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MEASUREMENT OF PRESSURES IN EXPLOSIONS OF GASEOUS MIXTURES WITH A PIEZOELECTRIC SENSOR

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I. S. Zheludev and
V. M. Makarov

[Numbers in parentheses refer to appended bibliography.]

Introduction

The large lag characteristics of mechanical pressure indicators do not permit their use for measuring pressures of fast flowing explosions of gaseous mixtures whose duration is in milliseconds. In the work we [the authors] conducted at the Central Scientific Research Institute of Fire Prevention we chose the piezoelectric method for measuring the pressures developed in the explosion process of certain gaseous mixtures; there are a great number of existing methods of measuring such short-duration pressures(1).

The piezoelectric method is widely used for recording and measuring pressures in internal-combustion engines(2). There is, however, some difference between the explosion of gaseous mixtures and the explosion of other combustible mixtures (for example, in internal-combustion engines). In view of this, we have, to a certain extent, developed a method for measuring pressures, for recording, for calibration, etc. Moreover, the adaptation of ceramic barium titanate for use as a piezoelement, which was used by us in earlier works(3,4), permitted, to a great extent, the simplification of the device for registering pressures during the explosion of a gaseous misture.

Device for Registering Pressures in Explosion Process

The complete unit consists of a piezoelectric transducer (see Figure 1, below), a DC amplifier and an MPO-2 loop oscillograph. A ceramic barium titanate disk 22 mm in diameter and 2 mm thick was used as the piezoelement in the transducer. Electrodes were attached to the side surfaces of the disk by means of silver fusion. After the electrodes were attached the barium titanate was polarized for one hour by a DC electric field of 20 kv/cm potential.

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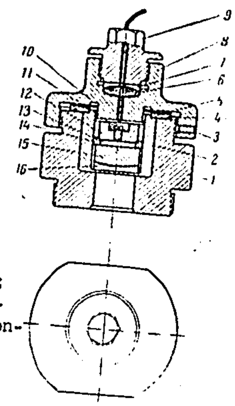

Figure 1. Piezoelectric Transducer. 1, case; 2, socket; 3, lock screw; 4, gasket; 5, washer; 6, packing; 7, conical washer; 8, cover; 9, plug; 10, insulation gasket; 11, screw; 12, contact plate; 13, crystal; 14, ring; 15, base; 16, bearing.

The explosion wave pressure, acting on the piezoelement of the transducer, results in the polarization of the barium titanate. The resulting difference in potential between the grounded and the insulated electrodes, due to the polarization, is proportional to the pressure. The great capacitance of the barium titanate piezoelement, which is 1,800 micromicrofarads in this case, makes it possible to develop a fairly high time constant for the instrument when the simple DC amplifier, previously described by us (5), is used. The time constant of our instrument was ~0.5 seconds, which, according to rule, increases the duration of the explosion process. The amplifier is made up of a balanced circuit on two 6Zh4 tubes. When the signal from the piezocrystal enters one of the tubes the amplifier balance is disrupted; thus the amplifier output current, which results from the unbalanced condition, deflects the loop of the oscillograph.

The piezoelectric transducer and amplifier are shown in Figure 2.

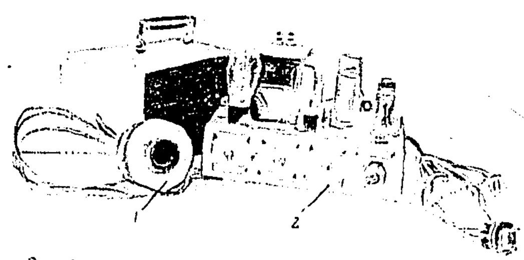

Figure 2. Over-all View of the Piezoelectric Transducer and DC Amplifier. 1, transducer; 2, amplifier

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Calibration of Transducer

To convert the current impulses recorded on the oscillogram into units of pressure, the transducer was previously calibrated with a special device. Dynamic calibration with compressed air and a calibrating temperature equal to the transducer operating temperature were selected and maintained in order to bring the calibrated range closer to the actual operating range.

During calibration the transducer was connected to a cylinder through a fast acting valve, the cylinder being filled with compressed air to a desired pressure. The air pressure in the cylinder was measured by means of a calibrating pressure gauge. On the application of pressure to the actuating lever, the valve opened momentarily and the transducer was subjected to the pressure of the compressed air, which simulated the explosive force of a gaseous mixture. As a result of the error-compensating calibrations introduced by the pressure gauge and through the "dead space" (the change in the volume of the cylinder chamber when the valve is open), a calibrating graph was plotted (Figure 3).

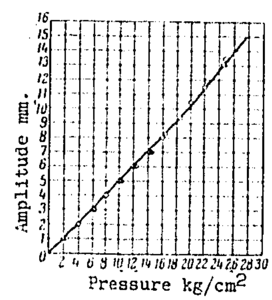

Figure 3. Calibrating Graph for the Piezoelectric Transducer.

The acting forces, in kg/cm^2, were plotted along the abscissa of the graph, while the amplitude of the current impulses, in mm, as recorded on the oscillograph film, were plotted along the ordinate axis. Repeated calibrations were made for the sake of greater reliability. As the graph shows, the graduated points, obtained from separate calibrations, coincide, thus establishing the linear relationship between the amplifier output current and the pressure measurements up to 28 kg/cm^2.

Range and Accuracy of Measurements

The explosive pressures, which it was necessary to measure, were expected to be of the order of 10-25 atmospheres. The registering device was therefore designed so that accurate pressure measurements could be made within the range of 2 to 25 kg/cm^2. To hold the measurement errors to a minimum the following precautionary steps were taken: (1) calibration and measurements were performed at the same surrounding temperature to eliminate the effect of temperature fluctuations on the behavior of the piezoelement and the transducer as a unit; (2) the rectified voltage was stabilized to eliminate the possible introduction of an error by the DC amplifier due to the fluctuation in the line voltage; as a result, during a line voltage fluctuation of $\pm$ 7.5% the stabilized voltage varied 0.08%; and (3) the influence of the fluctuation of tube emission was eliminated by means of preliminary tube adjustment under operating conditions.

Calculations show that the sum of all the errors under these conditions amounts to approximately 2.5%.

Testing the Transducer

The transducer was tested on test explosion installations for hydrogen-air and propane-air mixtures of various concentration ratios. Figure 4

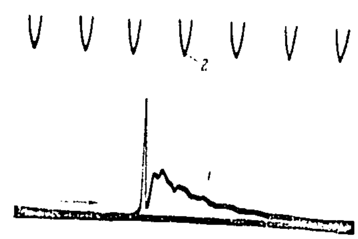

Figure 4. Oscillogram of the Explosion Process of a Hydrogen-Air Mixture. 1, the oscillogram of the explosion; 2, time marks.

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shows an oscillogram obtained from an explosion of a hydrogen-air mixture having a 34% hydrogen concentration at partial pressure. The direction of the recording process is indicated by the arrow. The recording speed was 25 cm/sec. The time marks are recorded at the top of the oscillogram (the frequency of the time marker was 50 hertzes). The explosion process was recorded on a loop having a sensitivity factor of 3.3 mm/ma. The process was recorded on photographic film, after which the oscillogram was enlarged during printing.

The resulting oscillogram permits the determination of the maximum pressure developed by the explosion and allows the study of the nature of the explosion. With the aid of the calibrating graph (Figure 3) [i.e., unit conversion graph] it was determined that the maximum pressure developed by the explosion in this case was 26 kg/cm^2.

The work conducted demonstrates the complete applicability of the apparatus described for recording the explosion process of gaseous mixtures and for the measurement of pressures thus developed. Evidently, the apparatus may also be utilized for recording other processes having analogous characteristics.

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BIBLIOGRAPHY

1. A. M. Turichin. Elektricheskiye Izmereniya Neelektricheskikh Velichin (Electrical Measurement of Nonelectrical Values), 1954

2. L. Volchok. P'yezoelektricheskiye Indikatory Dlya Dvigateley Vnutrennego Sgoraniya (Piezoelectric Gages for Internal-Combustion Engines), 1945

3. I. S. Zheludev, A. S. Shein, B. I. Shteynberg, N. A. Galybin. "Piezo-electric Transducer for Measuring Pressures," Zav. Lab., 7, 852-855, 1953

4. B. I. Shteynberg, N. A. Galybin, A. S. Shein, I. S. Zheludev. "Measuring Pressures in Industrial Peat Presses," Torfyannaya Promyshlennost', 4, 25-30, 1953

5. I. S. Zheludev, I. B. Ogiyevich. "Piezoelectric Instrument for Measuring Pressures and Pressure Jumps in Mechanisms of Intermittent Action (PID-2)," Trudy, Instituta Kristallografii, 12, 1956

Institute of Crystallography,
Academy of Sciences USSR;
Central Scientific-Research
Institute of Fire Prevention

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