Comparison of methods for absolute calibration of ultrasonic fields*

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Methods of determining the absolute ultrasonic pressure amplitude under identical circumstances are compared. Methods used are (1) radiation force on a small sphere, (2) thermoelectric probe, and (3) three optical techniques.

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At the recent Society meeting in Miami (28 November–1 December 1972), the Technical Committee on Physical Acoustics sponsored three sessions on ultrasonic energy and power measurements. These sessions included state-of-the-art invited papers, tutorial papers, round table discussions, and contributed papers on current investigations. The attendance and discussion participation clearly showed that such measurements, and their interpretation, are of fundamental importance in a variety of ultrasonic research programs. During the round table discussions and discussions following formal presentations, a question was raised about the degree to which various absolute measurement procedures compare. Though considerable interest was exhibited in this point, no published works were recalled, extemporaneously, for citation. The present authors were reminded that they carried out such a comparison involving five different methods, at two laboratory sites, in 1958, but that the results had not been published. We report herein our findings in the hope that we may answer some of the questions raised in Miami.

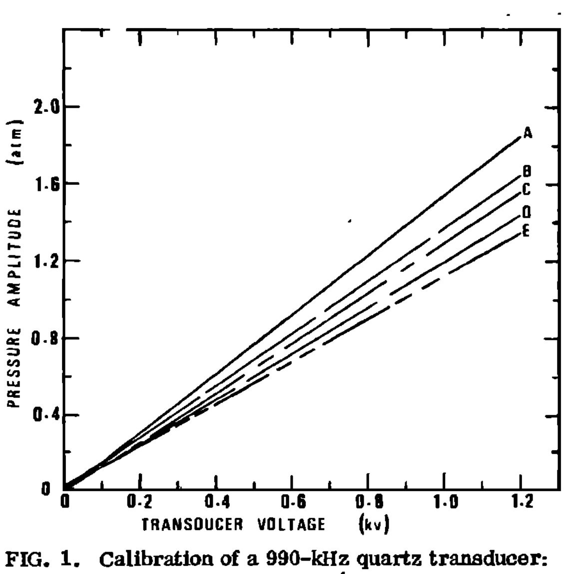

FIG. 1. Calibration of a 990-kHz quartz transducer: (A) calculated output with $e_{11}=4.77\times10^4$; (B) thermocouple probe; (C) optical image broadening (refraction); (D) light diffraction; (E) decrease of light intensity (refraction).

The circumstances of this comparison involved the research programs at Michigan State University under the direction of the late E. A. Hiedemann and at the University of Illinois under the direction of the late W. J. Fry. The former group had been concerned with three optical methods, viz., the refraction (image broadening) method,[1] the diffraction method,[2] and the refraction (decrease of light intensity) method,[3] while the latter group had been employing the method of radiation force on a small solid sphere[4] and the transient thermoelectric method.[5] While each group had found favorable comparison among the methods they embraced, more extensive treatment was considered desirable. The procedure involved the Illinois group calibrating one of its thermocouple probes against the radiation force detector (small solid sphere) and transporting it to the Michigan State campus where the former's experimental arrangement was duplicated. Thus the thermocouple probe was operated by the Michigan State group in the same way as in Illinois and its output compared with that detected by the three optical methods mentioned above. Figure 1 illustrates this comparison in water for the output from a 6-cm-diam quartz transducer, fundamental thickness resonant frequency 990 kHz. Curve A is the output calculated under the assumption that the transducer is a piston-like vibrator. The piezoelectric constant $e_{11}=4.77\times10^4$ was used in this calculation. Curve B is the average of values from the thermocouple probe, after correction for temperature variation of the output. Curve C is from the optical image broadening method.[1] Curve D is from the light diffraction method.[2] Curve E is from the decrease of light intensity method.[3] It is seen that the experimental results exhibit a total range of approximately ±10% about the mean, and that this mean is approximately 27% below that calculated from the voltage applied to the transducer. Because of the assumptions made in the calculation, one should consider this calculated value to be the maximum value possible under ideal conditions. The true value should be less than this, as the experimental results show.

Although further refinements of the optical methods[6] have reduced the scatter among the data, and the availability of lasers now makes the optical methods more direct, we present these results as a guide in estimating the accuracy to be expected when the research program requires such data, and the possibility of detailed investigation of pressure amplitude measurement techniques does not exist.

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