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Methodological Notes

SIMPLE DEMONSTRATION OF STANDING ULTRASONIC WAVE IN A LIQUID

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THE idea of the proposed demonstration experiment is not new. More than 30 years ago, Sollner and Bondy[1] demonstrated a standing ultrasonic wave in a liquid by using glass tubes filled with an emulsion of toluene in water and immersed with their sealed ends in an oil fountain over an ultrasonic radiator. Brief information on the results of similar investigations can be found, for example, in Bergmann's monograph[2].

We describe here a simple variant of these unjustifiably forgotten experiments. To excite an ultrasonic wave in a liquid, we use a magnetostriction radiator, the construction of which is shown in Fig. 1. The vibrator of radiator 1, 8 mm in diameter and 15–20 mm in length, is cut from a ferrite rod (type M-400 NN) used in the magnetic antennas of pocket radio receivers. The vibrator is mounted behind its core in a hole of 6 mm diameter drilled in rubber disk 2. The diameter of the rubber disk is 20--30 mm and its thickness is 2–3 mm. Such a disk is conveniently cut from a rubber stopper of suitable diameter. The disk 2 is secured to stand 7 with the aid of a washer 3 cut from thin bakelite and four bolts with nuts 4 (two of them are simultaneously the terminals to which the ends of the excitation winding are connected). The vibrator is magnetized by a stack of 3–5 annular ceramic magnets 6, the upper of which touches the lower end of the vibrator. The excitation coil 5 of the radiation has no core and its inside diameter is 9–10 mm. It is mounted in such a way that the ferrite vibrator does not touch it. The excitation winding contains 15–20 turns of PEL 1.0 wire.

The ultrasonic oscillator (Fig. 2), to the output of which the excitation winding of the magnetostriction radiator MR is connected, is based on a push-pull circuit with capacitive feedback, using two 6P3S tubes connected as triodes. The oscillator is fed with alternating current from a step-up transformer producing a voltage 400--600 V. The high-frequency transformer T_1 is wound on a flat form made of insulating material, 60 mm long and with a window cross section 4×22 mm. The primary winding I of the transformer contains two sections of 100 turns each: the secondary winding II, which is wound over the primary one, contains 20 turns. The wire in both windings is PEL 1.0. A flat ferrite core (from magnetic antennas) measuring $3 \times 20 \times 100$ mm, is placed inside the transformer form. Motion of this core regulates the frequency of the oscillations generated by the instrument (in the range from 100 to 190 kHz). The remaining circuit elements of the oscillator are as follows: $R_1 = R_2 = 30$ kilohm, $C_1 = C_2 = C_3 = 1000$ pF, and $C_4 = 0.04$ μF.

The standing wave in the liquid is demonstrated in the following manner. A drop of water is placed over the end face of the vibrator and the oscillator is tuned, by moving the tuning ferrite core of the high-frequency transformer T_1, in such a way that the vibrator is excited at its fundamental natural frequency. The drop of water then distends, oscillates strongly, and droplets are emitted from its surface frequently to a height of 10–20 cm. The intensity of the ultrasonic oscillations is slightly decreased, to keep the ferrite vibrator from breaking, and the anode voltage of the oscillator is turned off.

In a tall glass of water with a layer of starch (0.2–0.4 g per 10 ml of water) on its bottom is prepared beforehand, and the starch is stirred strongly to obtain a homogeneous suspension of white color. A glass tube of length 20–30 cm and inside diameter 3–6 mm is immersed in the glass with water, its top is covered with a finger or with a small stopper, and the tube transported together with the liquid column in it to the upper end of the vibrator. The water then wets the end of the vibrator, thereby producing the necessary acoustic contact between the vibrator and the column of the liquid in the tube. The anode voltage is turned on, and if necessary the oscillator is retuned slightly. After a few seconds, the starch particles gather in the antinodes of the standing wave. The continuous demonstration of this phenomenon should not last more than a few minutes, to prevent overheating the windings of the high-frequency transformer. If glass tubes with an inside diameter on the order of 3 mm is used, a standing wave can be demonstrated with a water column up to 1 m in length (the suspension of starch in water can be raised with the aid of a rubber syringe placed over the upper end of the tube).

It should be noted that if the magnetostriction radiator recommended in the present note is used, with a vibrator 15–20 mm long, there is no need to regulate the height of the liquid column in the tube in order to obtain in it an intense standing wave. This greatly facilitates the demonstration of the phenomenon (a vibrator 30–40 mm long does not make it possible to obtain a stable picture of the distribution of the starch

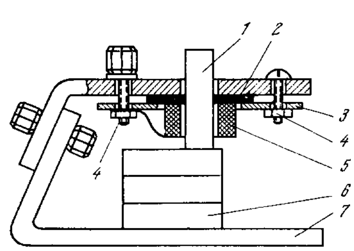

FIG. 1

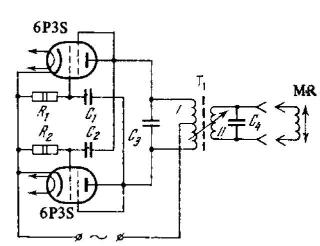

FIG. 2

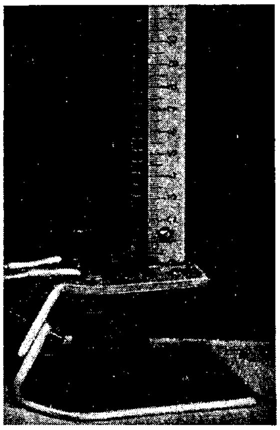

FIG. 3

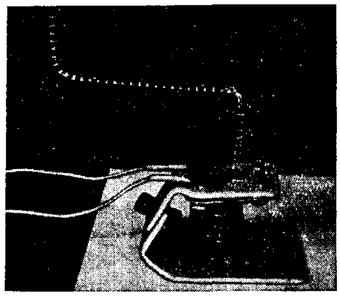

FIG. 4

over the antinodes, precisely because it is necessary to adjust exactly the height of the liquid column). During the time of the demonstration, it is necessary to call attention of the audience to the occurring intense coagulation of the starch particles. If the radiator is equipped with a ruler or a caliper gauge (Fig. 3), then one can measure the length of the ultrasonic wave, and with it also the speed of sound in the suspension used for the experiment. For example, the wavelengths in tubes with inside diameter 3 and 6 mm, using a ferrite vibrator of 20 mm length, turn out to be $\lambda_1 = 10.2$ and $\lambda_2 = 9.4$ mm, respectively. The fundamental natural frequency of the vibrator, according to direct measurements, is 130 kHz. Thus, the speed of sound in the tubes of the indicated diameter are $c_1 = 1320$ m/sec and $c_2 = 1220$ m/sec, respectively (waveguide effect).

The standing ultrasonic wave can also be demonstrated in bent tubes (Fig. 4).

[1]K. Sollner and C. Bondy, Trans. Fard. Soc. **32**, 616 (1936).

[2]L. Bergmann, Ultrasonics and Their Scientific and Technical Applications, Bell, 1938.

Translated by J. G. Adashko