TABLE 5

Frequency (c.p.s.)	Reference pressure for sound pressure level (μbar)	Reference pressure for hearing loss[a] (μbar)	Sound pressure level[a] corresponding to 0 db hearing loss (db)
125	.0002	.106	54.5
250	.0002	.0191	39.6
500	.0002	.00347	24.8
1000	.0002	.00137	16.7
2000	.0002	.00141	17.0
4000	.0002	.00114	15.1
8000	.0002	.00221	20.9

[a] These pressures are those that should be produced by a Western Electric 705-A earphone measured in a coupler built and used according to the specifications set forth in American Standard for Audiometers for General Diagnostic Purposes.[15]

audiometers designed for diagnostic purposes are 125, 250, 500, 1000, 2000, 4000, and 8000 c.p.s.[15] For industrial programs a so-called "screening audiometer" having only four test frequencies, 500, 1000, 2000, and 4000 c.p.s., may be used. Many of the "screening audiometers" being produced today have additional test frequencies at 3000 and 6000 c.p.s. because these test tones are very useful in industrial hearing conservation programs.

In general, the test frequencies are related in a simple manner. Each successive tone is an octave (a multiple of 2) above the previous tone. This rule also may be applied to the series of test tones that were originally used on audiometers. A frequency of 256 c.p.s., which is almost equal to that of middle C on the piano, was used instead of 250 c.p.s. The remaining test tones of the older sequence were 128, 512, 1024, 2048, 4096, and 8192 c.p.s. The slight differences from the present frequency series are, for all practical purposes, unimportant.

F. SOUND INTENSITY PRODUCED BY THE EARPHONES

The intensity of a tone produced in the ear of the person being tested will not always be indicated exactly by the setting of the hearing-loss dial. At low frequencies any air leak around the cushion of the earphone will be very important in determining the intensity of the tone actually produced in the ear canal. Since these leaks cannot be completely eliminated with present cushions, there is a significant amount of uncertainty in audiometer measurements at frequencies of 250 c.p.s. and below. The lower the frequency, the less meaningful the setting of the hearing-loss dial becomes. At 250 c.p.s. the range of variation in the intensity of the tone produced is about 15 db, and at 125 c.p.s. the range of variation may be as much as 20 db. There are similar limitations on the high-frequency test tones produced by the earphones. Their exact placement on the ear and the

[15] American Standard for Audiometers for General Diagnostic Purposes, Z24.5-1951. American Standards Association, New York, 1951.

shape and size of the ear canal will cause variations in the sound intensity produced. Also the problems involved in the calibration of an earphone become more serious at these frequencies. The range of variation in the intensity of the tone produced is 10 db at 4000 c.p.s. and is considerably greater at 8000 c.p.s. and higher.

With reasonable care hearing measurements at 500 to 2000 c.p.s. inclusive should be reliable within a range of 5 db on all except the most unusual ears. At both higher and lower frequencies the intensity generated in the ear canal for a given setting of the hearing-loss dial may be significantly different from person to person. These differences should be borne in mind when audiometer measurements at extreme frequencies are undertaken.

Neither the electronic components of the audiometer itself nor the earphones remain absolutely stable. Over long periods of time, changes may be observed in the sound intensity produced by the earphones for given settings of the hearing-loss and frequency dials. In recent years, however, the seriousness of this problem has been greatly reduced by advances in electronic and earphone design. It is still necessary, nevertheless, to maintain some sort of check on the calibration of the entire system. Otherwise one can never be sure that the sound intensity produced by the earphones corresponds as closely as it should to that indicated by the hearing-loss dial.

G. PHYSICAL METHODS OF CALIBRATION

The physical method for calibration of the audiometer utilizes a microphone and a small cavity, both of which are described in detail in recent American Standards.[15,16] The earphone is placed on the cavity and the intensity generated within is measured by the microphone. The sound pressure level that should be generated by a Western Electric 705-A earphone at each of the test frequencies for 0 db setting of the hearing-loss dial is given in Table 5. Similar requirements for other earphones are given in American Standard Specification for Pure-Tone Audiometers for Screening Purposes.[16]

Audiometers are calibrated routinely by this method by the manufacturer, but for others it is usually a complex and expensive procedure. An experienced acoustical engineer can accomplish these measurements without error, but others may have difficulty. Therefore, it seems clear that most audiometers will not have the benefit of frequent calibration by physical methods. Most organizations have neither the necessary funds nor personnel.

The electrical portion of the audiometer can be checked by simpler measurements. Upon receipt of a new audiometer the voltage at both earphones is measured accurately and recorded for each test frequency. Periodically this test can be repeated to determine if any electrical changes have taken place. Deviations of more than ±2 db indicate that the instrument is in need of repair.

[16] American Standard Specification for Pure-Tone Audiometers for Screening Purposes, Z24.12-1952. American Standards Association, New York, 1952.