BELL LABORATORIES RECORD

EVALUATING AIDS TO HEARING
Harvey Fletcher

MUSIC WIRE SPRINGS
I. V. Williams

METALLIC FINISHES TO COMBAT RUST
R. B. Mears

JANUARY 1933 VOL. 11 NO. 5

Bell Laboratories Record

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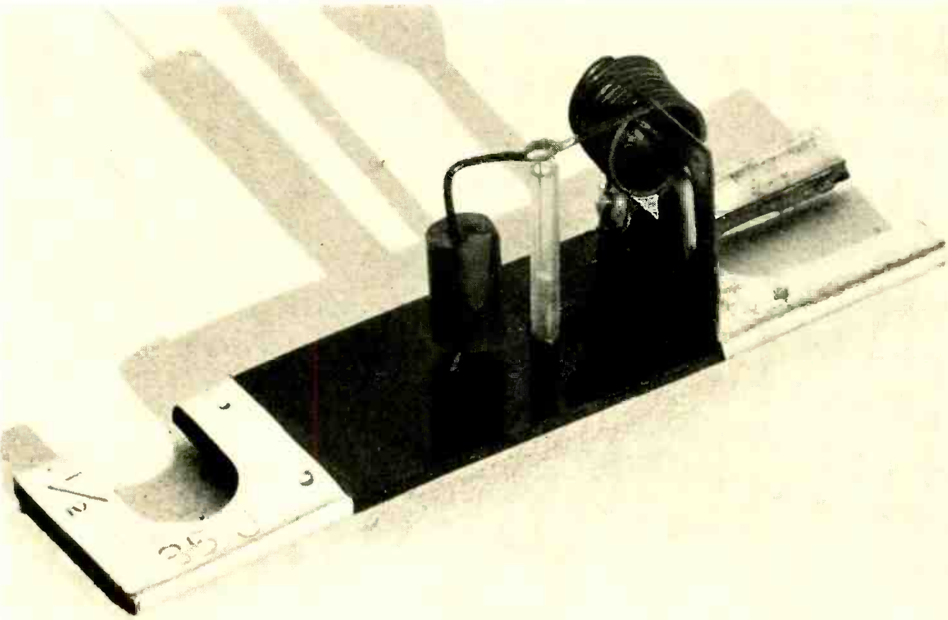
In this Issue

Frontispiece

When this central-office fuse blows, the spring makes a contact which rings an alarm, and at the same time raises the colored glass indicating head so that it can be quickly located and the fuse replaced.

BELL LABORATORIES RECORD



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Evaluating Hearing Aids*

By HARVEY FLETCHER
Acoustical Research Director

WHEN a patient who is hard of hearing asks an otologist to recommend him a hearing aid, the advice he may receive is to try two or three aids and determine for himself which if any is of service. It is not surprising that such advice is frequently unsatisfactory to him. Exhaustive trial would require the patient to use a great variety of devices under an even greater variety of conditions, and to hold in his "mind's ear" a sufficiently exact memory of his experiences to permit their comparison.

It seems entirely possible to replace this procedure by one far more convenient to pursue and more accurate in its results. The body of quantitative knowledge concerning speech and its interpretation, types of deafness, characteristics of hearing aids and the reactions of deafened persons is sufficient to permit very specific recommendations to those hard of hearing. A "figure of merit" for any device can be determined with considerable confidence for any patient without his even trying the instrument.

The successive sounds of speech vary considerably in loudness. This property of speech is well illustrated by Figure 1, where the loudness of the sentence, "Joe took Father's shoe bench out," is plotted against time. When conversational speech is delivered with normal intensity and observed at a distance of a meter, the loudest sounds are about 70 db, and the weakest about 40 db, louder than the faintest sound that can be heard by a normal person. Although the intensities of speech vary with different speakers, in ordinary conversation comparatively few persons speak as much as 10 db louder or softer than the average.

A person, then, whose hearing loss is not greater than 30 db, will have little difficulty in hearing ordinary conversational speech. One with a 40 db hearing loss, that is whose threshold of

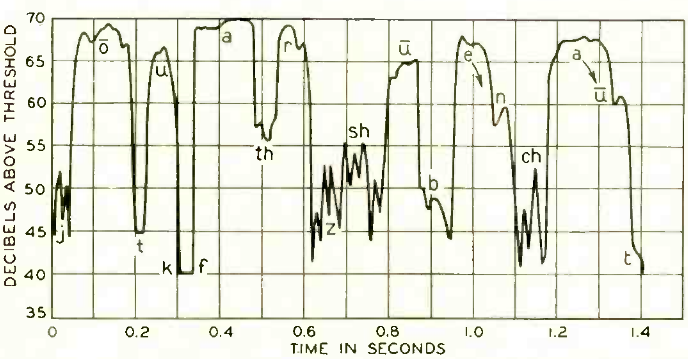


Fig. 1—The remark, "Joe took Father's shoe bench out" varies rapidly in loudness between 70 and 40 db above the threshold of audibility of a person of normal hearing one meter from the speaker

*This material was first delivered in a paper presented by Dr. Fletcher before the Annual Meeting of the American Laryngological, Rhinological and Otological Society, Inc., held in Atlantic City, May 23–25, 1932.

audibility is the 40 db line in Figure 1, experiences some difficulty in hearing the fainter portions of speech, but it is removed when the speaker, recognizing the difficulty, raises his voice or moves closer. In such case, any advantage from using an aid would be more than offset by its inconvenience.

If this hearing loss is between 50 and 60 db the listener will hear only the vowel sounds for a speaker one meter away, and "Joe took Father's shoe bench out" will sound like ō, u, a, r, ū, e, a, ū. When the hearing loss exceeds 70 db, no sounds whatever will be heard at a distance of one meter. Of course by bringing the mouth of the speaker close to the ear of the listener, and so increasing the speech intensity about 40 db, a person with a loss as great as 80 db can be made to hear speech, but this is an embarrassing expedient, and a hearing aid is preferable.

All these considerations are generalized in the observation that, since the softest speech sounds are 40 db above the threshold of audibility, for conversation at a distance of a meter a person who is hard of hearing will require an aid with amplification in db at least equal to his hearing loss in db minus 40. There are a number of hearing aids on the market which can be used to give amplifications variable between 0 and 40 db, and in that respect are serviceable to persons with hearing losses between 40 and 80 db. In cases of losses near 80 db it is frequently necessary to decrease the effective distance of the speaker to less than a meter by placing the microphone of the aid nearer the speaker.

Those whose hearing loss exceeds 80 db require greater amplification than the ordinary set will provide. At the present time the required amplification can best be attained by the use of vacuum tubes. The resulting sets are necessarily bulky and expensive, but they are a great boon to those who need them.

Where hearing loss exceeds 110 db, a new limitation, the threshold of feeling, complicates the problem. The patient's threshold of audibility is now so close to his threshold of feeling that there is not room between them for the 30 db variation in speech volume shown in Figure 1. Amplification sufficient to make the softer sounds audible will be so great that the louder sounds cause pain. Moreover, deafness of this severity is usually accompanied by defects in the hearing mechanism which so greatly distort the sounds that, even with sufficient amplification, it is difficult to interpret the sounds heard. These sufferers, unfortunately, cannot be helped by any acoustic equipment now in prospect.

Roughly speaking, then, the hard of hearing can be classified, with reference to hearing aids, into four groups. Persons whose hearing loss is less than 40 db will not be helped sufficiently by hearing aids to justify the inconvenience of using such devices. Those whose loss is between 40 and 80 db can be greatly helped by one or another of the usual aids. Those who lose between 80 and 110 db of speech volume, and unaided can hear only a speaker who shouts at very close range, can converse without much repetition by the use of vacuum-tube amplifying equipment. Sufferers from losses greater than 110 db are at present beyond assistance.

Satisfactory hearing, however, is dependent not only on the ability to hear the sounds of speech but the ability to understand them when they are heard. This latter ability depends greatly on the extent to which the relative intensities of the many pitches

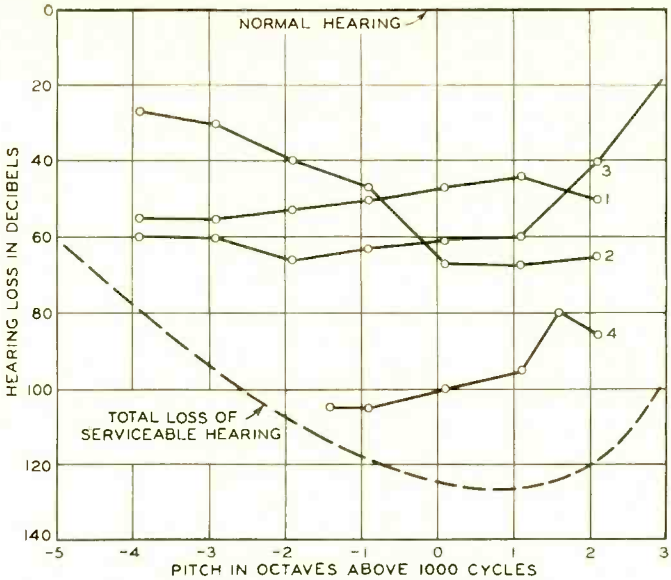


Fig. 2—These audiograms of the right ears of four persons hard of hearing typify three sorts of moderate hearing difficulty and one sort of extreme deafness

departures from uniform loss do not entirely destroy the intelligibility of speech because sounds can often be interpreted even when considerably distorted. Lack of uniformity may more or less impair intelligibility, however.

Generally speaking it would seem likely that a hearing aid, to be most useful to a patient, should give a greater amplification at the pitches where his loss is largest and vice versa, so that the overall effect of his ear and his aid would be a uniform amplification of the sounds, sufficient to bring the faintest above the threshold of audibility. In some types of distorting deafness, to be sure, the patient becomes adept at interpreting the distorted sounds. When first he listens through a set which corrects the distortion, he may experience greater difficulty in understanding, but in the long run he might expect to understand better with the set than he ever did without it. The phenomenon is somewhat similar to that of becoming accustomed to lenses which correct visual astigmatism. Such special design, manifestly prohibitive in cost and bulk, is not actually necessary, but a choice of the set which most nearly approximates this ideal is probably desirable.

It is in cases where hearing loss is greatest at the high pitches that such a choice is most important. Figure 1 shows that it is the consonant sounds of speech which are faintest. These sounds are also those whose intelligi-

which compose each sound remain unchanged as they pass from the speaker's mouth to the listener's ear. The conclusion so far reached would be strictly true, therefore, only if the patient's hearing loss and the hearing aid's amplification were uniform at all pitches. In fact, however, uniform loss seldom occurs, and uniform amplification is never even approximated by a hearing aid. Audiograms showing the hearing loss at different pitches for four persons hard of hearing are shown in Figure 2; and the amplifications provided at different pitches by three commercial sets are shown in Figure 3.

The upper audiograms illustrate three familiar types of hearing difficulty: (1) that in which the hearing loss is approximately uniform, (2) that in which the loss is greater at high pitches than at low, usually due to nerve deafness, and (3) that in which the loss is greater at low pitches than at high, not often encountered. These bility depends most greatly on their high-pitched components, and thus become inaudible to one whose hearing loss is greater at these pitches. The vowel sounds are the loudest, and thus a person whose hearing loss is greater at low pitches can tolerate an average hearing loss far larger than that of his consonant-deaf fellow, It is for this reason that patients whose audiograms are horizontal or slope upward (Figure 2) are usually helped by a commercial hearing aid, while patients with nerve-deafness are often told that they cannot be helped. They may, in fact, be helped by a set whose amplification is greater at the higher pitches, but since the impairment of their hearing is due to an abnormal condition of the auditory nerve, it will always be more difficult for them to understand than for those whose auditory nerves are unaffected.

Still more specific advice can be given, however, on the basis of the accumulated data as to the contributions by different pitch ranges to the intelligibility of speech. If a certain range of pitches is removed from speech before it reaches a listener's ear, the listener will misinterpret some of the sounds he hears. This proportion is nearly uniform for all those of normal hearing, but depends upon the particular pitch range which is removed. It is possible to assign to each range into which speech may be divided a fraction which measures the proportion which it contributes to intelligibility. The sum of all these fractions is approximately one, corresponding to the nearly perfect intelligibility which is secured where the entire region of speech pitches is unmolested (Table I). If one of these ranges is now removed it will not contribute its share toward making speech intelligible, and the omission of its fraction will result in a sum correspondingly less than unity.

Similarly if a certain pitch range is not entirely removed but merely lowered in volume, the effect of this lowering on intelligibility is fairly closely predictable for any pitch range and any amount of lowering. The fraction which measures this diminished contribution is smaller than that which measures the contribution of the unattenuated range. For each pitch range a series of fractions can be found, measuring its contribution to intelligibility when its volume is lowered by different amounts, and growing smaller as the volume is

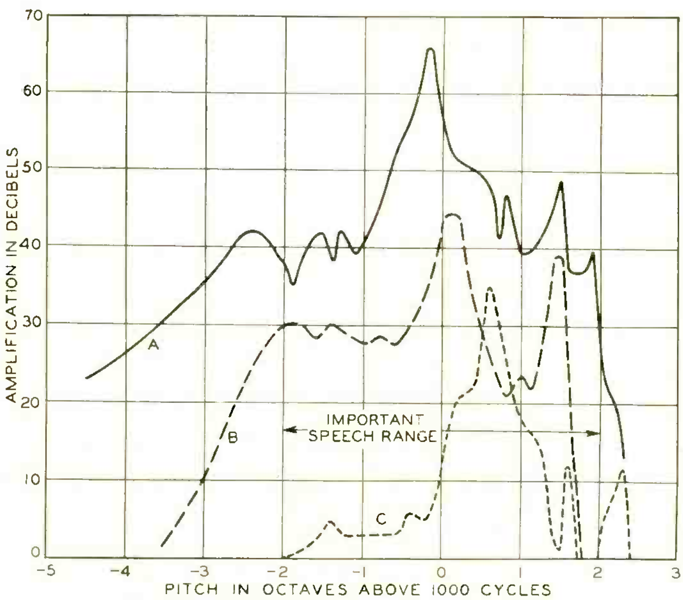


Fig. 3—The amplifications given by hearing aids may, as in these cases, vary greatly with pitch

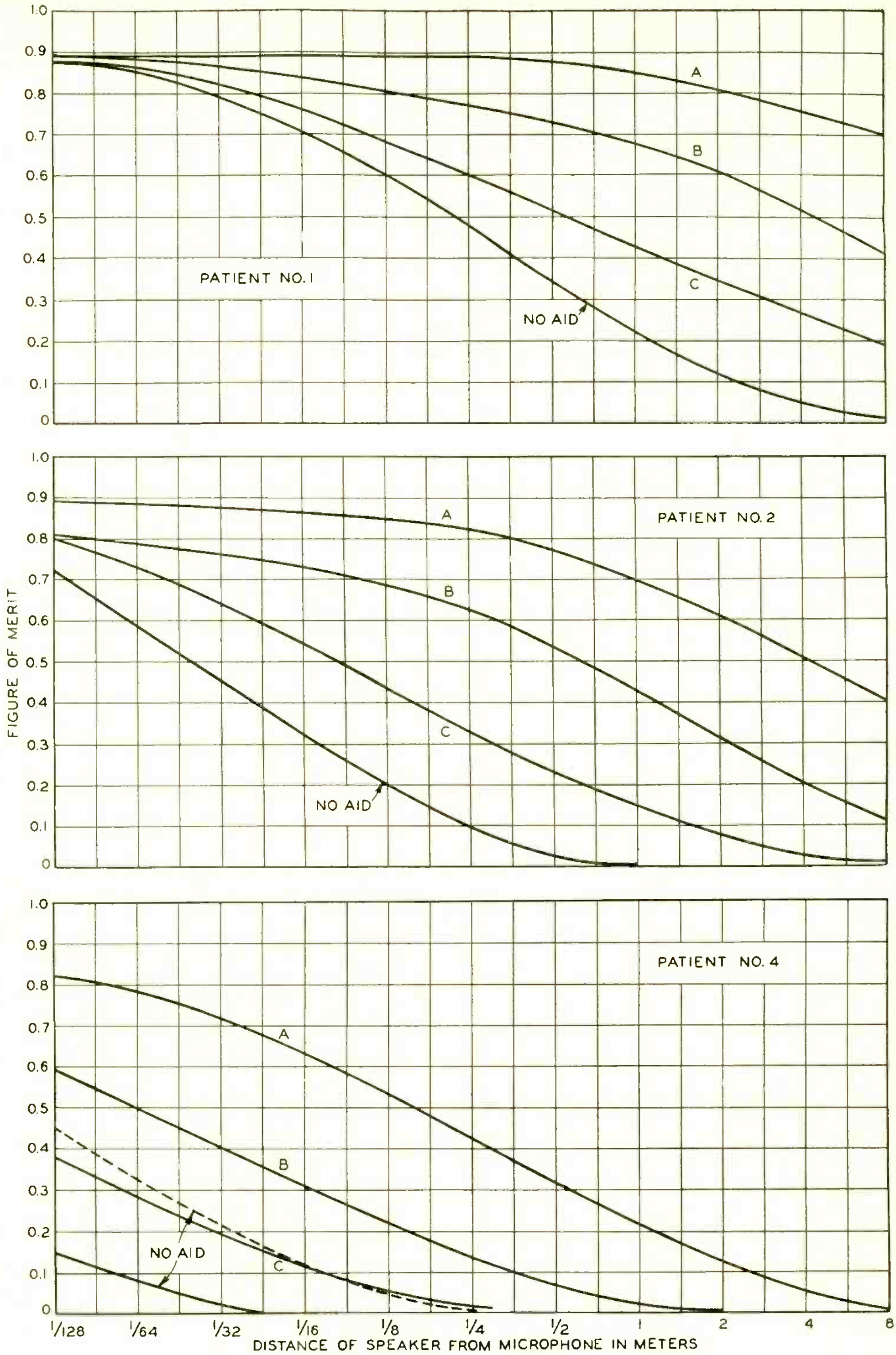


Fig. 4—Figures of merit for Patient No. 1, *No.* 2, *and No.* 4

lowered. To measure the intelligibility of speech when its several component pitch ranges are at different volumes, the fractions corresponding to each range at its volume are added. The smaller the resulting sum, the lower the intelligibility.

The intelligibility of speech to one hard of hearing can also be measured in this way, since the most important effect of an affection of the hearing is to reduce the apparent volumes of the various pitch ranges by the amounts shown as hearing losses on the patient's audiogram. Patient No. 1 of Figure 2, for instance, can be regarded as a person with normal hearing who is listening to speech through a device which reduces the volume of the range* between −4 and −3 by 55 db, between −3 and −2 by 53 db, and so on. The measure of intelligibility for him is the sum of the fractions for all ranges—each fraction corresponding to the volume shown on his audiogram.

TABLE I

Pitch	*Contribution to Intelligibility*
−2.0	0.008
−1.5	0.044
−1.0	0.075
−0.5	0.091
0.0	0.103
0.5	0.116
1.0	0.169
1.5	0.151
2.0	0.131
2.5	0.104
	0.992

Table I—*Different pitch ranges have different importances in contributing to the intelligibility of speech. In the above table these importances are given ratings, shown opposite ten frequencies representative of ten ranges. The sum of the ratings measures the intelligibility of speech when all these ranges are allowed to have their full effect. The number one denotes perfect intelligibility*

*Expressed in octaves above (+) and below (−) a pitch whose vibration frequency is 1,000 cycles per second.

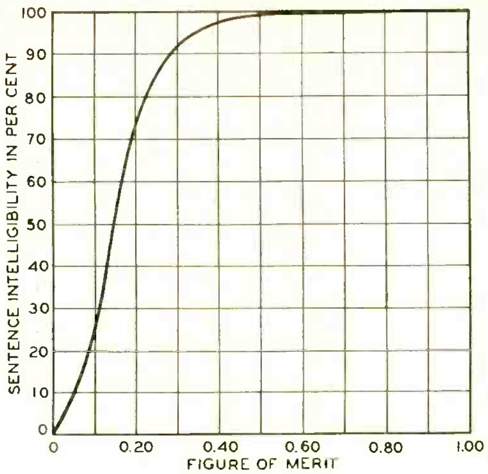


Fig. 5—The intelligibility of sentences to a person hard of hearing using a hearing aid with which he has had practice will have this relation to the figure of merit calculated for the aid and for him

The effect of a hearing aid is to reduce the patient's hearing losses in the various ranges by the amounts shown on the amplification characteristic of the set. The same tables of figures can be used, then, to measure the intelligibility which speech would have for a patient if he were aided by a particular set. In this case the effective lowering of the volume of each range is that which obtains after the range has first been amplified by the hearing aid and then attenuated by the patient's hearing mechanism. This *net hearing loss* can be computed for each range by subtracting the amplification of the set in that range from the hearing loss of the patient in the same range. The fractions corresponding to all the ranges when added give the measure of intelligibility which we shall call the *figure of merit* of the particular set for the particular patient. When such measures have been computed for a patient in conjunction with various sets, it is possible to compare the intelligibilities which speech will have for him when using the various sets. The set which gives the largest measuring number will be the most satisfactory for the patient. It is for this reason that the measure is called the "figure of merit."

Since the volume of speech varies according to the distance which it has travelled, the distance of a speaker from a patient introduces another variable which affects the figure of merit. Within limits it is possible to take account of distance by adding to or subtracting from the amplification of a set a fixed amount corresponding to the distance.

Justification for the use of the figure of merit is found in the relation which exists between it and the per cent of test sentences which the patient will correctly interpret with the aid of the set after he has had sufficient practice with it. This relation, shown in Figure 5, is derived from intelligibility tests using persons with normal hearing. Experience with a necessarily limited number of persons who hear with difficulty indicates that the curve may be expected to apply for them also. Thus not only can a set be justly called better for a patient if it has a higher figure of merit, but the satisfaction which it will give him can be predicted. In general, conditions and sets giving figures of merit greater than 0.4 will prove satisfactory, making practically all sentences intelligible, and those giving values less than 0.2 will be unsatisfactory, making less than seventy-five per cent of sentences intelligible.

It is instructive to observe how the figure of merit so calculated varies with patients Nos. 1, 2 and 4 (Figure 2), using Sets A, B and C (Figure 3) and also no set, at varying distances from a speaker. From Figure 4 it can be seen that Patient No. 1 unaided will be able to converse with no difficulty at distances less than one-half meter and with some difficulty at separations up to three times this distance. Any of the three sets will give him considerable help at any distance usually encountered in a small room. If the room is reverberant, however, the figure of merit may be inaccurate. Reverberation is not serious if the separation is one meter or less, but at larger distances the true merit of the set may fall to as low as one-half its calculated value. Set A, therefore, may give Patient No. 1 considerable help in a large auditorium, but only if the room acoustics are not too poor.

Patient No. 2, who will be able to understand speech without an aid only at very short distances, will obtain satisfactory aid from either Set A or Set B.

In the curves for Patient No. 4 a dotted line shows the figures of merit obtained for a uniform amplification of 15 db, on the assumption that the speaker can raise the volume of his voice this amount without impairing the clarity of his diction. This figure indicates that Patient No. 4 unaided will only be able to understand a voice shouting at a distance of three centimeters or less. With Set A he should be able to understand conversation by locating the microphone between a quarter of a meter and a meter from the speaker. Tests of this patient using this aid revealed that he could actually do so.

Certain precautions are necessary in applying this procedure. In obtaining data from the amplification characteristics of hearing aids, it must be remembered that the characteristics may change at the input volume levels corresponding to the different distances. The operation of Set B, for example, becomes unpredictable for the high input levels corresponding to normal conversation closer than 1/8 meter, and also for the low input levels received from further than about four meters. Allowance has not been made in Figure 4 for these changes.

A more accurate theory of the merit of hearing aids would take account of the fact that for all ears speech is distorted more and more by the hearing mechanism as the intensity of the sounds at the ear increases. Such distortion depends upon the type of deafness. Generally, however, this factor can be neglected.

The notion of the figure of merit, and the data and procedure used in determining it, grew out of researches in speech and hearing undertaken for telephone purposes in Bell Telephone Laboratories. The procedure has been presented to otologists because it offers them the possibility of recommending hearing aids to their patients with an accuracy greater than they can attain at present by other means. Otologists are becoming interested in obtaining the amplification characteristics of commercial hearing aids, trying the procedure, and checking its results against clinical experience.

Overseas Telephone Extended to Lisbon

Bell System overseas telephone service was extended on December 5 to Lisbon, Portugal. Lisbon is reached over the regular transatlantic radio telephone circuits between New York and London, and wire lines from London through Madrid. The service is available to all Bell and Bell-connecting telephones in the United States, Canada, Cuba and Mexico. The cost of a three-minute call between New York and Lisbon is $37.50, with a charge of $12.50 for each additional minute of conversation.

Music Wire Springs

By I. V. WILLIAMS
Telephone Apparatus Development

MUSIC wire might be termed the aristocrat of spring materials. It has a tensile strength, arising chiefly from its method of manufacture, which is greater than that of any other ordinary engineering metal. Associated with this extreme tensile strength are a high modulus of elasticity, a high elastic limit, and a surprising amount of toughness for steel of such great strength. Music wire only .005 inches in diameter may have a tensile strength of 700,000 pounds per square inch and yet be ductile enough to be kinked without breaking. Steel made by any other process and having a strength of 250,000 pounds per square inch would be almost sure to break at a very slight amount of bending.

As its name suggests, music wire was originally developed for musical instruments, principally the piano, but because of its excellent physical properties, it has become an important engineering material. The great majority of the helical springs employed in telephone apparatus are made from it. Commonly used sizes vary from one to twelve hundredths of an inch in diameter, although wire may be obtained as small as four thousandths of an inch, which is the size employed for "E" strings of mandolins and violins.

Like any other steel, music wire is very susceptible to corrosion, and because of the small diameters employed a very small amount may cause failure under the high stresses to which it is subjected. To diminish deterioration of this nature, the wire is commonly given a protecting coating of one kind or another—usually of tin. Such a coating is applied by drawing the wire through a bath of molten tin and then through a die which wipes off any excess.

Although the corrosion resistance of wire protected in this manner is much better than that of the unplated material, it is not entirely satisfactory. In most of the commercial wire the thickness of the tin coating is not sufficient to provide protection over a long period. Because of the softness of the coat it may be easily scratched through in the thin places. Because of the difference in electro-potential between steel and tin, the wire will then corrode at the points where the plating has been broken through, and the rate will be even more rapid than if the plate were not present. If a heavier and more uniform coating were commercially obtainable the tinned wire would be satisfactory from a corrosion standpoint. However, the high temperature of the molten tin produces a slight annealing of the steel. This would not be particularly objectionable if the annealing action were entirely uniform, but frequently some parts are annealed more than others, and soft spots result. These cause an uneven action of the springs, and a loss in tension, which necessitates readjustment or replacement.

Maximum life in service is obtained when a most favorable relationship exists between the resistance of a spring to corrosion and its ability to undergo a large number of operating cycles without failing under the applied stresses. In the large majority of springs used in the Bell System, the stresses set up upon operation are of a torsional nature, caused by a twisting of the wire as the coiled spring is compressed or extended. To determine the most satisfactory coating, therefore, the ability of the plated spring to withstand torsional fatigue must be determined, and the best combination of corrosion and fatigue resistance selected.

It is known from experience that a zinc coating offers the best protection against corrosion and that tin, applied as described above, is less satisfactory. Nickel, and a combination of nickel and copper in separate layers, rank with tin in effectiveness. Nickel and nickel-copper finishes as well as the zinc were considered satisfactory in regard to corrosion resistance and were included in a study made to determine the most effective plating. Tin was not included because of the uneven annealing effect mentioned above.

It is an unfortunate fact that all forms of protective coatings seem to decrease the life of the original wire. The effect of tin coatings has already been mentioned. The other coats are applied by electro-plating and it has been found that the hydrogen, released on the surfaces in the process,

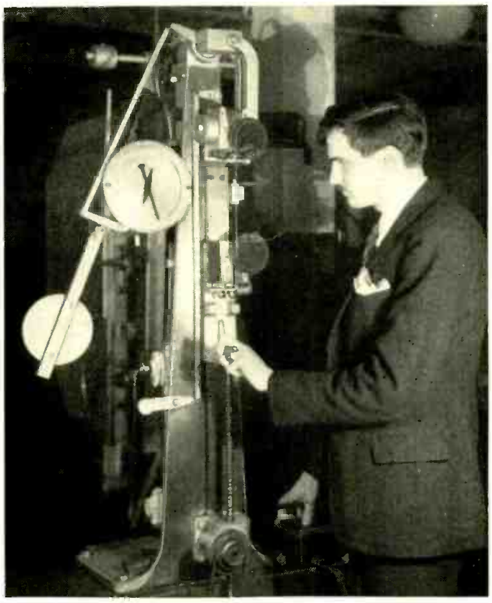


Fig. 1—The author making a tension test on a sample of plated music wire

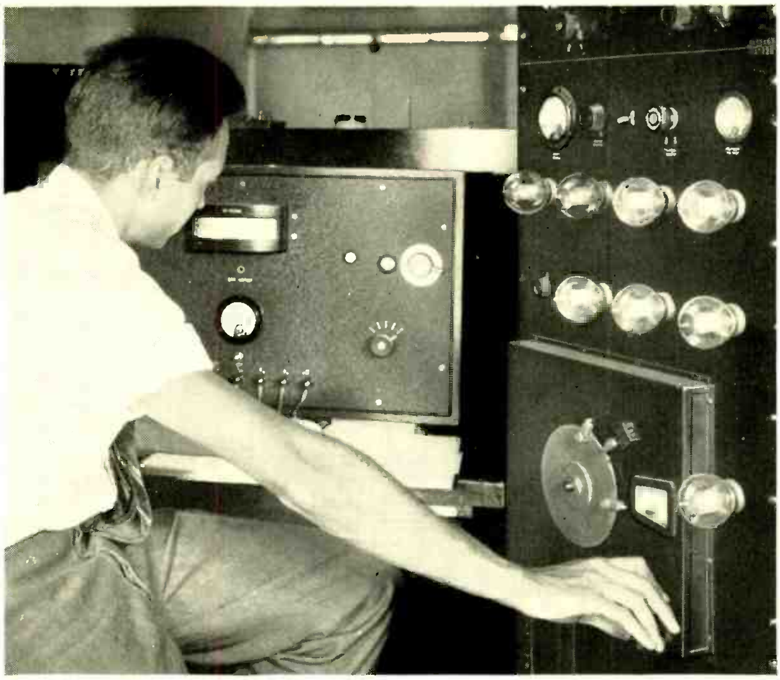
seems to produce brittleness. Hydrogen is also released in the cleaning step which precedes plating, with a similar effect.

Studies to ascertain the most satisfactory coating for music wire springs must determine the resistance of the plated wires to torsional fatigue stresses, regarding which there are, at the present time, no reliable data available. There is also no accepted method of making such studies on specimens of wire. It was necessary, therefore, to obtain the desired information by making up springs with the platings which were to be investigated, and by running life tests on them. These tests were performed on standard compression type springs and operated under simulated service conditions. It was found that nickel or zinc plated springs performed equally well and both were much better than those with the nickel copper plate which has been the previous standard electro-plated finish.

Tests of tensile and torsional strength were also made to determine what relationship there might be between the life of the springs and these characteristics. The tests showed no direct correlation between the life tests and either tensile strength or torsional strength. It was found in the tensile test that nickel had the least deleterious effect upon the strength of the wire, that the combination of nickel and copper ranked next, and that zinc was the poorest of the electro-plated materials, although tin applied in the molten state decreases the strength of the wire to an even greater extent. It was also found that by heating plated wires to a temperature slightly below 200° C. much of the brittleness due to cleaning and plating could be removed. It was also discovered that a slight increase in the tensile strength of the unplated wires could be obtained by a similar heating. This increase in strength was slight and so was not considered to have any great practical application.

The results of the torsional tests agreed quite closely with those of the tensile tests, although they indicated that torsion is much more affected by variations in the wire than is tension. These tests showed that both the nickel and the zinc decreased the ductility of the music wire to a considerable extent, and that the ductility could be restored in the case of zinc plated wires by heating at temperatures between 100° C. and 200° C. Such a heating, however, produced little effect on the nickel plated wires.

As a result of these tests, it has been decided to use either nickel or zinc plating for the great majority of springs; zinc because of its excellent corrosion resistance is to be preferred for general use. Nickel, which has a satisfactory corrosion resistance, is to be preferred where springs are subjected to abrasive wear, since the nickel plate is considerably harder than the zinc. It is also planned to include a low temperature heat treatment for all zinc plated springs made with steel. This heat treatment is being used to increase the resistance of the springs to sudden surges of stress although it is not expected that it will increase the life of the springs under ordinary stress conditions.



A Heterodyne Oscillator of Wide Frequency Range

By J. G. KREER, JR.
Transmission Research

OSCILLATORS operating at a single frequency, or at any desired frequency over a fairly wide band, are used throughout the Laboratories for a great variety of tests and studies. For a test set developed recently* to measure the reflection coefficients of filters, equalizers, and other networks, an oscillator was desired, however, which could be rapidly and easily passed through a wide range of frequencies. Such an oscillator would make it possible to measure with one operation the reflection coefficients at all frequencies over a wide band, instead of requiring a group of readings at discrete frequencies, which is necessary with the usual oscillator.

The range of frequencies required was from two hundred to thirty-five thousand cycles, and to maintain the same calibrations for all frequencies within this range, it was necessary that any variation in output voltage due to changes in frequency should be negligibly small compared to the overall accuracy of the measurements. This was set at 15% when measuring a 2% reflection coefficient, but since the oscillator was only one of the elements involved, there was but one-third of this total allowable error allotted to it. This meant that any harmonic frequencies generated, which

*Record, *July*, 1932, *p.* 374.

appear as interfering frequencies, must not affect the reading by more than 5%. A study of the characteristics of the detector showed that an interfering frequency would have to be six db below the level of the frequency being measured to meet this 5% requirement. Since the reflection coefficient of the network being measured might be considerably greater for the harmonics than for the fundamental, however, further discrimination against harmonics must be provided. Under worst conditions the reflection coefficient for the harmonics might be fifty times that for the fundamental so that it would be necessary to reduce the harmonic output of the oscillator another 34 db to offset the ratio of fifty to one. Thus the harmonic output of the oscillator must be 40 db (34+6) below that of the fundamental. To provide an adequate factor of safety and an allowance for other errors, the requirement for the reduction of harmonics was increased to 50 db.

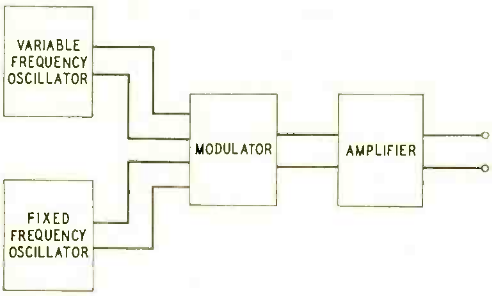


Fig. 1—By employing two oscillators and deriving a "difference" frequency with a modulator, the range over which the frequency of the oscillator must be varied is materially reduced

To meet this requirement for harmonic content, and at the same time make it possible to vary the frequency over the very wide range required with a single control, seemed impossible with the usual type of oscillator. To change the frequency from 200 to 35,000 cycles with a single control would require a continuously variable condenser with a capacity range of over ten thousand to one. Such a condenser is not mechanically practicable and even if it were, the harmonics generated would normally be only thirty db down on the fundamental. To reduce them the remaining twenty db would necessitate variable selective networks which, in turn, would require an additional control.

The difficulty was overcome by employing an oscillator of the heterodyne type arranged as shown in the block schematic of Figure 1. Two primary vacuum tube oscillators are adjusted so that the difference between their frequencies is equal to the desired output frequency. These two frequencies are combined in a modulator to produce a "difference" frequency which is passed through a filter so that the undesirable modulation products, such as the "sum" frequency and the second harmonics of the primary frequencies, are removed.

With one of the primary frequencies fixed at 100,000 cycles, an output difference varying from zero to 35,000 cycles may be obtained by varying the other oscillator from 100,000 to 135,000 cycles, a range easily covered by an ordinary air condenser, and in marked contrast to the 10,000-to-one ratio required for the same range using a single oscillator. Besides this advantage, the harmonics generated may be readily eliminated by a fixed filter, because the second harmonic of the lowest primary frequency is considerably higher than the highest primary frequency. The problem of reducing the harmonics in the output is thus reduced to that of designing a modulator and amplifier capable of carrying the desired load without introducing more than the allowable amount of distortion.

The circuit initially adopted is shown schematically in Figure 2. Both modulator and amplifier are balanced throughout to reduce the second harmonic in the output. This has the additional advantage of allowing the variable frequency modulator to be connected to a branch of the modulator which is conjugate to the output, so that harmonics of its frequencies do not appear in the output circuit. This arrangement very materially reduces the number of unwanted components to be removed by frequency selection. Overall tests show that the second harmonic is down the required fifty db at the lowest frequency, and that at higher frequencies it is down more than sixty, so that while the specified accuracy of 5% is met at all frequencies, the accuracy approaches 1% at the higher values.

Output-frequency characteristics are also highly satisfactory. The maximum variation of output with changing frequency is of the order of one-tenth db, which permits an accuracy of measurement, so far as this source of error is concerned, of one per cent instead of the specified five. Three volts across a six hundred ohm load is obtained at maximum output which is sufficient for most purposes and meets all requirements placed upon the oscillator.

Since its original development, the oscillator has been improved in many of its details and redesigned for Western Electric use by the Electrical Measurement Group. As redesigned it has been extensively used for measuring reflection coefficients as described in the article to which reference has already been made, and has proven highly satisfactory.

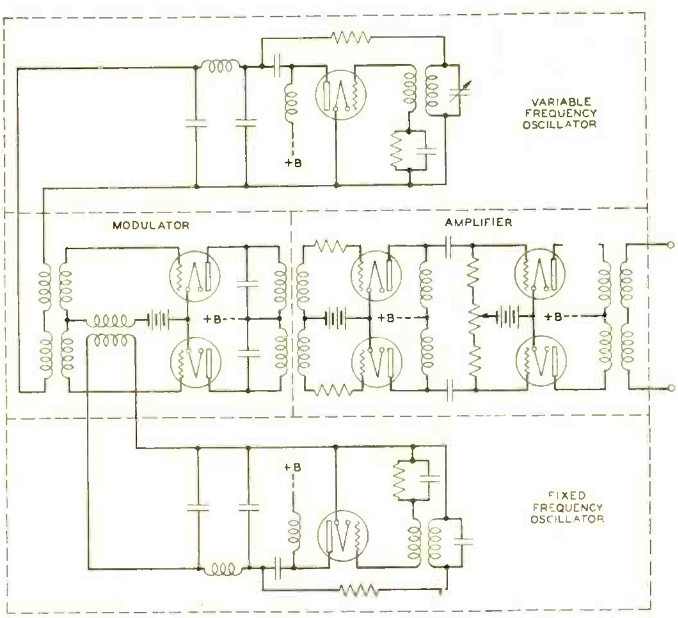
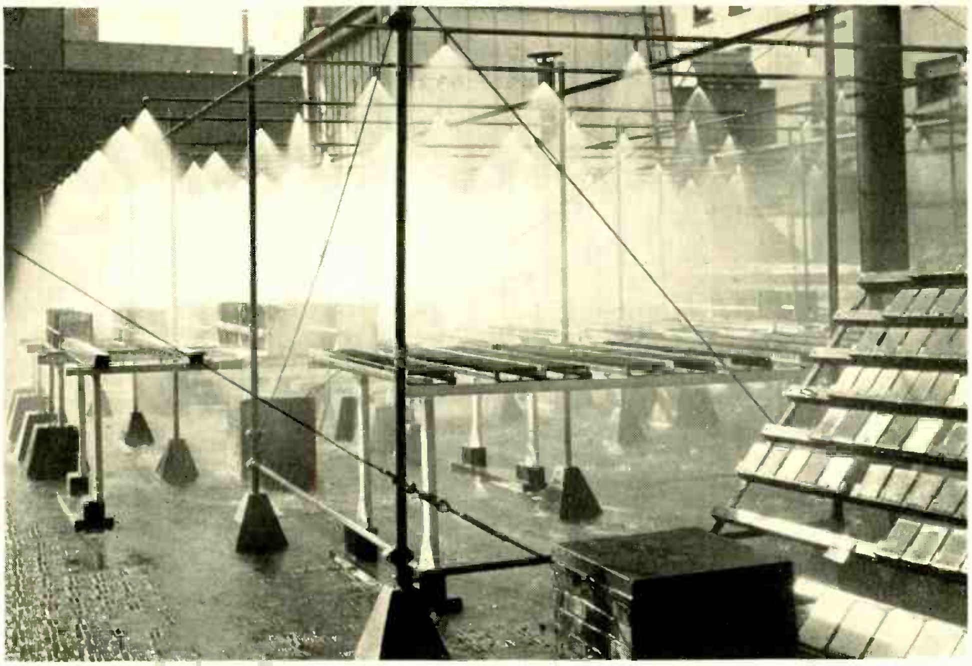


Fig. 2—Simplified schematic of the heterodyne oscillator

BANCROFT GHERARDI

to whom the American Institute of Electrical Engineers has awarded the Edison Medal for 1932 in recognition of his "contributions to the art of telephone engineering and the development of electrical communication." Among previous Edison Medalists are Alexander Graham Bell, John J. Carty, and Frank B. Jewett.

Mr. Gherardi is Vice President and Chief Engineer of the American Telephone and Telegraph Company, and a Director of Bell Telephone Laboratories.



Combating Rust With Metallic Finishes

By R. B. MEARS
Chemical Laboratories

THERE are some iron columns and beams, entirely unprotected from the elements, that have been standing in India since a few centuries after the beginning of the Christian era, and are still in serviceable condition. Their exceptionally long life can probably be attributed to the dryness of the climate where they are found. In the United States such a condition is rarely encountered. The rusting of iron and steel is usually so rapid under ordinary exposure that some protective coating must be used to give a ferrous structural member a reasonable service life. Yet, despite every protective measure, there is an estimated annual loss in excess of a quarter billion dollars from corrosion in the United States alone.

Two general types of coating have been employed: organic coatings, such as paints and varnishes, and coatings of another metal such as tin or zinc. The use of metallic coatings at critical points in the telephone plant has led these Laboratories to investigate the protective properties of such coatings.

Metallic coatings may protect the ferrous base metal in two ways: mechanically, by forming a continuous envelope around the steel and so excluding the corroding environment; electro-chemically, by being attacked preferentially. The ideal coating would be one which would not be attacked in the corroding environment and which would form a perfectly continuous envelope over the steel. At present, while several metals are known which form coatings that are very resistant to ordinary outdoor exposures, it is difficult to apply them commercially as coatings entirely free from small cracks or pores.

At these discontinuities in the coating, small electrical cells* are produced, when a film of an electrolyte is present. Between the two metals, an electric current flows, and the less noble or "anodic" metal dissolves. The electro-potential relationship between any two metals in a given environment determines which of the two metals will be protected (cathodic) in that environment at the expense of the other, or corroding (anodic) metal. The amount of corrosion occurring at such a couple can be considered as directly proportional to the current flowing between the two metals. This current is determined by the conductivity of the electrolyte, and by the polarization or back electromotive force which occurs at the protected and corroding metal surfaces.

Polarization is in turn determined by the formation of hydrogen on the cathode, and of surface films on the anode. In natural corrosion almost all the polarization occurs at the cathode, and since oxygen removes the polarizing hydrogen, the rate of oxygen supply is a large factor in determining the speed and extent of corrosion.

The electrolyte, in an outdoor environment, consists of rain or dew in which are dissolved any soluble industrial gases, such as carbon dioxide or sulfur dioxide, which may be present in the atmosphere. This electrolyte is usually of a high specific resistance, and consequently electro-chemical protection probably plays only a secondary part in the protection of a metal exposed to the atmosphere. For this reason the rate of corrosion of a metallic coating, even though it is porous, is not much greater than its corrosion rate as a solid metal sheet.

In general for outdoor exposure it is desirable, nevertheless, that the coating be of a metal which is anodic to the iron or steel base metal, since this will prevent the appearance of brown stains due to rusting of the iron at pin holes. Zinc and cadmium are two metals which are anodic to iron and steel in ordinary environments. Nickel, chromium, lead and tin coatings do not protect iron or steel electro-chemically at discontinuities and perhaps actually accelerate corrosion at these points. As a result these coatings become stained with the corrosion product of the underlying metal, the extent of discoloration depending on the porosity of the coatings.

Zinc is one of the earliest and at present the most widely used protective metal coating. Several different methods have been developed for applying zinc coatings to steel. Hot-dipped or galvanized zinc coatings are probably used to the greatest extent, but galvannealed (galvanized, heat-treated coatings) sherardized, and electroplated zinc coatings are also widely employed. For outdoor exposure hot-dipped coatings of other metals, especially lead and tin and alloys of lead and tin, have been used as protective coatings. As these latter metals are electro-positive (more noble than iron) in most exposures, satisfactory protection and good appearance can only be retained if they are applied as adherent, relatively pore-free coatings. This can generally not be done commercially to compete in

*Record, *March*, 1932, *p.* 230.

cost with zinc coatings. Furthermore lead is so soft that it is easily damaged mechanically. Recently, electro-deposited cadmium has had rather wide use as a protective coating.

Aluminum is now used as a coating to some extent, especially in Europe and would be more widely employed if its melting point were lower so that hot-dipped aluminum coatings could be applied without altering the physical properties of the steel. With the advent of metal-spraying devices, sprayed coatings of aluminum and other metals have found a limited use for corrosion protection.

Some indication of the quality and suitability of various coatings for specific uses can be obtained by laboratory tests for porosity, adherence, hardness, and the like, but so many factors are active in determining the relative corrosion resistance of the different metals that it is impossible to decide the relative merits of metallic protective coatings save by observing their performance in actual corrosive environments. To simulate in the laboratory the environments encountered in the field offers all the advantages of more convenient and accelerated testing, but can be justified only if the simulated correlate with the actual results. In the past much corrosion testing has been done in various laboratories, using salt sprays, intermittent immersion, or simulated atmospheres, but large discrepancies between life predicted from test and life realized in service have resulted, probably because of large differences in the mechanism of attack and in the resulting surface-film conditions. These Laboratories have accordingly undertaken basic tests on a fairly complete series of the metallic finishes commonly used outdoors, corroding under actual service conditions to provide a body of data with which the results of any proposed accelerated test must correlate before the test can be regarded as reliable.

Since the atmosphere of New York City exemplifies severe conditions of pollution and dampness such as are commonly met with in service, a part of the roof of the West Street Building was chosen for the testing ground. (headpiece.) Here for more than three years samples of steel coated with metallic finishes have been corroding in exposure to the normal weather. Another set of samples on the roof has been exposed to an excessive rainfall simulated by a water spray turned on

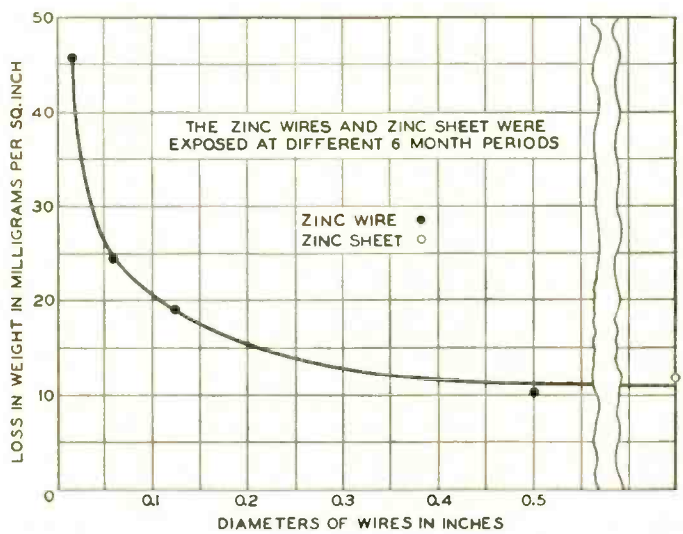


Fig. 1—The relation between the curvature of a zinc surface and its rate of loss in weight by corrosion indicates that heavier coatings must be used on wires than on sheets to obtain the same protection

the samples thrice daily during the eight months without freezing weather, as a first step toward developing an accelerated test. The finishes under test include sprayed coatings of aluminum, lead, zinc, nickel, and monel metal; electro-deposited coatings of zinc, cadmium, zinc-mercury alloy and zinc-cadmium alloy; hot-dipped coatings of zinc, lead, and tin; a cementation coating of zinc (sherardized); and a heat-treated, hot-dipped (galvanneal) coating of zinc. As a measure of the extent of corrosion, the losses in weight have been noted every two months.

Although the tests are not yet completed, certain significant results have been obtained. The sprayed nickel and monel-metal coatings failed in less than two months, probably because of their porosity. Sprayed aluminum, although discoloring soon after exposure, has shown little further discoloration up to the present. Sprayed lead was better than sprayed nickel but not as good as sprayed aluminum. The hot-dipped lead and tin specimens, carrying heavy weights of coating, have weathered slowly but now show signs of pinhole corrosion.

The most interesting of the results are those on the rates of corrosion of the coatings made from cadmium, zinc, and the alloys of zinc with iron, mercury, and cadmium. All of the coatings of zinc and its alloys had rates of weathering of the same order; the rate for the electroplated zinc cadmium coating was somewhat less than for the others. Provided the different types of zinc coating are adherent, free from pinholes and other porosity, and distributed uniformly, thickness of a coating is the chief factor determining its outdoor service life.

The unalloyed cadmium coatings, however, weather at twice the rate of the zinc coatings. This was unexpected, for the salt-spray test had shown them to be far better than equally thick zinc coatings. Hence it appears that the best field for cadmium as an outdoor finish for steel is in exposure to atmospheres prevailing on the sea coast.

Correlation between corrosion in the normal environment and corrosion under the simulated excessive rainfall is in general not close enough to make reliable even this apparently natural means of accelerating the test. The spray uniformly doubles the corrosion rate of zinc coatings, and thus appears to be a reliable method of accelerating their investigation. But it does not increase the rate of corrosion of the other coatings in the same proportion.

An interesting observation made during the course of the investigation is that the curvature of the surface has a pronounced effect on the rate of weathering of a zinc coating. The effect is illustrated in Figure 1, which shows the loss in weight per unit area of zinc wires of various diameters in six months. The wire of smallest diameter (0.02 inch) lost about 4.5 times as much weight per unit area as the thickest wire (0.5 inch). The rate for the latter is about the same as for a flat surface. The economic significance of this discovery is that much heavier zinc coatings are required on wires than on sheets to obtain the same protection.

Thus the basic tests are proving very valuable in furnishing a reliable guide to outdoor metallic finishes for steel. The same general plan of systematic corrosion testing is now being employed in studying the corrosion of all the common metallic finishes used in the telephone system, not only in the outside plant but in central-office equipment and elsewhere.

Measuring Microphonic Noise in Vacuum Tubes

By H. A. PIDGEON
Vacuum Tube Development

THOSE familiar with vacuum tube circuits know that when they listen to the output of an amplifier, particularly one operating at a high gain, certain noises may be heard which were not present in the input circuit. The most common of these, which are caused by small disturbances within the tube itself, are "microphonic noises." Two types are frequently distinguishable. One of them is characterized by rasping or sputtering sounds, and is designated sputter noise. It has a number of sources such as variable leak resistances and imperfect welds in the tube, but most commonly it is caused by variable contacts between the filament and one or more of its supporting hooks. Although this form of noise is particularly disturbing, it may generally be reduced to a very low level, or eliminated altogether, by careful design and construction. The second type, present in all vacuum tubes to a greater or less degree, arises from relative movements between the elements of the tube caused by externally applied agitation. Since the plate current depends on the spacial relations of the elements of a tube, any relative motions of them give rise to changes in space current that result in microphonic noise.

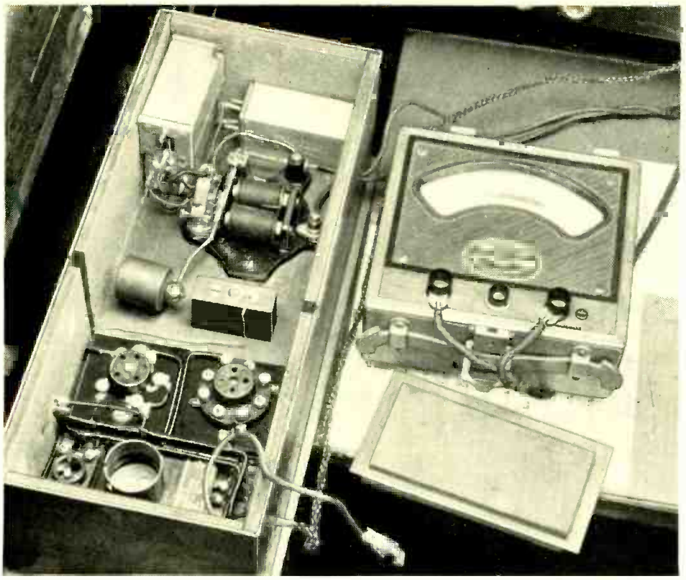


Fig. 1—The agitator unit is installed in a padded copper box which shields the tube under test from outside influences

ducing systems. In development work on vacuum tubes, therefore, and in testing manufactured product, it is very desirable to have some method of making measurements of noise output. Various schemes have been employed for this purpose, the principal one consisting of striking the base of the tube a single blow of a predetermined force. The momentary output of the tube immediately after the blow is passed through an amplifier and a vacuum tube detector to a sensitive ballistic meter, and the maximum swing of the indicator is taken as a measure of the microphonic response of the tube. Although this method has a certain advantage in its simplicity, it is handicapped by the necessity of reading a momentary swing of the indicator; several trials are usually required to obtain consistent results.

Such agitation may be produced by accidental jars, by vibration of the apparatus in which the tube is mounted, or by the impingement of sound waves either directly on the tubes or on the panel on which they are mounted. Any such disturbance will produce vibration of the various elements of the tube, and since all the elements are coupled together mechanically through their supports, a large number of modes of vibration are possible. As a result several different frequency components can usually be distinguished which differ in intensity and in the length of time they persist after the mechanical stimulation has ceased.

In recent years an increasing number of applications of amplifier equipment has required that internal disturbances be reduced as far as practicable. This is particularly true for repeaters used with high grade program circuits, and for amplifiers with sound-picture recording and repro-

To overcome this disadvantage, the Laboratories have developed a test set in which the microphonic response is indicated by a steady deflection of the output meter. It includes an agitation unit in which the tube under test is mounted and continuously agitated, and an amplifying and measuring circuit which gives a steady reading of the microphonic noise in db below an arbitrary level.

The agitation unit, shown in Figure 1, consists of an electro-magnetic hammer firmly attached to a massive slate base on which sockets for different types of tubes are rigidly mounted. The hammer is a modified

Faraday electric bell with its tapper heavily weighted with a cylindrical piece of steel. This permits an adjustment to steady operation at from eight to nine strokes per second—a frequency low enough not to overemphasize any of the natural frequencies of the tube and yet high enough so that the microphonic output, as measured by a thermocouple indicator, is essentially constant. The whole base vibrates with each blow of the hammer, and transmits the vibrations through the socket to the tube under test. The assembled agitation unit is mounted on a felt pad in a copper box with a heavy felt lining. A padded partition, shown removed in Figure 1, separates the tube and hammer compartments. The padded copper container serves both to deaden the sound and to shield the tube electrostatically.

The microphonic output of a vacuum tube will, in general, include a wide range of frequencies depending on the various modes of vibration of the several elements of the tube. The disturbance to the listener, however, will depend on the characteristics of the amplifier and of the ear. Certain ranges of frequencies will contribute much more to the general level of the disturbance than others of equal intensity. If the measuring circuit were to be used for determining the effect of microphonic noise in a particular type of circuit, therefore, its amplifier should have characteristics similar to those of the circuit with which the tube will be used, with the addition of a frequency weighting network to

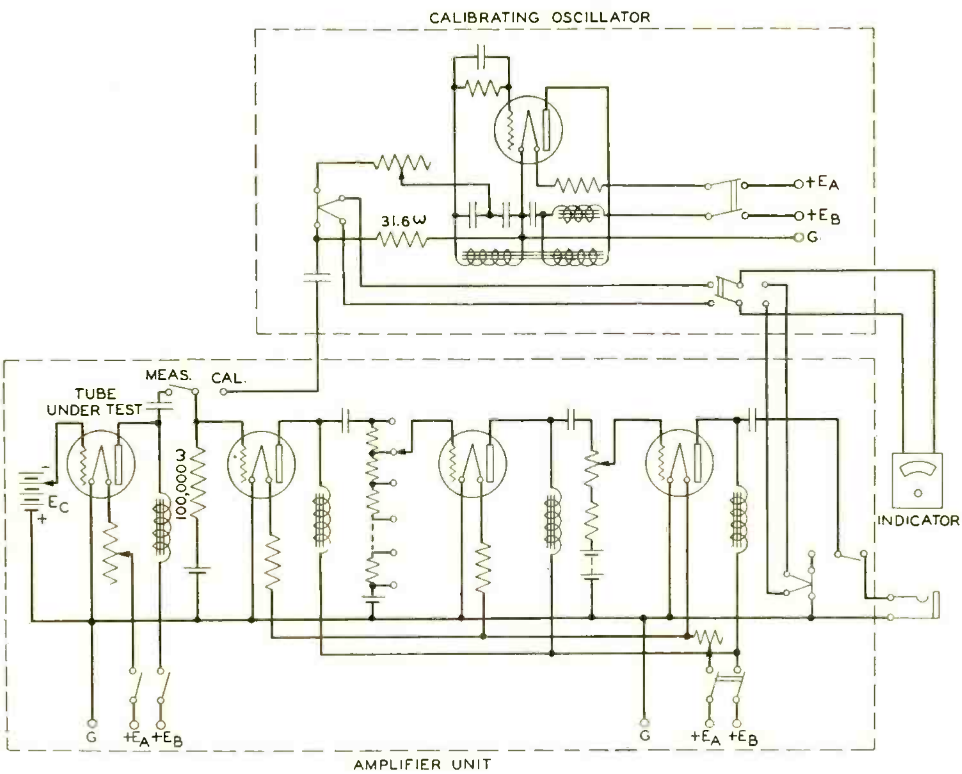


Fig. 2—Schematic diagram of testing circuit and calibrating oscillator

produce a measured output similar to what would be heard by a person using the circuit. Such a weighted amplifier has been developed for use in determining the effect of microphonic noise in telephone circuits, and has been coded the 1-A detector amplifier. Since the set here described, however, was developed not only for testing manufactured product but for fundamental studies as well, the amplifier was designed to have a nearly flat frequency characteristic from 80 to 6,000 cycles, and no weighting networks are incorporated.

The circuit, shown schematically in Figure 2, is essentially a three-stage impedance-coupled amplifier associated with an oscillator for calibrating it. The tube under test operates directly into a load resistance of 100,000 ohms, shunted by a high inductance choke coil. Gain control is provided in 3-db steps by a potentiometer placed across the output of the first amplifier tube. Another potentiometer, across the output of the second stage, is employed for adjusting the amplifier during calibration. A thermocouple galvanometer is employed to indicate the output of the final stage, and its readings are added to those of the gain control potentiometer to obtain the level of the microphonic noise. The action of the thermocouple indicator is sufficiently slow to give an essentially steady reading even though the current is in the form of pulses at intervals of a ninth of a second.

The measure of microphonic noise is of necessity relative and referred to an arbitary base. Its purpose is to compare the amount of noise produced under similar conditions by different tubes. The reference base employed in the present set is one volt of effective potential across the 100,000 ohm resistance in the output circuit of the tube under test, and the measure of microphonic noise is the ratio in db of its output in volts across this resistance to one volt. Since no ordinary tube, under the agitation supplied, produces an output as great as one volt, the usual measure is in db below one volt. The sensitivity of the amplifier permits microphonic disturbance as much as 55 db below the reference base to be measured with an accuracy of .2 db. The shocks applied by the agitation unit, how-

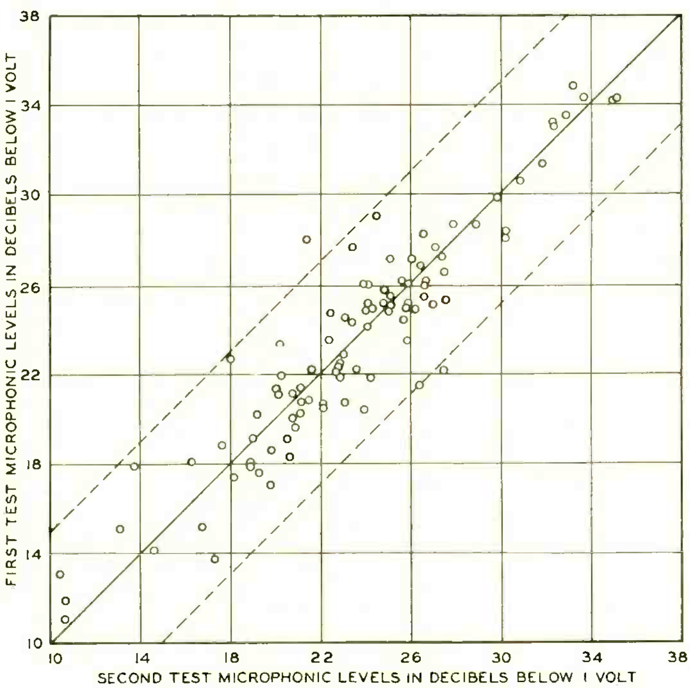


Fig. 3—Typical results of measurements of microphonic response on a lot of repeater tubes

ever, are of much greater intensity than those encountered in any ordinary installation, and so the microphonic disturbances produced under usual operating conditions are less than those obtained in the measuring set.

Since the basis of measurement is a voltage across a 100,000 ohm resistance, calibration of the circuit is simple, and is accomplished by means of the associated oscillator already mentioned. It is of the tuned-grid-circuit type adjusted to oscillate at 860 cycles per second. From a tap between the two tuning condensers, a portion of the output current is passed through a variable control resistance, a thermocouple, and a fixed resistance of 31.6 ohms. In calibrating, the voltage across this fixed resistance is impressed across the 100,000 ohm resistance of the amplifier, and the current through the 31.6 ohm resistance, as measured by the thermocouple, is adjusted to exactly one milliampere, thus giving a calibrating voltage of .0316 volts or 30 db below one volt. The gain-control potentiometer of the amplifier circuit is then set to the 30-db-down position, and the calibrating potentiometer between the second and third stages is adjusted until the output meter is at its zero position. Because of slight changes that may occur in the amplifier, it is advisable to calibrate every few hours while the set is in use.

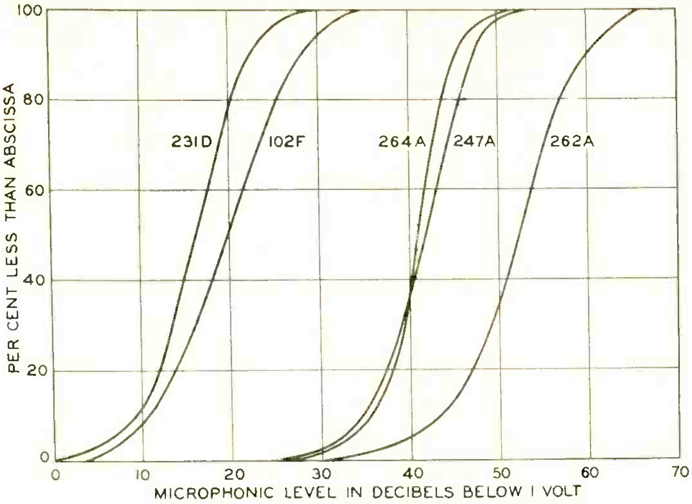


Fig. 4—Distribution of microphonic levels in five standard Western Electric tubes

To maintain a fixed intensity of agitation the unit is operated at constant current, and is calibrated from time to time. Very stable tubes are maintained as standards of microphonic disturbance and their response at the desired intensity of agitation is recorded. To calibrate at any later time the agitator unit is adjusted until the measured output reaches the previously obtained level.

All of the equipment except the agitator unit and the output meter, which are placed on a shelf attached to the front of the frame, is arranged on four panels mounted on a standard relay rack, as shown at the head of this article. A loud speaker, evident at the left of the photograph, is sometimes plugged into the output circuit of the amplifier to indicate type of response.

Typical measurements of microphonic noise made with this set are shown in Figure 3. A lot of 100 repeater tubes — 102-F type — were tested twice under as nearly identical conditions as possible. On the plot each tube is represented by a single circle so placed that its ordinate represents the microphonic response on the first test and its abscissa, that on the second. If the microphonic levels were perfectly reproducible all of the points would have fallen on a straight line passing through the origin at an angle of 45° with both axes. If some factor were present during one of the tests, which changed all the levels by a constant amount, the points would still fall on a 45° line but the line would not pass through the origin. To indicate the accuracy of reproducibility obtained, a 45° straight line has been drawn through the origin, and it is evident that it passes approximately through the center of gravity of the points. Paralleling dotted lines are drawn 5 db on each side of the central line, and only two of the tubes are beyond these lines on the chart.

The microphonic response of the tubes of the lot varied from about ten to thirty-six, a range of approximately 26 db. Such results are typical of those obtained in a large number of experiments including various means of agitation. Differences of the magnitude indicated occur even when tubes are as nearly alike as is practicable to obtain in a manufacturing process. A vacuum tube with its base, socket, and support is such a complex mechanical system that very slight variations between the tubes will produce the differences in response indicated among the lot, and inappreciable differences in applied agitation are sufficient to cause the differences recorded in repeated tests.

The variation in response of the tubes in a lot is about the same for all types of tubes although the mean responses may differ widely. Figure 4 shows results for lots of five types of commonly used tubes. Not only is the distribution, as indicated by the shape of the curve, approximately the same for all types, but the range is also similar—in all cases being from 30 to 35 db between the least and most microphonic tube. Such tests indicate that if the mean microphonic response of a type of tube is given, the variation of any individual tube may fall above or below the mean by as much as 15 db.

The range in mean microphonic response for the five types of tubes is from 16 db below one volt for the 231-D tube, which has a very small filament and thus one easily set in vibration, to 52 db below for the 262-A tube used in sound picture recording. This latter tube has the lowest microphonic response of any standard Western Electric tube, and its low level is obtained by very firmly supporting both ends of the elements with insulators which reduce the possible relative displacement and rapidly damp out vibrations that do occur.

These relative displacements of the elements of a tube, which cause microphonic noise, are extremely small. In the 102-F repeater tube, a microphonic output of 55 db below one volt is obtained with a variation in grid spacing corresponding to an amplitude of vibration of only a hundred-thousandth of an inch. This amount of movement produces a microphonic noise which when listened to in a telephone receiver is faint but easily audible. The agitation producing this amount of noise, however, as already pointed out, is much greater than would ordinarily occur in service. To duplicate the mechanical agitation that a tube is subjected to in a telephone repeater station, the energy of the agitator unit of the test set would have to be reduced about 40 db.

Bus Announcing Outfits

By J. H. COLLINS
Special Products Development

"ORATON Parkway next" says the voice, and the passenger on the forward end of the top deck of the bus prepares to alight. Thanks to the bus announcing system, he no longer needs to be on a constant look-out for his street nor does he have to sit near the driver if he is not familiar with the route of the bus.

Present-day methods of operating busses, which make one man both driver and conductor, brought forth the need for some system whereby announcements made by the driver could be clearly understood by all passengers. This need is most keenly felt on double-decked busses where it is virtually impossible for a passenger on the top deck of the bus to hear the street names as they are called off by the driver.

A system that would fulfill this need must be as simple as possible and still furnish adequate volume level and intelligibility of speech. It must, in addition, be of very rugged construction since it will have to withstand excessive vibration on the bus. With these facts in mind, engineers of the Laboratories started development work on a bus announcing system, and a number of preliminary outfits were set up for tests. One of them, consisting of a carbon transmitter

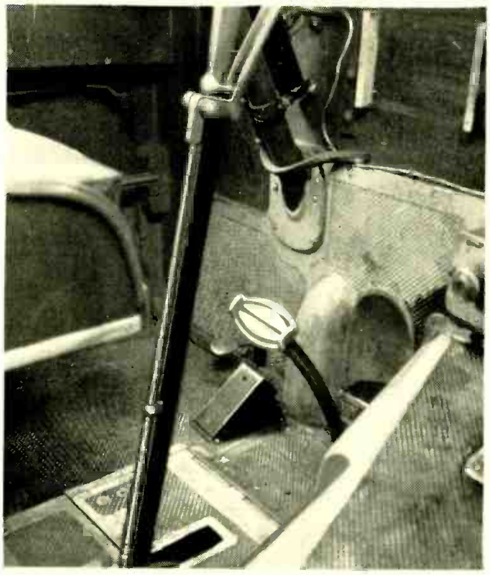


Fig. 1—A rectangular foot switch is employed by the driver to switch the system into service

energized by a six-volt battery and working through an induction coil into a loud speaker, proved to be satisfactory in regard to both intelligibility and volume. In addition it possessed qualities which would permit the design of a simple and inexpensive system.

Several new pieces of apparatus, of course, had to be developed. A collapsible bracket for mounting the transmitter, shown in the photograph at the head of this article, was designed for mounting on the roof above the driver. It holds the transmitter in talking position without interfering with the driver's movements or vision. When the system is not in use, the transmitter may be pushed up out of the way. The induction coil and the necessary connecting blocks are covered by a metal housing which may be located under the dashboard of the bus or in any out of the way location. A new foot switch has been provided for operating the system, since the standard switches available were not adapted for use on a bus. This switch, shown in Figure 1, is of adequate size and is sufficiently rugged in construction to be suitable for use on busses. It may be placed in a convenient location on the floor so that the driver will have no difficulty in operating it.

To secure the most effective distribution of sound, the horn is normally located at the rear of the bus, as shown in Figure 2. On double-deck busses the horn is, of course, placed on the upper level. In this position it is possible for passengers on the upper deck, as well as those at the rear of the lower deck, to hear announcements through the system. The passengers near the driver will, of course, hear the announcements directly.

A second system was developed for use on busses with two men in attendance. The bracket type transmitter and foot switch of the first system were replaced by a hand type transmitter with a switch in the

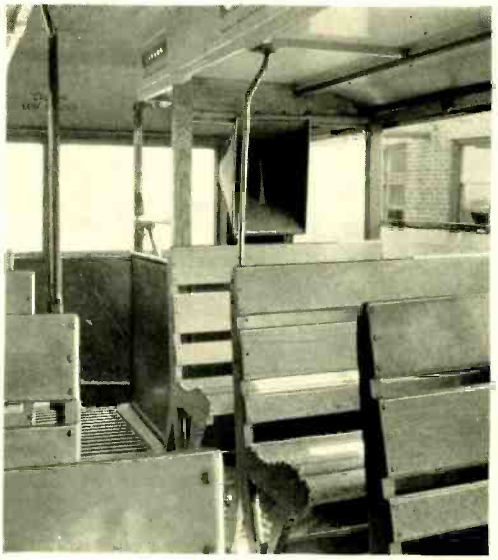


Fig. 2—The loud speaker is usually placed at the rear of the bus and on the upper level of double-deck busses

handle for operating the system. The apparatus unit housing the induction coil was modified to provide a handset hanger for the handset. It is necessary, therefore, to locate this unit at the place where the transmitter is to be used. This type of system is particularly adapted for use on sight-seeing busses since it relieves the announcer from the necessity of shouting in order to be heard.

These systems, while primarily designed for busses, are not limited to this use. They can be used for making announcements from one room or one floor to another. It is entirely possible to employ them for addressing small groups such as a crowd gathered outside a store window in which some article is being demonstrated, or a crowd around a counter in a store. A number of other uses suggest themselves where it is desired to advertise some article by means of speech.

An exhibition interpreting for the layman the historical, industrial and engineering phases of aviation, will occupy two floors of the Newark Museum until the end of February. The Bell System's part in aviation is shown by a collection of Western Electric aviation radio-telephone equipment developed from 1917 *to the present. D. K. Martin and F. C. Ward of the Radio Development Department, who prepared this exhibit in coöperation with the Western Electric Company, are shown above in the corner of the Museum containing the current line of equipment*

Contributors to This Issue

HARVEY FLETCHER received his undergraduate degree from Brigham Young University in 1907 and the Ph.D. degree from the University of Chicago in 1911. During his years of graduate study he was Instructor in Physics first at Brigham Young and then at Chicago, and on receiving the graduate degree became Professor of Physics at Brigham Young. In 1916 he came to these Laboratories, undertaking the investigations of speech and hearing which have made him one of the foremost authorities in this field. As Acoustical Research Director he is in charge of groups devoted to inquiry into many aspects of sound, including the development of methods for aiding those who hear with difficulty.

J. G. KREER received a B.S. degree in Electrical Engineering from the University of Illinois in 1925 and immediately joined the technical staff of the Laboratories. Here he has been with the Transmission Research group where he has been engaged largely in studies of vacuum tube circuits. Since joining the Laboratories he has taken work at Columbia University and received his master's degree in 1928. For two years he has taught the dynamics of vacuum tubes in out-of-hour classes.

I. V. WILLIAMS received the B. S. degree in electro-chemical engineering from Pennsylvania State College in 1926. He had been employed by the Bell Telephone Company of Pennsylvania during the summer of 1925, and after graduation he was transferred to the Apparatus Development Department of these Laboratories. Mr. Williams has been concerned with metallic materials and their testing.

R. B. MEARS specialized in electrochemistry at Pennsylvania State College. On receiving the B.S. degree in 1928 he came at once to our Chemical Laboratories to assist in the investigation of electroplating processes. Later his work was extended to include corrosion testing and the investigation of corrosion phenomena, and he took part in the development of new types of protective coatings.

H. Fletcher

J. G. Kreer

I. V. Williams

R. B. Mears

H. A. Pidgeon

J. H. Collins

Last September he resigned from the Laboratories to pursue graduate study at Cambridge University.

H. A. PIDGEON received the B.S. degree from Ohio University in 1911 and the M.S. degree in 1912. During the years 1910 to 1912 he acted as instructor in physics in this institution. In 1912 he went to Cornell University where he engaged in work in engineering and physics, acted as instructor in physics and received the Ph.D. degree in 1918. He came to the Laboratories, then the engineering department of the Western Electric Company, in October, 1918, and for a number of years was engaged in fundamental studies in electron emission. Since that time he has had charge of a group engaged in vacuum tube development work.

J. H. COLLINS received a B.S. degree in mechanical engineering from Carnegie Tech in 1929 and at once joined the Technical Staff of Bell Telephone Laboratories. With the Apparatus Development Department he has been associated with the Special Products group where he has worked on vacuum tube circuits, loud speakers, and sound picture systems.

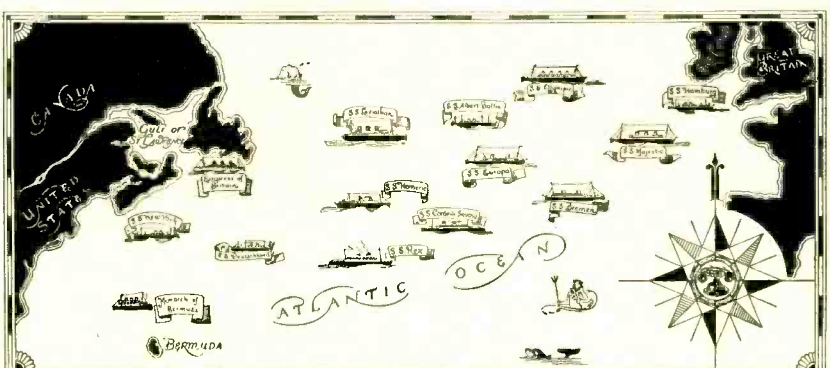
"Organized Common Sense"

"SCIENCE," wrote Huxley, "is organized common sense." Had the great English thinker been able to foresee some of the developments in the field of applied research since his death, he might well have rephrased his aphorism into a declaration that this branch of science is the organization of common sense to meet common needs.

To find means of doing more efficiently or more economically the work which the world's millions of people share in common; to make the lives of these millions, as members of a world community, more comfortable, more convenient and more wholesome; to enable them to live together more happily; to bring, in a word, the sense which they hold in common to bear on their actions as individuals and on their relations with each other—such is the world's problem today, and such must be the end and aim of all applied research.

Viewed from this standpoint, few branches of modern science are more important than those which deal with the development of the art of communication. They have to do directly with the search for means of bringing men and nations into closer touch and better understanding. They strive to enable people, though widely separated, to exchange ideas and opinions and thus to find a solution for the common problems which confront them.

In Bell Telephone Laboratories, New York, many hundreds of trained scientists and their assistants are engaged in a continuous search for new materials and equipment for making America's telephone service more extensive, more efficient and more economical.



A page from the Telephone Almanac for 1933