QUARTZ DILATOMETER WITH CAPACITANCE TRANSDUCER

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A quartz dilatometer with capacitance transducer has been designed. The electrical circuitry and operational technique are described. The dilatometer design and measurement circuitry make it possible to detect an increase of $6 \cdot 10^{-5}$ mm in specimen length.
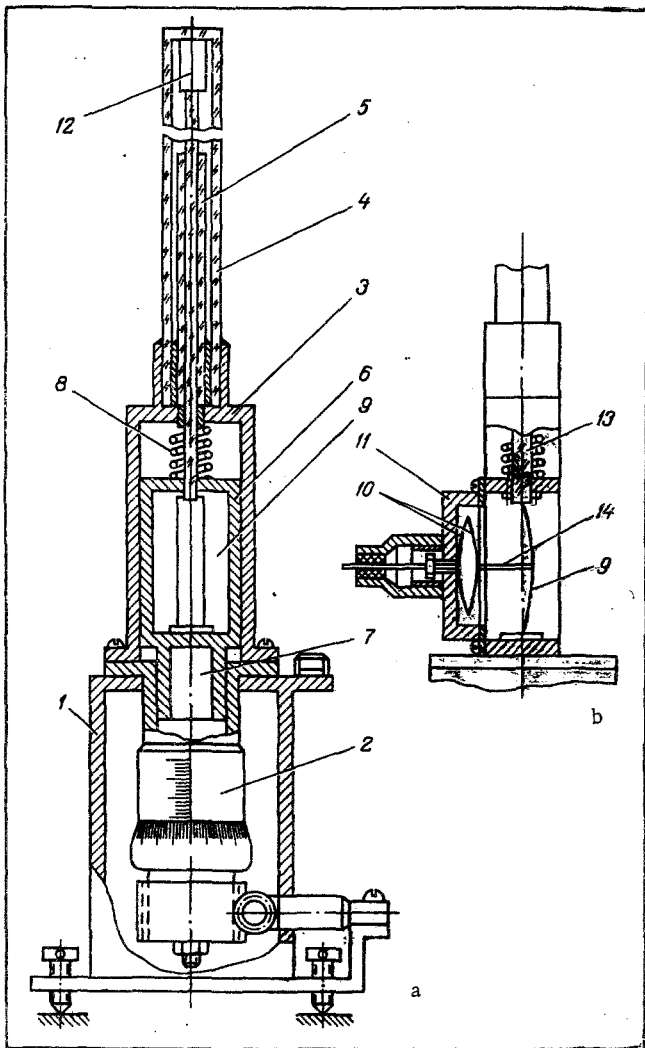
Fig. 1.   Quartz dilatometer.

Electrical transducers are among the most promising means for increasing the sensitivity and accuracy of dilatometric measurements [1]. They not only facilitate automating the measurement process, but also amplify length increases by a factor 10^6 [2].

A recently developed instrument for measuring small capacitance changes [3] makes possible the use of a capacitance displacement transducer [4] with a quartz dilatometer, whose design is shown in Fig. 1.

A micrometer screw 2 and neck 3 are rigidly attached to the cylindrical base 1. The upper part of the neck contains a quartz guide tube 5 and support 4, in the upper part of which is an opening for installing the specimen 12. The guide tube contains a quartz plunger 13, whose lower end bears against a disk-shaped spring 9. The latter applies a load to the specimen and also serves as the active component of the capacitance transducer.

The neck contains the transducer block 6 with cylindrical cup 7 which bears against the micrometer screw and is loaded by the compression spring 8. The capacitance sensor 11, shown in Fig. 1b, is located in the block.

The disk-shaped spring 9 is connected to the deformable capacitor plate 10 via the stem 14. As shown in [4], this form of transducer construction has high sensitivity and good linearity. The block is insulated from convection currents, for thermal stability.

The dilatometer is combined with circuity for measuring small capacitance changes, shown in Fig. 2.
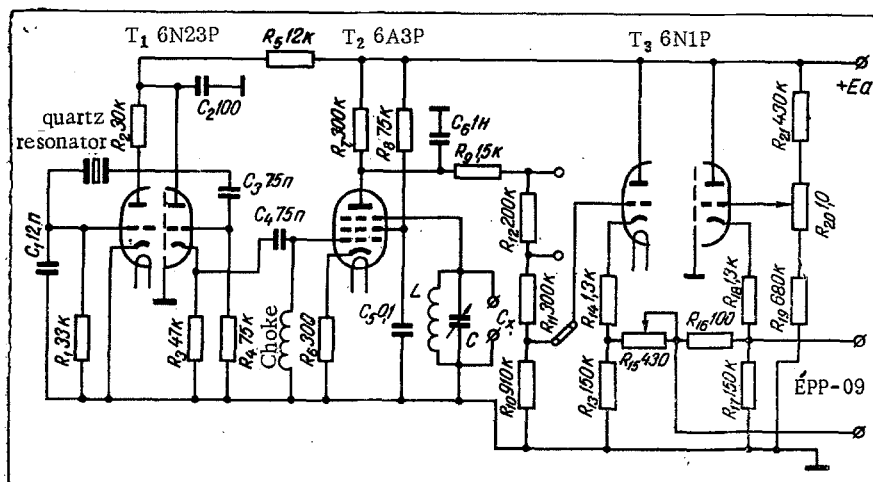
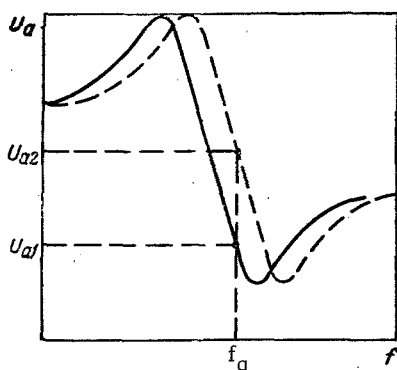Fig. 2. Circuit for measuring small changes in capacitance.

Fig. 3. Voltage-frequency characteristic used in capacitance measurements.

A high frequency quartz resonator, whose output is fed via a cathode follower (the second half of tube T_1) to the first control grid of tube T_2, is connected to the first half of T_1. The tube output is frequency-dependent, with an S-shaped characteristic.

Figure 3 shows the transducer's operating principle. The LC circuit is tuned to the quartz resonator frequency, f_q, by varying C_x in such a way that the operating point lies on the linear portion of the S-curve, corresponding to the anode voltage u_{a1}. The T_3 output balances this voltage.

When the capacitance C_x decreases, the curve is shifted to the right, resulting in a new anode voltage, u_{a2}, i.e., an error signal which is proportional to the change in capacitance.

The dilatometer is operated as follows. With the plunger lowered, the circuit is balanced, i.e., electrical zero is established. The plunger is brought into contact with the bearing surface, by turning the micrometer screw, and a recorder reading is obtained. This reading is taken as the mechanical zero. A larger plunger displacement is possible within the limits of the recorder scale, but this produces excessive specimen loading.

After establishing the mechanical zero, the plunger is again lowered, the specimen is inserted, and the dilatometer set at its original setting — mechanical zero. The specimen length l_0 is determined from the micrometer readings.

A tubular electrical heater is placed over the upper part of the dilatometer. The specimen temperature is measured by a thermocouple located alongside it and recorded with an ÉPP-09 or an xy recorder.

The basic dilatometer parameters are the following. Maximum specimen length, $l_0 = 25$ mm, micrometer smallest division, n = 0.5 µ, sensitivity = 32 mm/µ, drift = ± 0.062 µ/h. The error in linear expansion coefficient measurement is ± $3 \cdot 10^{-8}$ deg^{-1}.

NOTATION

L, oscillator inductance; C, oscillator capacitance; f_q, quartz resonator frequency; u_{a1}, u_{a2}, the voltages; l_0, original specimen length; n, value per micrometer division; C_x, transducer capacitance.

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