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ULTRASONIC UNIT FOR RESTORING OIL WELLS

M. S. Mullakaev, V. O. Abramov, and A. A. Pechkov

A new generation of unit has been developed for acoustic stimulation of wells. Two design schemes are proposed for ultrasonic units, i.e., with a surface-based source of supply (generator) and with placement of it in a submersible device. A features of the new US generators is the presence of two channels for forming an ultrasonic signal, and this makes it possible to connect two magnetostrictive transducers, each with a power of 4 kVA from both sides of the emitter. US submersible well unit is prepared with a diameter of 42 and 108 mm, whose construction makes it possible to use it in two versions: in the first basic version, it is proposed using one well unit fastened to a pump-compressor pipe. In the second version, it is possible to connect a second well unit fastened to the pump-compressor pipe. The ultrasonic unit created may operate at high pressures and temperatures, and it displays high technical characteristics (power, reliability, etc.).

In the technology of extracting water during oil recovery, there is a serious problem of blockage of the critical zone of a well, i.e., formation in the area adjacent to the well of deposits blocking access to it of a liquid phase (water, oil, processing solution). Various physical and chemical methods are used in order to unblock wells [1–3].

Recently, there has been intense development of technology using ultrasound in order to restore the productivity of oil and water-supply wells, since with the use of traditional methods for resolving this problem there is considerable material expenditure, and in addition traditional methods are unsafe ecologically (there is contamination of ground water) and they often lead to damage of the well structural elements.

One possible method for unblocking a well is the use of ultrasonic (US) vibrations (the acoustic well sounder (AWS) method) [4, 5]. Special submersible unit is lowered into the well to the depth of the productive zone of the formation. Powerful ultrasound breaks the blockage, increases the permeability of the critical zone and the flow of non-Newtonian fluids.

A US generator type PS 8000/20 has been developed for the electrical supply of well installations whose distinguishing feature is the potential to supply high-frequency energy for well instruments through a geophysical cable.

The generator is placed in a metal container with a size of $400 \times 400 \times 220$ mm fitted with a face panel. The main components of the generator (electrical and radio components) are placed on a chassis in the from of a galvanized steel sheet.

There is also a water-cooled radiator on the chassis, to which components are fastened that release a considerable amount of heat (a three-phase bridge rectifier module, a half-bridge IGBT module, a high-frequency rectifier bridge, a choke).

A US generator type PS 10000/23 has also been developed for the electrical supply of well installations, providing supply of high-frequency energy supply for well unit through a three-core power cable, used in the oil industry for the supply of submersible centrifugal pumps. The cable length should not exceed 2500 m.

Generator PS 10000/23 is distinguished from generator PS 8000/20 by construction of a magnetizing unit. The transformer of the compatible power unit assembly has a secondary winding with taps that make it possible to regulate the alternating component of the output current.

Kurnakov Institute of General and Inorganic Chemistry, Russian Academy of Sciences (IONKh RAN), Moscow, Russia. Translated from Khimicheskoe i Neftegazovoe Mashinostroenie, No. 3, pp. 15–17, March, 2009.

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TABLE 1

Property	Type of generator		
	TS4M1	TS6MD1	TS10M1
Output power, kW	1.2–4	(1.2–4) × 2	2.4–8
Working frequency, kHz	20–27	20–27	20–27
Output voltage, V	120–420	(120–420) × 2	180–620
Magnetizing current, A	≤20	≤15 × 2	≤15
Charging cable length, m	≤10	≤10	≤3000
Power supply, V(Hz)	3 × 380 (50, 60)		
Power consumption, kVA	<5	<12	<12
Cooling water flow rate, liters/min	4–5	4–5	4–5

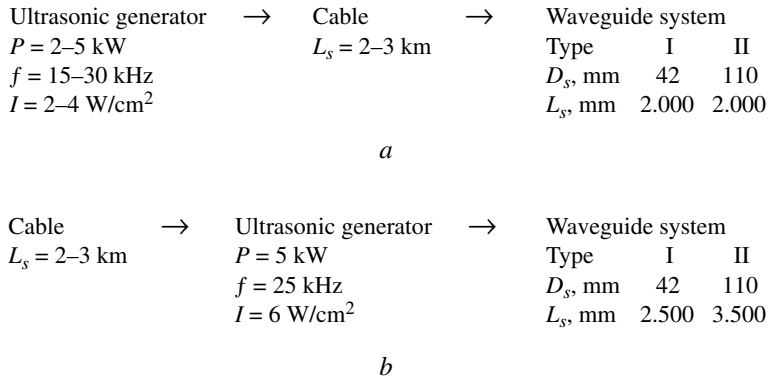

Fig. 1. Ultrasonic unit lay-out: *a*) surface-based generator; *b*) placement of generator in submersible device.

Subsequently, the generators were modernized in order to increase their reliability. Recently, a set of design documents have been developed for the basic model of stationary generators (TS) whose properties are provided in Table 1.

A feature of generator TS6MD1 is the presence of two channels for forming an ultrasonic signal that makes it possible to connect two magnitostrictive transducers (each with a power of 4 kVA) from both sides of the emitter (two-contact Push–Pull system) [6].

All generators are built of standard modules. A module MK-2 is used as the controller in generators. The computing nucleus of the controller is based on a AT89S8253 microprocessor operating at a signal frequency of 18 MHz. Controller supply is accomplished with a voltage of 220 V 50 Hz through a TPM10512 transducer.

In developing unit for ultrasonic well stimulation, two US layouts were proposed: with a surface-based source of electrical supply, i.e., a generator (Fig. 1*a*) and placement of it in a submersible device (Fig. 1*b*). In the second case, the loss of electrical energy in the cable, connecting the generator with the vibratory system, may be considerably reduced. A geophysical cable or a supply cable for submersible pumps was used for the connection.

In order to restore (clean) water-supply and oil wells, special submersible unit has been developed whose basic component is a US unit of vibratory waveguide systems.

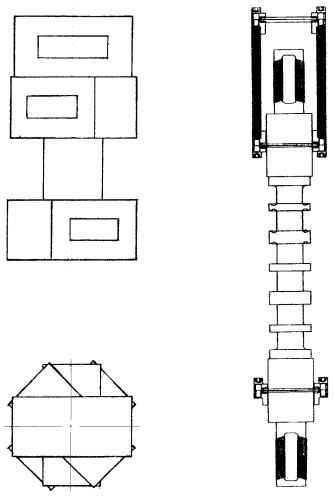

Fig. 2. Vibration systems of submersible devices: *a*) made of four magnetostrictive transducers; *b*) made of two magnetostrictive transducers, connected by a Push–Pull scheme with a dumbbell type sonotrode.

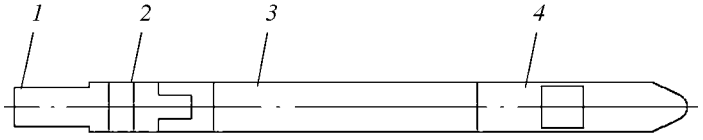

Fig. 3. Functional diagram of well unit PP 42-00-00: *1*) end piece (for sealed connection to end of cable NK 42-00-00); *2*) assembly of sealed electrodes of magnetostrictor magnet wires; *3*) emitter assembly, consisting of a waveguide and two magnetostrictors; *4*) piston compensator assembly.

Two versions of vibratory systems have been developed for water-supply wells:

1) using several (four) magnitostrictive transducers of the rod type, placed in submersible unit in order that there axis was directed normal to the axis of the unit and were turned with respect to each other through 90º (Fig. 2*a*);

2) with the use of two rod magnitostrictive transducers, connected by a Push–Pull scheme with a sonotrode with a developed emitting surface. Alongside the sonotrode, made in the form of a tube, dumbbell type sonotrodes are used. In a number of cases, two Push–Pull systems were connected successively (Fig. 2*b*).

The submersible unit for operation at depths greater than 1000 m was equipped with a US vibratory system and a system for compensating static pressure.

Taking account of the different dimensions of existing oil wells two types of submersible unit were created: PP 42-00-00 with a diameter of 42 mm and SP 108-00-00 with a diameter of 108 mm.

Well unit type PP 42-00-00 is intended mainly for operation in oil exploration and injection wells. Cleaning of the critical zone is realized by the action of elastic high-frequency vibrations, that are created by a waveguide emitter excited by magnetostrictive transducers.

The technology for performing the work assumes periodic swabbing of the well. During operation of the unit in gas-lift wells, oil recovery does not cease within them.

Fig. 4. Device for US treatment of water-supply wells with submersible unit 108 mm in diameter.

The well unit is a cylindrical structure with an outer diameter of 42 mm and a length of 1300 mm (Fig. 3). There is a waveguide in the central part of the unit, within which in a free running regime a standing wave is excited by means of two magnetostrictive transducers, joined to the ends of the waveguide. The radial vibrations of the waveguide that occur create an elastic high-frequency field in the surroundings. The vibration frequency is 20000 Hz.

Supply to the well unit is accomplished by the surface-based generator PS8000/20 through a logging cable type 7-H-464K, and a maximum cable length of 3000 m.

A shell is attached to part of the waveguide, within which a piston is placed serving for compensation of thermal expansion of transformer oil within the inner cavity of the well unit. Components are placed on the piston intended for preventing ingress of dirt under the piston and jamming. Use of the piston makes it possible to maintain oil pressure in the unit approximately equal to the pressure of the surroundings. Through a hole in the piston, which is closed with a plug, transformer oil is evacuated filling the internal cavity of the well unit.

The shell is covered with a cap with a hole through which well fluid is fed beneath the piston and transfers the pressure of the surroundings to the piston.

A shell is fastened to the upper part of the waveguide, to which a housing is fastened by means of a screw where there are two electric leads type 16-13-01878-00 with seals type 16-B-00430-29. The magnet wires of the magnetostrictors are connected through the electric leads with the cores of the logging cable by a cable head HK-42-00-00. The housing is covered with a transportable lid.

The well unit is made of corrosion-resistant materials. Lowering of the well unit is accomplished by means of the logging hoist.

Well unit SP 108-00-00 is intended for operation with viscous high-paraffin oils.

The well unit is made in the form of a cylindrical structure with an outer diameter of 108 mm and a length of 1410 mm (Fig. 4). Cleaning of the critical zone is accomplished by a field of high-frequency vibrations that are created by magnetostrictive transducers, placed in the lower part of the well unit (four rod magnetostrictive transducers are used that are turned in pairs with respect to each other through 90º). The magnitostrictors are fastened to a stud with nuts. The upper end of the stud is fastened to the nut, and the lower to the body.

The magnetostrictive transducers are covered with a cylindrical perforated shell. The shell is fastened by means of nuts with four studs to the core. The flat end of the shell is covered by a cone and a cap. The presence of cones on these components provides accident-free lowering of the well unit into a well.

The magnet wires of the magnetostrictive transducers through a hole in the nut and a central tube are led to the upper cavity of the well unit and fastened with clamps to the central tube.

There is a longitudinal groove in the central tube 37 mm wide within which there is a coupling for electric connection of a three-core cable and magnet wires of the magnetostrictive transducers. Electrical connection of the cable and magnet wires is made by soldering with an adapter. After soldering, the internal cavity is filled with Permatex sealant and fastened by means of blocks and clamps to the central tube of the core.

After assembly connections of the three-core cables are made to the central tube, and then a tube, threaded bush, cone and screw are assembled. The threaded bush makes it possible to achieve strong locking of the well unit structure, weakened by the central grove in the tube of the core. An adaptor serves for securing the well unit to the pump-compressor pipe (PCP).

The generator is connected to the well unit by a three-core cable normally used for submersible electric pump. Lowering of the well unit into a well is performed by means of the PCP, to which the well unit is fastened.

The construction of the well unit makes it possible to use it in two versions.

The *first version* (basic) is the use of one well unit fastened to the PCP.

The *second version* is a well unit, fastened to the PCP, connected to a second well unit.

Connection of the second unit: the cap is removed from the well unit, installed on the PCP, and instead an adaptor is set up and the PCP is fastened to it with the second well unit.

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