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Hearing Aids

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Hearing Aids

Edith L. R. Corliss

National Bureau of Standards Circular 534

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Preface

This Circular contains information, useful to the hard of hearing, on several topics relating to hearing and hearing aids. It is assumed that the individual has already consulted a physician on the diagnosis of his hearing loss, for this is the necessary first step in correcting any faulty hearing condition. The Circular may also be of interest to teachers and others wishing to explore this field.

For several years the National Bureau of Standards has been active in studying the properties of hearing aids—largely for such Government agencies as the Veterans' Administration. To aid in answering inquiries on the selection of such devices, a mimeographed leaflet (NBS Letter Circular 945) was issued in 1949. In 1951 Circular 516, "Selection of Hearing Aids," based on the Letter Circular was issued. The present circular is a revision of Circular 516: the contents of the two circulars are substantially the same although some minor changes have been made, including several suggested by manufacturers of hearing aids.

The Bureau acknowledged "the assistance and suggestions provided by the National Research Council's Committee on Hearing, the Volta Bureau, the American Hearing Society, the Audiology and Speech Correction Center at Walter Reed Hospital, and many interested individuals" in the Preface to Circular 516. The Bureau is again indebted to these groups for their advice on the present Circular—especially to the National Research Council's Committee on Hearing. The Bureau also appreciates the comments and advice of the American Medical Association (Council on Physical Medicine and Rehabilitation), the Veterans' Administration, the Army, the Navy, and the Air Force. Acknowledgment is also due to a number of manufacturers who made valuable suggestions.

A. V. Astin, *Director.*

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Hearing Aids

By Edith L. R. Corliss

1. Introduction

Loss of hearing creates a serious problem. For most of us, the spoken word is our most important channel of communication. Even slight losses can interfere with participation in public affairs, and it does not take a very high degree of loss to hamper a person in conversation within a group.

Most individuals who have difficulty in hearing speech in a group conversation will find that wearing a hearing aid makes it easier for them to carry on their daily affairs. In addition, many people who have difficulty only with faint speech may be considered as "marginal" hearing aid users. These are the individuals whose hearing loss hinders them in public places—at lectures, meetings, and the theater. A hearing aid would be of decided assistance even to them. The instrument need not be very powerful. On the other hand, because persons with a slight loss can make direct comparisons between their unaided hearing and that with an instrument, they tend to be quite critical of the acoustic qualities of the hearing aid.

A person in need of a hearing aid has a special problem, for he himself must decide which instrument gives him the greatest benefit. Hearing aids cannot at present be fitted to individual hearing losses with the same exactitude as eyeglasses can be fitted to the refractive imperfections of the eye. A loss in hearing can occur either because the auditory nerve has become insensitive or because the sound vibrations are conducted inefficiently from the outer to the inner ear. Each of these conditions produces a hearing loss that behaves in a distinctive manner. Loss of hearing is often due to a combination of these causes in various proportions; it is not easy to measure the proportions. Therefore, the effectiveness of a hearing aid with known physical characteristics can be predicted only in a general way. The user must therefore pay close attention to the selection of his own hearing aid if he wishes to be well fitted.

Sections 3, 4, 5, and 6 describe the important properties of hearing aids, some of the criteria for judging them, and recommendations for their special care. To judge a hearing aid and to understand its limitations, it is helpful to consider the properties of sound and hearing that influence the performance of hearing aids. Section 2 contains a brief sketch of this background.

2. Some Properties of Sound and Hearing

The origin of the sensation of hearing is always some kind of energy. The most usual path through which hearing is stimulated starts with periodic pulsations of pressure in the air around us. These pulsations of pressure enter the outer ear and travel down the ear canal.

They induce a to-and-fro motion of the drum membrane. Attached to the inner side of the drum membrane is a little chain of bones, so anchored that they take the relatively free flexible movement of the eardrum and convert it to small but very stiff motions of the fluid that fills the inner ear, or cochlea. (Cochlea is the Latin word for "snail"; the fluid chamber in the inner ear is coiled into a tight little spiral.) Within the cochlea, the fibers of the auditory nerve end in contacts with numerous tiny structures called hair cells. The periodic motions of the fluid surrounding the hair cells give rise to electrical signals in the auditory nerve. The signal ultimately reaching the brain is electrical.

Experiments have been made in which electrical signals applied to electrodes on the head produce the sensation of hearing. The conditions under which this can be done are so special that the method is not at present adaptable for hearing aids. However, these experiments do show that the ear must translate sound pulses into electrical energy. On animals, it has been possible to measure the electrical signals sent out by the inner ear to the brain when ordinary air-borne sound is applied to the ear. In the type of hearing loss called a "nerve" loss, either the inner ear mechanism no longer converts the motion of the fluid efficiently into electrical energy, or the auditory nerve simply does not carry the electrical signals to the brain. An interesting and mystifying quality of nerve loss is that it often acts as though a steep barrier had been placed in the path of hearing. Sounds that have enough energy to override the barrier may appear almost as loud to the person having a nerve loss as they do to a person with normal hearing. Doctors call this effect "recruitment".

If the drum membrane or the bones in the middle ear are defective, they are unable to move the fluid in the inner ear very efficiently. The resulting impairment in hearing is called "middle-ear", or "conductive", loss, because the bones in the ear do not conduct sound very well. A person having this type of loss can use two alternative types of hearing aids. He can use a hearing aid that will supply, by means of an earphone, sound pulses with increased power to his drum membrane, so that even though the middle-ear mechanism is defective, the fluid in the inner ear is set into sufficient motion. Another type of hearing aid by-passes the eardrum altogether. It moves the bones of the skull by means of a vibration device, called a "bone conductor". The motion of the skull induces motion in the fluid of the inner ear, and the sensation of hearing is produced. The bone conductor is employed where use of an earphone is precluded.

We are accustomed to hearing our own voices—in part, at least—through the bones of the head. The quality of the sound transmitted through the head is usually rather different from the sound transmitted through the air. As a result, phonograph recordings of our own voices sound strange to us, though each person can recognize his friends' voices from the recording. Because the sounds of their own voices reach them through the bones of the head rather than through the middle ear, persons with a "conductive" loss often have little difficulty in hearing themselves speak.

A tremendous range of energies will produce audible sound. The loudest sound to which the ear can be exposed without injury has about 1,000,000,000,000 times the energy of the faintest sound that can just be heard. Our experience tells us at once that the ear must use a scale different from that on which these numbers have been written

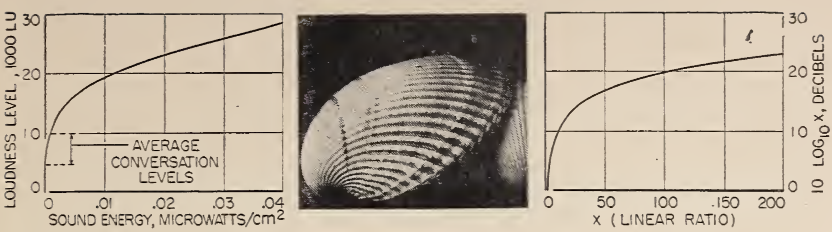

FIGURE 1. *As the curve at the left shows, if the energy of a sound is increased, the sensation of loudness perceived by a listener does not increase as rapidly as the increase in energy.*

The curve at the right shows that the logarithm of a number has much the same property. These curves show that the decibel scale, which is logarithmic, is directly related to loudness. The logarithmic scale is natural—as is shown by the profile of the sea shell (center). The animal must grow in such a way that it retains its shape, so that it continues to fit into the older part of its shell. Growth must therefore be distributed in proportion to the size of the creature already there, the shell thus forms a logarithmic curve.

down. The listener does not judge a very loud sound to be nearly a million million times as loud as the faintest sound he can hear.

The rate at which the sensation of loudness increases with sound energy is most nearly proportional, not to the total amount added, but to the size of the amount added in comparison to the sound energy already present before the addition was made. Everyone agrees that three violins playing together sound louder than one. Suppose you want to double that increase in loudness. It is necessary to persuade more than six violinists to play in unison—you need nine, each playing at the same intensity as the original player. Unless the solo violinist is playing very softly, the problem of producing a sound several times as loud soon exceeds the resources of a symphony orchestra.

The sense of hearing follows a scale that is widespread in nature. The same scale describes such diverse things as the rising of bread dough, the spread of epidemics, and the shape of sea shells.

In figure 1 (left) the curve of loudness is plotted against equal increases in sound energy. Notice that as you move to the right on the horizontal scale (increasing energy), the vertical distance representing increased loudness becomes smaller for equal increases in energy. To a close approximation, the increase in loudness is proportional to the ratio that the sound energy added bears to the total energy present. The scale that deals with increases proportional to the amount already present turns out to be a rather familiar one. Mathematicians call it a logarithmic scale. Loudness is therefore nearly proportional to the logarithm of the sound energy, and in estimating loudness the ear acts on a logarithmic scale. The relation of this scale to the ordinary number scale that we see on rulers and yardsticks—the "linear" scale—can be shown by a line drawn on a graph, as in figure 1 (right). In the horizontal direction, equal distances along the scale are proportional to the ordinary number scale. In the vertical direction, equal distances along the scale are proportional to the common logarithmic scale, which expresses the numbers in terms of the number of times (whole or fractional) that the base number 10 must be multiplied by itself in order to give the ordinary number. This curve has much the same profile as the loudness-energy graph.

Logarithms can be calculated for bases other than 10, and their properties are independent of the base chosen. Squaring the ordinary number always doubles the logarithm, and cubing triples it.

The logarithmic scale agrees with our observation about the violinists no matter which number we choose for a base. However, the number 10 is most often selected as a base because it applies directly to the decimal system of ordinary numbers that we use in our daily life.

The roughly logarithmic relation between the loudness sensation and the sound energy is the reason that sound engineers adopt the decibel unit. The bel, which is equal to 10 decibels, was originally defined as the logarithm to the base 10 of the ratio of the energy put out by a system to the energy applied to its input. However, in dealing with hearing, it is used to express the ratio of the sound energy under discussion to the sound energy at the threshold of audibility. A change of 1 decibel in sound level is about the minimum difference that can be perceived by a careful listener. This amounts to a change of about 26 percent in energy.

Describing hearing loss in decibels gives the ratio between the least sound that a person can hear and the normal threshold. Thus, the sound that can just be heard by a person with a 20 decibel hearing loss has 100 times the energy of the sound at the threshold for a person with normal hearing; correspondingly, a hearing loss of 40 decibels means that the threshold energy required is 10,000 times as great as that for normal hearing. A scale of degrees of hearing loss in decibels is given in appendix 1.

In addition to loudness, we perceive two other properties in a sound: pitch and quality. Pitch is the word used to describe how low or how shrill a sound is. The sensation of sound is produced in our ears by periodic pulsations of pressure in the air around us. Although it is affected by loudness to some minor extent, the pitch of a sound depends primarily upon the rate at which the pulsations occur. This rate, the "frequency" of the sound, is usually expressed in cycles per second (i. e., the number of pulsations per second). Here, again, there is a logarithmic behavior in the ear, that is, doubling the frequency changes the pitch we perceive by what we recognize as one octave. To the ear there is as great an interval between 100 and 200 cycles per second as between 4,000 and 8,000 cycles per second—one octave in each case. The frequency range of pulsations giving rise to auditory sensation extends from 30 cycles per second to about 15,000 cycles per second.

From the quality of their sounds, we recognize at once the difference between a tin whistle and a flute. It turns out, upon investigation, that the sounds of a whistle, though of the same apparent pitch as those of a flute, have an admixture of pulsations of higher frequency than the base tone that determines the pitch. It is the composition of this mixture that we recognize as the quality of the sound.

There is a property related to sound that is often important in the consideration of hearing aids. That property is called "resonance." It describes the ease with which objects are set into sympathetic motion by the rhythmic pulsations of the sound. If the object has a natural mode of vibration (in which it would vibrate by itself if set off) that is of nearly the same frequency as the pulsations in the sound, it may vibrate strongly in sympathy with the sound. A system that is easily set into large motion at its natural frequency is described as "highly resonant." On the other hand, if energy is absorbed by friction, so that the sympathetic motions are limited in extent and duration, the system is said to be "damped."

3. General Properties of Hearing Aids

A hearing aid is simply a personal public-address system. It has a microphone to pick up sounds, a vacuum-tube amplifier to supply additional energy, and an earphone to transmit sound to the ear. Its performance is the result of a number of factors, some of them primarily related to the ear and the brain of the user.

A person with impaired hearing has the right to demand from a hearing aid something more than bare intelligibility. Actually, the brain is capable of piecing together an entire idea from mere fragments of speech sounds. As a result, an individual whose hearing loss is not severe can probably hear and understand speech with almost any hearing aid on the market. This does not mean that he will find it effortless or pleasant. However, at best he can describe the hearing-aid characteristics he desires only in a general manner, as a pleasing or "natural" quality of the transmitted sound. Or he may note that it is easier to hear through some hearing aids than it is through others.

The following discussion describes some of the characteristics of a hearing aid that are directly related to the "something more" in the relationship between the user and his hearing aid. It is only the listener himself who can determine which factor has the most weight in his particular case.

The "gain" of a hearing aid is its fundamental property. Gain represents the relative increase in power that a hearing aid produces in the sound it transmits. If there is a hearing loss, only a small fraction of the sound signal striking the unaided ear reaches the sensory organ in the brain. The hearing aid builds up the sound energy reaching the inner ear until it yields auditory sensation. The gain is a numerical measure of the extent to which the sound energy is built up, or "amplified."

The gain of a hearing aid is not as a rule independent of the frequency (pitch) of the sound signal. However, if the instrument is to function as an aid, it must have a useful amount of gain for sound signals in the frequency range important for speech. Most speech sounds occupy the range between 150 and 6,500 cycles per second. Certain parts of this range are particularly important for the reproduction of speech sounds. The distribution of speech sounds, in frequency and sensation (loudness) level, is shown in figure 2. No sounds necessary for understanding speech occur in the frequency region below 200 cycles per second. As the figure shows, many consonant sounds will be suppressed by hearing aids that do not respond to sound in the upper part of the speech frequency range. The majority of the sounds that give speech its distinctive characteristics lie in the frequency range between 1,000 and 3,000 cycles per second. The older carbon hearing aids, dependent upon resonant microphone and receiver diaphragms to increase their efficiency, were tuned to favor this frequency range. With these instruments, speech can be understood, but many individual vowels and consonants will not be clearly identified.

The curves shown in figure 3 are acoustic gain curves measured on two representative makes of hearing aids. Some idea of how speech sounds through them can be obtained by considering what it would be like if the gain curves were traced over the syllable chart in figure 2. The hearing loss of the user is, however, an additional factor involved in the performance of a hearing aid in service.

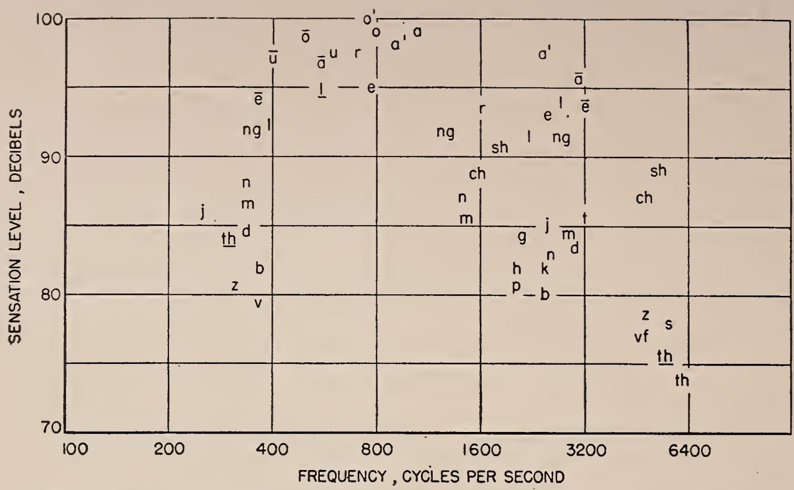

FIGURE 2. *This chart shows how the sounds that make up ordinary speech are distributed both in frequency and in relative loudness.*

For instance, we can see that the "d" sound has important frequencies around 350 cycles (vibrations) per second, and also around 3,000 cycles per second. Unless a hearing aid reproduces these frequencies, the "d" sound will not be clearly heard. The height of the "d" symbols in the chart shows that they are ordinarily spoken with medium loudness compared with other consonant sounds. (Chart from *Speech and Hearing*, by Harvey Fletcher of Bell Telephone Laboratories. D. Van Nostrand Co., Inc., New York, N. Y. Copyright 1929.)

In general, a young or middle-aged person with the type of hearing loss caused by failure of normal conduction of sound to the inner ear can expect good results from a hearing aid. However, if the inner ear itself has become insensitive (as it frequently does in elderly persons and sometimes in young persons), it may not be possible to obtain satisfactory results from a hearing aid.

Ideally, a person using a hearing aid should hear sounds with the same loudness and tone quality as those heard by a listener with unimpaired hearing. In practice, quite a few compromises must be made. A hearing aid cannot provide hearing where the auditory nerve is inactive; it can only amplify sounds for which the user has some auditory nerve perception, however insensitive. In some cases of nerve impairment, sounds when heard at all are perceived to be loud. They may appear as loud to the person with nerve loss as they do to an individual with no hearing loss. But a person who has a hearing loss must wear a hearing aid to enable him to hear sounds he could not hear without the aid. When the sound is amplified to a high level, the intense sound put out by his hearing aid may be intolerably loud to the person suffering from nerve loss, and he may choose to do without the aid.

A listener recognizes large variations of the hearing aid gain with frequency as a "distortion" in the transmitted sound. If the combination of his hearing loss and the gain of the hearing aid results in sudden large changes in compensation near a particular frequency or set of frequencies, sounds occurring near those frequencies will appear to be changed in their characteristics—e. g., the tapping of heels on a floor may sound metallic or thumping. Under such circumstances, some sounds may become difficult to recognize. This type of distortion is commonly called frequency distortion, because it results

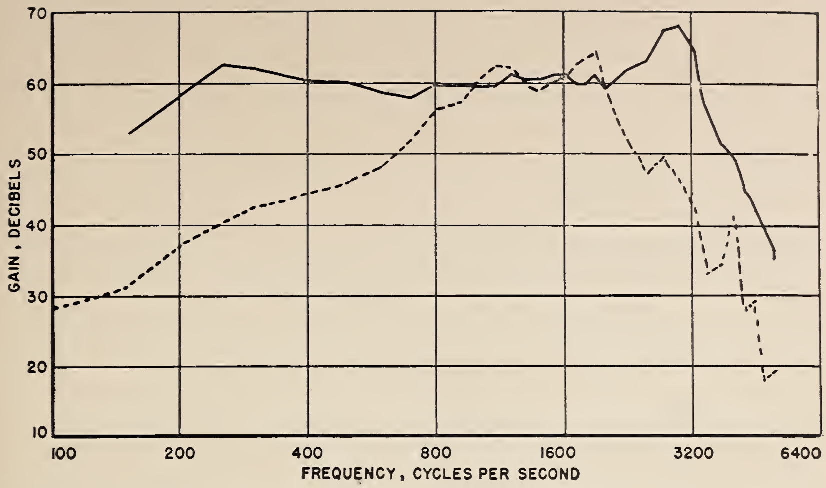

Figure 3. *These curves show the acoustic gain, or amplification, of two individual hearing aids.*

The instruments were of representative makes. Amplification of the two instruments is about the same in the middle frequency range, but differs considerably at higher and lower frequencies.

from inadequate frequency range or from too-sharp variations of gain with frequency.

Another type of distortion may have serious effects upon the sound transmitted by the hearing aid: when the incident sound level is too high for the power handling capacity of the hearing aid, the excess sound energy is converted by the overloaded instrument into sounds of extraneous frequencies. Overload distortion appears to a listener as a noisy blurring of loud speech sounds.

Both frequency and overload distortion in a hearing aid result from the compromises made in order to satisfy the demands for compactness and economy. Some hearing aids are built with microphones and earphones tuned to resonate in the middle of the speech frequency range. This is done to gain battery economy at the expense of uniform amplification, since uniform amplification over a wide frequency range is attained by heavily damping the natural resonances of the microphone and receiver, thus reducing their efficiency. Speech transmitted over a resonant system may sound tinny, but it will probably be intelligible.

In the quest for reduction in size, the "B" battery voltage has been continually decreased. When vacuum tubes are operated at lower voltages they cannot handle as large a signal without overloading. If a hearing aid is designed to operate on two or more "B" battery voltages, the battery having the higher voltage is usually preferable if overload distortion is noticed. Earphones have generally less power-handling capacity when their size is small. Overloading due to small size is most likely to occur at the lower frequencies, introducing overtones in the output sound that blur the sounds of higher frequencies that are important for the recognition of words.

An ear mold that fits properly is necessary for best performance from a hearing aid. The ear mold provides a speaking tube leading to the eardrum of the user from the earphone, which is worn at the entrance to the ear. If it is too loose, sound energy is lost through leakage. The sound energy escaping may be sufficient to reach the microphone of the hearing aid. When this happens, the hearing aid will "squeal" on loud sounds, and it may even squeal continuously.

4. How to Judge a Hearing Aid

In a general way, certain qualities of the sound transmitted to a user's ear by his hearing aid indicate how well his hearing is being compensated for loss. If, without reading lips, he can hear what is said but has some difficulty in recognizing which person is speaking to him, his aid provides insufficient compensation at low frequencies. If, on the other hand, he can recognize the speaker's voice but cannot tell what is being said, the aid does not offer enough compensation at high frequencies. If speech of low intensity is intelligible but loudly spoken words are blurred and noisy, the hearing aid is being used at amplifications greater than those for which it is designed. For higher amplification, it is preferable to use a more powerful instrument. An occasional person with nerve loss may notice this effect with all hearing aids. In this case, however, the distortion arises within his own ear rather than in the hearing aid.

However, blurring of loud sounds may also be noticed in a hearing aid in which some part is wearing out, or when the batteries become weak. If a hearing aid that has not previously overloaded on loud sounds begins to do so and the insertion of new batteries does not remedy the condition, it may be in need of repair.

Where components with natural resonances are present, the amplification is much greater in the immediate neighborhood of the resonant frequencies. As a result, sharp sounds such as heel clicks, drum beats, or typewriter tapping, acquire a musical ringing quality. Certain speech sounds will also be affected by the resonances and will be accompanied by a ringing overtone in the transmitted sound. This may affect the intelligibility of the transmitted speech. A hearing aid that affords uniform amplification over a wide frequency range will transmit sharp sounds with their unmusical and incisive character unaltered.

A person who has unimpaired hearing can locate the direction from which sounds are reaching him because his two ears are independent and located at a distance from one another. The part of the hearing aid that picks up sounds (the microphone) is worn at only one point on the body. Therefore, with a hearing aid, directions from which sounds originate cannot be recognized. This increases difficulties with extraneous noises, since the listener cannot restrict his attention to sounds from a particular direction. In an effort to develop some type of binaural hearing when a hearing aid is used, experiments are now being carried out at several laboratories in the use of two separate instruments.

Tone controls are provided on some hearing aids to enable the listener to adjust the gain characteristics to suit himself. Such controls operate by reducing the amplification at lower frequencies or, sometimes, at both the low and high extremes of the frequency range. Sometimes they are suggested as a means for reducing background noise. Their use may be indicated by the following hypothetical illustration: suppose that one wants to increase the amplification but discovers that increased amplification creates an unpleasant reception because of noise in the higher frequency range; then by cutting the gain in this region by use of the tone control one may be able to increase the volume without the higher frequencies. It should be remembered, however, that reducing the gain at some frequencies—particularly the higher—reduces the amount of information the user gets, and the higher frequencies are particularly important in speech.

A hearing aid cannot discriminate between pleasant and unpleasant sounds. Over the same range of frequencies in which desired sounds occur, there are many irritating noises that cannot be shut out. The screeching of a hinge and the scraping of a fingernail occupy the same frequency region as do the consonant sounds essential for the recognition of words. Moreover, what may be called the "annoyance factor" of sounds is greater at higher frequencies. A person who has for years suffered a progressive loss of high-frequency hearing is therefore likely to find his first experience with a hearing aid somewhat dismaying. If it will enable him to comprehend speech, he will also rediscover the squeaks and clatter previously screened from him by his own diminished hearing. Almost any one inured to the semi-silence of hearing loss may require some time to become readapted to loud sounds. Sensitive individuals may need several months or more to become accustomed to fuller hearing. Eventually most users of hearing aids come to overlook the inevitable noises for the sake of hearing speech with ease.

Feeling that a hearing aid worn in the open is too conspicuous, some people wear their aids under the clothing. Recently, some manufacturers have provided a transparent plastic tube that acts like a speaking tube, leading from the earphone—which may then be concealed in the hair or beneath a collar—to the transparent plastic earmold. Both of these means for hiding the hearing aid decrease the efficiency of the hearing aid for high-frequency sounds. The consonant sounds, which are very important in the understanding of speech, are in the highest pitch range. If the decreased efficiency at high frequencies gives the user trouble, he should discard the devices used for concealment; inadequate hearing may be more permanently conspicuous than an effective hearing aid worn in full view.

There are several tests that an individual can use to assist him in deciding whether he is getting the most help from his hearing aid. An inexact but very practical method for finding out how it behaves is to make an articulation test.

An articulation test is based upon the idea that the primary purpose of a hearing aid is the communication of speech. It is simply a refined method for talking to a subject and determining how much of the speech he can understand. Because understanding is involved, ordinary words common to everyone's daily life must be used. An attempt is made to choose words that represent a good sample of the sounds that make up speech. A set of such word lists, the PB or "phonetically balanced" word lists, has been developed at the Psycho-Acoustic Laboratory of Harvard University.

Two of these PB word lists are given in table 1. One list suffices for a single test, but smaller parts of a single list will not be adequate, because all the speech sounds will not be tested in their proper ratio. To avoid the effects of memory, the words should be copied on cards so that they can be presented in random order. A person who is trying out a hearing aid should get a friend to make this test with him.

Table 1. *Word lists for articulation tests*

PB–50 List 1		PB–50 List 2	
1. ache	26. muck	1. bath	26. neat
2. air	27. neck	2. beast	27. new
3. bald	28. nest	3. bee	28. oils
4. barb	29. oak	4. blonde	29. or
5. bead	30. path	5. budge	30. peck
6. cape	31. please	6. bus	31. pert
7. cast	32. pulse	7. bush	32. pinch
8. check	33. rate	8. cloak	33. pod
9. class	34. rouse	9. course	34. race
10. crave	35. shout	10. court	35. rack
11. crime	36. sit	11. dodge	36. rave
12. deck	37. size	12. dupe	37. raw
13. dig	38. sob	13. earn	38. rut
14. dill	39. sped	14. eel	39. sage
15. drop	40. stag	15. fin	40. scab
16. fame	41. take	16. float	41. shed
17. far	42. thrash	17. frown	42. shin
18. fig	43. toil	18. hatch	43. sketch
19. flush	44. trip	19. heed	44. slap
20. gnaw	45. turf	20 hiss	45 sour
21 hurl	46 vow	21 hot	46 starve
22 jam	47 wedge	22 how	47 strap
23 law	48 wharf	23 kite	48 test
24. leave	49. who	24. merge	49. tick
25. lush	50. why	25. move	50. touch

He should not face the reader, in order that lip reading will not affect the result. The most favorable position is for the reader to be diagonally at one side from the listener so that his face is just removed from the listener's direct line of sight. Interposition of any large obstacle between the reader and the microphone of the listener's instrument should be avoided in the test.

The presentation of the words should be done carefully. To present them naturally, they should be spoken in a sentence in a normal conversational tone. The sentence must be chosen so that the test words cannot be inferred from the rest of the sentence. A carrier sentence commonly used is "You will say * * * now." This sentence has the advantage that the "a" sound in "say" is a high-level sound and can be used by the speaker for checking on his voice level. The sentence should be spoken at ordinary conversational level.

It is unlikely that the person making the test will get 100 percent of the words correctly. Even under ideal communication conditions (with two persons in the same quiet room, but not facing each other) the random word articulation scores are usually 95 percent. Apparently, individuals with normal hearing actually judge the remaining 5 percent of the words in ordinary conversation by familiarity, context, or lip reading.

By noticing the particular speech sounds that are missed by the listener in writing down the word list, and comparing them with the chart in figure 2, it is possible to get some idea of the particular way in which the hearing aid fails to compensate for hearing loss.

Perhaps the simplest way for determing whether a hearing aid has a resonance is to listen to footsteps or a typewriter and note whether a particular note seems to be favored. If there is access to a piano, the resonance can be noticed by having someone play through the keyboard range several times with a uniform touch. If the hearing aid gain is uneven, certain notes will sound markedly louder or softer than the rest. Experimentation shows that peaks can be detected in this way if they are greater than 20 decibels in magnitude.

5. Guidance in Choosing a Hearing Aid

The first step in overcoming loss of hearing is to determine whether the condition responsible for the loss can be remedied or at least checked in its progress by medical treatment. The nature of the hearing loss should be found in order to know whether the loss can be compensated by a hearing aid. For the answers to these questions a physician, preferably an ear specialist, should be consulted.

If medical examination indicates that a hearing aid will be helpful, the next problem is the selection of the instrument. Numerous makes are on the market offering a wide variety of choices. Most manufacturers offer two or more models. Some dealers undertake to provide assistance in the selection of a particular model (from among their own instruments) by methods more or less similar to those outlined in the previous section.

A person shopping for a hearing aid may find it helpful to take with him a person with normal hearing so that, as he tries out different instruments, he may listen to words spoken by the same person. The prospective user should if possible try out one or more hearing aids in his own ordinary surroundings. Some companies provide a trial plan, occasionally charging a nominal rental that may be applied to the price of the instrument if it is purchased.

The American Medical Association maintains a list of hearing aids that meet its standards as to acceptability. An "accepted" instrument provides amplification that is at least sufficient for a person with moderate hearing loss. The list of accepted hearing aids may be obtained from the Council on Physical Medicine and Rehabilitation, American Medical Association, 535 North Dearborn Street, Chicago 10, Ill. The same list is also available from the American Hearing Society, 817 14th Street, N.W., Washington 5, D. C.

After the hearing aid is selected, there is often the problem of indoctrination and of learning to make the best use of the hearing aid. This problem may be severe if the user has waited so long before purchasing a hearing aid that he has begun to forget what voices and noises really sound like and how noisy the world is. Also he may have waited until he is too old to learn readily how to adapt himself to a new device. The quality of speech heard through a hearing aid may be different from that to which he has become accustomed. The transition may be considerably helped by wearing the instrument for only an hour or two each day at first and by some systematic "auditory training" or practice in listening.

To assist the hard of hearing in some of these problems a number of "hearing centers" have been established throughout the country. Most of them are nonprofit civic enterprises under the auspices of local universities or hospitals; frequently a nominal fee for their services is charged to those who can pay it.

These centers provide a variety of services, including in many cases advice on the selection of hearing aids. Practically all of them give hearing tests. Many offer otological examination by an ear specialist, and the majority provide other forms of assistance such as auditory training, lip reading, speech training, and vocational counseling.

The hearing centers that offer demonstrations of hearing aids give prospective users an opportunity to try the types they have. Manufacturers are invited to submit instruments representing their current models, and although not all manufacturers are represented a wide variety of makes is usually available. This program has been assisted by a number of manufacturers and dealers who have supplied hearing aids voluntarily to the hearing centers. In general only instruments accepted by the American Medical Association are used by the centers. Partly because hearing centers cannot provide samples of all makes of hearing aids, they cannot be sure of guiding a person to the hearing aid best suited for him, but can give him a general idea of the compensation provided by hearing aids of various types. The centers do not sell hearing aids; an individual goes to commercial sources of supply to purchase his own instrument.

An information service on the problems of the hard of hearing is maintained by the Volta Bureau, 1537 35th Street, N.W., Washington 16, D. C. This organization was founded by Alexander Graham Bell to serve as an information center for the hard of hearing and for teachers of the deaf. It has prepared literature on the problems of hearing loss, available to the public upon written request. Similar assistance is offered by the American Hearing Society. The American Hearing Society will send to any inquirer a list of services for the hard of hearing available in its own chapters and in colleges and universities. Information as to hearing aids accepted by the American Medical Association and also concerning hearing centers can be obtained from the Audiology Foundation, 1104 South Wabash Avenue, Chicago 5, Ill. A list of hearing centers, as of 1951, compiled from information furnished by the Volta Bureau and by the Audiology Foundation is given in appendix 2.

6. Care of a Hearing Aid

A hearing aid is somewhat different from other devices that a person uses in his daily life, and a small amount of special care in handling it may pay substantial dividends in increased usefulness and better performance. The sensitive crystal element in most microphones and in some earphones is injured by exposure to high temperatures, and will be ruined permanently by temperatures above 120° F. Such temperatures may be produced locally if the aid is left lying in the sun, in a closed parked car, or too near a radiator. In several instruments these components are made of special high-temperature crystals or of magnetic materials which can withstand somewhat higher temperatures. However, batteries also deteriorate more rapidly at elevated temperatures. For such reasons, it is well to protect aids from extremes of temperature. The aluminum foil on the microphone is a basic part; the foil should not be pressed or scratched, or the quality of the transmitted sound may suffer.

The electrolyte in the batteries is either a moderately strong acid or a strong alkali and may cause damage if the battery cases leak. This is likely to happen when the batteries are run down. For this reason, it is advisable to separate the batteries from the instrument when it is not being worn, especially if the batteries are mounted in the amplifier case. Since the battery case is consumed in the chemical process that produces electricity in the battery, it is usually not practical to recharge the batteries. Although this is sometimes suggested as an economy measure, the probability of leakage or bursting is greatly increased because the case material is not renewed by recharging. There are some cells on the market designed for recharging. They are true storage batteries and are usually somewhat larger, heavier, and more expensive than dry-cell batteries. In an emergency, flashlight cells can be substituted for hearing-aid cells of the same size. However, flashlight cells are designed for heavy but intermittent drains, and may not give as long service as the hearing-aid cells, which are built for the continuous light drain taken by hearing aids.

In warm, humid climates a hearing aid may "pass out" temporarily on a particularly damp day. The microphone and earphone are hermetically sealed, but the seal may not remain perfect, and occasionally the loss in sensitivity is due merely to moisture condensing on the exterior surfaces of the amplifier parts, between the wiring. A hearing aid may be dried out by keeping it in a desiccator [1] when not in use (fig. 4). It can also be dried out by placing it overnight in a

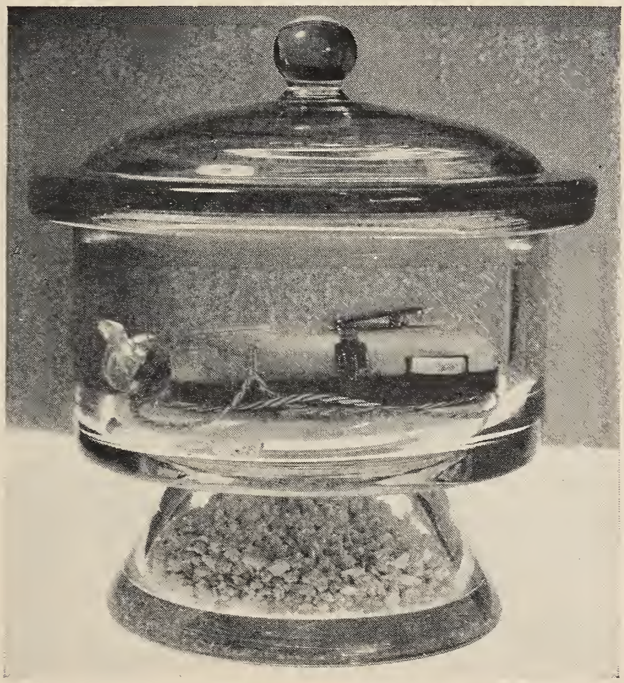

FIGURE 4. *A hearing aid that has "passed out" because of humidity is easily dried out by putting it in a desiccator—a tight container with a chemical drying compound.*

The aid rests on a perforated plate above the drying agent (base of desiccator). The desiccator shown is the type used by chemists, but any tight box will do. The hearing aid must be kept from direct contact with the drying agent.

[1] A desiccator is a container having a chamber in which a chemical compound for absorbing water may be placed. The compound will remove moisture from objects stored in the container, and may be renewed when saturated. Desiccators are sold by chemical and laboratory supply firms.

mechanical refrigerator, provided it is not exposed to moist air before it returns to room temperature. Neither a "cold-wall" refrigerator nor an ice-box will work, however, because the drying action depends on condensing the moisture on the refrigerator coils.

Appendix 1. Scale of Degrees of Hearing Loss[a]

(Prepared by the Committee on Hearing of the National Research Council)

Class	Name	Loss for speech, in decibels[b]	Remarks
A	Normal	Not more than 15 in worse ear.	Both ears within normal limits. No difficulty with faint speech.
B	Near normal	More than 15 but not more than 30 in *either* ear.	Has difficulty only with faint speech.
C	Mild impairment.	More than 30 but not more than 45 in *better* ear.	Has difficulty with normal speech but not with loud speech.
D	Serious impairment.	More than 45 but not more than 60 in *better* ear.	Has difficulty even with loud speech.
E	Severe impairment.	More than 60 but not more than 90 in *better* ear.	Can hear only amplified speech.
F	Profound impairment.	More than 90 in *better* ear	Cannot understand even amplified speech.
G	Total loss of hearing in *both* ears.		Cannot hear any sound.

[a] This scale refers solely to hearing and does not take into consideration a man's competence with hearing aids, lip reading (speech reading), etc.
[b] The classes are defined by "decibels loss of hearing for speech." Until suitable technical facilities for direct measurement by speech audiometry are available, the loss of hearing for speech shall be calculated from pure-tone air-conduction measurements by averaging the hearing losses at 500, 1,000, and 2,000 cycles per second, or at 512, 1,024, and 2,048 cycles per second if the available audiometers are so calibrated. A person should be classified one class lower than indicated by the average value if, with an average loss of 10 decibels or more, his hearing loss for any one of the three frequencies is greater by 25 decibels (or more) than the least of his three losses.

Appendix 2. Hearing Centers

The following list of hearing centers has been compiled from lists furnished by the Volta Bureau, 1537 35th St., N.W., Washington 16, D. C., and the Audiology Foundation, 1104 So. Wabash Ave., Chicago 5, Ill. The list below is incomplete: full and up-to-date lists may be obtained from the above organizations. For lists of chapters of the American Hearing Society, write to the American Hearing Society, 817 14th St., N.W., Washington 5, D. C. This list is included as an aid for the reader. The listing does not constitute an endorsement either by the National Bureau of Standards, or the Audiology Foundation, or the Volta Bureau.

(1) Hearing Centers for the Public

Appointments must generally be made in advance. Some of these centers charge a fee: inquiries should be made about this to avoid misunderstanding.

ALABAMA

Talladega: Dowling Hospital, Alabama Hearing Center.
Tuscaloosa: University of Alabama, Speech and Hearing Clinic.

CALIFORNIA

Alhambra: National Auricular Foundation, Inc., 612 W. Shorb.
Bakersfield: Kern County Hospital, 1830 Flower St.
Inglewood: Inglewood Hearing Clinic, Masonic Temple, 230 S. Grevillea Ave.
Los Angeles: Speech and Hearing Clinic, University of Southern California, 930 W. 37th St.; Los Angeles Eye and Ear Hospital, 500 S. Lucas Ave.; Los Angeles State College, 855 N. Vermont Ave.

Palo Alto: Stanford University, Department of Speech.
Pasadena: Huntington Memorial Hospital, Pasadena Dispensary.
San Diego: San Diego Hearing Society, 3843 Herbert St.
San Francisco: Mount Zion Hospital, 1609 Scott St.; San Francisco Hearing Society, 414 Mason St.; San Francisco State College, Herman and Buchanan Sts.
Stockton: College of the Pacific.
Whittier: Whittier College Speech and Hearing Clinic.

COLORADO

Denver: Hearing Clinic, Denver University; Evans School, School District No. 1.

CONNECTICUT

Hartford: Hartford Hearing League, 252 Asylum St.
New Haven: Audiology Clinic, Grace-New Haven Community Hospital, 789 Howard Ave.

DELAWARE

Wilmington: Delaware Hospital, Audiology Clinic, 501 W. 14th St.

DISTRICT OF COLUMBIA

Washington: Hearing Rehabilitation Center, 1911 R St. N.W.; Washington Hearing Society, 2431 14th St. N.W.

FLORIDA

Gainesville: Speech and Hearing Clinic, University of Florida.

GEORGIA

Atlanta: Davison School of Speech Correction, 1780 N. Decatur Ave.; Grady Memorial Hospital.

ILLINOIS

Chicago: Chicago Hearing Society, 30 W. Washington St.; Speech and Hearing Rehabilitation Clinic, University of Illinois, 904 W. Adams St.; Department of Otolaryngology, University of Chicago; Hearing Clinic, Department of Otolaryngology, Northwestern University, 303 E. Chicago Ave.; Speech and Hearing Rehabilitation Service, St. Luke's Hospital, 1439 S. Michigan Ave.
Evanston: Hearing Clinic, School of Speech, Northwestern University.
Normal: Illinois State Normal University, Department of Speech.
Peoria: Speech and Hearing Clinic, Bradley University.
Rockford: Rockford College, Speech Department.
Urbana: Speech Clinic, University of Illinois.

INDIANA

Bloomington: Speech and Hearing Clinic, Indiana University.
Indianapolis: Indiana University Medical Center.
LaFayette: Speech and Hearing Clinic, Purdue University.
Muncie: Speech and Hearing Clinic, Ball State Teachers College.
South Bend: South Bend Hearing Society, 203 Poledor Bldg.
Terre Haute: Special Education Clinics, Indiana State Teachers College.

IOWA

Des Moines: Des Moines Hearing Society.
Iowa City: Speech Clinic and Department of Oral Surgery and Otolaryngology, State University of Iowa.

KANSAS

Kansas City: University of Kansas Medical Center, 39th and Rainbow.
Wichita: Institute of Logopedics, Municipal University of Wichita.

KENTUCKY

Louisville: Louisville General Hospital.

LOUISIANA

Baton Rouge: Speech Department, Louisiana State University.
New Orleans: New Orleans League for Better Hearing, 530 Capdeville.

MAINE

Portland: Portland Hearing Society, 653A Congress St.

MARYLAND

Baltimore: Baltimore Hearing Society, Inc., 322 N. Charles St.; Hearing and Speech Center, Johns Hopkins University and Hospital.

MASSACHUSETTS

Boston: Boston Guild for the Hard-of-Hearing, 283 Commonwealth Ave.; Institute for Speech Correction, 419 Boylston St.; Massachusetts Memorial Hospital, Boston University School of Medicine; Winthrop Foundation and Clinic for the Deaf, Massachusetts Eye and Ear Infirmary, 243 Charles St.
Springfield: Springfield Hearing League, Inc., 1694 Main St.
Worcester: Worcester Hearing League, 306 Main St.

MICHIGAN

Ann Arbor: Institute for Human Adjustment, Speech Clinic, University of Michigan.
Detroit: Detroit Hearing Center, 535 W. Jefferson.
East Lansing: Speech and Hearing Clinic, Michigan State College.
Kalamazoo: Constance Brown Society for Better Hearing, 210 Pratt Bldg.
Mount Pleasant: Central Michigan College of Education, Speech and Hearing Clinic.

MINNESOTA

Minneapolis: Speech Clinic, University of Minnesota.
Rochester: Mayo Clinic, Audiological Section.

MISSOURI

Columbia: Speech and Hearing Clinic, University of Missouri.
St. Louis: Central Institute for the Deaf, 818 S. Kingshighway.

NEBRASKA

Lincoln: Speech and Hearing Laboratories, University of Nebraska.

NEW JERSEY

Newark: State Teachers College, 187 Broadway.
West Trenton: Hearing Clinic, New Jersey State School for the Deaf.

NEW MEXICO

Albuquerque: Speech Laboratory, University of New Mexico.

NEW YORK

Albany: Conservation of Hearing Clinic, Albany Hospital.
New York: Apostolate for the Deaf and Hard of Hearing, 191 Joraleman St., Brooklyn; Department of Otolaryngology, New York Hospital, Cornell Medical Center, 525 E. 68th St.; Hard of Hearing Clinic, Jewish Hospital of Brooklyn; Harlem Eye and Ear Hospital, New York City; Hearing Rehabilitation Center, Mary Wood Whitehurst, 330 E. 63rd St.; Manhattan Eye, Ear, and Throat Hospital, 210 E. 64th St.; New York City Hospital, Welfare Island Dispensary, 80th St. and East End Ave.; New York Eye and Ear Infirmary, 218 Second Ave.; New York League for the Hard of Hearing, 480 Lexington Ave.; New York University, Bellevue Medical Center, New York City; Section of Audiology and Phonology, Presbyterian Hospital, 622 W. 168th St.; Queens College Speech Department, Flushing.
Rochester: The Genesee Hospital. Rochester Hearing Society, 130 Clinton Ave. S.
Syracuse: Conservation of Hearing Center, Syracuse University.
Utica: Speech and Hearing Center, The Children's Hospital Home.

NORTH CAROLINA

Durham: Duke University, Division of Otolaryngology.

OHIO

Athens: Speech and Hearing Clinic, Ohio University.
Bowling Green: Speech and Hearing Clinic, Bowling Green State University.
Cincinnati: Cincinnati League for the Hard of Hearing, 616 Walnut St.
Cleveland: Cleveland Hearing and Speech Center, 11206 Euclid Ave.
Columbus: Speech and Hearing Clinic, Ohio State University.
Kent: Speech and Hearing Clinics, Kent State University.
Oxford: Speech Department, Miami University.
Toledo: Toledo Hearing League, 2313 Ashland Ave.
Youngstown: Youngstown Hearing Society.

OKLAHOMA

Chickasha: Speech and Hearing Clinic, Oklahoma College for Women.
Norman: Speech and Hearing Clinic, University of Oklahoma.
Oklahoma City: Crippled Children's Hospital (University of Oklahoma), Speech and Hearing Clinic.

OREGON

Eugene: Speech and Hearing Clinic, University of Oregon.
Portland: Portland Hearing Society, Inc., 39 Selling-Hirsch Bldg; Department of Otolaryngology, University of Oregon, Medical School.

PENNSYLVANIA

Lancaster: Hearing Conservation Center of Lancaster County, Inc., 24 N. Lime St.
Philadelphia: Philadelphia Society for Better Hearing, 2115 Chestnut St.; Department of Oto-Rhinolaryngology, Temple University; Audiology Center, University of Pennsylvania.
Pittsburgh: Department of Audiology, Eye and Ear Hospital, Medical School of Pittsburgh, 230 Lothrop St.; Pittsburgh Hearing Society, Granite Bldg., Sixth and Wood.
Reading: Clinic for Rehabilitation of the Hard of Hearing, Reading Hospital.
State College: Speech and Hearing Clinic, Pennsylvania State College.

RHODE ISLAND

Providence: Providence League for the Hard of Hearing, 42 Weybosset St.

TENNESSEE

Memphis: Memphis Speech and Hearing Center, University of Tennessee, College of Medicine.
Nashville: Tennessee Hearing and Speech Foundation, Vanderbilt University Hospital.

TEXAS

Austin: Speech Clinic, University of Texas.
Denton: Hearing and Speech Clinic, Texas State College for Women.
Galveston: Department of Otolaryngology, University of Texas, Medical Branch.
Temple: Scott-White Clinic.

UTAH

Salt Lake City: Speech and Hearing Center, University of Utah.

VIRGINIA

Charlottesville: Speech and Hearing Clinic, University of Virginia.
Richmond: Hearing-Speech Center, Medical College of Virginia.
Roanoke: Gill Memorial EENT Hospital.

VERMONT

Rutland: Vermont Association for the Crippled, Inc.

WASHINGTON

Seattle: Speech and Hearing Clinic, University of Washington.

WISCONSIN

Madison: Speech and Hearing Clinic, University of Wisconsin.
Milwaukee: Marquette University, Speech Clinic and Hearing Laboratory, 625 N. 15th St.; Hearing Clinic, Milwaukee State Teachers College.

(2) Hearing Centers for Veterans

CALIFORNIA

San Francisco: Veterans Hospital, Fort Miley, 42nd and Clements Sts.

DISTRICT OF COLUMBIA

Washington: Walter Reed General Hospital, Audiology and Speech Correction Center, Forest Glen Section.

GEORGIA

Atlanta: Veterans Administration Regional Office, Belle Isle Bldg., 105 Pryor St., S. E.

MICHIGAN

Detroit: Wayne University Speech and Hearing Clinic, 467 Kirby.

MISSOURI

Kansas City: Veterans Administration Regional Office, 1828 Walnut St.

NEW YORK

New York: Audiology Clinic, New York Regional Office, Veterans' Administration, 252 Seventh Ave.

PENNSYLVANIA

Philadelphia: Aural Rehabilitation Center, U. S. Naval Hospital.

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