TECHNIQUE FOR DYNAMIC CALIBRATION OF ELECTROMAGNETIC FLOWMETERS

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When studying several processes in the circulatory system it is essential to know the blood flow in the arteries at a particular instant. To record pulse changes in the blood flow, the flowmeters used must have appropriate frequency characteristics: The instrument must measure signals at different frequencies without distortion. This requirement can be expressed as follows: The amplitude–frequency characteristic curve must level out on a plateau over the whole range of physiologically essential frequencies (usually 0-25 Hz), and the phase shift must be small.

However, the introduction of output filters into electromagnetic flowmeters not only reduces noise, but also gives rise to a significant phase shift and a reduction in amplitude of high-frequency signals at the output of the flowmeter [9]. Accordingly, when a pulsating blood flow is recorded, the frequency properties of the flowmeters must be investigated to make sure that they do not give rise to substantial distortions, or it is necessary to introduce appropriate corrections into the results of the measurements corresponding to known frequency characteristics.

The usual method of dynamic calibration of electromagnetic flowmeters is based on the creation of sinusoidal flow waves of different frequencies (but of the same amplitude) by means of special pumps and comparing the output signal from the flowmeter with the calibration signal [6, 7, 10]. However, the design of a good pump capable of creating sinusoidal flow waves over a wide range of frequencies is a difficult task. There is a much simpler method of calibration, making use of the Hall effect.

The principle of action of an electromagnetic flowmeter is based on the Faraday electromagnetic induction phenomenon, i.e., on the appearance of an e.m.f. in a conductor moving in a plane perpendicular to the direction of the lines of force of a magnetic field [3, 8]. The Hall effect is similar to the Faraday effect, the only difference being that instead of a moving conductor, a conductor or semiconductor (Hall's detector) at rest in a magnetic field, through which a current flows, is used. The mechanism of development of these two effects is identical and consists of the action of a magnetic field on charges moving in it [4]. The sinusoidal current in the Hall's detector is the analog of the sinusoidal change in the flow of fluid through the detector of a flowmeter.

The Hall effect has been used for developing and adjusting electromagnetic flowmeters [1, 12]. In these investigations the Hall's detector, serving as imitator of the signal of a pulsating blood flow, was placed in a special coil, supplied with current from the power unit of the flowmeter. In a recently published short report [11] this method reached its logical conclusion when the Hall's detector was placed inside the flow detector, so that the frequency properties of the whole measuring circuit — from the flow detector to the output of the flowmeter — could be investigated. However, nothing was said in this report about the way in which this method was put into operation. We give below a description of a technique developed by ourselves for dynamic calibration of the Soviet RKÉ-1 [5] and RKÉ-3 electromagnetic flowmeters.

The Hall's detector which we used in a parallelepiped (20 × 3 × 1.5 mm), made of indium antimonide (InSb). An ordinary pencil is split into two halves, the lead is removed, and in its place is fitted a Hall's detector with leads soldered to it (Fig. 1). Grooves are cut with a saw on axially opposite sides of the pencil, into which a length of copper wire 1 mm in diameter (the current collecting bars) are fitted. The leads 3 and 4 are soldered

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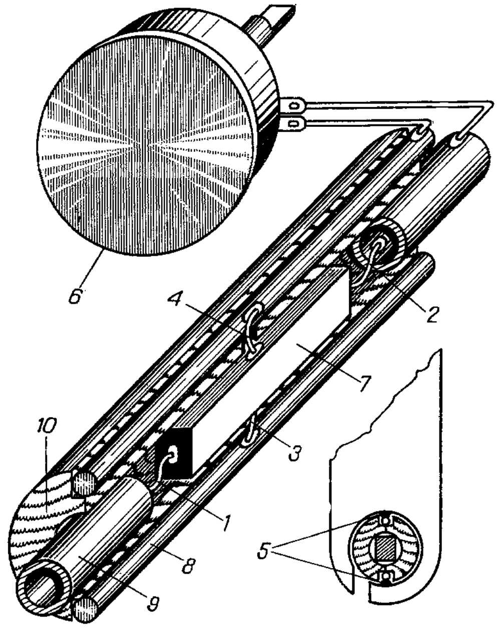

Fig. 1

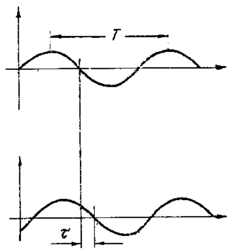

Fig. 2

Fig. 1. Device for dynamic calibration of an electromagnetic flowmeter. The device consists of a Hall's detector (7) with power (1, 2) and signal (3, 4) leads, plug-type terminals for connecting the G6-15 generator (9), current collecting bars (8), and compensation rheostat (6), mounted in a wooden case (10). The diagram below shows how contact is made between the collecting bars and electrodes of the blood flow detector (5).

Fig. 2. Method of determination of phase shift between input and output voltages. Top curve — input voltage (ordinate) of calibration device; bottom curve — output voltage of RKÉ flowmeter. Abscissa — time, T — period of oscillations.

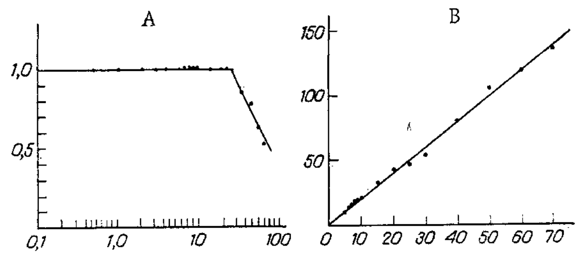

Fig. 3. Amplitude (A) and phase characteristics (B) of RKÉ flowmeter. Abscissa, signal frequency (in Hz); ordinate, ratio of amplitude of output signal at a given frequency to amplitude of output signal at "zero" frequency (A) and phase shift (in degrees) between input and output signals (B).

to the collecting bars, and leads 1 and 2 are connected to a G6-15 generator of specially shaped signals. The "pencil" with Hall's detector is placed inside the cuff flow detector (diameter 6 mm) so that the collecting bars make contact with the sensitive electrodes of the flow detector. To compensate for nonequipotentiality of the signal electrodes of the Hall's detector, a potentiometer connected as shown in Fig. 1 is used [2]. The G6-15 generator created a sinusoidal current of the same amplitude but of different frequency in the Hall's detector. Signals were recorded from the G6-15 generator and flowmeter (Fig. 2).

By measuring the amplitude of the signals of different frequency at the output of the flowmeter, the amplitude—frequency characteristic curve was obtained. By measuring the shift between the sinusoidal waves at the output of the G6-15 generator and flowmeter, a phase—frequency characteristic curve was obtained. If at frequency f (in Hz) the shift between the nearest zeros of the sinusoids from the generator and flowmeter is τ (in sec), the phase shift at this frequency $\Delta\varphi(f)$ is given by:

$$\Delta\varphi\,(f)^\circ = \tau \cdot f \cdot 360^\circ.$$

Amplitude— and phase—frequency characteristic curves were obtained for the RKÉ-1 and RKÉ-3 electromagnetic flowmeters. The amplitude— and phase—frequency characteristics of the RKÉ-3 instrument are shown in Fig. 3 (50 Hz band). Within the frequency range from 0 to 25 Hz the amplitude—frequency characteristic curve of the RKÉ-3 instrument is plateau-shaped. The amplitude of the recorded signal at a frequency of 50 Hz is 72% of the amplitude at a frequency of 1 Hz. The phase—frequency characteristic curve is linear over the whole range of frequencies. The phase shift is 2.4 deg/Hz.

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