HIGH POWER LOW-FREQUENCY SOURCES WITH ELECTROMAGNETIC TRANSDUCERS

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1. SOURCE WITH CENTER FREQUENCY 250 HZ

In researches on acoustic tomography of the ocean, conducted at the Pacific Oceanological Institute in 1998, a source with electromagnetic transducer, had center frequency f_0 of 250 Hz was applied. The source was developed for operating in structure of an autonomous system, radiating phase-modulated coded signals. Radiated power W_r up to 420 W (source level up to 197 dB re 1 μPa @ 1 m) with an efficiency of about 60 % near 250 Hz. Bandwidth at level -3 dB $\Delta f_{0.7}$ (excitation by harmonic voltage of constant amplitude) makes 25 Hz. Mass of the source of 44 kg. At development of the source the rigid requirements of small mass and of minimum manufacturing cost were presented to it. Therefore its design differs from conventional.

As a rule, the sources with electromagnetic transducers are made in the form of cylinders of small height. Flexible metallic radiating membranes are placed at cylinder faces. Parameters of membranes should satisfy to the mutual - inconsistent requirements of high strength and of enough large an effective radiation surface area at given resonance frequency f_0. Therefore high parameters W_r and $\Delta f_{0.7}$ are reached usually by manufacturing of membranes of the large sizes, by use expensive elastic alloys and, accordingly, by large mass and high cost of sources. At designing was resolved to refuse of the conventional approach, supposing association in membrane of properties of springs and of radiating surface.

Fig.1 shows schematic picture of the source. The membranes 1 are made of low-sort steel. The rigid central parts of membranes with diameter d_1 of 200 mm, thickness S_1 of 8-12 mm and flexible periphery (d_2=400 mm, S_2=4 mm) are ensure sufficient parameters W_r and $\Delta f_{0.7}$ at moderate tensions. Magnetic core of the transducer are made up of E-shaped steel laminations stacked together in blocks 2, fastened in central parts of membranes. The surface area of the pole heads of one block of 68 sm^2. A coil 3, containing of 85 turns, stationary fixed on flange 4. The own elasticity of membranes enough for maintenance of the source resonance in a water at frequency of 103 Hz. Resonance frequency of 250 Hz is reached by use of flat springs 5 made of steel 65 (are applied in springs of lorry cars) with cross section of 40×10 mm. The springs are bending in a plane of greater of cross sizes, therefore the sufficient rigidity is reached at small effective springs mass. The springs 5 fasten to membranes 1 by screw 6 and among themselves by tightening screw 7. The pressure of air in the source cavity was supported equal an external static pressure with accuracy 10^4 Pa. The practice has shown, that the changes of pressure up to $0.5 \cdot 10^5$ Pa are not dangerous for the source, but has influence on stability of a signal amplitude.

It is interesting increase of frequency f_0 up to 400 Hz, since it gives high-resolution of acoustic tomography method by distances up to 100 km. For that springs cross section of 70×10 mm is needed. A bandwidth increases up to 40 Hz.

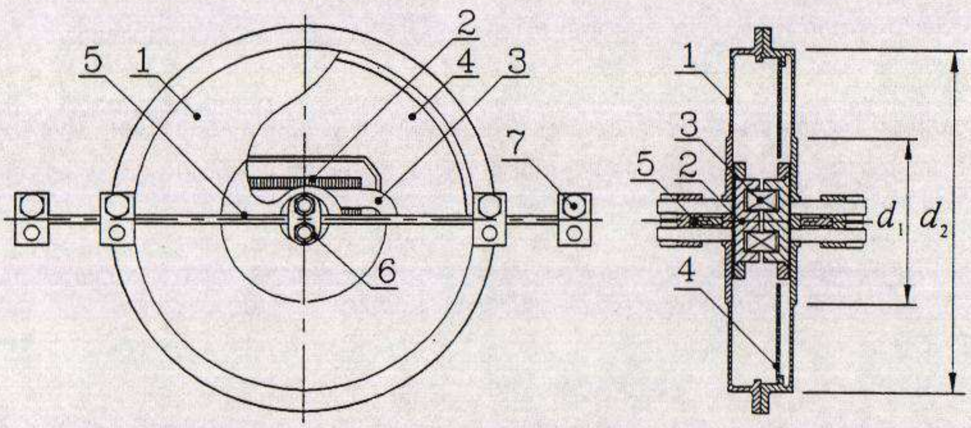

Fig.1. Schematic picture of the source with center frequency 250 Hz.

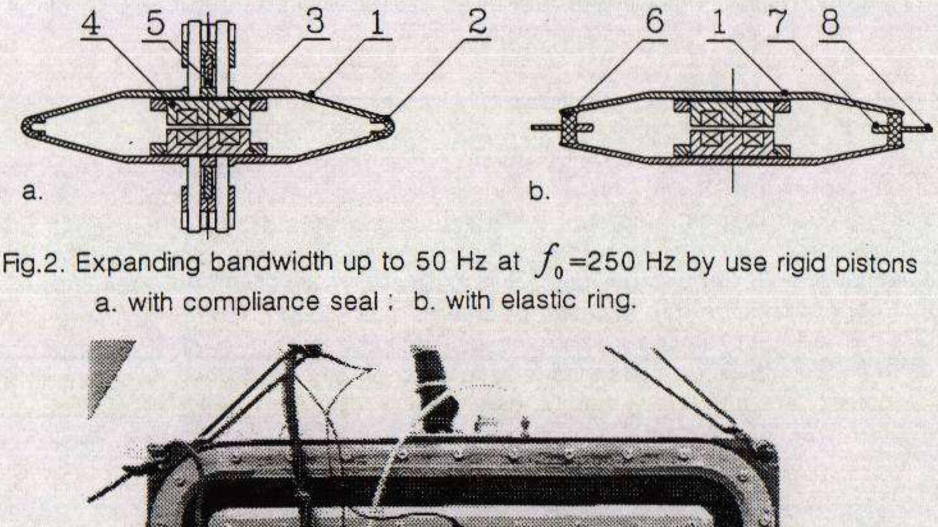

Fig.2. Expanding bandwidth up to 50 Hz at f_0=250 Hz by use rigid pistons
a. with compliance seal ; b. with elastic ring.

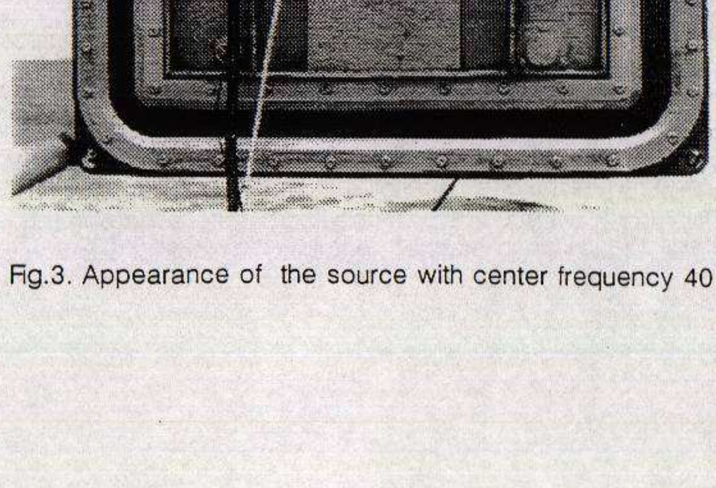

Fig.3. Appearance of the source with center frequency 40 Hz.

It is possible to expand $\Delta f_{0.7}$ up to about 50 Hz at f_0=250 Hz without application of damping and without an increase of the source sizes, if instead of membranes to use rigid pistons 1 (Fig.2, a) with elastic seal 2. Each of two sections of the coil 3 is fixed in splines of magnetic core 4. The coil power supply is carried by means of flexible wire. It is possible to remove the spring 5 from a design, if instead of seal 2 to the ring 6 of a dense rubber (Fig.2,b). For the source with f_0=250 Hz and d_2= 400 mm, axial ring size of 30 mm and radial size of 14 mm are needed. A problem of strong attachment of the ring 6 to pistons 1 will be except by maintenance of gas pressure in the source cavity lower than external static pressure by 1.2 x10^5 Pa. For maintenance of radial acoustic rigidity of the ring 6 serves steel ring 7. Ring 8 serves for fastening of the source.

2. SOURCE WITH CENTER FREQUENCY 40 Hz.

Since 1991 the source appearance of which shown in Fig.3 works reliably. Source was developed for generation of continuous tone signal with a power up to 3000 W (source level - up to 205.5 dB) at frequency f_0=40 Hz with an efficiency of about 50 %. Dimensions of the source of 1.1 x 0.7 x 0.3 m.. Mass of 300 kg. The source consumes AC power only.

Fig. 4 shows the images of cross section of the source, having the case 1 with a pair of rigid radiating pistons 2, oscillating in opposite directions. The pistons are installed on sliding bearings 3 with motion terminators 4. Between the case wall 5 and pistons 2 are placed 400 cylindrical springs 6 (rigidity of one spring of 33 x10^3 N/m, frequency own longitudinal resonance of 310 Hz, springs are applied in engines). Magnetic core of the transducer are made up of E-shaped steel laminations assembled in blocks 7. The surface area of the pole heads of one block of 360 sm^2. The coil 8, contains 12 sections of 18 turns each, placed in the dielectric case 9. The channels 10 of case 1 are filled in by. transformer oil. Due to circulation oil in the channels 10 and in clearances between sections of the coil 8 is carried heat removing from the coil. For compensation of oil volume changes due to temperature and static pressure changes elastic membranes 11 serve. A clearances between the case 1 and pistons 2 are sealed by membranes 12 of a reinforced rubber. Static gas pressure in the source cavity is lower then external static pressure by 1.2x10^5 Pa. Setting of pistons at the middle position, preliminary compression of springs and in phase of pistons 2 and membranes 12 oscillations are thus reached.

3. SOURCE WITH CENTRAL FREQUENCY 70 HZ (PROJECT)

In 1993 was developed a project of source similar to above-stated, having output level up to 205 dB at 70 Hz, Q=4, and of 15-25 % efficiency. The source also has an electromagnetic transducer without bias and a pair of opposite oscillating plate pistons. Fig.5 shows schematic picture of the axial cross section of the source. Pistons 1 are made of hard aluminium alloy. Sufficient piston rigidity is achieved by means of their honeycomb-like construction. Pistons have a hundreds of round holes 2 in which steel cylindrical springs 3 are placed. The holes 2 can be plugged by spheroplastic stoppers 4. Transducer elements are made up in the form of rings fixed at the edge of each piston. The armature 5 is made of steel П-shaped laminations stacked together. The coil 6 has two sections fixed in the splines of the armature. The rubber shell 7 ensure source waterproofing and oscillation system

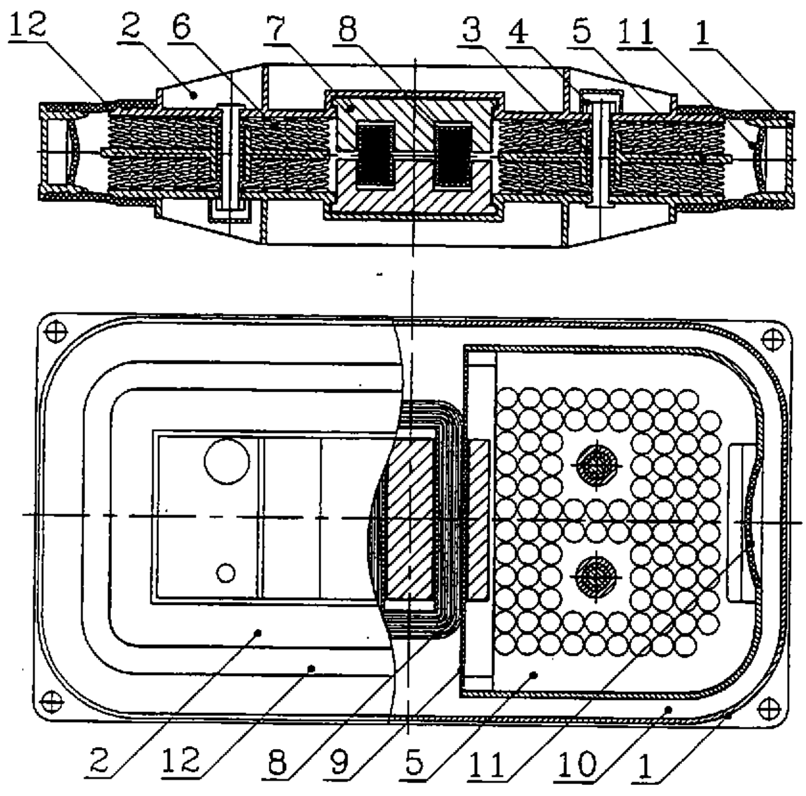

Fig.4. Schematic pictures of the source with center frequency 40 Hz.

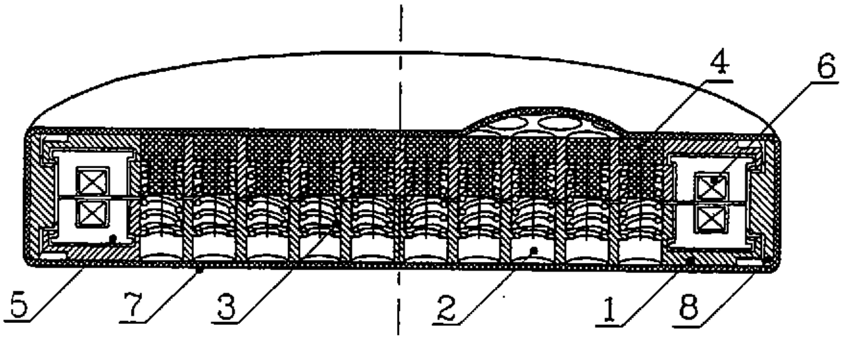

Fig.5. Schematic picture of the axial cross section of the source with center frequency 70 Hz.

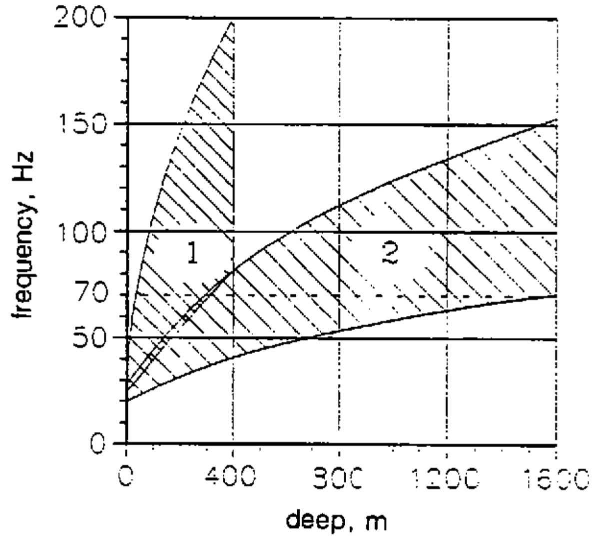

Fig. 6. Curves bounding the range of possible central frequency depending on a source for two construction variants which are distinguished by source cavity volume.

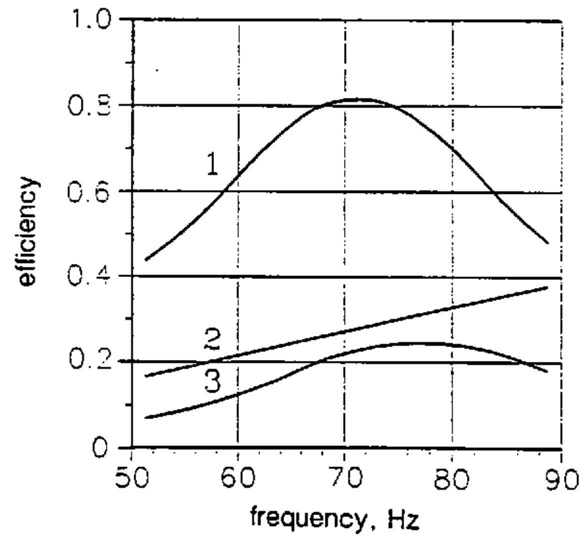

Fig.7. Frequency dependencies of electrical-mechanical (1), mechanical-acoustical (2) and full (3) efficiency.

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

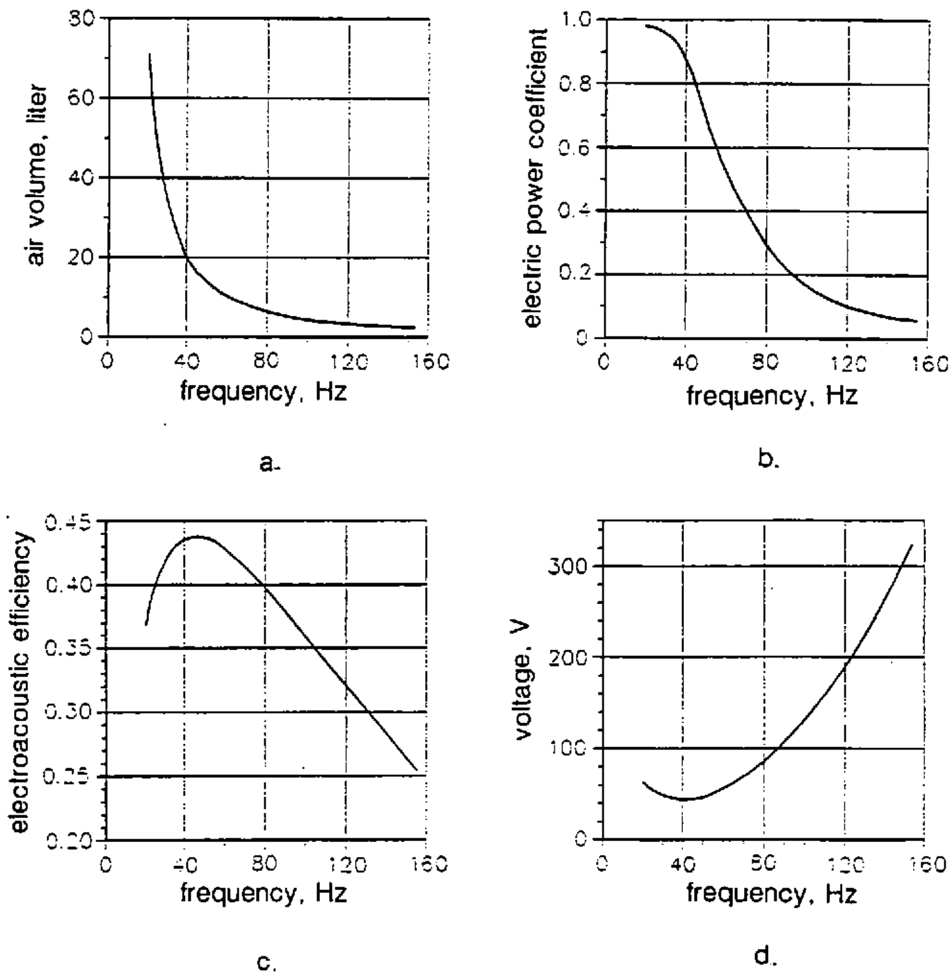

Fig.8. Calculating frequency dependencies of:

a. the air volume in the source cavity (by deep of 20 m);
b. the electric power coefficient;
c. the electrical-acoustical efficiency;
d. the amplitude of excitation voltage by radiated power of 1000 W.

damping (at the expense of inner viscous losses). Power supply of the coil 6 is carried out by means of flexible wire built in the shell. The source also has circular acoustical baffle 8. Static gas pressure in the source cavity is lower than external static pressure by 10^5 Pa. Thus tight shell fitting to the pistons and to the baffle is achieved. The main part of mechanical-acoustic oscillating system elasticity is determined by air elasticity in the source cavity. So for the specific source depth the resonant frequency can be set during a source assembly by means of preliminary cavity volume setting with the aid of changing number of stoppers 4 plugging the holes 2. In the operation position of the source its symmetry axis is vertical. The lower piston is supported in cylindrical frame construction by elastic synthetic strings.

Some parameters: pistons diameter of 1.2 m; springs elasticity of 33×10^6 kg /s^2; loss resistance of the rubber shell of 1.3×10^5 kg/s; width of transducer air gap of 4 mm, surface area of the pole heads of one block of 1000 sm^2; number of the coil turns of 46; coil resistance of 0.075 Ohm.

Fig.6 shows the calculated curves bounding the ranges of possible central frequency for two construction variants of the source which are distinguished by source cavity volume. Maximum cavity volume for the first source variant of 0.078 m^3, second variant of 0.39 m^3. Electroacoustical parameters of both source variants are practically identical. For radiating signal frequency range of 50-90 Hz feeding voltage frequency range must be 25-45 Hz. Fig.7 shows frequency dependencies of electrical-mechanical, mechanical-acoustical and full efficiency when the source is excited by voltage with 1000 V amplitude. Fig.8 shows frequency dependence of effective electric impedance of the transducer which input terminals are connected to capacitor bank for reactive current compensation at central frequency of feeding voltage and by 1000 V amplitude.

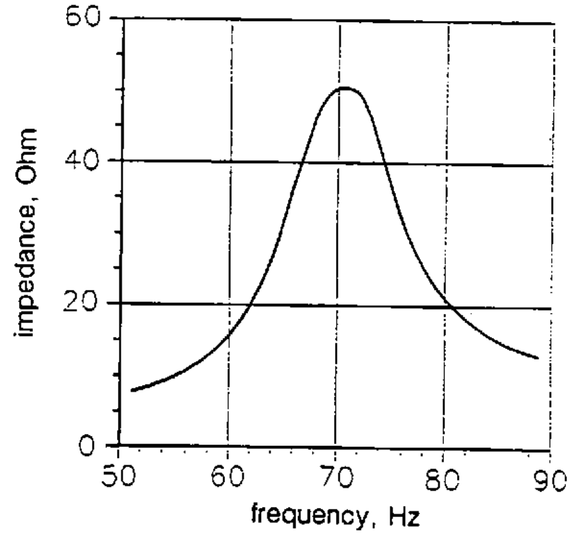

Fig.8. Effective electric impedance of the transducer which input terminals are connected to capacitor bank for reactive current compensation at central frequency of feeding voltage.

Input current of the transducer differ from sine one. Crest factor is 1.53-1.92 in the operating frequency range. Electric impedance is decreased according to exciting voltage increase. Electrical-mechanical and full efficiency are increased according to exciting voltage amplitude increase up to 1200 V. Their further increase is limited by magnetic saturation of the transducer armature.