PRIMER ON NOISE

by

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PREFACE

Times are changing — there is greater concern on the part of the people for the quality of life, and the people are increasingly aware of how to affect public projects they think will be detrimental to their well being. Thus, the highway engineer must give consideration to disciplines previously outside the limits of his responsibility.

Acoustics, a science dealing with the nature of sound, is one of these disciplines. This primer on the subject is directed to the district and resident engineers of the Virginia Department of Highways, who are responsible for conducting highway public hearings, and to the environmental specialists of the Department's Environmental Quality Division, responsible for the Department's work in noise pollution. The purpose of the primer is to provide these persons a source of information on noise that will help them in dealing with the public on this subject.

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INTRODUCTION

Within the past two years, the public's concern for the environment has become so acute that highway departments have been hard pressed to justify the need for new facilities and to guarantee that these facilities will not grossly pollute the environment. One form of pollution receiving particularly close attention from the public is noise.

There are so many new concerns with which the highway engineer must deal that those of us whose principal professional activities have been the building and maintenance of highways sometimes have difficulty in keeping up with local experts who may question the Department's competency in a field such as noise. It is the purpose of this primer to provide the highway engineer a source of information on noise that will help him in dealing with the public on this subject.

The primer comprises a list of definitions; a section containing facts and data that should help in answering some of the more commonly asked questions; and a description of a method for measuring the sound pressure levels generated on our highways.

It is a first effort and will be amended as the need to do so becomes apparent. It is expected that the primer will not completely satisfy every need of its users and hopefully the users will make its deficiencies known to the author.

Decibel (dB): Decibel is the unit term for the measure of the sound pressure level. It is defined as 20 times the logarithm, to the base 10, of the ratio of the measured sound pressure to the sound pressure that produces the lowest audible sound; i.e., $20 \log_{10} (\frac{p}{0.0002})$ where p and 0.0002 are in microbars (see below).

dBA: The dBA is the unit of sound pressure level in decibels measured with a "frequency weighting network" (see below) corresponding to the "A-scale" (see under frequency weighting network) on a standard sound level meter. The A-scale tends to suppress lower frequencies (i.e., below 1,000 hertz).[3]

In interpreting traffic noise levels in dBA, one may note that a change of 10 dBA corresponds to a subjective judgement of the halving or doubling of the noisiness of the sound. In other words, a sound judged to be twice as noisy as another sound would have a sound pressure level rating approximately 10 dBA greater than the first sound. An increase in the sound pressure level from 30 dBA to to 50 dBA would generally be rated as a quadrupling of the sound.[3]

Diffracted Wave: A diffracted wave is one whose front has been changed in direction by an obstacle or other nonhomogeneity in a medium, other than by reflection or refraction.[1]

Frequency (f): The frequency of a sine wave of sound is the number of times it repeats itself in each second, seeFigure 1. The unit of frequency is called the hertz, abbreviated H_z, or the cycle per second.[3]

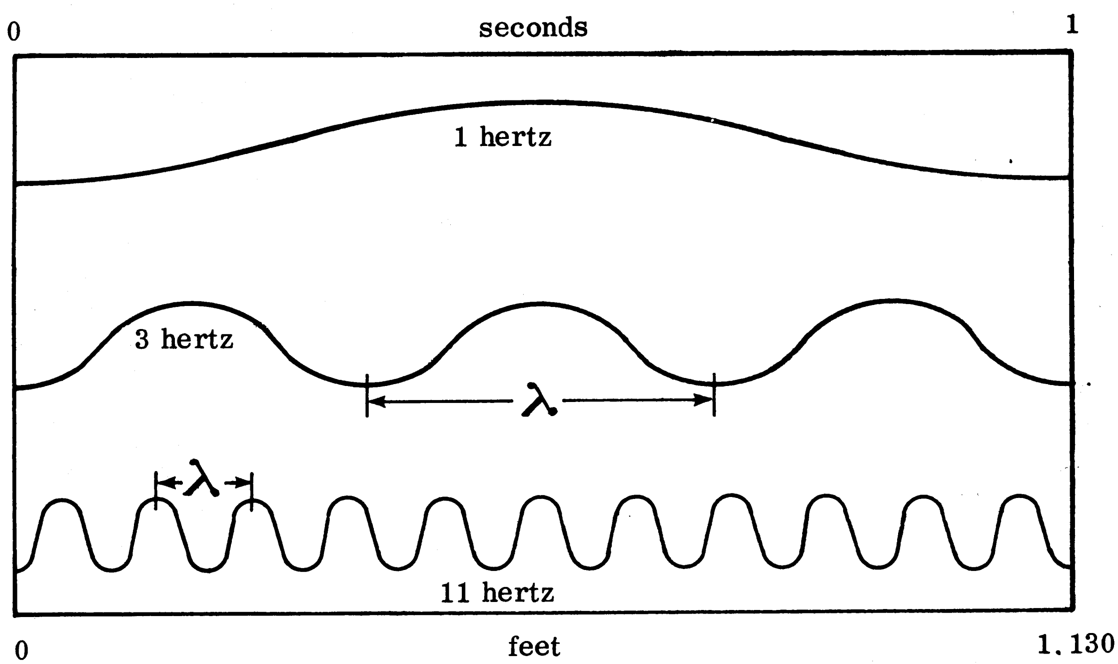

Figure 1. Illustration of different frequencies showing the inverse relationship of frequency to wavelength (λ). The greater the frequency, the smaller is the wavelength (λ).

Loudness (N): Loudness is the intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from soft to loud. Loudness depends primarily upon the sound pressure of the stimulus, but also upon the frequency and wave form of the stimulus. [1]

Microbar: A microbar is 10^{-6} bars or 1 dyne per square centimeter.

Noise: Noise is unwanted sound. [1]

Noise Level: The noise level is the measured sound pressure level (see below), in decibels, of any unwanted sound. [2]

Octave: An octave is the interval between two sounds having a basic frequency ratio of two. [2]

Octave Band Pressure Level: The octave band pressure level of a sound is the pressure level for a frequency band corresponding to a specified octave. [1]

Period: The period of a periodic quantity is the smallest time interval in which the function repeats itself. Period = 1/f. [2]

Pitch: Pitch is the attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high. Pitch depends primarily on frequency. [2]

Reverberation: Reverberation is the sound that persists at a given point after direct reception from the source has stopped. [1]

Sound: Sound is a physical disturbance, i. e., vibrations or pressure changes, in an elastic medium (air, water or some solid). [2]

Sound Absorption: Sound absorption is the process by which sound energy is diminished in passing through a medium or in striking a surface. [1]

Sound Level: Sound level, in decibels, is the weighted sound pressure level obtained by use of a sound level meter whose weighing characteristics are specified. [1]

Sound Pressure: Sound pressure is the measure, in microbars, of the force of the sound wave. See Figure 3 for the relationship of the sound pressure in microbars to the sound pressure level in decibels.

Sound Pressure Level (SPL): The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure, 0.0002 microbar.[1]

Spectrum of Noise (Frequency Spectrum): The spectrum of noise produced by a noise source may be represented by a plot of sound pressure level versus frequency.[2]

Speed of Sound: The speed of sound in air is about 1,130 feet per second at standard atmospheric pressure and 68 degrees F.[2]

Wavelength (λ): The wavelength of a periodic wave is the perpendicular distance between two wavepoints in which the displacements have a difference in phase of one complete period. λ = speed/f = 1,130/f.[2]

Change of Sound Pressure Level with Distance: For a point source in a free field, sound pressure varies inversely with distance. Thus, for each doubling of distance, the sound pressure is halved. From Figure 3, it is seen that halving the sound pressure results in a reduction of 6 dB.[2]

For a line source in a free field, sound pressure varies inversely with the square root of distance. Thus, for each doubling of distance the sound pressure is reduced from p_1 to p_2 where $p_2 = \frac{p_1}{\sqrt{2}}$.

Figure 3 shows that this results in a sound pressure level drop of 3 dB.[2]

If, as stated above, the sound pressure (p) varies inversely with the square root of the distance, then for p_1 at a distance d and p_2 at 2d,

$p_1 \propto \frac{1}{\sqrt{d}}$ and $p_2 \propto \frac{1}{\sqrt{2d}}$. Introducing k as a constant,

$p_1 = \frac{k}{\sqrt{d}}$ and $p_2 = \frac{k}{\sqrt{2d}}$; then $p_1\sqrt{d} = k$ and $p_2\sqrt{2d} = k$;

and $p_1\sqrt{d} = p_2\sqrt{2} \cdot \sqrt{d}$ and $p_1 = p_2\sqrt{2}$ or

$$p_2 = \frac{p_1}{\sqrt{2}}$$ as shown above.

Combination of Sound Pressure Levels — Decibels: In combining two or more separate sound pressure levels, the decibel values cannot be added directly. To eliminate the calculations, a chart is commonly used.

Examples of such charts, which may be used as they are, are presented in Figures 6 and 7. The chart in Figure 7 from "Handbook of Noise Measurement"[4] may also be used to subtract levels.

appendix II

CHART FOR COMBINING LEVELS* OF UNCORRELATED NOISE SIGNALS

TO ADD LEVELS

Enter the chart with the NUMERICAL DIFFERENCE BETWEEN TWO LEVELS BEING ADDED. Follow the line corresponding to this value to its intersection with the curved line, then left to read the NUMERICAL DIFFERENCE BETWEEN TOTAL AND LARGER LEVEL. Add this value to the larger level to determine the total.

Example: Combine 75 dB and 80 dB. The difference is 5 dB. The 5-dB line intersects the curved line at 1.2 dB on the vertical scale. Thus the total value is 80 + 1.2 or 81.2 dB.

TO SUBTRACT LEVELS

Enter the chart with the NUMERICAL DIFFERENCE BETWEEN TOTAL AND LARGER LEVELS if this value is less than 3 dB. Enter the chart with the NUMERICAL DIFFERENCE BETWEEN TOTAL AND SMALLER LEVELS if this value is between 3 and 14 dB. Follow the line corresponding to this value to its intersection with the curved line, then either left or down to read the NUMERICAL DIFFERENCE BETWEEN TOTAL AND LARGER (SMALLER) LEVELS. Subtract this value from the total level to determine the unknown level.

Example: Subtract 81 dB from 90 dB. The difference is 9 dB. The 9-dB vertical line intersects the curved line at 0.6 dB on the vertical scale. Thus the unknown level is 90 - 0.6 or 89.4 dB.

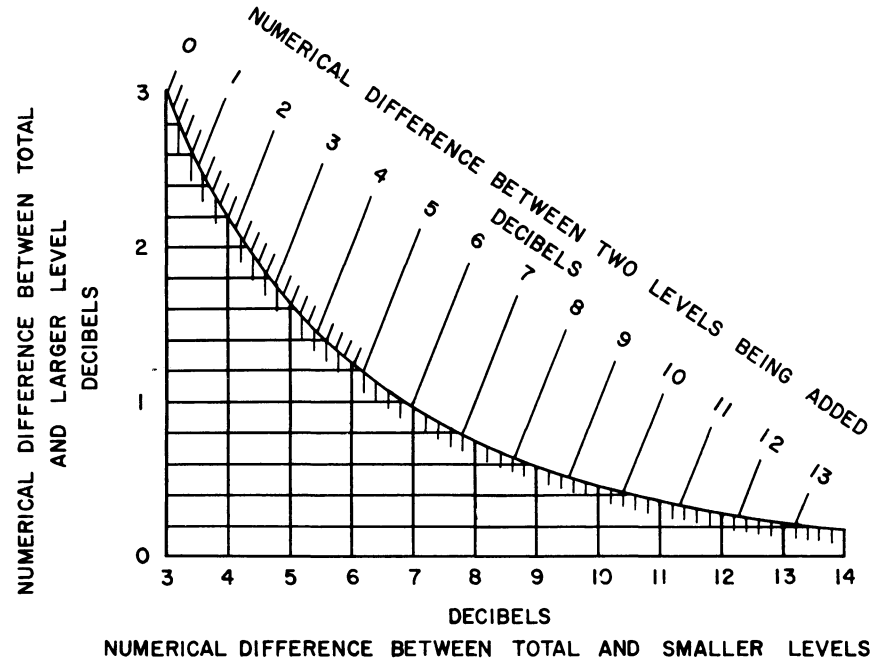

Figure 6. Chart used in combining sound pressure levels (from reference 2).

*This chart is based on one developed by R. Musa.

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TABLE 2

Speech Interference Levels of Noise that just Permit Conversation with Marginal Reliability at the Distances and Voice Levels Indicated[6] (from reference 2)

DISTANCE FROM LISTENER (FT.)	SPEECH INTERFERENCE LEVEL (PSIL) IN DB*			
	NORMAL VOICE	RAISED VOICE	VERY LOUD VOICE	SHOUTING
0.5	76	82	88	94
1	70	76	82	88
2	64	70	76	82
3	60	66	72	78
4	58	64	70	76
5	56	62	68	74
6	54	60	66	72
12	48	54	60	66

** Average SPL in db of noise in the octave bands centred at 500, 1,000 and 2,000 Hz. (PSIL) Sound levels in dbA are 7 db greater than PSIL db.*

Psychological Effects: The human response to noise appears to be pressure sensitive and thus it should not be expected to respond linearly with changes in decibel readings. Table 3 shows the apparent noise reduction caused by various magnitudes of decibel reduction.

TABLE 3

Noise Reduction Experienced by the Human Ear (from reference 2)

DECIBEL REDUCTION	NOISE REDUCTION EXPERIENCED BY EAR (%)
2	15
4	23
6	38
8	48
10	56
12	63
14	68
16	73
18	77
20	81

A decibel reduction of 10 is often considered to represent an apparent noise reduction of 50%.

Abatement Techniques: There are numerous methods by which the anticipated noise level of a highway can be attenuated. In Figures 8 and 9 several methods are illustrated and the degree of attenuation is stated.

Hearing Range: Humans generally have the ability to hear sounds in the frequency range from about 20 to 20,000 hertz. A young, healthy ear, in the absence of extraneous noise, should be able to just hear sounds of different frequencies at the sound pressure levels shown in Figure 10.[6]

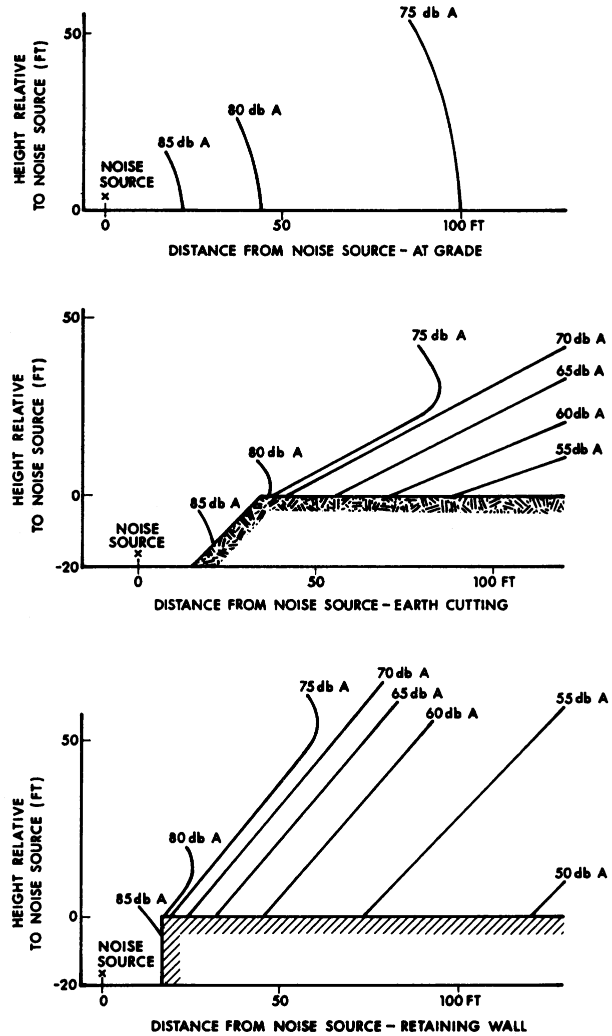

Figure 9. Noise intensity at grade versus earth-cut and retaining wall [16] (from reference 2).

Sound Level Meter: Read instruction manual carefully, paying special attention to warnings about manipulations that might damage the meter, such as:

(a) Set the power switch to off before installing the battery, see Figure 11.

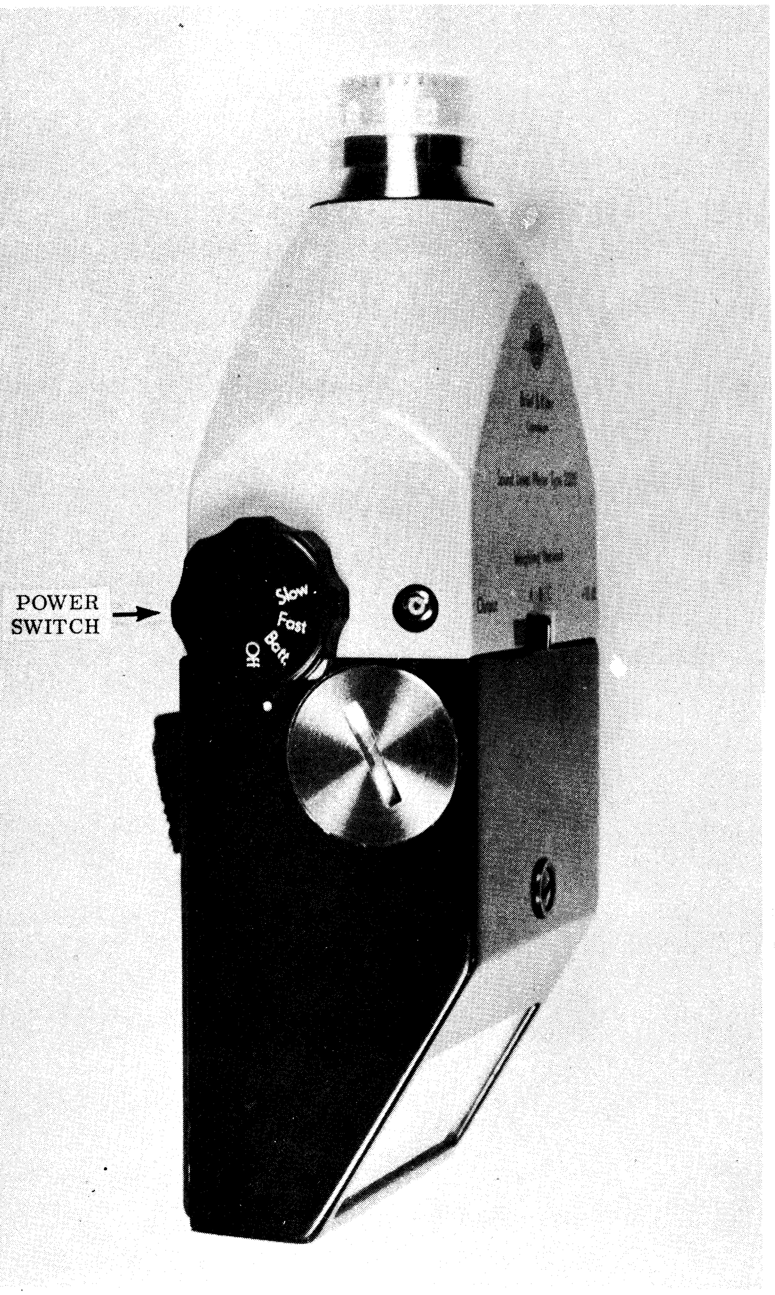

Figure 11. Power switch off.

(c) Install or remove the microphone cover or the calibrator slowly so that the pressure or suction created will not deform the microphone diaphragm, see Figure 13.

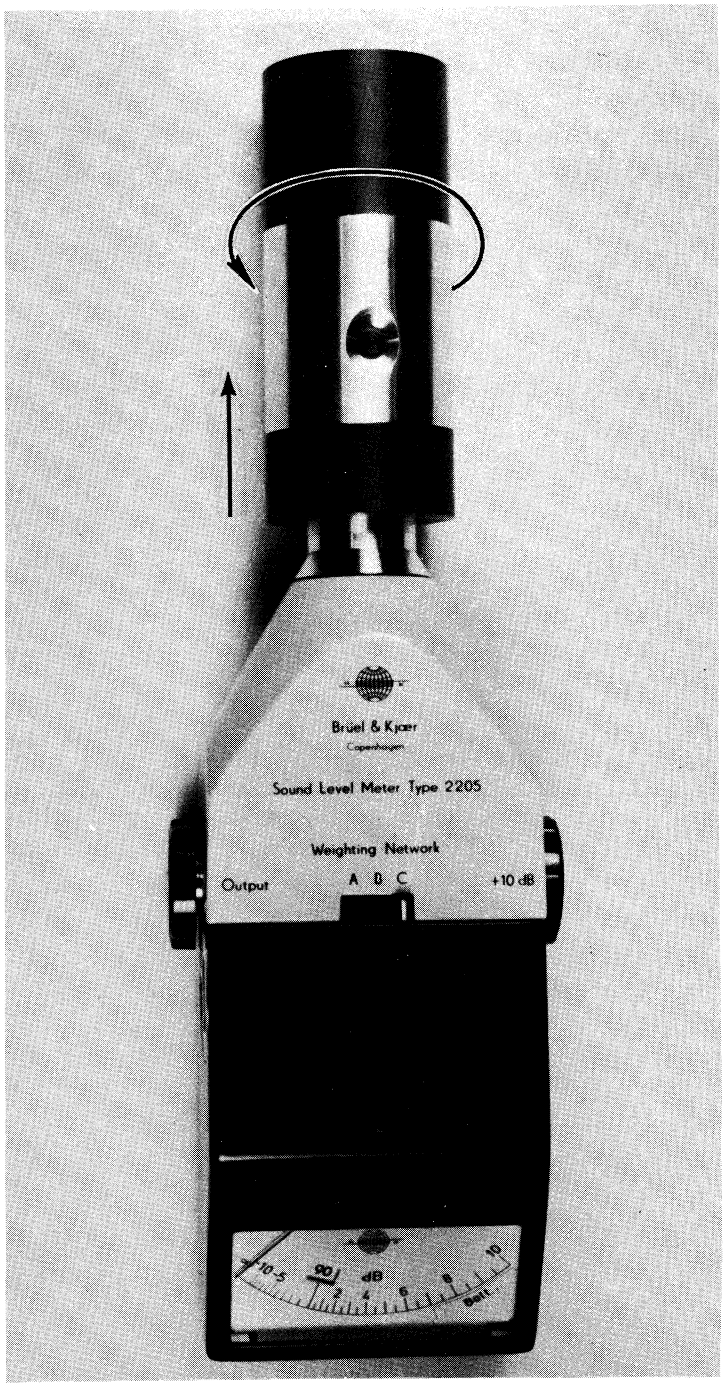

Figure 13. **Removing any type cover from microphone, turn and pull slowly.**

(d) Do not disassemble the meter in the field.

2. Calibrate the instrument.

(a) Carefully and slowly place the calibrator on the microphone.

(b) Set the range switch on 90 dB, the weighting selector on "C", see Figure 15, and the power switch on fast. Press the button on the calibrator and the meter should indicate 4 dB. If it does not, adjust the sensitivity with the aid of a small screw driver until a correct deflection is obtained.

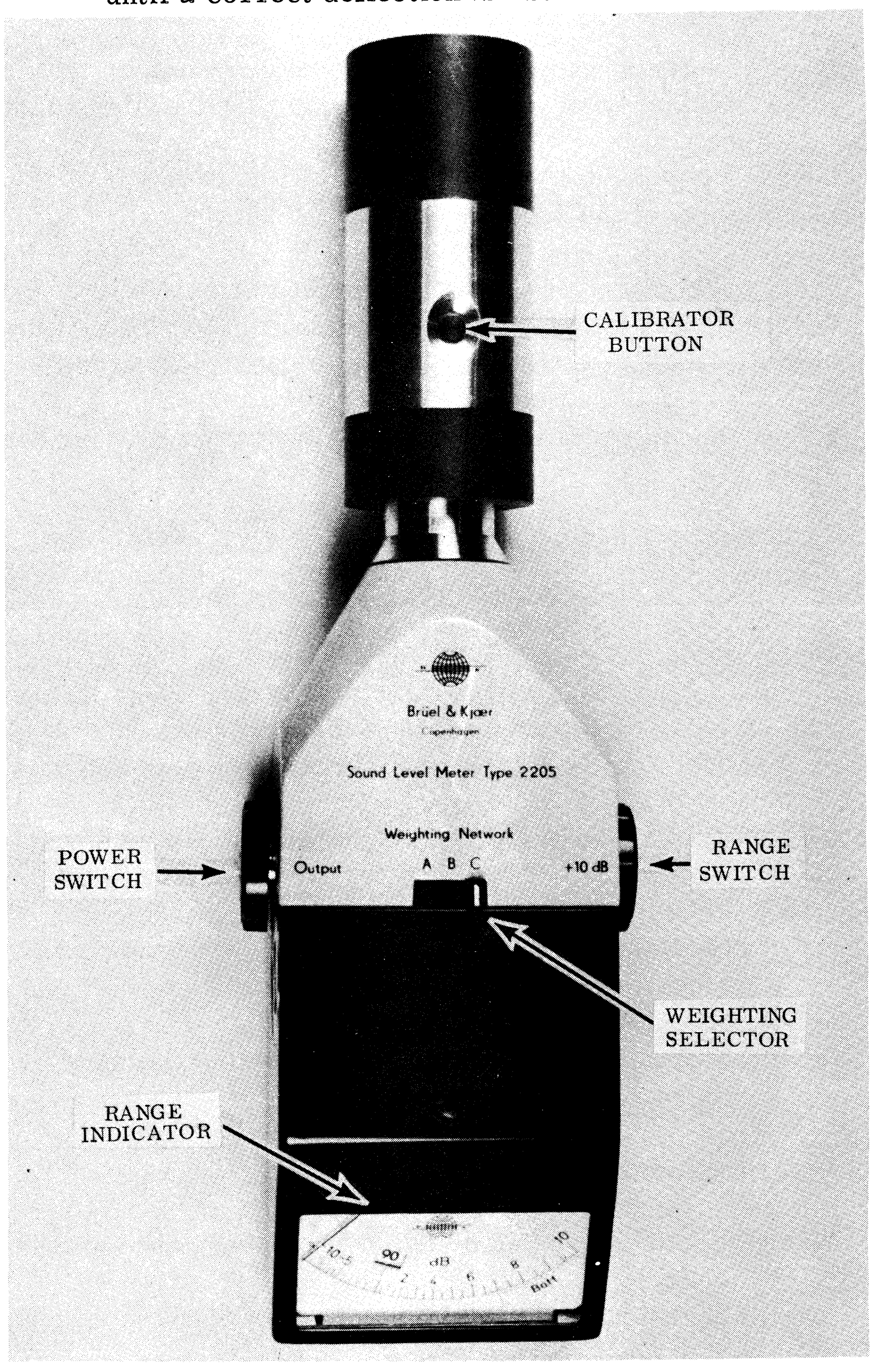

Figure 15. Weighting selector switch and calibrator button.

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