Proceedings

of the

Radio Club of America

Incorporated

September-October, 1932

Volume 9, No. 9-10

RADIO CLUB OF AMERICA, Inc.
11 West 42nd Street + + New York City

The Radio Club of America, Inc.

11 West 42nd Street - New York City

TELEPHONE—LONGACRE 5-6622

Rates: Annual subscription to non-members, $5.00; single copies, $.50, except certain out-of-print copies, specially priced. Special rates on quantities of single issue.

PROCEEDINGS of the RADIO CLUB OF AMERICA

Vol. 9 SEPTEMBER-OCTOBER, 1932 No. 9-10

Voice recordings for industrial and social uses†

By S. Young White

The most convenient and natural form of communication is speech. The spoken word was developed for ages before writing was in general use. The individual reflects the history of the race in learning to talk with comparative ease in infancy, but seldom acquires the same facility in expressing his thoughts with the limited means available to the writer.

THE voice carries thoughts only partly within the machinery of words, grammar, and the parts of speech. The color and flavor are carried by countless inflections and tones which express meanings familiarly and thoroughly. The communicating of what we call personality is far better managed by the straight voice than by print. Sentiment, which is a big element in speech, is difficult of handling in writing, requiring more learning than we realize it does, a lot of practice, and a baggage of culture not possessed by most beings.

The purpose of this paper is to discuss the mechanical technique that can be developed for the average person, of average monetary means, so that he may fully use voice communication. If he can use voice communication he will get ease of understanding because that advantage flows automatically from ease of expression.

There are three means of conveying spoken intelligence, which means are direct talk, the telephoned conversation, and the recorded or frozen speech. We propose here to go into the recorded form of sound.

Several methods of recording, each advantageous in its special way, exist. All of them come under the general heading of a relatively fine-grained material moving under a point of some kind. Recording may be done optically, on film or on paper, as on the sound track of talking moving pictures, a medium which varies in its ability to pass light and thus causes the desired fluctuations of sound to register on a light-sensitive device. This method is obviously unsuited to individual use. Another means of considerably more promise in this field is recording upon an iron wire by variably magnetizing it in limited areas. Reproduction is accomplished by simple reversal. This system does not necessitate any physical contact with the wire, and in the numerous classes of service where the recording would be played only once or twice the system has the marked advantage that the wire can be easily wiped clean of recording, and hence used indefinitely. However, the apparatus of this system is not as yet in general distribution.

†*Presented before the Radio Club of America, September 14, 1932.*

Availability

The field thus narrows itself to the use of phonograph records because people are familiar with them and since machines capable of playing them are universally available. Because this type of apparatus is almost universally adapted to play the laterally recorded disc record we shall confine our discussion to this form of disc.

We find no literature generally available on the subject of recording as practiced before the advent of the electric amplifier, so our history is made up of such glimpses as the Patent Office affords. Originally, good recording was apparently confined to waxes and soaps. That was because of lack of power in the voice itself to actuate a diaphragm strongly enough to drive a heavily loaded cutting or pressing tool; one capable of recording satisfactorily upon the more difficult sorts of materials. About the only patent that shows a clear grasp of the problem was one filed by George K. Chaney, of the Victor Company, in 1902, which describes the most practicable method of attack.

Since our choice is narrowed to the laterally cut phonograph disc, we shall examine here the two fundamentally different methods of forming the groove, the first by cutting, a process which actually removes material in the form of shavings, the second a pressing method, which is altogether analogous to drawing one's finger over the top of a tub of butter, leaving a groove, although no material (butter) will have been removed from the tub.

We must reject the cutting method,

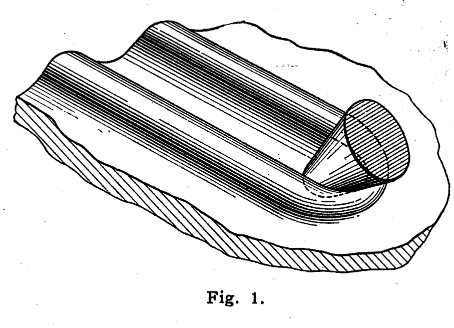

Fig. 1.

despite the fact that it is standard in wax recording because it requires too fragile a tool for general use. The difficulties connected with removing or disposing of the shavings is another reason for not taking on this method for universal application.

Since we are obliged to use the pressing method, we must examine its phenomena with considerable care. Fig. I shows the profile of a groove made by this process. It will be noticed that the material piles up in front of the traveling stylus under what must be enormous pressure, pressure which is, in fact, usually far beyond the tensile strength of the material itself. These pressures sometimes approach 200,000 lbs. to the square inch and very high temperatures are developed. This piled up material then splits and flows to either side of the stylus precisely like the formation of the bow wave in front of a boat. At either side it freezes into permanent shoulders. Fig. 2 is the cross-section of an ordinary phonograph groove of a wax record with the material removed leaving a shallow trench approximately as shown. Fig. 3 shows the type of groove under discussion, with the usual below-the-surface portion and the above-the-surface shoulders. Fig. 4 shows the laminated type, in which a surface material is superimposed upon the main body. These illustrations suggest the division of records into several clearly defined classifications.

Class I record is homogeneous throughout. Class II record is a two-ply laminated record, as shown in Fig. 4. The top material is usually chosen for low noise level and attractive surface while the body of the record is usually composed of a cheaper material. There are three different methods of forming Class II records. What we will call II A Class has a top coating with a thickness of the order of the depth of the groove. Class I B record has a surface material of a greater thickness than the groove's depth. Class II C has a soft top which is graded in hardness down to the hard base within depths of the order of the groove itself.

Class III record has a cheap base supporting a Class II record. Between its base and its top there is usually a layer of adhesive stuff which is, of course, itself protected from needle-wear by that top layer. Consequently, the top layer being a thin one, the adhesive material itself can be given recording properties.

Returning to Fig. 1, we observe that the stylus has a smoothly rounded point. An infinite variety of styles are practicable, from the pointed, through the

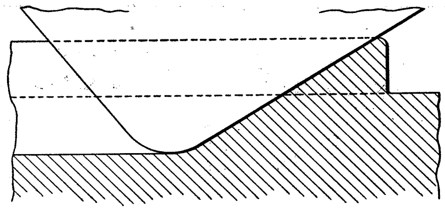

Fig. 1a.

truncated cone, to the ball point, in all angles and of all radii of curvature. Various materials may also be used, from chromium plated steel to the diamond.

The Stylus

We must first design a desirable groove profile from the known characteristics of the record material, having due regard for the number of grooves per inch, for a useable playback needle, and for the class of service desired. It will then be found that the most important factor in the design of the stylus is the rate at which the work is done. From its first point of influence, which is ahead of its path through the material to its last point of contact the stylus must cause the material to flow as rapidly as possible without exceeding at any point a certain critical rate of doing work.

From a recording viewpoint the weight on the point of the stylus should be as light as is practicable and we desire the stylus to be as nearly vertical as possible to the record surface. Under these conditions high frequencies are impressed upon the record more easily, the weight on the stylus can be a minimum, and the load on the motor is light. In general, it will be found that due to the small area of such a stylus, which is actually employed in forming this groove, the rate of doing work is extremely high, and the record material no longer flows like a liquid under these enormous pressures, but begins to tear, resulting in a very rough lining of the groove with the side wall thrown out in chunks, which causes a very high noise level. It will be found that this rate of doing work can be decreased by using a stylus having a minimum coefficient of friction to the record material, having a relatively blunt point that is highly polished and which rests upon the record with a considerable trailing angle. These considerations seriously curtail our ability to put on really high frequencies with readily available recording materials, but it is altogether necessary to minimize the all-important noise level.

The stylus is the middle link of a three-element chain, the other two being the cutting head and the record. Before further detailed study of the stylus we should observe some of the actions of the cutting head. In Fig. 5 we see a skeleton diagram which will aid us in discussing the main elements of cutting head design. The portion above the bearing represents the moving armature, its driving force furnished by a simple magnetic iron system, or by a moving coil, or by a Rochelle salts crystal. Since we are asking this device to move at least 5,000 times a second it must usually be designed to be relatively small, the entire series of elements not exceeding one inch in length. As this tiny moving element is to be pressed into the record with a weight of the order of twenty ounces, it will readily be seen that the most difficult point of design is the bearing, which must withstand this weight plus the great drag on the record with no sidewise play whatsoever. To faithfully record faint breathing sounds, the bearing must transmit without loss armature motions of from 20 to 50 millionths of an inch. With the best design at present practicable it will generally be found that at some frequency in excess of 2,000 cycles it will be the bearing and not the stylus point that will move.

Because the actuating force and the damping are at some distance from the bearing, we can, obviously, allow no bending of the armature.

In commercial wax recording one of the most serious points of design is avoiding a resonance spot due to the armature mass and elasticity. In direct recording, however, the load is so great that resonance phenomena, due to any cause, are almost entirely absent, but in return for this blessing many difficulties are found in recording the higher frequencies. The function of damping is confined to centering the armature, avoiding hysteresis and cooperating in limiting the motion to prevent one groove from crossing over into another. This latter function will be discussed further under remarks on monitoring.

Bearings

The most immediately practicable form of actuating means was found to be the balance armature, magnetic-drive type, with rubber wrapped bearings. The design of dynamic units met great difficulties in the bearing. Among bearings tried for this type of head were knife-edge, torsion, pivot, ball and plain metallic sleeve. Results were indifferent throughout the list. The Rochelle salts head had the marked advantage of being its own bearing, but difficulties were encountered in impressing smooth low frequencies, as well as with the fragility of the element. But this type has considerable promise, nevertheless.

The rubber wrapped sleeve bearing has a certain lack of permanence, but will pass the highest frequency for the longest period of service of any type tried. This is due to the fact that rubber can be considered as a liquid, with considerable inertia, and while at very low frequencies movement is general throughout the mass, when the frequency is increased it tends to localize itself on the surface, until at extreme high frequencies it becomes remarkably solid. We have recorded 8,000 cycles with medium success through this type of bearing.

Since resonant peaks are not apparent, damping can be obtained by metallic springs or by rubber, in its forty odd varieties. If rubber is used it may be of considerable thickness in the direction of compression with a consequent uniform reaction through the ordinary distances of travel of the armature; or it may be quite thin with exponentially increasing reaction through relatively short distances. The rubber may be in a state of high initial compression, or in no state of compression at all, when the armature is at rest, a major factor in determining hysteresis.

This brief review of some cutting head and stylus limitations will allow us to more intelligently choose a recording material. Such a material must above all be inexpensive, attractive in appearance, light in weight, capable of being mailed at an ordinary post box, of relatively low noise level, of at least fair quality, and resistant to wear.

The surface must obviously be of a fine grained, homogeneous material with very small crystals. It must smoothly flow under proper stylus conditions and must have a minimum of resiliency.

Record Materials

Materials for Class I (homogeneous) records are rather limited in number. Among the metals, brass, copper, zinc, cadmium, lead, tin, and steel are ruled out by several factors, such as weight, noise level, too easy bending, or other defects, leaving only aluminum and magnesium. Aluminum has most of the desired qualities, but its cost is excessive, it cannot be played with a steel needle, and its noise level is rather high. Of the non-metallic substances suitable for Class I records, there are practically none available at a reasonable price, and we are forced to conclude that the universal direct recorded record of the future will be a laminated article. Normally we associate qualities of fineness of texture, toughness, and attractive appearance with rather expensive materials, so it is logical to use such materials for the recording surface because recording never descends more than two one thousandths of an inch below the surface, allowing, of course, the body of the record to be made of a far less expensive material. Although it has been determined that for wide commercial use the manufacturing cost of a six-inch disc must not exceed a fraction of a cent, nevertheless one may find a wide variety of surfaces at this economic level.

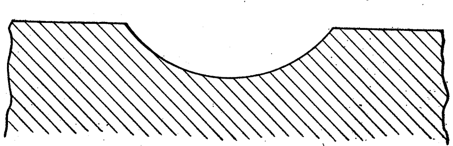

Fig. 2.

Metal rolled to a few mils in thickness has had its crystalline structure broken down somewhat and is an excellent recording material because of its resultant low noise level. The greatest difficulty is to find a method of forcing the metal to closely adhere to the base without piling up and wrinkling in front of the moving stylus, especially in the Class II A record, where the top layer is of a thickness of the order of the depth of the groove. The most practical form seems to be the Class III record, consisting of a metal foil top, a rather thick layer of adhesive, and a base that merely forms the physical body of the record. Some success has been achieved in recording on pulp paper, suitably protected by metal foil, where actual compression of the paper takes place, resulting in great density at the bottom of the groove. A large choice is available among these ductile foils because the method of forming the groove is radically different from those of the homogeneous Class I record, and many materials will meet these conditions.

Approximately 150 non-metals have been experimented with for recording. A familiar substance is cellulose acetate which has low noise level, attractive appearance, moderate cost, but which has too great elasticity; that is, if one pushes it ten units it bounces back one, and if it is displaced only one unit it bounces back practically the full unit. In recording the low frequencies we do displace ten units, and the loss of this single unit due to resiliency is relatively insignificant. The high frequencies, however, displace the material only one unit, which promptly disappears after the stylus has passed, resulting in a very serious high frequency cutoff. Hard rubber shows somewhat the same phenomena, whereas another large class of non-metals tends to crack before recording stresses are reached. Materials employed as fillers, such as wood-flour, chalk, or fibres, generally display too high a noise level to be practicable. Some artificial waxes show promise where a limited number of record playings is enough.

Cellophane belongs to a class of materials which shows excellent promise. Some difficulty has appeared in developing here an adhesive of desirable characteristics. We will dismiss all other non-metals as being still in the experimental stage.

Monitoring

In most classes of general service no monitoring is possible, microphones used must be non-blasting, the amplifier of limited power, the cutting head incapable of cutting over to the next groove. The serious monitoring is that below 200 cycles, and the system must have a response characteristic such that the weak signals are handled in a linear manner built up above the noise level on the record, but stronger signals asymptotically approach the high intensity limit imposed by the proximity of the next groove.

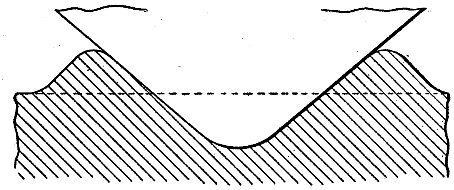

Fig. 3.

To prevent an irregular rate of rotation of the turntable during recording (wows), it will be found best to place the motor in a shock-absorbing cradle coupled to a heavy flywheel type turntable through a flexible means, such as a rubber belt or the equivalent. This has proven more effective than precision machine work where the motor was coupled by stiffer means.

Average values of recording elements for metal are: stylus 50 per cent. to 100 degrees; cones with ball points 1 to 3 mils in radius and operated at angles in the neighborhood of 25 degrees. Weights on stylus are from 6 to 25 ounces. Amplifiers are of 1 to 5 watts output. Cutting head impedance may be any convenient value. Grooves per inch may be 80 to 150. Actual cutting load as reflected into turntable motor is one to three watts if the record is lubricated, more if it is not. Any lubricant will do, although paraffin oil seems to be most practical.

The quality of the recording is determined by a rather large number of factors. The main ones to keep in mind are background noise level, hysteresis in the head, high and low frequency response. Noise has been discussed. Hysteresis is quite common in cutting heads

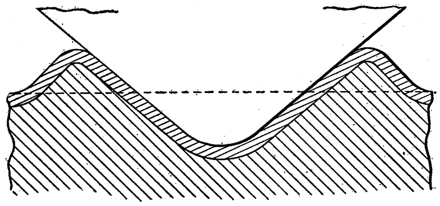

Fig. 4.

under these heavy loads and results in "mushy" recordings. It is quite difficult to add a strong restoring force to the armature and still allow large low frequency swings. There is considerable difficulty in impressing high frequencies due to inefficiency, heavy load on the head, large stylus point, record elasticity, bearing losses, inability of the needle to take them off and numerous other factors.

Needle Design

Assuming that a record has been made, we must of course use a needle of some sort to play it back. The chief point in needle design is to achieve maximum permanence without appreciable wear on the record. The needle must be of a material that is not costly and which is easily worked into shape. It must have considerable longitudinal strength and must successfully resist bending. The needle's point should fit the groove to provide maximum coupling and must have a low coefficient of friction.

Both metal and non-metal needles were tried. Of all familiar metals chromium plated steel was moderately successful upon non-metal records, but a needle of any metal upon a metal record developed too high pressures, tending to re-record and to straighten out the groove. This erosion effect is confined to the smaller deflections, as in general there is no wear on the large low frequency swings. Of the more practicable non-metals suitable for needle use on metallic records a bakelite-impregnated birch wood needle has been most successful of the commercially produceable forms. Moulded bakelite needles have been tried, as well as wooden bamboo needles impregnated with a number of grades of bakelite, and beetleware, as well as those hardened by chromic acid and by other means. Various shapes have been tried, but the only departure from the conventional that seemed worth while was a bent needle of the shape of the tail-skid of an airplane, to reduce the drag, but, as with all asymmetrical needles, the public would never learn to insert it properly. A well polished sapphire needle with a two-ounce Rochelle salts pick-up is the best permanent play-back arrangement that we have developed.

The Amplifier

Little need be said concerning the characteristics of the amplifier. A gradual cutoff below 200 cycles will tend to prevent overload and a considerable rise from 1,000 to 6,000 cycles will tend to compensate for the numerous factors which tend to prevent satisfactorily recording the higher frequencies.

It is quite difficult to couple an amplifier to a magnetic type head because it requires a large amount of power and has approximately the frequency—impedance characteristic—of an air-core coil, which it is difficult to compensate in such manner as will allow the output tube to work into an optimum load. If the tube impedance is matched by the head at high frequencies, it will tend to compensate for the numerous other factors which militate against the highs, and since it will be a serious mismatch at the lower frequencies it will tend to break them up into harmonics, which is a very desirable form of distortion, inasmuch as it is not practicable to put true lows on a laterally recorded phonograph disc.

The actual amount of power required

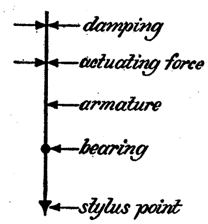

Fig. 5.

to record a good standard intensity note is only five milliwatts or so, but because, as is the case with all electromechanical translators of sound, the less efficient the head the better the recording, it is not practicable to design a magnetic head of greater than one per cent. efficiency. Consequently, several watts must be available from the amplifier. The Rochelle salts head, being an electrostatic device, is voltage operated, and requires from 100 to 200 volts across it for satisfactory low frequency response.

Uses for Recordings

A few years ago it would not have been practicable to introduce this art to the public in the many forms of its useful destiny because the essential electric elements had not descended to their low price and had not reached their ruggedness of today. But with contemporary technical background it should be fairly simple to introduce equipment suitable for these wide uses.

The three main uses of personal recording are communication, delayed transmission and storage of speech. To obtain immediate wide recognition of this art the first requirement would seem to be the offering of facilities to the average person to make his first record for amusement or communication use. A machine providing this facility was developed and placed in contact with the public. Several experimental types of this machine were actually put out over a period of almost one year in these times of money stringency and they were used to the extent of several hundred records at 25 cents apiece per day over the entire period. These results would seem to indicate that the larger public will use recording facilities if they are presented under proper psychological conditions, at reasonable price, and of easy access and use. The average person's first recording was just to find out how he really sounded to others while the second record was usually mailed to somebody. The recipient was usually so pleased at such a faithful expression of the personality of the sender that requests came back from relatives or friends to carry on future correspondence by this means. Because the sentimental value was prized, the sender was glad to comply, and he was also pleased because the horrible ordeal of writing home regularly was done away with, to the saving of much mental anguish. The medium was also used to find out whether one had a foreigner's accent or other eccentricity of speech. Mothers fetched their babies to squall for posterity, or for their own mature embarrassment. Very old folks dictated moral maxims and ethical counsel to be played yearly on anniversaries of their deaths. Many illiterate foreigners used it for correspondence. In fact, about 60 per cent. of the records made were posted in the mails. These simple statistics rather strongly indicate that if engineers extend this service of recording in the direction of the public, which has its mind already educated to the talkie and the radio, the medium will be rather generally adopted into daily life.

The most obvious use of delayed transmission is in connection with the telephone message, which may take several forms. Most important would seem to be the telephone answering machine. This is being developed in a form that does not cut in to the telephone line or interfere with the service in any way and that can still

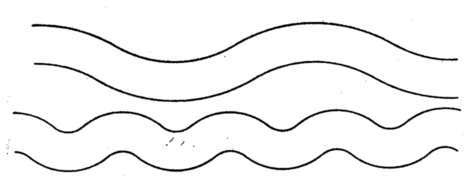

Fig. 6.

take a number of messages when nobody is at the 'phone. To be practical this requires the utmost simplification of equipment, such as motors, lead-screws, means of suppressing wows, and the numerous checks against imperfect operation of the machine.

A talking night-letter service would be practical with a message 'phoned to a central office, there recorded for retransmission when the wires are less busy, for re-recording at the other end on a small record to be delivered to the addressee or on a very large record, individual message being played over the telephone for delivery. The advantages over a written night letter are, again, ease of composition, full understandability when received, plus the sentimental value of hearing the voice of somebody which one can play over and over again when one is lonely.

The Telecheck machine that has been developed records both sides of a telephone conversation. The importance of this can be realized when one thinks of the enormous amount of business done over the 'phone, the orders given and taken, with all the opportunities of *lapsus linguae,* mistaken meanings, and forgetfulness. The recording is done with no connection to the 'phone at all. There is only a small button near the telephone which is held down as long as one wishes to record.

The same checking idea can easily be extended to recording meetings, taking testimony, or to any situation where a dispute is likely to occur. The full grasp of any proceedings depends not only on what is said, as reflected in a stenographic report, but on how it was said, which can only be done through a record.

The list of uses of direct recording can be extended indefinitely, but we hope enough has been shown to allow realization of the opportunities the engineering profession has to develop the new art of direct recording to the point of use in everyday life.

▲ ▲ ▲

Book Review

"RADIO PHYSICS COURSE." Second Edition. By Alfred E. Ghirardi. Published by Radio Technical Publishing Co., New York City. Price, $3.50. (992 *pp.;* 508 *illustrations; Cloth.*)

This is the new revised and enlarged edition of a popular textbook that has been generally well received by numerous students and practical radio men. It is compiled in the form of a comprehensive elementary course in radio practice and has been prepared from teaching experience gained by the author as an instructor in a technical school.

The author has a unique method of writing which may be said to be responsible for the wide acclaim this work has received. Ghirardi is a genius for lucid exposition who not only thinks clearly, but can also apply his ideas in technical writing as to be easily and thoroughly comprehended by the reader. Throughout this book one comes into contact with constructional details and explanations that are not to be found in other texts and it is these that add to make interesting and instructive reading. This with the generously illustrated volume make the study especially appealing to the reader, particularly so if he is a student. In addition this work is unusually up-to-date and contains considerable new material which other books are devoid of or which is usually treated only in a superficial manner.

An especially desirable feature of the *Radio Physics Course* is the inclusion of an elemental study of electrical principles such as forms the basis of radio practice. This study, grouped in the introductory chapters of the book, forms a suitable background for the understanding of the principles of radio operation that follow. Among the initial chapters there is also included a study of acoustics as applied in general to the human organs and musical instruments, all of which is particularly interesting as it assists many in the appreciation of sound in radio broadcasting. A number of chapters are allotted to the discussion of vacuum tubes, their operation and application to radio circuits. Following in order the reader is next introduced to radio receiving systems and various forms of signal amplification wherein the author discusses the design operation, and applications (etc.) in an ambidextrous manner. The continuing chapters are of a varied nature considering among other subjects, power units, mobile and aircraft receivers, phonograph pick-ups, and short wave reception.

The book also outlines the principles of operation of various television systems and the applications of photoelectric cells together with the study of sound motion pictures and allied apparatus. This material is to be found in the last chapters of the text where there also appears a chapter on testing and servicing. Herein is included a descriptive discussion of aids to the service man and reviews a number of common methods employed when "trouble-shooting." The appendix is composed of symbolic and technical data tables such as are of value in common radio practice.

The book can be recommended to the student and practical man who desires to understand modern radio practice in general.—*Reviewed by Louis F. B. Carini.*