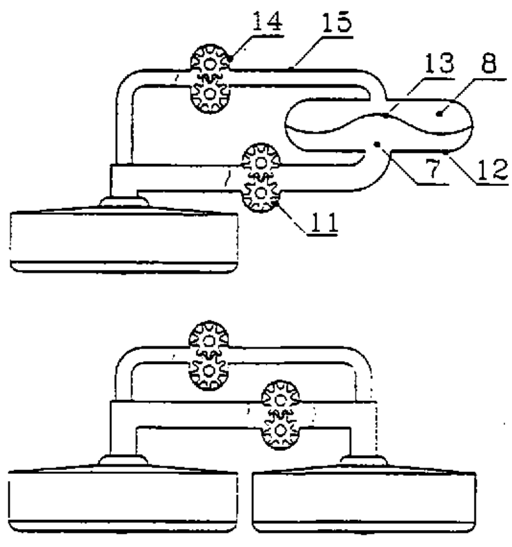

Fig.7. a. Scheme of pipelines of the source. b. Possibility to use of two sources.

1. Shashaty A.J. The elastic problem of the flattened cylinder type of underwater acoustical compliance element. - J.Acouct.Soc. Amer., 1979,V.66,N6, p.1818-1825.