TR-14

VIBRATION SENSITIVITY MEASUREMENTS ON SUBMINIATURE CONDENSER MICROPHONES

by

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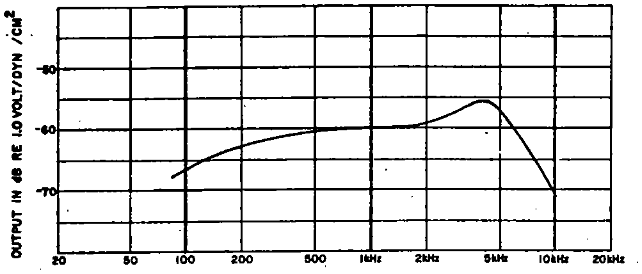

Fig. 1. Typical frequency response of BT-1750 and BT-1751 condenser microphones.

The difference between the intrinsic vibration sensitivity and the free-field vibration sensitivity is due to the pressure generated by accelerating the air in front of the microphone. Simply put, a microphone vibrating freely in space acts as a small loudspeaker, generating oppositely phased sound pressure on the two faces of the unit. For such a small microphone this "radiation pressure" component is nearly independent of frequency over the audio band[2] and amounts to approximately 0.3 dyn/cm² at the center of the face of the unit, when the unit is driven with a constant 1 *g* acceleration. Since the sound inlet on the microphone is a small hole located at the center face of the unit (and directly over the diaphragm), this acoustic pressure adds directly to the intrinsic acceleration pressure. At a vibration level of 1 *g*, therefore, the total pressure acting on the diaphragm is equivalent to 1.4 dyn/cm² or about 77-dB sound pressure level.

MEASUREMENT PROBLEM

Assume that an attempt is made to measure the vibration sensitivity of the condenser microphone of Fig. 2 by mounting it to the surface of a typical vibration driver having a total vibrating area of several square inches. Ones ears warn that the vibration driver is also a loudspeaker. A quick check by holding the microphone slightly off the surface of the driver will confirm that the radiation pressure developed at the vibrating surface far exceeds the acceleration pressure we are trying to measure. A typical vibration driver will produce sound pressure levels of 80 to 90 dB at the vibrating surface when driven to a vibration level of 1 *g*. The electrical output of the microphone placed on such a surface would obviously give the experimenter little clue to the true vibration sensitivity of the microphone.

The first solution that comes to mind is to close off the microphone inlet, making the microphone insensitive to any externally generated sound fields. Unfortunately, this tends to immobilize the diaphragm due to the stiffening effect of the air trapped between the diaphragm and the microphone inlet. Thus a measurement uncontaminated by external sound fields can be made, but it does not represent the true vibration sensitivity of the microphone.

MEASURING VIBRATION SENSITIVITY

In this section, some of the experimental techniques we have used to measure vibration sensitivity will be discussed. The task of verifying experimentally what has been calculated theoretically is made easier if the same basic microphone is available in several different configurations. The basic microphone case, for example, is essentially a rectangular box approximately 0.3 inch long by 0.2 inch wide by 0.1 inch thick (7.6 by 5.8 by 2.5 mm). The 0.2 by 0.3-inch (5.8 by 7.6 mm) surface is normally called the "top" of the microphone, and the plane of the diaphragm is parallel with this surface as shown in the cross-sectional view of Fig. 2. The sound inlet is in the center of the top.

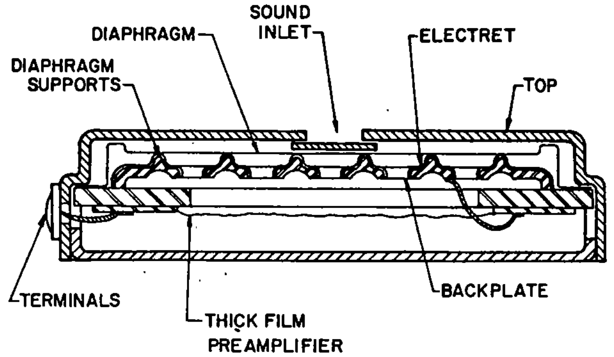

Fig. 2. Cross section of BT-1750 condenser microphone. Length—0.312 inch (7.9 mm); width—0.218 inch (5.6 mm); height—0.09 inch (2.3 mm).

Another version of this microphone is identical in construction except for the position of the sound inlet, which is a tube centered on the edge of the case in what is informally called the "end fire" configuration (Fig. 3). This configuration is useful for several reasons. First of all, the sound inlet remains at the same location in space whether the unit is mounted right side up or upside down. Since inverting the unit reverses the phase of the vibration response but leaves the phase of the acoustic response unchanged, this provides a ready check for the contribution of any external acoustic field. If the two vibration curves are different, this indicates the presence of an external sound field at the microphone inlet, since such an external sound would tend to add to the vibration response in one case and subtract from the response in the other case. (The only exception would occur in the unlikely event that the acoustic and vibration stimuli were exactly 90° out of phase.)

By turning the unit 90° while leaving the inlet tube in the same position in space, moreover, a direct measurement of the acoustic field can often be made. With the unit turned 90° to the axis of its maximum vibration response, its vibration sensitivity will typically be 20 to 40 dB below that at 0°.

One of the most attractive features of the "end fire" configuration, however, is that its gross free-field vibration sensitivity is equal to its intrinsic vibration sensitivity. This comes about as follows: Recall that a disc vibrating in free space acts as an acoustic dipole producing sound of opposite phase on the two faces. At the edges of the disc, therefore, one finds a velocity maximum and a pressure null; in effect, the two sound waves cancel at the edges. Since the sound inlet tube on the "end fire" microphone is centered on the edge of the unit, the radiation pressure component at the inlet will thus be zero when the unit is vibrated perpendicular to the plane of the diaphragm.

Thus the "end fire" microphone was chosen for the initial set of vibration measurements experiments.

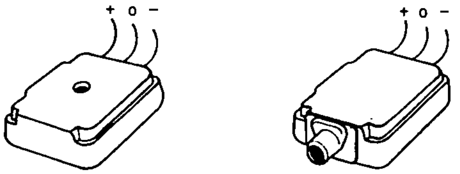

Fig. 3. **a.** BT-1750 "Top fire" microphone. **b.** BT-1751 "End fire" microphone.

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[2] The radiation pressure is due almost entirely to the mass reactance portion of the radiation impedance in this frequency region. See, for example, [2].

the rod at 1 *g* vibration is shown as a dashed curve in Fig. 6. As would be expected from theoretical considerations, the sound pressure developed at the center of the end of a long rod is higher than that at the center of a thin disc having the same dimensions, amounting to approximately 0.4 dyn/cm² in this case compared to the 0.3 dyn/cm² mentioned earlier for the unit vibrating as a free disc. (The perturbation of the sound field shown in Fig. 6 in the 500- to 700-Hz region was caused by a resonance in the double-walled enclosure built around the vibration driver.)

The second experiment was thus performed by mounting a "top fire" microphone on the end of a rod as shown in Fig. 7. The acceleration provided at the tip of the rod was measured using a special vibration pickup which had mass and dimensions identical to the "top fire" microphone, but no sound inlet. This was calibrated initially by placing it next to a known accelerometer on the main surface of the vibration driver. It was then attached to the end of the rod as a permanent reference and the unit under test placed on the top.

The total vibration sensitivity of the "top fire" microphone measured on the end of this rod is shown as the solid curve in Fig. 6. Measured in this manner, it has a gross vibration sensitivity at 1 kHz equivalent to a 1-kHz sound pressure level of 77.5 dB, or 1.5 dyn/cm². As expected, the radiation pressure added directly to the intrinsic vibration sensitivity. As illustrated in Fig. 7, the intrinsic vibration sensitivity of 1.1 dyn/cm² plus the radiation pressure component of 0.4 dyn/cm² gave the expected total of 1.5 dyn/cm at 1 kHz. It should be noted that the radiation pressure contribution to the total vibration sensitivity is dependent on frequency because of the tailored frequency response of the microphone (see Fig. 1).

SLOTTED-ROD MEASUREMENT OF INTRINSIC VIBRATION SENSITIVITY

In a third set of experiments we were able to obtain results essentially identical to those obtained in the closed cavity by use of a 0.312-inch (7.9-mm) diameter by 10-inch (254-mm) long rod in which a 0.220-inch wide by 2-inch long (5.6 by 25.4-mm) slot had been milled starting 3/16 inch (4.8 mm) down from the top. The special vibration pickup mentioned earlier (with mass and dimensions identical to the "top fire" microphone but with no sound inlet) was placed midway up the slot in order to calibrate the system. The vibration pickup was then replaced with the microphone under test and a measurement made of the latter's vibration sensitivity. Direct measurement of the acoustic pressure developed at the position occupied by the "end fire" microphone inlet indicated a sound field which was nearly everywhere at least 26 dB below the equivalent sound pressure level of the unit's vibration sensitivity.[5] Fig. 8 shows the typical gross free-field vibration sensitivity measured on several "end fire" microphones in the slotted rod. Also shown for comparison is the theoretically calculated vibration sensitivity of the microphone based on its electrical analog.

Two units were carefully measured both in the slotted rod and in the closed cavity setup. In both cases the measurements agreed within 0.2 dB, confirming experimentally that the intrinsic and gross free-field vibration sensitivity of the "end fire" microphone are indeed the same.

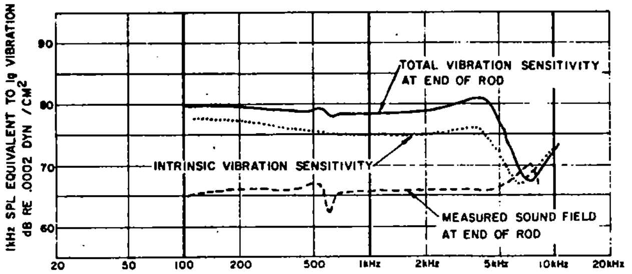
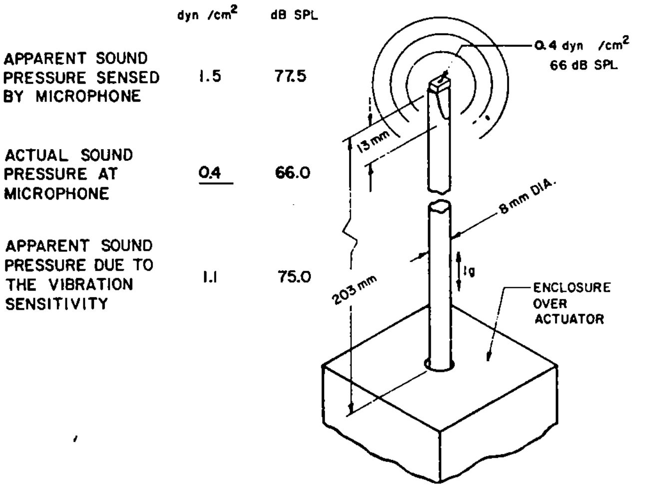


Fig. 6. Vibration sensitivity of BT-1750 microphone measured at end of rod.



	dyn /cm²	dB SPL
APPARENT SOUND PRESSURE SENSED BY MICROPHONE	1.5	77.5
ACTUAL SOUND PRESSURE AT MICROPHONE	0.4	66.0
APPARENT SOUND PRESSURE DUE TO THE VIBRATION SENSITIVITY	1.1	75.0

Fig. 7. End-of-rod measurement.

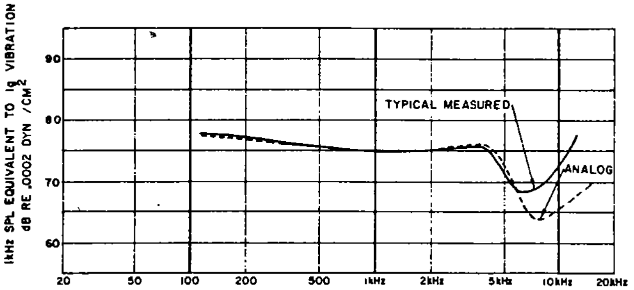


Fig. 8. Comparison between gross free-field vibration sensitivity of typical BT-1751 microphone and theoretical sensitivity based on complete electrical analog.

TWO MISCELLANEOUS OBSERVATIONS

While the subminiature cases of the condenser microphones are normally considered quite sturdy, we have observed that a variety of peculiar vibration response curves can be obtained if the vibrating force is applied so as to cause flexure of the case walls. We have found that this can be avoided by applying the driving force along the edges of the unit or uniformly over the entire face of the unit.

A similar problem can arise using commercial accelerometers. One can be tempted to mount a microphone (or transfer accelerometer) directly to the top of a commercial accelerometer. Many commercial accelerometers, however, use a compression spring between the top of the accelerometer and the vibration element to help hold the vibrating mass in place. Placing any mass on top of such an accelerometer can markedly change its calibration.

VIBRATION SENSITIVITY COMPARISON

Fig. 9 shows a normalized comparison of the vibration sensitivity of several commercially available subminiature microphones. This is similar to the graph shown in a previous paper [5], but has been revised slightly to reflect the refinements in measurement

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[5] The same double-walled enclosure mentioned previously was used to contain the sound generated by the vibration driver, with the slotted rod protruding through a small hole as in the end-of-rod experiments.

ADDENDUM TO TR14

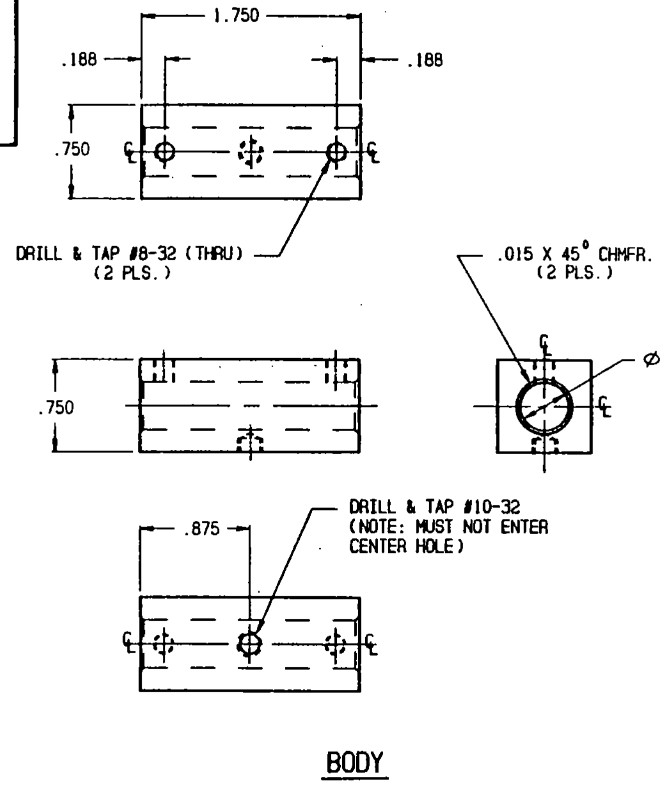
We have prepared a drawing of the vibration test fixture described in AES article "Vibration Sensitivity Measurements on Subminiature Condenser Microphones", M.C. Killion, 1975. A copy of this drawing (XD-1223-01 is attached).

This is used, mounted on a BF EA-1500 exciter. Acceleration is normally held constant by a servo-system with feedback from either a small (specially constructed) accelerometer mounted within the fixture or conventional accelerometer secured to the top of the fixture.

The opening of the sound port of the sample must be close to the centerline of the cavity. The sample is secured at its end walls with a stiff wax or an adhesive to the walls of the slot in the "plug". The chamber must be acoustically sealed to prevent contamination by the sound from the exciter and other ambient sounds.

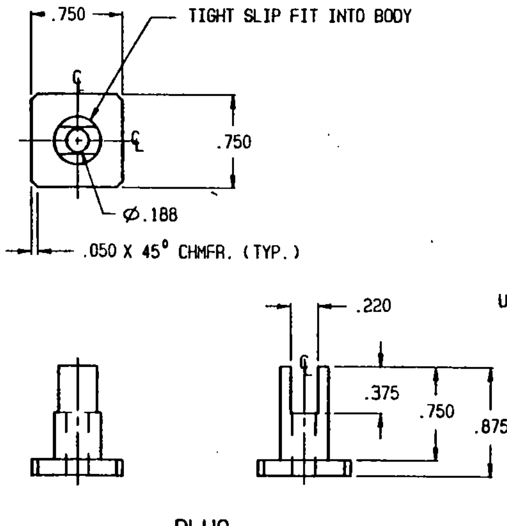
Interfering "cross-talk" signals can be checked by rotating the "plug" 90° and 180°.

The exact size of the bore through the body is not critical. The .389" (which is near 1 cm) on the drawing was measured. It was probably the result of using a letter size "W" twist drill.



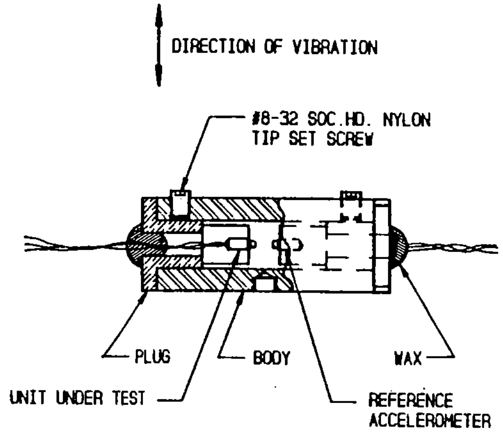
BODY

MAT'L.: C.R. STEEL



PLUG

MAT'L: BRASS



MATERIAL SEE NOTE

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