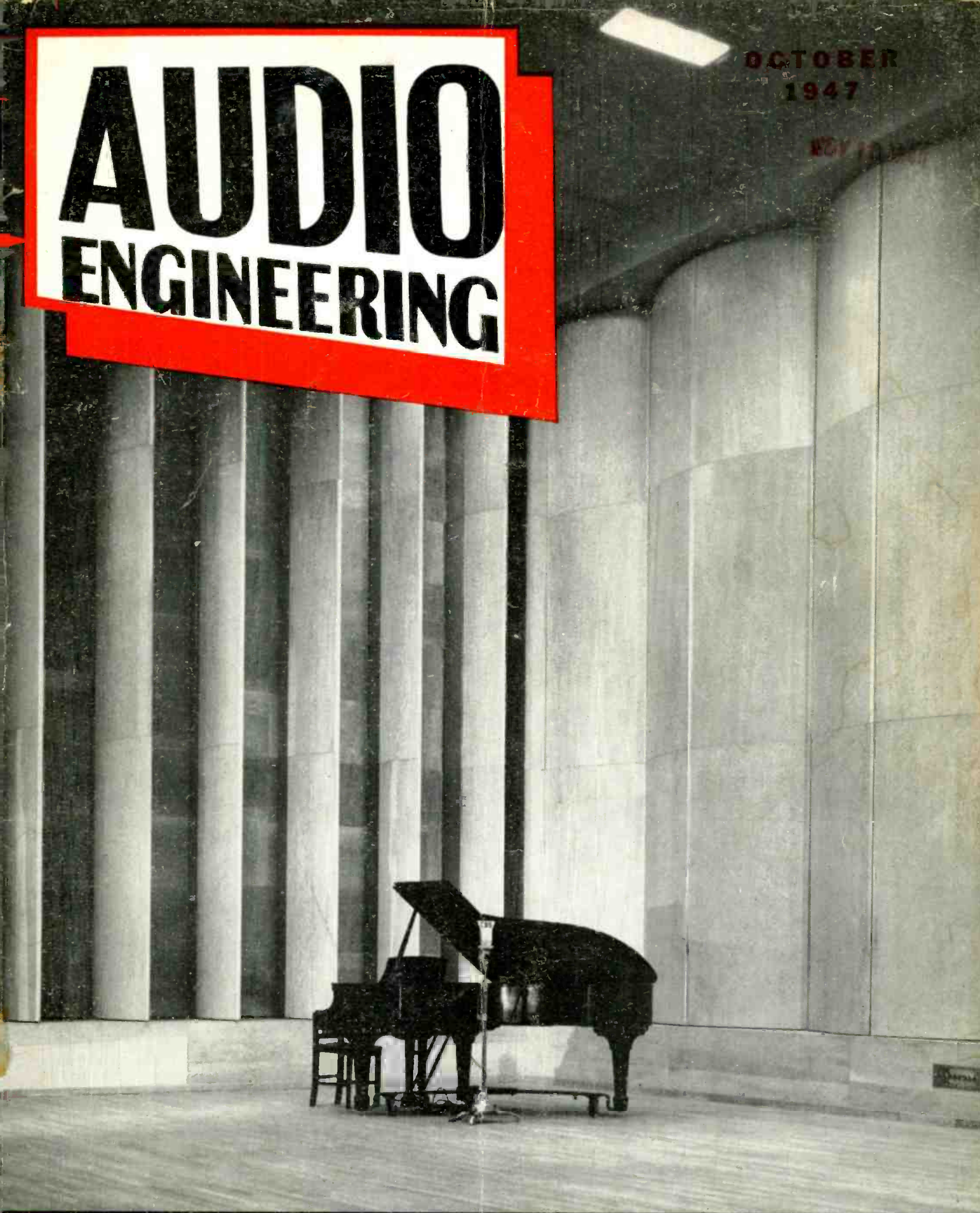
AUDIO ENGINEERING

OCTOBER
1947



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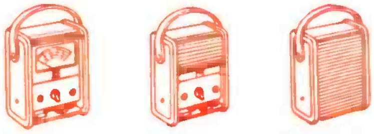

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10	10	10 V.	100			+52DB	(12 ohms center)
50	50	50 V.	500				0-200,000
250	250	250 V.					(1200 ohms center)
1000	1000	1000 V.					0-20 megohms
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CONTENTS

OCTOBER, 1947 Vol. 31 No. 9

COVER ILLUSTRATION

An experimental studio of the Columbia Broadcasting System showing the acoustical treatment of the walls. The walls are lined with wooden panels, known as "acoustivanes" which extend from floor to ceiling. The panels may be rotated and when closed form a continuous sound-diffusing wall surface. With the panels in the open position, a sound absorbing outer wall is exposed. Control of the reverberation and sound diffusing properties of the studio is thereby made possible.

AUDIO ENGINEERING (title registered U. S. Pat. Off.) is published monthly at 28 Renne Ave., Pittsfield, Massachusetts, by Radio Magazines, Inc., J. H. Potts, President; S. R. Cowan, Sec'y-Treas. Executive and Editorial Offices at 342 Madison Avenue, New York 17, N. Y. Subscription rates—United States, U. S. Possessions and Canada, $3.00 for 1 year, $5.00 for 2 years; elsewhere $4.00 per year. Single copies 35c. Printed in U. S. A. Entered as Second Class Matter, under the Act of March 3, 1879.

Letters

Re: "Psycho-Acoustical Aspects of Listener Preference Tests"

Dear Mr. LeBel:

"The vorpal blade went snicker-snack"—and the heads rolling on the floor all bear the same expression of pained surprise. I am referring, of course, to the effects of your article in the August issue of AUDIO ENGINEERING.

Few things in this confused art of sound reproduction have given me as much pleasure as reading your logical summary of the origins of our vast supply of misconceptions. If only ten percent of the people in the high places will sit down and think for half an hour about what you have written, you may have started an upheaval. Thinking is such a painful process, however, and the smug complacency of engineers such good insulation against the common people, that the likelihood of a revolution seems to me to be very slight. I am a cynic, you see.

As one of the crop of Johnny-come-latelys, we are grateful for your help in interpreting the road signs. If we drive into a swamp it won't be your fault.

Norman C. Pickering
309 Woods Ave.,
Oceanside, N. Y.

Dear Mr. LeBel:

Our engineering staff has read with considerable pleasure your article on Listener Preference Tests in the August edition of AUDIO ENGINEERING magazine.

We pride ourselves on being "cranks" relative to "high fidelity." We subscribe most heartily to your comments. You are a gentleman of great perspicacity.

R. J. Tinkham
General Manager,
Magnecord, Inc.

Re: "Musical Acoustics"

Sir:

Mr. Benjamin F. Tillson's articles on Musical Acoustics have been much enjoyed, as a real contribution to the art. We feel, however, that his remarks on comparative frequency range of lateral-cut commercial phonograph records and on vertical-cut discs are not up to date.

One leading maker of lateral-cut commercial phonograph records has recorded with uniform response up to 10,000 cps, undistorted, for at least eight or nine years. Another has so recorded up to 8,000 cps for at least nine or ten years. A leading organization, recording many independent makers' discs, has so recorded up to 8,000 cps for at least eight years. Uniform response up to 8,000 to 10,000 cps means an effective upper limit of 12,000 cps, which compares favorably with the 11,000 cps vertical cut claim which Mr. Tillson quotes.

Wide range lateral pickups have been widely available for an equal length of time.

[Continued on page 35]

EDITOR'S REPORT

MIKES FOR THE MOSQUES

• When we think of religious worship among the Moslems, somehow we envision ancient traditions with ancient trimmings. Thus it comes somewhat as a shock to learn that, for the past ten years, many mosques and minarets have been wired for sound. In a letter published in a recent issue of *Time* magazine, the former manager of Philips Orient explains how it came about. Naturally there was considerable opposition to the idea among the more conservative muezzins (Moslem priests), who wanted to adhere strictly to the letter of the teachings. But a highly respected Moslem, the Rector of El Ashar University in Egypt, thought differently. So the equipment was installed.

When we come to realize how arduous the duties of the muezzins are, the advantages of public address become even more impressive. Devout Moslems go to prayer five times a day, starting at sunrise. Before p.a., each muezzin had to climb the stairs to the top of the minaret to lead the faithful in prayer. Now, he simply uses a mike installed at the base. Those designers and manufacturers who may feel that tradition and prejudice may constrict their foreign markets can take heart from this illustration.

"HIGH FUTILITY"

• We are indebted to Benjamin Drisko for the priceless expression which heads this paragraph. And, insofar as many audio fans are concerned, the term certainly fits. How often do we find people who buy every new speaker or pickup as soon as it appears on the market with the fond hope that faults which they notice in their equipment are thus going to be corrected! And then, when they find that no improvement results, they condemn the product. Yet the new product generally is an improvement. Just how this comes about may not be immediately evident, but let us consider, for example, the loudspeaker. If we substitute a new one with a more extended frequency range for one which has been used, naturally it will bring out with greater emphasis portions of the frequency spectrum which were formerly attenuated. Now, if the equipment feeding the loudspeaker tended to distort these portions of the spectrum, the new loudspeaker would simply emphasize these faults.

Again, it is obviously possible for a poorly recorded selection to sound better when reproduced by inferior equipment than by apparatus which brings out everything in the record, good or bad. And, in addition, each of us has individual likes and dislikes regarding the kind of reception, as well as the kind of music, we prefer. Getting a conglomeration of equipment, even the best, will not perforce provide us with satisfactory reception under all conditions. Along with it must go some means of controlling the frequency response, some care in selecting the surroundings in which the equipment is to be used, and at least a dash of tolerance.

Concerning broadcast reception, Mr. Drisko has the following interesting comment: "...Has it ever occurred to you that just as the owner of a $19.95 squawk box adjusts his volume control to the optimum compromise between realistic levels and distortion, the broadcasters over a period of years have equally carefully if unwittingly evolved the particular type of program which suffers least when reproduced on said $19.95 squawk box? In other words, maybe the reason why we have so many variety programs and so little good music is because the receiving set manufacturers have failed to give us adequate listening equipment." We believe there is much to be said for Mr. Drisko's viewpoint. And, by the same token, those sponsors who want to get and hold the attention of people who own and appreciate fine radio equipment should give some thought to the quality, as well as the character, of program which they present.

NAB CONVENTION NOTE

• Prize remark of the year was made by Chairman Denny of the FCC. Faced by a large audience of hostile broadcast station executives, and with his back to the Atlantic Ocean, he brought down the house by saying he was "between the devil and the deep blue sea." —*J. H. P.*


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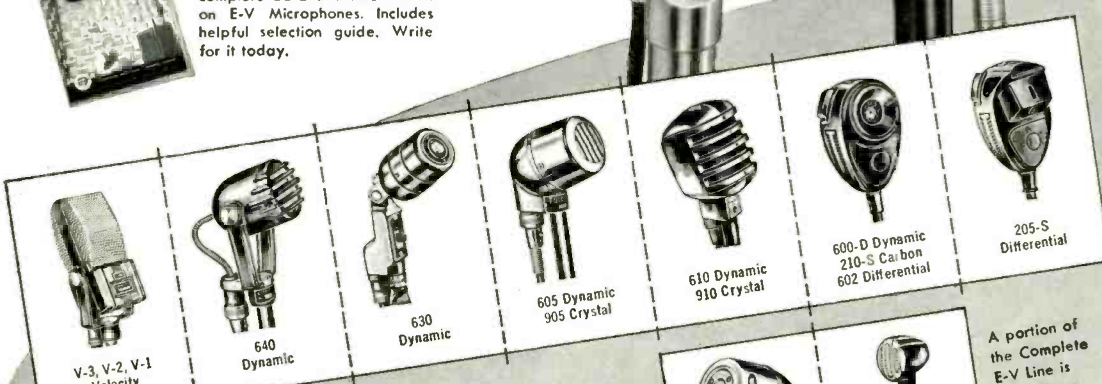

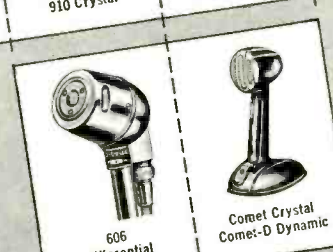

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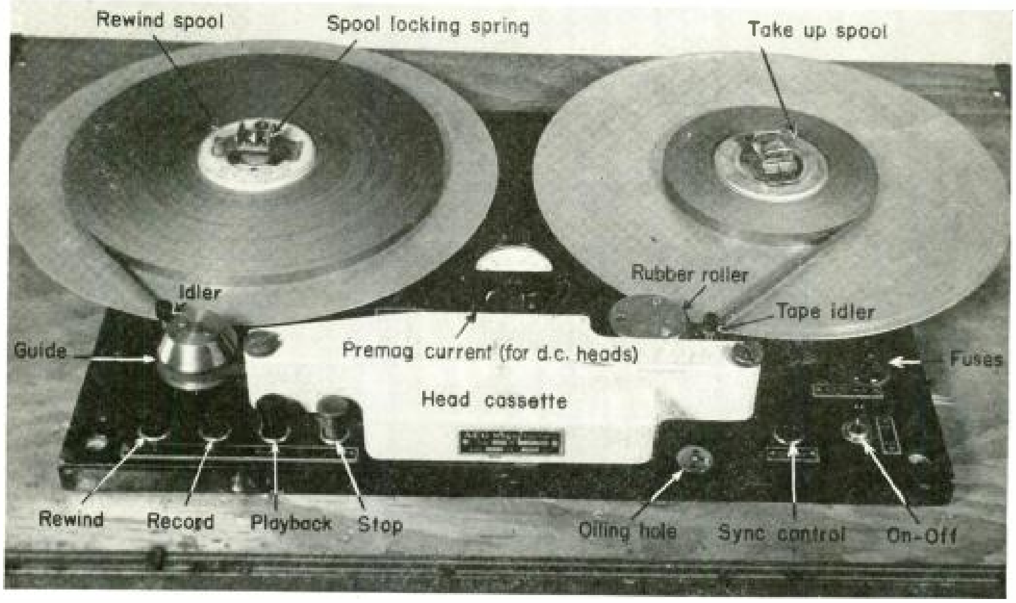


Top view of the Magnetophon described in this article.

The Magnetophon

DON V. R. DRENNER*

This is the first complete discussion of the studio model R22A Magnetophon which has greatly influenced the design of tape recorders in this country.

THE MAGNETIC TAPE RECORDING system to be described was developed prior to and during the war by the German General Electric Company (Allegemeine Electrische Gesellschaft), in co-operation with I. G. Farben. The equipment was used quite extensively not only for radio broadcasting, but by the army and the navy.

The principle of magnetic recording dates to the beginning of this century, when Poulsen found it possible to magnetize a steel wire to different degrees along its length. In 1924 this principle was used, again in Germany, in the design of a dictating machine. In 1931 the steel wire was replaced by a flat steel tape.[1]

The Marconi Co., of England, in cooperation with the BBC, produced a machine based on researches by Blattner and Stille, and put this into general use in 1934.

AEG and I. G. Farben began experiments in 1932 on a method to replace the steel wire and tapes then in use. The relatively high "hiss" level, and general background noise of steel mediums then available prompted this inquiry. In 1939 a satisfactory tape with a nonmetallic base was produced, together with a machine for utilizing the tape in recording and reproduction.

Although the literature covers the principles of magnetic recording, this article will deal briefly with the subject as it touches upon the use of high-frequency bias current in the recording process.

The Tapes

The success of the AEG-I.G. Farben machine—*The Magnetophon*—is due mainly to the tapes. The three types of tape developed in Germany were known as the type C, L, and LG and their production is covered in detail elsewhere.[2] Briefly, the Type C tape, the first produced, was an acetyl-cellulose-base tape 6.5 mm wide, .045-.05 mm thick. The magnetic material used was ferric oxide, derived from ferro-sulphate, ammonia and ammonium nitrate. The oxide was cast on the tape with a suitable binder.

The type L tape differed in that the tape material and the magnetic oxide were mixed, and the magnetic material thus was a part of the base tape, as opposed to being cast. The tape was a polyvinyl chloride. Thickness and width were the same as the C type.

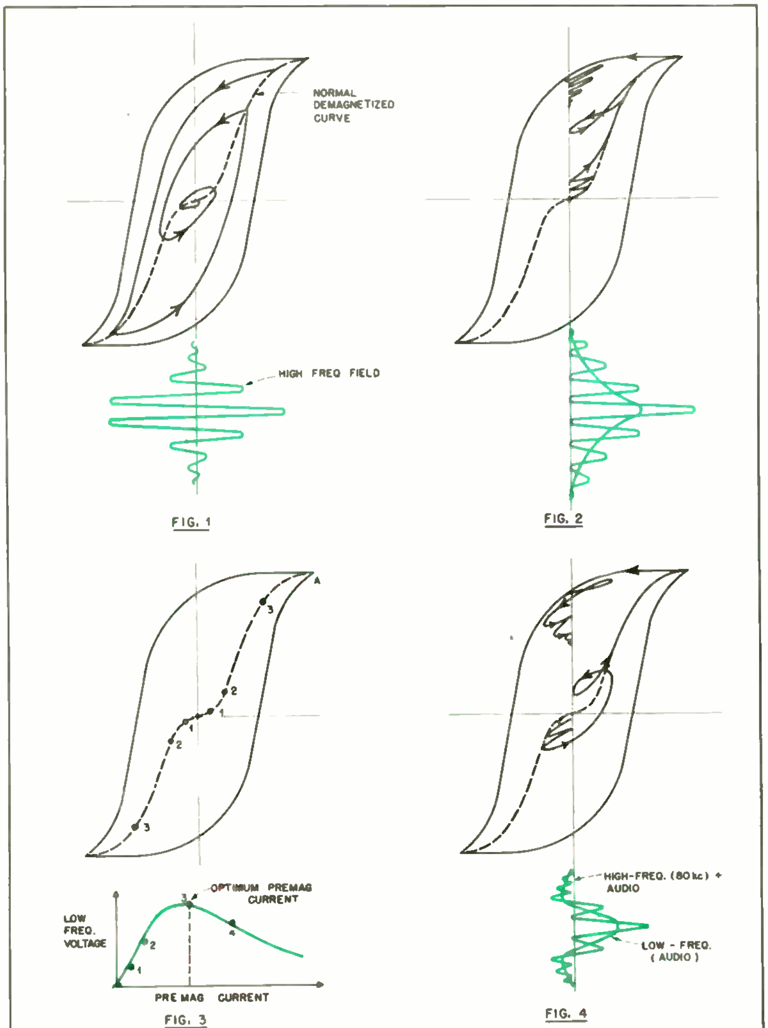
The latest tape was called Type LG, and consisted of a base tape with the magnetic material cast upon it, as in the C types. The tensile strength, frequency response and dynamic quality were all highly superior to the C type; however, this tape was never produced in quantity before the end of the war, and the L types were used almost exclusively.

In use the tapes are run in contact with the surface of ring magnets, arranged in a suitable cartridge containing the erasing magnet, the recording magnet, and the reproduction magnet. The magnets are miniature electromagnetic armatures, with the laminated cores ring-shaped. The gaps of the magnetic armatures vary with the three types, and run cross-wise to the tape.

The erasing head has a gap of 0.5 mm, an inductance of 1.7 mh. The erasing current is about 40 kc at 160 ma. The recording head has a gap of 40 microns, and a gap of 0.3 mm in the rear. Inductance is 8 mh, and the recording current (bias current) about 80 kc at 10 ma. The reproduction head has a gap of 20 microns, inductance is about 80 mh.

In practice, wearing of the tape-bearing

**513 Highland Rd., Coffeyville, Kan.*
[1] "The Blattnerphone."
[2] Dept. of Commerce report No. PB-1346.



HYSTERESIS LOOPS: MAGNETOPHON TYPE L TAPE, 80-kc BIASING

surface of the erasing head improves the demagnetization, that of the recording head tends to increase the loss of the higher frequencies, and wearing of the reproduction head causes an increase of the higher frequencies from 2000 cycles.

The tape speed for the latest machines, capable of reproducing frequencies from 50 cycles to 10,000 cycles was 77 cm/sec.

High-Frequency Bias

The specific characteristic of the Magnetophon, aside from its use of plastic tapes, was the utilization of high-frequency bias current in the recording process. This not only removed the most objectionable feature of the early steel wire and tape machines—high noise level—but resulted in greatly increased frequency response. The direct-current models of the plastic tape machines, introduced in 1939 with the nomenclature K4, used an erasing head fed by direct current. The recording head was also fed by direct current, upon which was superimposed the audio current. The hysteresis loop was quite conventional, and the direct current served to raise the recording to the linear portion of the loop.

In the high-frequency bias current system, the coil of the recording head contained not only the audio component, but a supersonic biasing frequency of about 80 kc. Over the gap of this head a magnetic field was formed with a maximum at the center of the gap, and a steady falling-off to both sides. Because of the high frequency nature of this field, a magnetic particle in passing undergoes a constant demagnetization, at first with a constantly increasing field and, on the other side of the gap center, with a constantly decreasing field.

Fig. 1 shows this process graphically, although for the sake of clearness only the fading part of the process is shown. Beginning at or near zero, hysteresis loops are created, getting larger and larger with increasing current until, at the maximum, the peak hysteresis loop is reached. After this a constant decrease of amplitude results, till the magnetic zero point is again reached. The tape therefore leaves the recording head in a completely demagnetized state. In the reproduction of such a tape, the unmagnetic medium cannot induce any noise.

Now, if the high-frequency premagnetizing current has at the same time a low frequency (audio) current superimposed upon it, then the recording field will have an appearance as in *Fig. 2*. The audio-frequency field remains substantially constant for the length of time the tape passes by the head. Because of the unsymmetrical position of the high-frequency field in respect to the zero axis, the tape now no longer leaves the field in demagnetized state. Rather, it contains a residual magnetism which is proportioned to the recording (audio) current.

The curve shown in *Fig. 3* shows the non-linear behavior in the vicinity of the zero point, and after a short linear space, the turning-off into saturation. In the direct-current recording systems a large premagnetizing direct-current was used, to transpose the working point into the linear part; or, in the case of the Marconi-Stille (BBC) steel tape machines, a heavily saturated medium was used and by means of a counteracting current (superimposed with the audio component) the linear portion of the curve was used. The use of high-frequency premagnetizing current permits the utilization of the curve from the zero point with few non-linear distortions. The amplitude of the premagnetizing current is important. In the case of small amplitudes there is a slight steepness, which increases as the amplitude is increased, but which again decreases when the working maximum is reached, as shown in *Fig. 3*.

Recording Field

The effective recording field exists over about 0.5 mm from the center to each side of the gap in the recording head. This area is taken to include only that portion of the field which is not below 1/10th the maximum amplitude existing at the center. With such a field it is assumed that during the passage of the tape a constant low-frequency field exists only at the low frequencies, and at high frequencies—in the vicinity of 10 kc—the low-frequency field will have changed in its phase before the tape has left the effective limits of the recording head. At 180 deg., however, the two will work against each other, so that the difference between the low and high frequency fields remains as magnetization. The remanent induction on the tape falls off from about 2 kc insofar as constant magnetization is concerned, *Fig. 4*. In practice this is counteracted by preemphasis in the recording and reproducing amplifiers.

It is necessary for good high-frequency results in recording that the magnetic field at the recording head be limited. This limitation is largely dependent upon the thickness of the tape, and its specific magnetic conductivity. Tapes with a greater permeability of the magnetic layer, or material, exhibit a falling-off at the high frequencies since they produce a flatter curve. A thicker medium will cause the same results; or poor (i.e. removed) contact with the recording head, since the magnetically poorly conducting air layer between the tape and head results in the same thing.

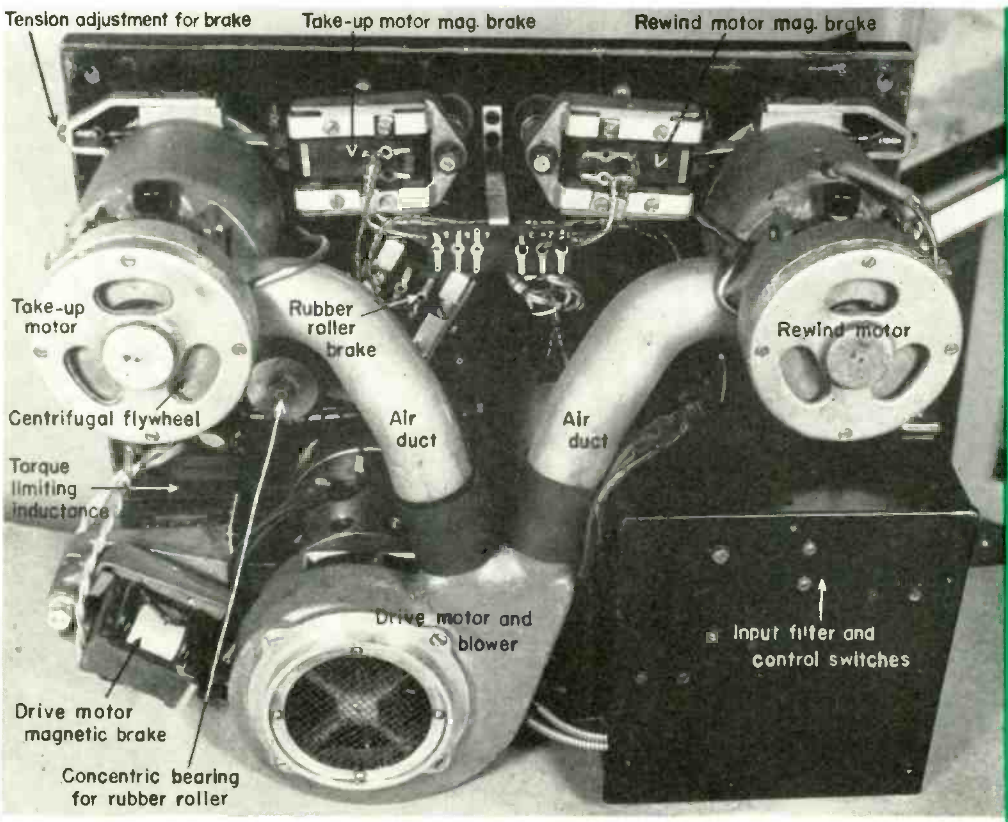
As previously stated, the tape runs past the three heads at 77 cm/sec. The first head—erasing and the second—recording—are fed from an amplifier, shown in *Fig. 5*. This amplifier produces the 40-kc erasing current, the 80-kc biasing (premagnetizing) current, and has a single-stage amplifier, with high-frequency preemphasis networks, for the audio. The normal input level from the audio source is 1.5 v. The output of the audio amplifier is mixed with the 80-kc current at the point where the connection is made to the recording head. The network in the secondary of the output transformer blocks the 80 kc from reacting on this. The amplitude of the audio portion is about 8 ma, and that of the 80-kc current between 5 and 15 ma. Each recording head is usually calibrated for a certain current, and the amplifiers adjusted to conform with this value.

It is important that the plate voltage for the biasing oscillator be connected before the recording head is placed into the circuit, otherwise the current surge when the plate voltage is connected will tend to magnetize the recording head. This results in noise on the tape, since the tape becomes slightly demagnetized as a result of the magnetization remaining in the recording head. The proper sequence of switching is done through the recording controls, shown in the schematic. A curve for this amplifier is shown, with the preemphasis control set at zero, one-half, and full on.

Reproduction Amplifier

Fig. 6 shows the reproduction amplifier, and its frequency-response curve. The control circuits and motors are shown in the over-all schematic, *Fig. 7*. Three motors are used to drive and rewind the tape. The drive motor, which runs the tape, (usually in lengths of about 1 kilometer) has a spindle extending from its shaft, which bears against the tape against a rubber roller. The pressure of this roller against the drive spindle is controlled by a device, actuated by a magnetic brake which operates simultaneously with the application of power to the drive motor, to the brake on the drive motor, to the rewind and take-up motors and to their magnetic brakes.

The normal pressure of the roller against the drive-motor spindle (and the tape, since it is between the two) is about 250 gram/sq. mm. This will result in the motor spindle's steel shaft attaining a depth into the rubber of the roller of .8 to .9 mm, representing a pressure sufficient to give a normal tape transport. The pressure of the roller against the tape and the drive-motor spindle can be adjusted by the concentric bearing which houses the shaft of the actuating lever. Two lock-screws are fitted which control the minimum/maximum throw of this lever, (actuated by the magnetic brake mentioned above). The tangential movement of the lever is taken from the point of contact with the tape and motor spindle to the point of greatest swing of the lever. This movement can be measured by a small spring-tension scale, or "pressure watch," so that the depth which the spindle attains when the roller is pressing against it is .8 to .9 mm. (.1 mm tolerance). The tape will run up and down if the roller surface is not parallel to the driving spindle, or vice-versa. After a time the tape wears a small groove in the roller, and consequently the transport is bad. This can be



Under-chassis view of the Magnetophon.

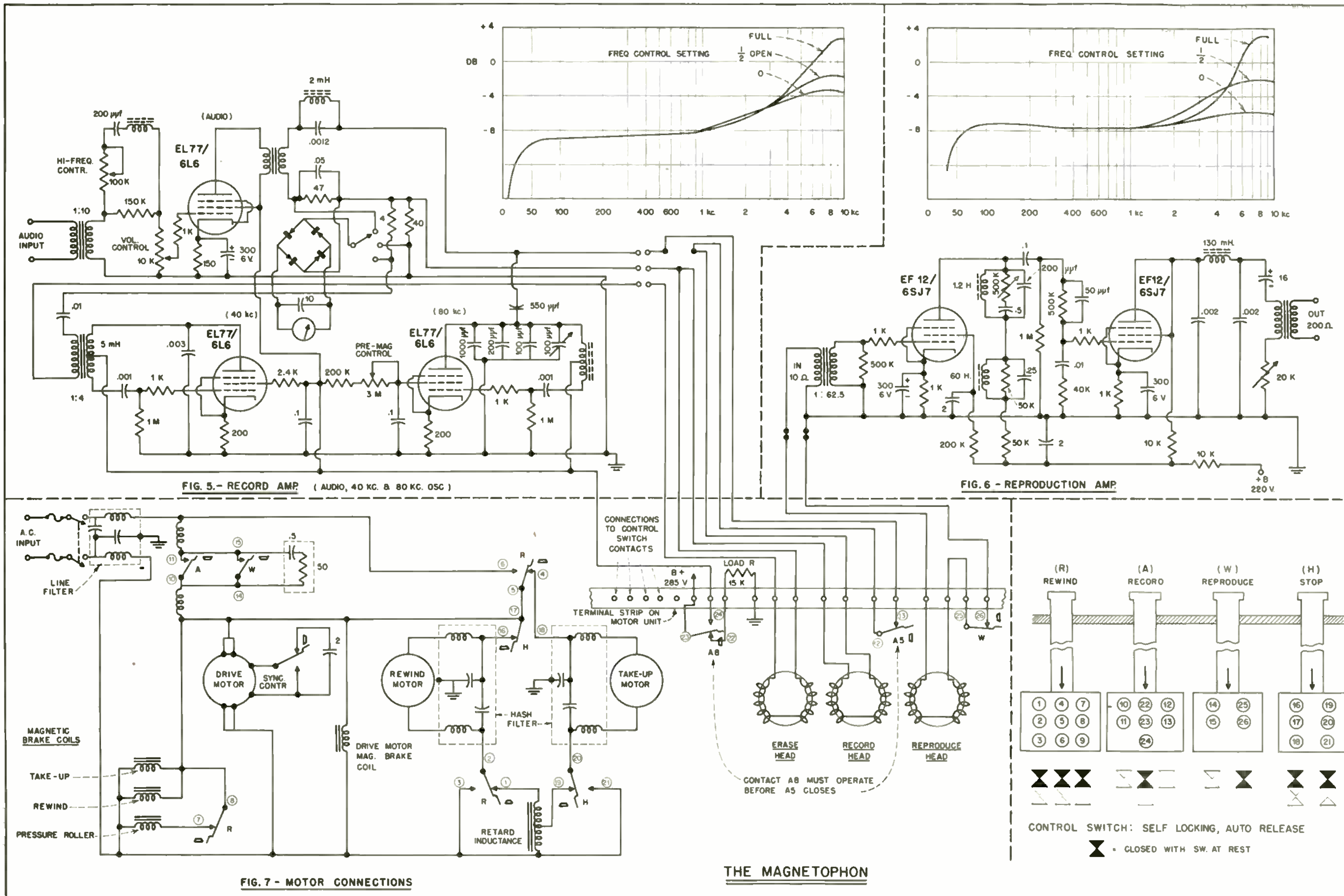
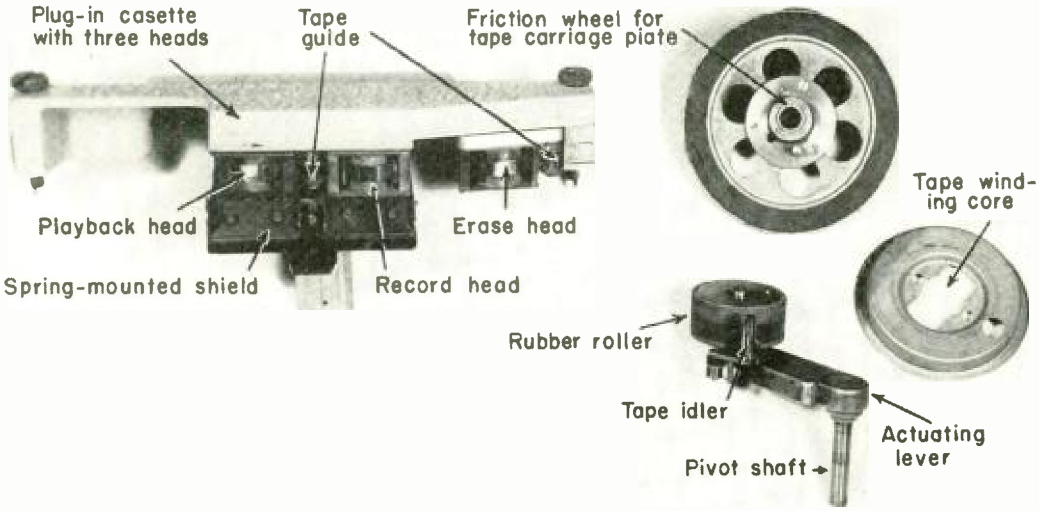


FIG. 5.- RECORD AMP. (AUDIO, 40 KC. & 80 KC. OSC)

FIG. 6 - REPRODUCTION AMP.

FIG. 7 - MOTOR CONNECTIONS

THE MAGNETOPHON



A few of the components used in the Magnetophon.

remedied by buffing the roller down, or replacing it with a new one.[3]

The drive motor is a synchronous motor, while the rewind and take-up motors are brush, series-type motors. While the drive motor is running the tape past the recording/playback heads, the take-up motor is running in the same direction, at approximately the same speed. The rewind motor, however, tends to run in the *opposite* direction, to exert a pull against the tape. When in the record or playback position the rewind motor is fed through an inductance which limits its torque. In the rewind position this motor has full power, while the drive motor operates only to provide blower ventilation (it is fitted with a small fan and ducts to cool itself and the other two motors).

Since the speed of the series brush motors depends on the load, the rewind and take-up motors begin at fairly high speed, and tend to slow down as the tape load on their spindles increases. This insures that the tape is held at sufficient tension at all times, and with the operation of the magnetic brakes—fitted on the small flywheels in the end bells of the motors—the tape does not snarl or run loose. However, tape troubles, such as snarling, breaking, or running with loops can almost always be traced to misadjustment of the magnetic brakes, or variations in the motor speeds, due to faulty brushes, burned commutators, etc. It is essential that the three magnetic brakes on the motors, and that on the pressure roll, operate simultaneously.

The average tape, of 5/8ths mile in length, runs for about 20 minutes, and takes about 3 minutes to rewind. Since two machines are necessary for continuous playing, each machine is fitted with a synchronizing control so that the program on the machine about to be switched into the audio circuit can be matched with that of the one playing. This control is on the drive motor, and serves to short the series condenser with which this motor is fitted. In practise, the tapes are recorded with a "lapped" recording, so that the end of one and beginning of the other are the same. The second machine is started ahead of time and then slowed down until the two are in sync, and at the proper moment the change-over takes place—without any indication to the ear whatsoever. The control switches—push-button locking type—have been labeled on the schematic, and their function can be easily followed.

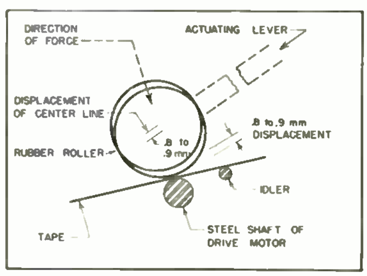


Fig. 8. Detail of tape drive mechanism.

Electrical Troubles

The following electrical troubles sometimes occur:

A "whistling noise" on the tape. This is caused by the 3rd harmonic of the biasing oscillator. Small padders are provided in the oscillator grid circuit so that this can be transposed out of the audible range.

A "rushing" noise due to residual magnetism in the recording head. (Usually caused by the biasing oscillator receiving its plate voltage after the recording head is in circuit.) The contacts should be spaced for their proper temporal sequence, and the head demagnetized.

Magnetic objects, tools, etc., should not be placed at rest near the head pieces, as this will result in magnetization of them.

Insufficient erasing is usually the result of low plate voltage on the 40-kc oscillator. Other sources can be misalignment of the tape with respect to the erasing head, or a short circuit in the coils of the erasing magnet.

In reproduction, the output from the amplifier may decrease due to the cathode by-pass condensers deteriorating or because of the filament and plate voltages being low. Distortion in reproduction which is not directly due to the amplifier can usually be traced to insufficient high-frequency premagnetizing current.

Various Models

The various models of the Magnetophon differ mainly in physical size, length of recording time, and in one model, variability of the tape speed. The Model K4 was arranged for portability. Most of the material contained herein concerns the R22A, which was used by the German Broadcasting System (The RRG) for programming. The frequency response of this system was uniform from 50 to 10,000 cycles within less than 5 db., the noise level approximating —45 db,* and the distortion at 500 cycles measured 4%. These figures are not necessarily

[*Continued on page 35*]

[3]Almost the only difficulty experienced with the Magnetophon is tape troubles, such as above. The elimination of some of these difficulties will be mentioned in the description, since users of the American version of this machine may experience them, and find these comments helpful.

*A figure of "greater than —70 db" is given by "Braunbuch," a manual of technical maintenance published by the Reichs-Rundfunk (German Broadcasting System), but is weighted according to a hearing curve.

Dynamic Symmetry and Acoustic Room Design

M. RETTINGER*

How properly proportioned acoustic rooms improve appearance and increase utility.

THE APPLICATION of dynamic symmetry to the acoustic design of rooms appears to hold considerable promise. Dynamic symmetry is well-known to architects, and many mechanical engineers avail themselves of it in the design of machines.[1] Unfortunately, the numerous popular expositions of the subject are fraught with a jargon of their own, both confusing and repulsive to the more mathematically minded. In the following discussion, therefore, the subject will be treated without apparent esoteric verbiage.

Consider *Fig. 1*, showing a rectangle of width 1 and length $\sqrt{2}$. When such a rectangle is divided into two equal parts as indicated by the dotted line, the resulting smaller rectangles will have proportions similar to the large rectangle:

$$\sqrt{\frac{2}{1}} = \frac{1}{\sqrt{\frac{2}{2}}} = \frac{2}{\sqrt{2}} = 1.414$$

Popular theory prefers to speak of such a figure as a "root 2 rectangle;" or, in the case of the smaller rectangles described above, as "One over root 2 rectangles"—plainly a disturbingly abbreviated description. Because the smaller rectangles are similar in shape to the large oblong, such a sub-division appears pleasing, and is frequently employed in industry, as in proportioning the doors of a cabinet or the panels of a window. Similar results are achieved when a rectangle of width 1 and length $\sqrt{3}$ is divided into 3 parts; or a rectangle of width 1 and length 2 (that is, $\sqrt{4}$) is divided into 4 parts; or a rectangle of width 1 and length $\sqrt{5}$ is divided into 5 parts; etc. as shown in *Fig. 2.* The fact that in each case the resulting smaller rectangles are proportional to the large rectangle, makes the figure so divided more attractive than when a similarly large rectangle had been divided into the same number of parts which were not proportional to the original figure.

Golden Rectangle

A rectangle to which a good deal of attention has been devoted is known as "the golden rectangle," of which the ratio of width to length is obtained as follows (see *Fig. 3*):

$$\frac{W}{L} = \frac{L}{W + L}$$

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[1] R. S. Elberty, "The Shape of Things," *Machine Design*, Aug., Sept., Oct., 1943.

Pleasing design results when smaller rectangles are similar in shape to a larger one of which they form a part.

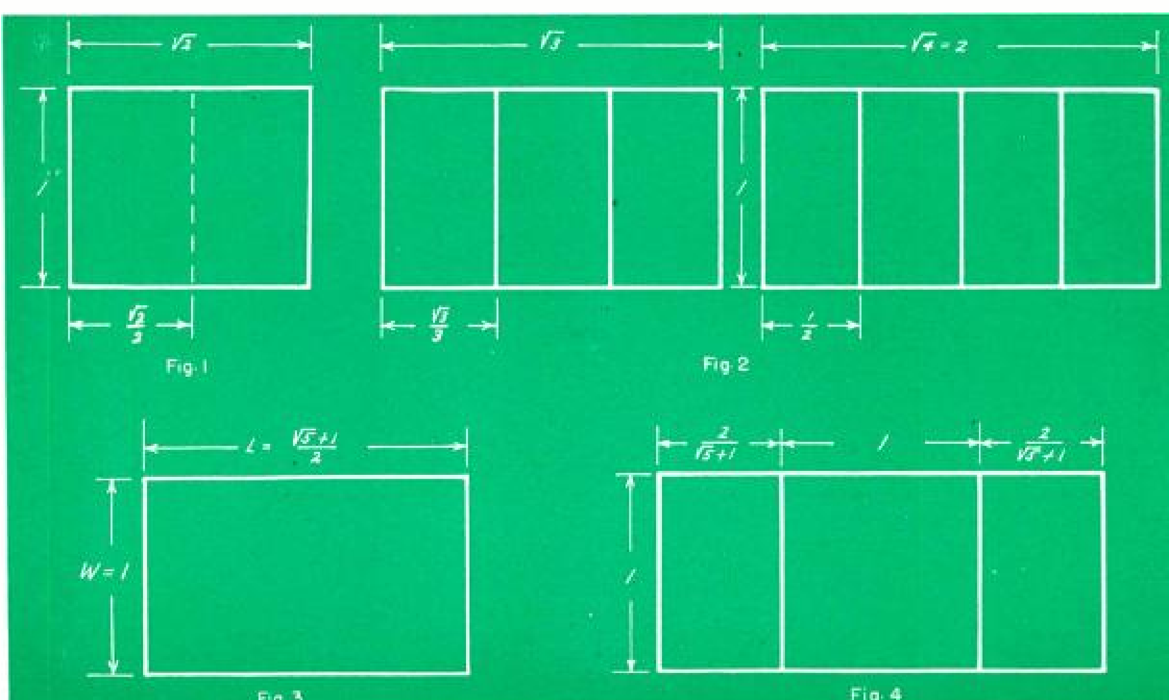


Fig. 1 Fig. 2 Fig. 3 Fig. 4

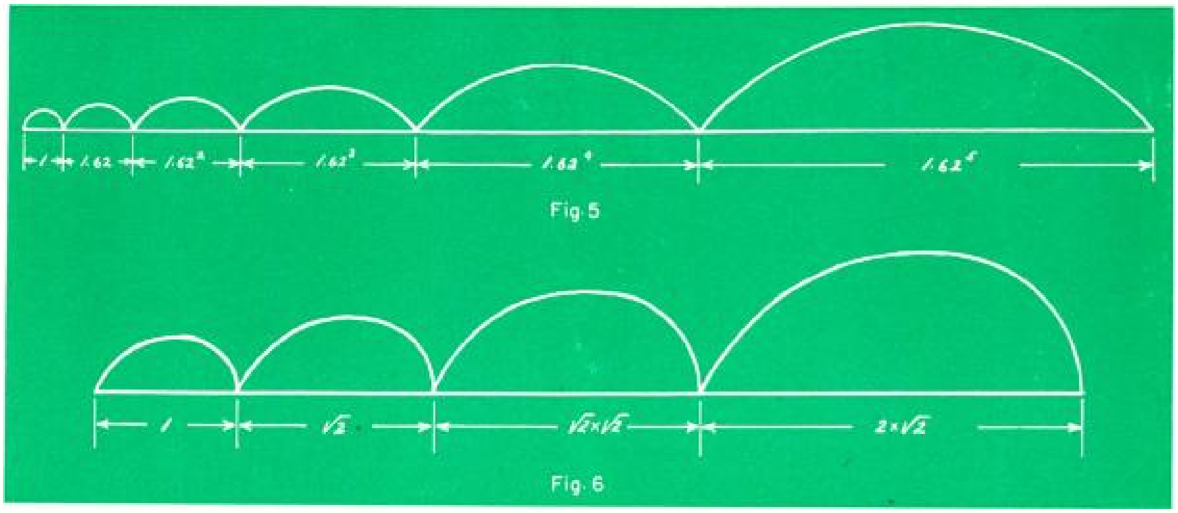
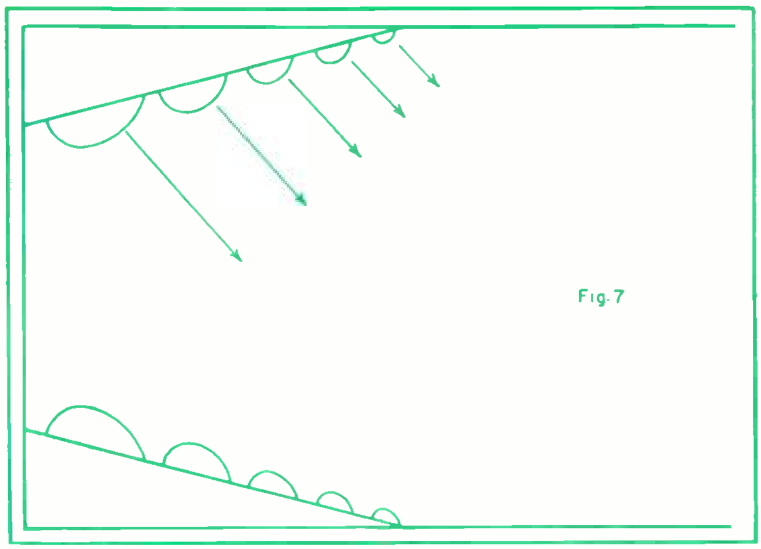


Fig. 5. Examples of static and (Fig. 6) dynamic forms. Fig, 7 (right). Schematic of acoustic treatment of music and band shell.



By letting W be equal to 1, the length can be computed to be 1.618, as follows:

$$\frac{1}{L} = \frac{L}{1+L}$$

$$1 + L = L^2$$

$$L^2 - L + \tfrac{1}{4} = \frac{5}{4}$$

$$(L - \tfrac{1}{2})^2 = \frac{5}{4}$$

$$L - \tfrac{1}{2} = \frac{\sqrt{5}}{2}$$

$$L = \frac{\sqrt{5}+1}{2}$$

$$\cong 1.618$$

The factor of 1.618 can be approached by the ratio of any two succeeding numbers in the series 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144 . . . where each number is the sum of the two preceding numbers. For instance $144/89 = 1.619$; or $34/21 = 1.62$. This ratio is often observed in nature, as in the number of seeds in the sunflower contained in the large and in the small seed-row spirals (say 55 seed sockets in the large and 34 seed sockets in the small spiral); or in the number of seeds contained in pine cones, etc. In music, the intervals of the major and the minor chord (3:5:8) are similarly related by the factor 1.618. Of course, a "golden rectangle" cannot be divided into a number of equal smaller rectangles proportional to the large rectangle; but a rectangle of width 1 and length $\sqrt{5}$ can be divided into a square, and two equal smaller rectangles, the ratio of whose length to width equals $(\sqrt{5}+1)/2$, or 1.618, as shown in *Fig. 4*.

Room Design

The question arises now how such (and other) principles of dynamic symmetry can be applied to the acoustic design of rooms. As indicated above, dynamic symmetry concerns itself with pleasing proportions, with an attractive arrangements of parts. While such proportions are not strictly functional factors, their esthetic or artistic value should not be underestimated. A room such as a broadcast or motion picture studio provides a locale for a band of musicians—artists—to whom the pleasing environment can be of a marked influential character. Hence, in the final results, the purely artistic may have a functional bearing on the result, so that it appears to the interest of the design engineer to concern himself with the subject.

To illustrate the point, let us consider the prevalent use of cylindrical wood splays in recording studios. To avoid selective absorption in such an enclosure, the splays are built of various sizes, that is, of various widths and various radii, and are, moreover, non-uniformly braced in the back. Why, then, would it not be possible to vary the size of these splays in a "dynamic symmetric" fashion, for greater eye-appeal, as shown in *Fig. 5*?

Static and Dynamic Forms

The above was written merely to suggest possibilities of treatment: the acoustic engineer called upon to design a room will have to exercise his own faculties in this respect, not only because the individual parts of a room should harmonize with the enclosure as a whole, but also because each room must be treated individually, depending on its purpose, size, etc. So far, we have concerned ourselves merely with the fundamentals of dynamic symmetry. The advanced student of this school of art will soon learn that circles, or circular arcs, because of their patently obvious symmetry, are less forceful than elliptical, parabolic, or hyperbolic sections. For this reason, circles are spoken of as static; ellipses as dynamic. Wood splays built of such non-

[*Continued on page 48*]

A New Phonograph Pickup Principle

ALBERT E. HAYES, JR.*

A simple method of obtaining high audio output from a capacitive pickup.

ALTHOUGH rather old as a laboratory curiosity, the capacitive phonograph pickup has only recently attained a status of importance in the art of sound reproduction. In its early days when it was hooked up like a condenser microphone, as in *Fig. 1*, it suffered from the shortcoming that at least two stages of amplification were required to bring the signal level up to that obtainable from the then-popular magnetic pickup. However, the manifest advantages of this type of pickup were well recognized; these were: 1) low vibratory mass, 2) relative freedom from resonance peaks within the desired signal spectrum, and 3) ease of obtaining linearity.

"Wireless" Player

With the development of practical frequency-modulation circuits, interest in the capacitive phonograph pickup revived when it was realized that it provided a relatively simple and reasonably linear device for modulating the frequency of an oscillator. This led to several arrangements similar to that shown in *Fig. 2* wherein a capacitive pickup C_p provides the capacitive element of a frequency-determining tank circuit for an oscillator. The frequency-modulated output of the oscillator was coupled to an f-m detector either by means of a coupling link L_2 coupled to the tank coil L_1, by direct radiation (as a "wireless" player) to an f-m receiver, or by coupling to an f-m detector comprising an integral assembly with the oscillator. These arrangements permitted the obtaining of sufficient audio signal voltage from the f-m detector to operate into a conventional audio channel, but suffered the shortcoming that the f-m detector used had to be tuned rather accurately to the center or "rest" frequency of the oscillator in order to minimize distortion. It has been this necessity of accurate tuning which has heretofore limited the field of applicability of this type of pickup, for the frequency drifts caused by aging, temperature changes, and physical mishandling have kept the "f-m phonograph pickup" in the gadget class.

The following is a description of a new principle of phonograph reproduction, using the capacity pickup, which is not subject to the shortcomings of the arrangements described above.

Circuit

In *Fig. 3* there is illustrated a conventional T.N.T. high-frequency oscillator including a tube V_1 and a plate tank circuit tuned to resonance by an inductor L_1 and a condenser C_1. The grid circuit comprises an inductor L_2 having a self-resonant frequency near that of the plate tank circuit, and conventional grid-leak biasing from the parallel circuit including a grid-leak resistor R_1 and a grid condenser C_2. A pair of audio output terminals are shunted by a condenser C_3, and the ungrounded terminal is connected to the ungrounded end of the grid-leak through a radio-frequency choke. A capacitive phonograph pickup C_p is connected between the grid and plate of the vacuum tube.

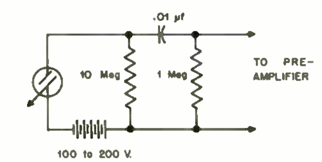


FIG. 1

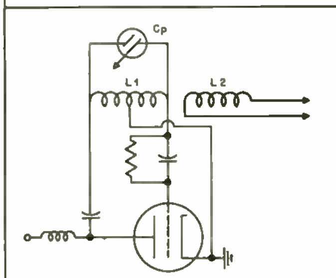


FIG. 2

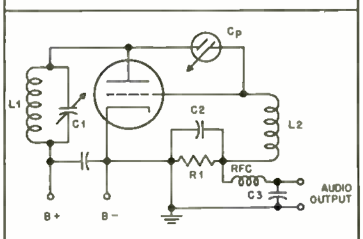


FIG. 3

Fig. 1. Early type of capacitive pickup, which was connected like a condenser mike. Fig. 2. Using a capacitive pickup to frequency modulate an oscillator. Fig. 3. Using the capacitive pickup to vary the voltage drop across the resistor R1, in accordance with the a-f signal.

Operation

In operation it will be obvious that the above-described arrangement comprises a well-known type of high-frequency oscillator with the addition of a variable capacitor C_p connected between grid and plate of the tube. It will further be obvious that an increase in the capacity C_p will increase the amount of feedback energy or "drive," and that a decrease of capacity will decrease the drive.

It is well known to those skilled in the oscillator art that the magnitude of the d-c bias voltage developed across the grid-leak R_1 will be increased with an increase in drive, and will be decreased with a decrease in drive. It will be manifest, therefore, that a variation in capacitance of the pickup C_p in accordance with the physical convolutions of a record groove will cause an alternating potential to appear across the resistor R_1 which will comprise an audio-frequency signal. The choke and the condenser C_3 comprise a filter circuit to isolate stray r.f. developed in the oscillatory circuits from the audio output terminals.

Because the signal is derived solely from the bias circuit, there is no need to compensate for any long period variations in either amplitude or frequency of the r-f signal.

Although the T.N.T. oscillator has been shown for reasons of simplicity, it has been found that T.P.T.G., Hartley, Colpitts, and Armstrong oscillator circuits perform equally well in this scheme.

The output signal obtained using a 955 tube as the oscillator with 150 volts applied to the plate is comparable to that obtained from a high-level magnetic pickup, and retains all the advantages of the capacitive pickup.

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Factors Influencing Studies of Audio Reproduction Quality

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Listener preference tests are often inconclusive because important factors are given insufficient consideration in interpreting results. The author shows how such pitfalls may be avoided.

THE RENEWED ACTIVITY of f-m broadcasting plus the normal and natural tendencies for improvement in a-m transmission have resulted in the initiation of a variety of tests to determine the characteristics of the transmission and reproduction system that is preferred by listeners.

The need for this kind of experimentation and data is exemplified by the comments of the investigators,[1,4,6] the urging of editors to continue this type of research[2] and the resulting discussions.[3,9]

When it comes to researches relating to human behavior and the more elusive aspects of reaction to the relative esthetic quality of reproduced programs, we are confronted with many variables, and paradoxically speaking, "we don't always know just what variable it is that we are really measuring." It is therefore apparent that, in order to avoid the waste of time, effort, and money, some reasonable agreement should be obtained between the researchers in the field before costly experiments are carried out, so as to insure against accumulation of masses of unrelated or unusable data.

Statistical Interpretation

Experimental tests to show the effect of variation of band widths upon the esthetic quality of music have been reported.[1] These tests utilized high- and low-frequency cutoffs which correspond to liminal units previously reported in tests conducted at the Bell Telephone Labs.[5] The final results were tabulated in percentages and conclusions drawn therefrom.

It has most recently been clearly expressed by Gannett and Kerney[8] in discussing the ability to *detect* differences in band widths, "A significant measure of the detectable difference in band width will be taken to be a difference such that 75% of the observers correctly select the wider band and 25% wrongly select the narrower band."

The significance of the vote of 75% to 25% is *assumed* to be as follows: On a particular test some of the observers can *detect* the difference between the conditions while the remainder will guess. Of the latter, half are likely to guess right and half wrong. When 25% vote wrongly, they are assumed to be guessing and must be paired with another 25% who also guess, but happen to guess right. Therefore, a vote of 75% to 25% was taken to indicate that 50% of the observers were guessing and the remainder could actually *detect* the difference. It should be remembered that this reasoning was used in conjunction with tests dealing with the ability to detect changes, rather than with listener preference tests.

Fletcher[4] used an 80% to 20% straight percentage majority to indicate a significant judgment, probably reasoning that a 60-40 majority shows some significance. Of the 40%, half would guess wrong, finally showing up as an 80% to 20% vote.

Tests which do not produce any positive significant results should be carefully scrutinized for unjustified elements which may be interfering with the variable under test. It might be argued that data indicating 50-50 preferences are valid and useful. Certainly, but for study purposes only! Just as soon as 50-50 preferences enter into design parameters of audio equipment, it follows that 50% of the ultimate users may be discriminated against and those who would like to hear everything must be disappointed.

The inadvisability of using averages as parameters in design can best be illustrated by the following hypothetical situation. Let us suppose, for a moment, that manufacturers of spectacles decided to do away with the wide variety of lens types. A million pairs of eyes are tested and a mean average is used for the design of all available eye glasses. Everybody thereafter, regardless of his individual deficiencies, would obtain only this standardized spectacle.

Admittedly this analogy is strained, but potentially the end result closely parallels conditions which prevail in audio reproduction whenever systems are designed for "averaged" preferences.

It therefore appears, that until valid inferences are formulated, audio reproducing systems should be developed to approach as closely to the "ideal" as possible. Such systems, however, should give the ultimate listener complete control of the variable in question so that he, and only he, can adjust performance characteristics to coincide with his immediate and particular esthetic preference at any time.

The "Ideal" System

An ideal transmission system from an engineering viewpoint might be defined as one which would transmit any sound to a distant point and reproduce an exact replica of the original performance.

Mills[7] indicated that it is a safe assumption, for the ultimate future, to develop methods for recording and reproducing music which will cover the entire range of intensities and frequencies that the human ear can appreciate. This thought undoubtedly has the support of all engineers and researchers not pressed by expediency. Nevertheless, tests proving the contrary will be welcomed by all, but the burden of the proof will have to be borne by the validity of the test and all associated factors which influence the final conclusion.

The requirements for an ideal system are known to be extremely stringent, and possibly unattainable in the present state of the art. Here, then, lie the reasons for investigation seeking to determine how far from the ideal audio transmission may be deteriorated, without materially affecting the esthetic qualities of program material.

Esthetic Appreciation

For our purposes of discussion, the term "esthetic" will be confined to that branch of emotional experience which deals with the beautiful as interpreted by the hearing mechanism. Here we have a complex subject which encompasses acousto-psycho-physiology. Unless all of the factors influencing esthetic choices are carefully analyzed, erroneous statistical data can be easily accumulated. It seems desirable to set up a standard for

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estheticism before any tests are conducted to measure the effect of any single variable audio design factor upon esthetic appreciation.

It must be obvious to most researchers in the field, that not all types of music are considered esthetic by any one or any group of individuals. It therefore follows that if any program material is used which does not, at the start, appeal to all listeners, any variation, whether it be in reduction of volume range or frequency band width, which tends to eliminate some of the unesthetic qualities of the original program material, may be erroneously reported as a listener preference.

The acoustic balance of the original orchestration may, in turn, similarly effect the results of research into the relative esthetic value of predetermined band widths in audio transmission. Experience indicates that much esthetic appreciation of music is based upon familiarity with a particular selection, melody, past association, or virtuosity of the performer. Any tests which do not take into consideration these characteristics may produce results of doubtful value.

Musical Enhancement

Some tests, designed to correlate esthetic appreciation of programs with program transmission width, are in effect testing for the desirability of improving musical instruments. It does not necessarily follow, when a musical instrument emits undesirable bowing or blowing noises and these are considerably reduced by restricting the pass-band of the audio reproducing system, that transmission bands should be universally restricted.

It is obvious that the human ear has played the important determinative role in the development of music and musical instruments. There is no doubt that musical enhancement will improve the esthetic qualities of many types of programs. For example, the introduction of a controlled vibrato into the program circuit may, in terms of listener preferences, improve the appreciation of a singer's voice. Similarly, increased dynamic range may in terms of some listener preferences, improve the composer's concept. Fundamentally, however, researchers in program transmission should not, unknowingly, step into another branch of music and unwittingly jump to false conclusions.

In addition to the normal characteristics usually furnished along with an audio reproducing system, it is also desirable to indicate the crossover characteristics of multi-speaker systems, as well as phase shifts at or near crossover or cut-off points. Consideration should also be given to the possible generation of inharmonic sub-frequencies by the loudspeaker. Of course, full data covering the distortion vs. frequency characteristics of the over-all system should be given. When recorded programs are compared with live programs, it is also necessary to include complete data on the distortion introduced by the recording system, pickup, microphone and cutting-head. Data should also include all intermodulation distortion characteristics, as well as frequency vs. distortion data.

In addition, the acoustic characteristics of both the original studio and the reproduced room must be carefully compared in order to evaluate the possible contributing influences introduced by this variable.

Coached and Uncoached Reactions

It is known by many experimenters that suggestion plays a very significant role in tonal range preferences. Therefore, experiments involving subjective reactions must be carefully controlled and objectively interpreted. Whenever tests involve unusual physiological reactions, it would seem highly desirable to conduct a set of uncoached and coached reactions, so that the result could be properly codified as to its significance. Uncoached reactions would clearly indicate what listeners prefer without any explaining or "coaching." In other words, it would disclose the existing attitude, and might also incidentally indicate how much they know about it, or how little they know about it, and to what degree their impressions are in harmony with fact. It would also disclose valuable data indicating preferences based on lack of, or erroneous experiences.

While there can be no question that spontaneous reactions are highly significant for the present and the immediate future—deliberative or analytical reactions would be more significant for the long range future or ultimate trend of listener preferences. True, this is a subtle point, but in a complex investigation of this nature, any fact which throws additional light into a dark corner, is bound to be helpful in the over-all investigation. It may reveal that choice was based on a factor totally foreign to the intended variable in the test.

To coach the reaction, on the other hand, would forecast what listeners' preferences will be after the listener has experienced the effect of the variable. The coached reaction explains the variable in the test, and indicates its action before checking listener preferences.

Listeners who have never heard live cymbals, snare drums, triangles, or an organ, would be severely handicapped in an attempt to evaluate the esthetic properties of their reproduced versinos, as no standard of esthetics will have been established for these instruments.

One might argue, "What difference does it make whether or not listeners have heard these live instruments so long as they preferred to hear their reproduced version through a restricted band width?" In a coached reaction the listener would be given an aural demonstration of the effects of a restricted band width upon the reproduction of a triangle in an orchestra. The results from such a test would indicate listener preferences, after being fully acquainted with the effect of having the triangle in or out of the orchestration, whereas, in an uncoached test, the listener may never become aware of the presence or absence of this musically embellishing instrument.

When comparative tests[1,4,6] are made on relative band widths or volume ranges, and these are compared during a program wherein changes in transmission characteristics are made for short lengths of time, it is important that the "switch-in" and "switch-out" do not coincide with any potentially inharmonious or other esthetic-destroying phenomenon in the program. For example, if the horn sections of a symphony orchestra are not in perfect tune, an amplitude changing condition may appear to improve the esthetic quality in the program. Similarly, the introduction of varying band widths on different passages of music in the same selection may appear to produce both noticeable and unnoticeable effects. In both cases, erroneous subjective reactions would be indicated.

Qualification of the Listener—Hearing Acuity

In all recently reported tests covering the esthetic preferences of listeners, a great deal of descriptive data about the listeners were given, including sex, age, education, musical preference, musical training, and musical experience, in an effort to show that a reasonably typical cross-section of listeners was used. In not one of these tests was the hearing acuity of the listeners given. This omission was evidently intentionally committed, as the prime purposes of the tests involved were "determination of the method of reproduction which is most pleasant to the observer, rather than a study of his ability to detect changes in tonal ranges, or to hear sounds of various frequencies and intensities."[1]

It appears to be both highly desirable and statistically valuable to identify each of the listeners and indicate his frequency and dynamic hearing acuity. Possibly, such preliminary tests on the listeners might disqualify some from participating on the grounds that they are physiologically incapable of hearing the particular variable for which the test is designed. Acousti-psychological tests should also be conducted upon listeners in an attempt to determine any anti or pro preferences for particular instruments, composers, music style, orchestrations, arrangements, performing artists, and other factors influencing esthetic appreciation.

A reasonable agreement on esthetic test material should exist among all qualified listeners. In other words, program material, which in some form or other appeals to everybody, should be used as a base. Single variations then, upon the transmission characteristics in reproducing this mutually agreed test material, will produce results more closely in line with the researcher's intent.

From time to time, musicians are interposed into the listener's group with the idea of getting some "expert" opinions. Many observers know that the average musician sitting in a symphony orchestra never hears the complete orchestra in its best balance. A French horn player who has had his instrument wrapped around him for 20 years "of experience," certainly acquires an unusual musical perspective. Similarly, the player who continuously pounds his kettle drums is by no means, because of his experience, an expert on the esthetic qualities of the harp. The conductor of the group is probably the only one who gets a reasonably balanced version of the performance (to be sure, the musicians probably *do* go to the concerts of other orchestras). In no case, of all reported tests, was any indication given of the number of times a listener actually heard a live orchestra similar to the one used for test. It is true that one may argue, "What has realism to do with esthetics?" A listener need not have had any experience with a live orchestra in order to indicate how much deterioration in an audio transmission system he can tolerate without effecting his esthetic sense. Nevertheless, other researchers, in the same field, studying the results of a given test would like to know how qualified the listeners really were to detect the variable for which the particular test was designed.

There is reason to believe that music lovers who have gained their esthetic appreciation of music through reproduced versions have been aurally disillusioned, and possibly are incapable of discernment of esthetic improvement under conditions which differ markedly from the sum total of their previous experiences.

Listeners who have never sat close to a live heavy symphonic orchestra can easily have their esthetic senses "tied" to an experienced volume range. Similarly, a listener who has never experienced the "feeling" of the low frequencies of a large organ can exercise but doubtful significance in a test involvingthe esthetic value of a reproduced version of organ program material.

Range of Test

In order to insure the significance of the results of the test, it is desirable to increase the range of the test in opposite directions so as to serve as a double-check. For example, in testing for the effect of esthetic appreciation of a program vs. program band width, the test should not be confined to three high-frequency cut-off points, such as 5,000, 7,000 and 10,000 cycles. The test should be continued for at least one or possibly two liminal[8] units below the interested range. By following this procedure, some deficiency in the test technique may be uncovered, particularly when the results do not bear some logical relation to each other. Furthermore, it gives the listener a greater range to exercise his preferences, and therefore insure improved accuracy. If, for example, during an extended test, listeners indicated a preference for an extremely restricted range the researcher would be warned to suspect or confirm his test technique and over-all planning.

Future Tests

Those who can recall the parable of the three blind men trying to identify an elephant can best appreciate the condition which exists in the present state of the art of determining the effect of esthetic appreciation upon the design of audio reproducing systems.

In order to avoid a waste of time, effort, and money, it is suggested that a National Bureau of Standards sponsored committee be established to make an impartial and valid investigation into this complex field (assuming that the taxpayer can be convinced of the need for such government-suggested work). The committee should evaluate all of the variables involved, and devise standardizations, tests, and testing techniques which will produce significant and scientifically accurate results. Or, if the work is too involved for one committee, standards and fields of investigation may be set up so that individual researchers could fill in the large gaps. By following this procedure, all efforts and work done will at least have a common denominator of validity, and will unquestionably result in a rapid and accredited solution to this complex problem.

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[*Continued on page 35*]

Toscanini conducting his orchestra in Studio 8H, WNBC, New York. *N.B.C. photo*

Analyzing Sweep Frequency Transcriptions

WAYNE R. JOHNSON*

Describing a simple method of making instantaneous frequency response tests of audio apparatus.

PARALLEL with the scientific developments in other electronic fields, many new devices have appeared that have applications to audio work. Important among these is the first successful recording of a fast sweep of the audio frequency spectrum.

The sweep frequency transcription provides a new method of making instantaneous frequency response checks of many types of audio equipment. A logarithmic frequency sweep has been recorded on both disk and film. The sweep, which is repeated twenty times a second, starts at 60 cps and extends to 10 kc. Further extension to 15 kc is expected in the near future. Played back and viewed through a cathode ray oscilloscope, the characteristics of the frequency response, its amplitude, and other important parameters may be ascertained instantaneously for entire audio systems or for their individual components and parts.

To properly interpret the readings on the oscilloscope, frequency marker pulses have been provided on the transcription at one, three, five and seven thousand cps. These markers stand up as small "pips" on the positive extremities of the sine waves. To synchronize the oscilloscope a pulse of 200 microseconds is provided at the beginning of the sweep. Correction factors were included in the original recordings so that charts and graphs are not needed. Some of the recordings have been made, using the National Association of Broadcasters' curve.

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The Vertical Scale

To read the amplitude frequency response directly in decibels a vertical scale for any size oscilloscope can be derived from the formula $20 \log E_1/E_2$. With the marker pulses and the amplitude scale, both qualitative and quantitative readings can be made instantaneously of many of the variables in audio systems, starting with entire studio transmission systems, recording and playback systems, through individual pieces of equipment such as amplifiers, transmission lines, reproducers, microphones, electrical filter networks, acoustical networks down to the various components and parts used in them.

The sweep frequency transcription can be used to locate such phenomena as harmonic distortion, amplitude distortion, resonant peaks, intermodulation, mechanical distortion and transient response. Being logarithmic, the higher frequencies are swept at a much faster rate. This shows the transient response performance of the playback system at the higher frequencies. By using an expanded sweep of the oscilloscope clear detail can be obtained. With a high quality playback system, the transcription can be utilized as a secondary sweep frequency generator of sufficient accuracy for most laboratory measurements as well as for production line inspection and testing.

For production testing, go and no-go markers can be placed on the oscilloscope permitting high-speed checking of complete equipments and many components. Operators may be readily trained to read the oscillograms with accuracy and speed.

The sweep frequency transcription as an electronic aid and engineering tool is simple in its analyses. Some of the typical oscillograms are presented in *Figs. 1 to 12*, inclusive.

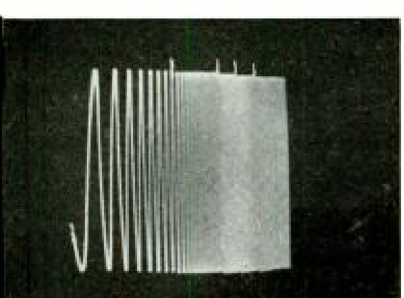


Fig. 1

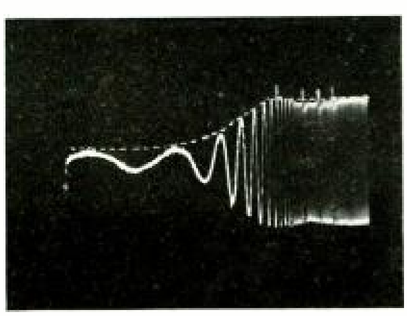


Fig. 2

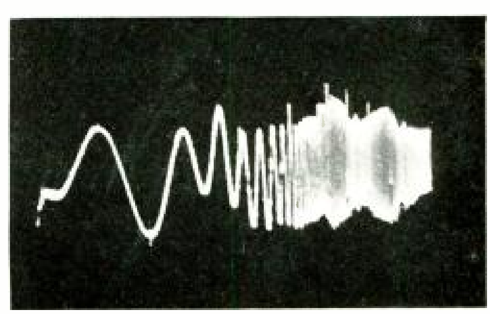


Fig. 3

Fig. 1. An oscillogram of the pattern produced by the primary standard sweep frequency generator from which the sweep frequency transcriptions have been made on both disk and film. The frequency variations are within 1/4 db. The marker pips are shown at one, three, five and seven thousand cycles per second. Fig. 2. Calibration of the sweep frequency taken at the outside edge of a 12" record with constant velocity Clarkstan Type RV wide-range pickup of known flat characteristics and without equalization. The logarithmic curve of the attenuation of 6 db per octave below 500 cps is indicated by the dotted curve. The flat response of both the record and pickup is shown by the horizontal pattern from 500 cps to 10 kc. Bass equalization will bring the low frequencies in line. Fig. 3. This represents a crystal pickup reproducing the sweep frequency 12" record, with equalization set for response as nearly flat as possible with simple r-c filters. Note the drop in response at around 100 cps where the amplitude of the second sine wave is attenuated. Slight peaks are noticeable at 4,000 and 8,000 cps.
(Courtesy Allen B. DuMont Laboratories, Inc.)

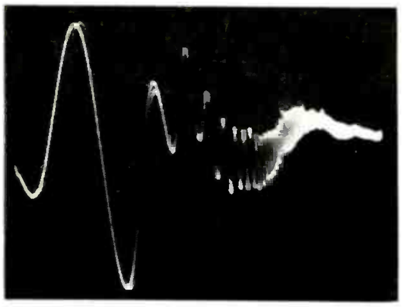


Fig. 4

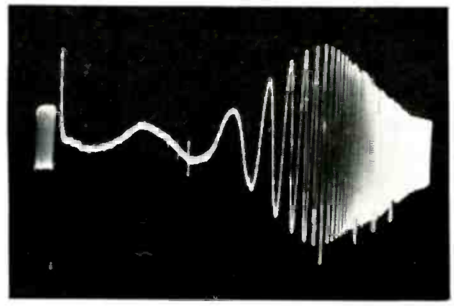


Fig. 5

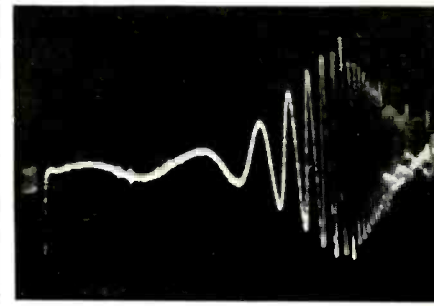


Fig. 6

Fig. 4. Considerable low frequency accentuation is noted at approximately 70 cps with attenuation beyond 150 cps, increasing with frequency above 1,000 cycles. The transient shock excitation of the tuned circuits produces a dampened wave train or displacement of the pattern represented by the horizontal S figure of the sweep. *(Courtesy Allen B. DuMont Laboratories, Inc.)* Fig. 5. Actual reproduction under same conditions as shown in Fig. 2, but reproduced on the inside grooves of the 12" record. Note the attenuation of the high frequencies due largely to the action of the spherical tip of the playback point whose radius is large in comparison to the wavelengths of the high frequencies. Fig. 6. A variable reluctance type of pickup reproducing the sweep frequency at the inside of the record showing high frequency bass, accompanied by harmonic distortion between 3,000 and 7,000 cps. The amplitude of the synchronizing pulse is attenuated also by the high frequency attenuation to such an extent that it becomes difficult to hold synchronization on the oscilloscope. Note, also, that the polarity of the synchronizing pulse should correspond with the synchronizing polarity of the oscilloscope.

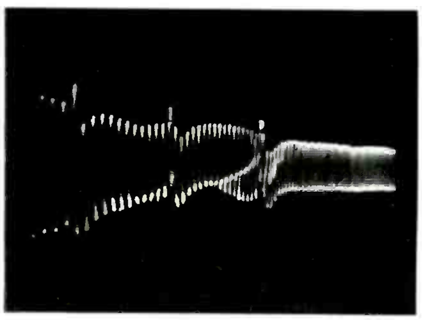


Fig. 7

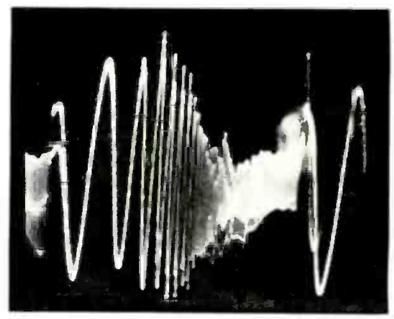


Fig. 8

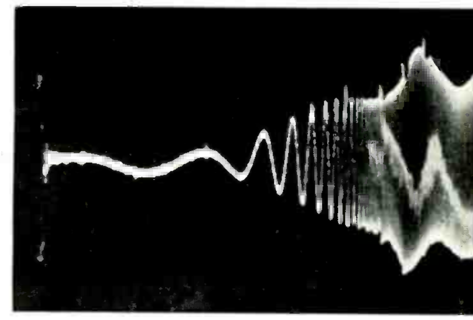


Fig. 9

Fig. 7. Reproduction under the same conditions as Fig. 6 with the pattern expanded on the oscilloscope to analyze the harmonic distortion. Note the complete 180° phase reversal of the harmonics in relation to the fundamental starting at the upper portion of the wave at 3,000 cps and completing the reversal at 7,000 cps. The reproduction of the synchronizing pulse and the marker pip is distorted because there is no low-frequency compensation for the magnetic reproducer. This may be seen as a displacement appearing immediately after the marker pulse. Adequate low-frequency compensation will minimize this effect. Fig. 8. Photographic exposure at 1/10th second to show two sweeps. Note the mechanical vibration or rumble as shown between 3,000 and 7,000 cps by the displacement of the pattern. *(Courtesy Allen B. DuMont Laboratories, Inc.)* Fig. 9. A universal type constant velocity pickup reproducing the sweep frequency, without any equalization on the outside grooves of a 12" record. This shows harmonic distortion starting at approximately 3,000 cps with a phase shift alternating as the pickup goes through resonance around 6,000 cps. The distortion continues to 10,000 cps.

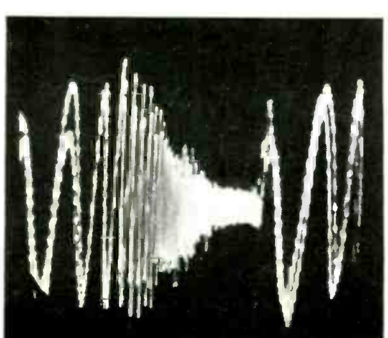


Fig. 10

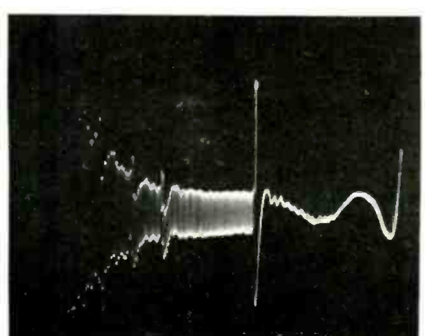


Fig. 11

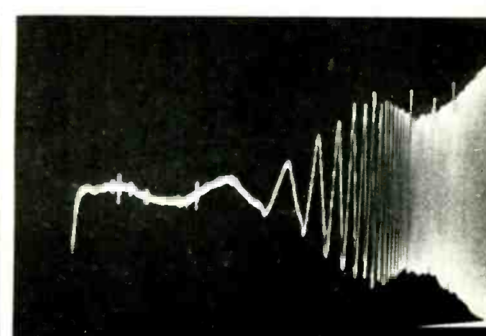
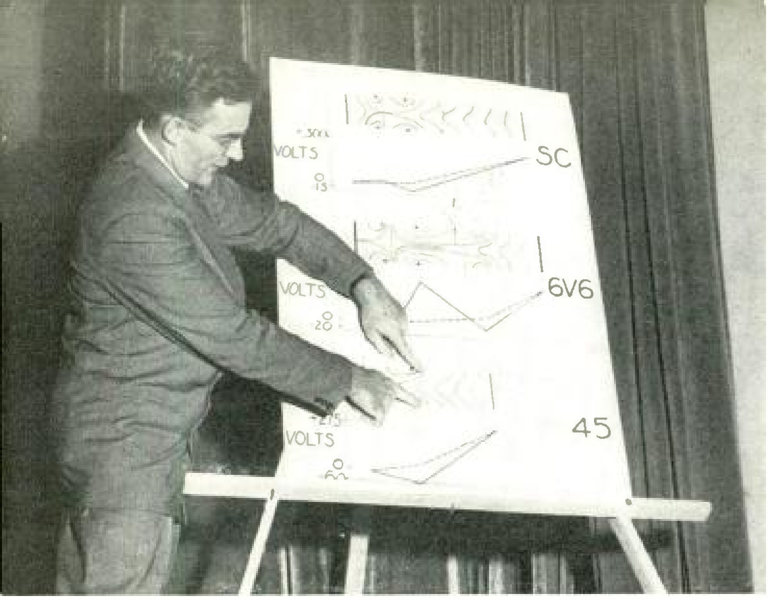


Fig. 12

Fig. 10. Reproduction by means of a crystal pickup. A noisy point is evidenced by superimposed modulation of the low-frequency waves. *(Courtesy Allen B. DuMont Laboratories, Inc.)* Fig. 11. Reproduction by crystal pickup. This is an expanded view of a portion of the low and high frequencies showing the transients initiated by the synchronizing pulse. Fig. 12. Reproduction by a constant velocity type pickup on the outside grooves of a 12" record. Note the resonant peak of 4 db around 9,500 cps. The low frequencies are distorted by a high order of even harmonics as evidenced by a sharp point and a triangular shape of the sine waves. Filtering or bass compensation will reduce this apparent distortion due to the fact that the harmonics are attenuated in relationship to the fundamental.



Advantages of

Describing new application of an old principle—the space-charge-grid output tube achieves triode performance at tetrode efficiency.

Norman C. Pickering pointing out the lines of equal potentials within the structure of a triode, as compared to those in the beam and space-charge tubes. The solid lines on the chart represent conditions between the cathode at the left side of each diagram, and the plate at the right when the control grid is at zero-signal conditions. The dotted lines represent conditions at maximum positive swings of the control grid.

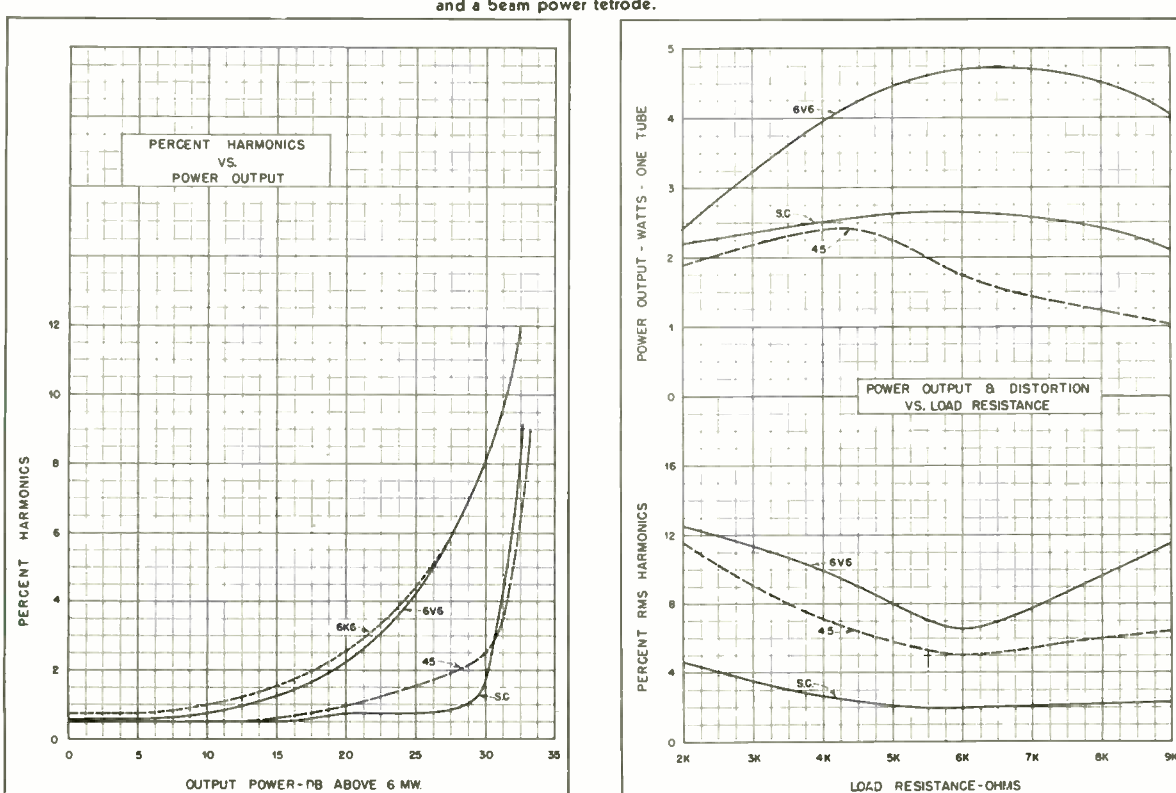
NORMAN C. PICKERING, designer of the magnetic pickups and cartridges bearing his name, presented a paper on the space-charge-grid output tube at a meeting of the New York section of the Institute of Radio Engineers held in the Western Union auditorium on Sept. 18.

While the investigation of this tube was started in the early 30's, the advent of the beam power tube effectively overshadowed the space-charge tube, and it was never introduced publicly. The desire for the lowest possible distortion caused the tubes to be resurrected, and further measurements have shown them to have many advantages. Triodes, of course, have long been favored for low-distortion amplifiers, but they are hard to drive properly. Pentodes and beam-power tubes are easier to drive, but have intrinsically higher distortion. The tests on the space-charge-grid tube show it to combine the low distortion characteristics of the triode with the easy-to-drive characteristics of the beam power tube.

This tube has certain points of similarity to the beam power tube in construction, using two grids aligned in the same manner. The spacing between cathode and the space-charge grid is greater than is customary with beam power types. The low positive potential applied to the space-charge grid causes the effective cathode diameter to be increased appreciably, and the tube is able to perform in a manner similar to a triode without the necessity for the control grid to be in close proximity to a thermally heated cathode, with its attendant disadvantages.

If an ordinary beam power tube were connected as a space-charge tube, the cur-

Per cent harmonics vs. power output, and (right) power output and distortion vs. load resistance for a typical triode, a space-charge-grid tube, and a beam power tetrode.



Space—Charge—Grid Output Tubes

rent drawn by the space-charge grid would be excessive, due to the close positioning with respect to the cathode. In the experimental tubes, this was overcome by mounting a pair of side rods between the space-charge grid and the cathode, and connecting these rods to the control grid, thus shielding the space-charge grid from the cathode in the areas where the effect of the first grid is not necessary. The voltage for the space-charge grid is obtained from the plate supply through an unbypassed series dropping resistor, the absence of a bypass capacitor causing some degenerative action on the signal current. The tube is not critical with respect to load resistance.

A comparison between the space-charge tube and the types now in use—triodes and beam power tubes—involved the construction of three separate amplifiers, using nearly identical circuit arrangements, the same output transformer, and the same power supply. Since the only available space-charge tubes were relatively small, the comparison was made between them, the 45 representing the triodes, and the 6V6 representing the beam power tubes.

Measurements of power output, and intermodulation and harmonic distortion were made on the three amplifiers, each being arranged for optimum load impedance, and the results indicated some promise. In practically every test, the space-charge tube was superior to the others.

The space-charge tubes were about twice as good as the triodes at low values of harmonic distortion, with the latter being about 1 db better on the intermodulation tests. The effective amplification of low-mu triodes is naturally small, and while the mu of the 6V6 is 230, the useful gain, considering the high plate resistance of the tubes and the low value of load required for optimum operation, is only about 13.3. The space-charge tube with a mu of 20 manages to afford a useful gain of 16.6.

Damping Factor

The damping factor, a result of the effective generator impedance, varies considerably with the tube types. The impedance of the generator, as seen from the load, is five times the load resistance in the case of the beam power tube, 0.8 times the load resistance for the triode, and 0.5 times for the space-charge tube. This property makes for cleaner bass response and the elimination of "hang-over," an effect so objectionable with pentodes and beam power tubes. One additional advantage of the low effective generator impedance is the prevention of a voltage rise at high frequencies; with the space-charge tubes, there is less necessity for the use of inverse feedback.

While the plate-to-plate load for the space-charge tubes was found to be higher than for either the triodes or the beam tubes, no more primary inductance is required in the transformer, it being necessary only to match the impedance of the loudspeaker properly by reducing the secondary turns in the output trans-

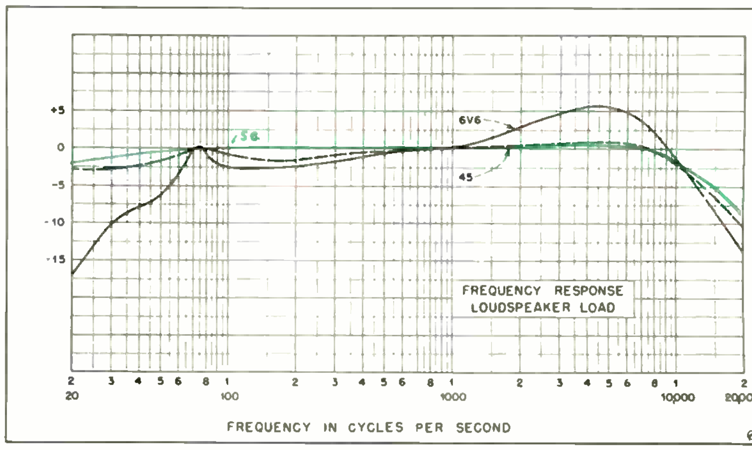
[*Continued on page 45*]

TABLE I

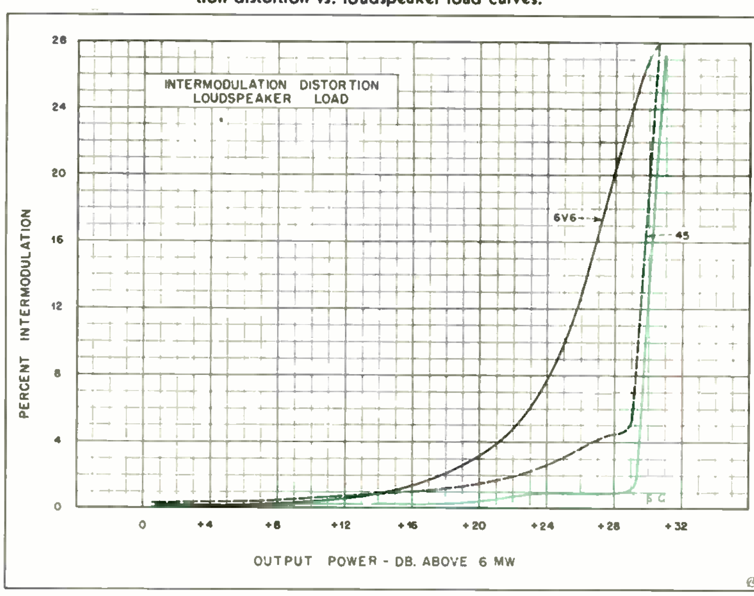
(Values are for two tubes)

Tube type	1 Plate res ohms R_P	2 Trans-conductance G_M	3 Ampl factor μ	4 Plate supply volts E_B	5 Total cathode current ma.	6 Total d c input watts	7 Optimum load res-ohms R_L	8 Ultimate power output watts	9 Peak grid volts for ult pwr out	10 Power at 5% harm watts	11 Power at 2% harm watts	12 Power at 10% intermod watts	13 Eff at 5% dist	14 Gain $\frac{\mu R_L}{R_L+R_P}$	15 Gen imped at 500 Ω tap ohms
6V6	65,000	3,600	230	285	74	21.2	8,000	12.5	42	2.4	.32	.76	11.3%	13.3	2,500
6K6	75,000	2,100	150	285	62	17.7	12,000	8.5	54	2.4	.50	.61	13.5%	11.1	2,000
SC	4,000	5,000	20	325	110	35.7	20,000	11.0	36	10.7	6.6	4.8	30.0%	16.6	250
45	1,700	2,050	3.5	325	92	29.8	5,000	13.5	150	12.0	3.8	6.0	40.0%	2.6	400

Characteristics of typical tetrodes, space-charge-grid tube, and a triode.



Comparative frequency-response vs. speaker load for three tube types. Below, intermodulation distortion vs. loudspeaker load curves.



Ultrasonics in Solids

S. YOUNG WHITE*

More industrial applications of ultrasonics.

AS WE LOOK over fields of possible application of ultrasonics, every so often we come across an application where several characteristics of this form of energy flow together naturally to give us an especially attractive picture.

In solids, we meet this situation in two fields—one of considerable personal interest to most of us—the possible application to engraving to give us painless dentistry; the other in the great field of metallurgy in general.

Let us ignore the subject of tooth extraction, where we have nothing to offer, and examine the normal work done on the teeth as a problem in low-speed engraving.

We are all familiar with the vibrating hand tool that is widely used in handicraft work at home. It is merely a 60-cycle magnetic device of limited power, having a chuck in which we can insert phonograph needles and similar engraving tools. It is quite noisy, of course, but it does a special job in a special way sufficiently well that many are in use.

Grinding Tool

The basic dental tool is a rotary burr of various numbers of teeth. It removes material rather quickly on occasion, taking a relatively large bite per tooth on the burr. Every time a cutting tooth does its work, we receive a blow on the jawbone. The frequency is, of course, the number of teeth times the revolutions *per second*—not r.p.m. If we are revving up 6,000 r.p.m., that is only 100 r.ps., and if there are ten teeth on the burr the frequency is 1,000 cycles.

So we have a powerful 1,000-cycle sound or vibration generator solidly coupled to the jaw through the anchorage of the solid tooth. Thence it travels without loss to the cochlea or inner ear, and gives a very unpleasant sensation to many people, including, definitely, the writer. There is also some sound from the chuck-driving mechanism which comes into the inner ear through normal air conduction. The tool also develops some heat in cutting, and being rotary, cannot well be water-cooled.

There would be little advantage in employing the 60-cycle vibrating tool for this work, as it is quite as noisy. But we can definitely hope to drive a reciprocating tool at ultrasonic frequency. A quick experiment made some time ago indicated that there is no way to tell if the tool is turned on or not, since there is no detectable noise or vibration when operating at 24 kc. A groove was cut in very good bakelite. The particles removed were so small they floated in air, showing they were of colloidal dimensions. The amount of material removed per blow is very small indeed, and if you progress in the groove at the rate of say half an inch per second, you have 50,000 tool marks per inch, which even under the microscope is a dead smooth surface.

As was to be expected, the best cutting rate was with a very light pressure. The tool was resonant, and had to be free to oscillate over quite a range without engaging the work, in order to build up resonant amplitude. It then struck only at the extreme end of travel, giving a high acceleration shock to the material which dislodged a particle only a few millionths of an inch in cubic dimensions. Since we were removing 24,000 of these per second, however, the material removed per second was a commercial amount, at least for fine engraving.

A sharp chisel point driven at ultrasonic frequencies will cut only resistant material. If you jam it in your flesh, for instance, the flesh just rides along with the blow, and no cutting takes place.

It was noted by some that when such a sharp 24-kc chisel was firmly pressed into the flesh, a deadening of nerve response was observable, extending about a half-inch around the point of application. This anesthetic effect should be enhanced in dental work, since the vibration would be well coupled to the pulp center of the tooth.

Precautions

In applying ultrasonic energy to flesh some caution must be exercised if you have a very high power source. With a density of about 50 watts to the square centimeter the energy is rapidly dissipated in a comparatively few layers of cells of the skin, and they are quickly carbonized by crepitation on each other. The first time you try this you immediately feel you have a cure for surface cancer, as you can destroy cells so quickly and painlessly that you feel the cancer cells will be carbonized before they can migrate into the blood stream.

Unfortunately, the next day you have a subcutaneous rash for an inch or so around the place you treated. In another day or so this disappears and no complications ensue, and there is no pain. But the rash is due to the fact that there are enormous numbers of capillary veins in the healthy flesh, of all lengths, alone and in combination with others. Consequently, whatever frequency you choose to apply you will resonate a considerable number of them, set up very high intensity standing waves, and the capillaries will rupture. This is a dangerous thing to do in the presence of wild cells, as there is an ideal opportunity for them to migrate into the blood stream, and you have a dozen cancers instead of one. In the dental application we would be much below this power density, of course.

The dental tool assembly would include a power generator in a box, possibly hanging from the ceiling, delivering the power into a flexible tube filled with some "stiff" (non-compressible) liquid such as carbon tetrachloride. This would terminate at the lower end in a resonant diaphragm with a very well-made chuck for the tools. There would be some difficulty in engraving the back of a rear tooth, as wave transmission in a fish-hook-shaped tool might not be too good. To compensate we would have the advantage that the dentist could do very artistic work on the front teeth, where it is most important.

So ultrasonic dentistry seems to offer complete absence of either noise or vibration, a very light pressure, some anesthesia, no cutting of the pulp if the dentist miscalculates and tries to work in the soft material or gum tissue, and since the tool is non-rotary, we can probably water-cool it to take away the heat developed by the cutting action.

From the dentist's point of view, we would offer him a non-vibrating noiseless tool that would give smooth precision cuts, especially in front teeth where fine workmanship is most needed.

Silent Riveting

This application leads naturally to the idea of "silent riveting" at high power. Here we must stress the metal beyond its elastic limit, and probably 5 or 10 kw would be necessary. However, the riveter would not have to add his body weight to the tool, since at 25 kc the reaction of a twenty-pound tool would be almost infinite, so his job would be lighter, and the ears of the neighbors would not suffer at all.

The transmission of ultrasonic energy

through homogeneous solids is often very good. Some of you will have the apparatus to try this experiment. Take a low-frequency radio receiver, such as are sold surplus for $50 (RAK-5) and tune as low as 15 kc. They often give a good signal on one microvolt, and since they are tuned r.f. they have little spurious response. Take a small Rochelle salt crystal, such as comes in a phono-pickup. Now take an ordinary wristwatch and lay it on some cotton batting or other loose material, to act as a shock-excited oscillator of ultrasonic energy. Using any convenient wire—(for instance, bare number 18 copper), support one end in light contact with the Rochelle crystal, which you connect to the input of the receiver. Lightly touch the other end of the wire to the center of the watch glass. You will hear the watch ticking up to about a quarter megacycle. At 50 kc you can hear the watch through hundreds of feet of wire strung loosely around the room. It is certainly surprising that the watch movement has enough high-frequency component to be heard at all, much less through a hundred feet of wire by sound transmission through it. And the pass band of the receiver is only about 1 kc wide at 50 kc.

Heating Effects

When the solid is in the form of powder the attenuation is usually very high, as it consists of a series of boundary layers with poor mechanical coupling from particle to particle. Since high attenuation occurs, the energy must appear as heat, so in materials of this nature we will have a heating effect similar to electrostatic heating. If the path is not too long, as for instance a "biscuit" of molding powder, the particles will be rubbed on each other so that the heat will appear uniformly through the mass. This may be of considerable commercial importance in molding, since we can seldom hold the piece in the mold long enough to thoroughly polymerize it in the center of the biscuit, as it would tie up the press too long for it to be economical. We may have a nice competitive position if we can derive our energy from steam as a power source, as it is cheaper than r-f power. We should also not worry about the "low loss" characteristic of polystyrene which makes it so difficult to heat with r-f dielectric heating.

Since we have reflection from boundary layers that would produce local heat, we may find we can selectively heat glue layers in wood.

Metallurgy

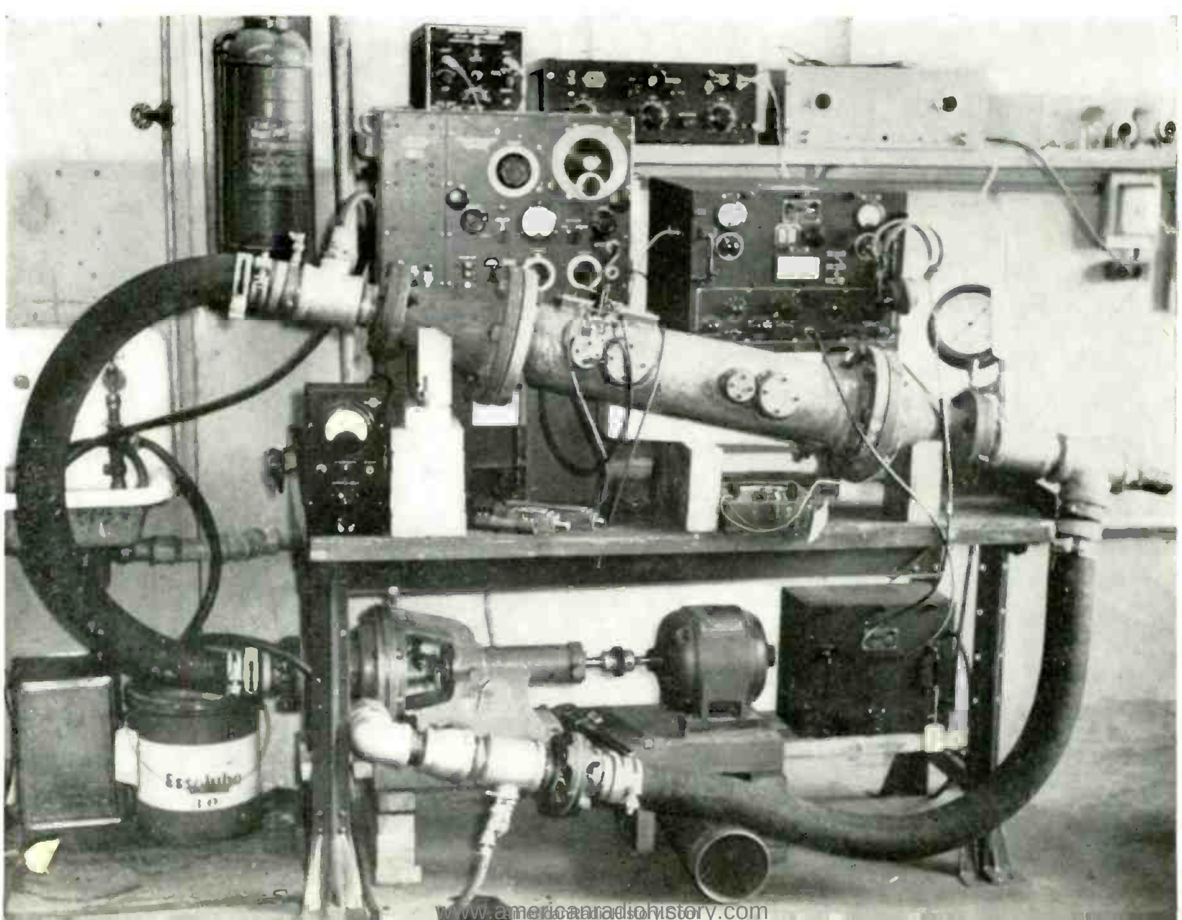
In the metallurgical field there are several effects of ultrasonics, and apparently all are good. Practically all metals start their commercial life in liquid form. As they cool, nascent crystals begin to form at center separations governed by laws that we do not fully understand. These grow individually, and as they grow they push slag and gas ahead of them. When they meet, there is a little pocket of gas and slag at the edges of the crystals, and there are often a few molecules there which are unable to make up their minds which crystal lattice they belong to. Thus no metal has ever developed its full potential strength or density. An excess of gas also will appear as a bubble in a casting. This explanation is a very simplified one, but is substantially correct.

The Germans have done considerable work with the simple metals zinc and aluminum. There is apparently no literature on the ferrous metals, which are much more complex.

The first effect noted is that as the crystals are forming they can be broken up into many smaller crystals, because of the tremendous accelerations we can apply to them. Many alloying materials are used in metallurgy to merely minimize crystal size. Apparently we can accomplish the same object by acceleration alone. It is also inherent in acceleration that a large object will have more force developed in it than a small object, so if we have an exceptionally large crystal it will definitely be reduced to size, thus giving great uniformity of product.

The second effect was noted as the complete de-gassing of the melt. Apparently they attempted to cast aluminum with gas pockets in it, by too rapid chilling, for instance, and they were unsuccessful. So apparently we can make fine grain castings without danger of bubbles.

Ultrasonic test equipment setup.



The third effect was that density and tensile strength were greatly increased. There was no gas pocket at the corner of the crystal, and it is possible the slag or other solid impurity was spread into a thin film instead of remaining in one concentration.

The fourth effect was the melt solidified more quickly. This is rather unexpected, as in applying ultrasonic energy you are adding heat. Note we do not say the melt cooled more quickly.

Cast Metals

There is some effort in industry now to apply forces to metals while being cast, as, for instance, centrifugal casting. This has been a great aid in producing dense castings without bubbles, and with very fine detail, but the forces involved are very small compared to the enormous "G" values we can attain by ultrasonics.

This field is of enormous importance. For small batches, useful work can be done with a crystal putting out about 100 watts, since you need only to test pieces to check hardness, ductility, tensile and the like. For the low melting point metals and alloys a ceramic boat in a controlled atmosphere is about all that is needed. Quartz has a high and sharp Curie point at above 1000 degrees F., so you can bring the crystal pretty close and join it with a resonant rod, probably of titanium oxide ceramic, or beryllium ceramic. The shape of the boat and the point of application of the energy must be designed so that you have a very confused field pattern in the melt, otherwise you are operating with standing waves, and will

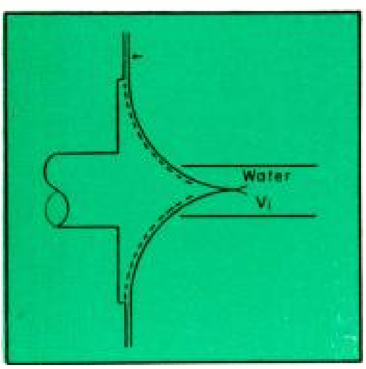


Fig. 1. Side view of centrifugal pump.

have areas a half wave apart that are inactive. At this power it is very difficult to frequency modulate the crystal enough to thoroughly cancel the pattern.

With a simple set-up you can try all the known mixes, and make many that are normally impossible, such as stable mixes of lead and aluminum, by the emulsifying action of ultrasonic acceleration.

The British did some work on duralumin welds, and found complete degassing and improved uniformity and strength. They also found an amorphous form of dural developed that had great strength. This is an application of great promise, but also great difficulty in applying the energy to the molten and semi-molten metal of the weld.

A rough approximation shows we probably need about one to two kw of power per hundred pounds of casting. For large castings we should have to have several places to apply the power to insure complete coverage, but it is common practice to have several pouring points in such castings anyhow. The "bullet" method discussed in the last article offers great advantages in this application.

A hundred-pound casting would probably need a half-hour application, and if we obtain our energy from steam we can figure a cent per kw hr., so the power cost would be about two cents. This is certainly reasonable.

We should also keep in mind that we have another opportunity to apply acceleration while the metal is being heat

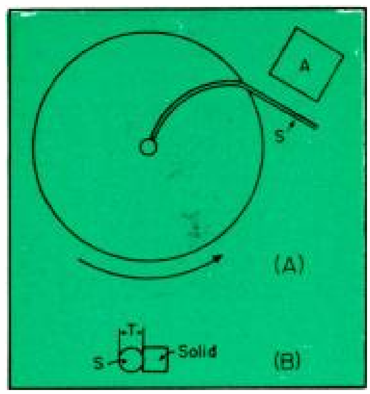


Fig. 2A. Centrifugal generator and, Fig. 2B, how the stream gives up its energy in its own thickness.

treated and re-crystallized. It is not so easy to visualize the effects here, but we should obtain rapid aging and stabilizing actions.

There is some hope of overcoming a difficulty in plastic lenses by this power. The writer has been informed that such lenses can be made to accurate dimensions, and the cold flow problem reasonably solved, but there is no way to stress relieve the lens after it is made. It is possible that by warming the lens and applying some large values of acceleration the molecules will rearrange themselves to relieve the stress.

Given the general premise that any melt that solidifies can well repay the effort in trying ultrasonics on it, we find an absolutely unlimited field of application. Chocolate could undoubtedly be homogenized. Rubber is such a queer material itself that the imagination is staggered to visualize what would happen in various cases, but some of the effects are bound to be commercial. Glass is another odd material that would repay some study.

The Germans have shown that very small and uniform metallic powders can be produced by hammering a stainless steel plate on which the metal is being plated. As soon as a micron of metal is plated on, it is knocked off.

A similar but reverse effect was noted by the French metallurgist, Mahoux. He plated ordinary chrome on steel, and of course had a very sharp boundary layer between the two metals. This is why chrome allows rust to form on your auto bumper. By hammering for some time with ultrasonics he noted a dispersion layer formed between the chrome and the steel. This promises much greater adhesion and rustproofing action. It is useless to build up a layer of chrome on a die-casting die, as it will strip off under the high stresses and temperatures encountered in this service. This may possibly be the answer, and may have great promise for other platings as well.

Welding

A standard experiment with a crystal generator is to excite a flat-bottomed flask of glass dipped into the oil over the crystal. If you draw the neck of the flask to a point, there will be great energy density at the point. You can now rest a sheet of glass on this glass point, and the glass point will drill into the glass sheet held against it. Little balls of melted glass will be thrown off in the process, as the locally generated heat is quite high.

This suggests that by suitable choice of materials, you will either have a controlled drilling action when you use a material for the point that is much harder and heat resistant than the sheet you wish to drill; or if both materials have similar hardness and melting point, that they will weld.

Since it is not necessary that either element conduct electricity, one or both could be glass or other non-conductor. For instance, in making vacuum tubes you may wish to support some structure by locally welding a wire to the glass. Ultrasonic welding would lend itself most readily to very small parts that need to be welded.

Very High Power Generator

In looking around for high-power ultrasonic generating means, let us review the "bullet" type generator described in the last article. It brought out the point that the generator itself does not have to be an oscillator. A magnetostriction rod actually oscillates through a range of motion, and is capable in effect of pulling as well as pushing. Actually the pulling effect is hard to use effectively, as the load, if liquid for example, is then driven into the end of the rod only by the static head of the water, which is very small in most cases in comparison to the tremendous acceleration force the rod develops in pushing. Of course, if the load has standing waves properly phased the water will also be driven against the rod end by that pressure.

[*Continued on page 41*]

MUSICAL ACOUSTICS

BENJAMIN F. TILLSON*

PART V

This is the fifth of a series of articles on music theory, written especially for sound engineers.

A LACK OF NATURALNESS ALSO occurs because the room in which a program is reproduced does not have the same acoustic properties as that in which it originates. If listeners all wore headphones instead of listening to loudspeakers this difficulty could be eliminated, providing the headphones gave the same frequency range and fidelity. However, that is not and will not be the case because of the discomfort it entails.

The acoustic properties of a room are expressed in the arbitrary unit of reverberation time. Reverberation means the overlapping and merging of reflected sounds (echoes). The latter lose amplitude, therefore energy and power, both because of imperfect reflection from the various forms and materials of surfaces, and also from the viscous resistance of the transmitting medium (air). Both convert sound energy into heat losses. See *Figs. 1, 2 and 3.*

Reverberation Time

The reverberation time is assumed as that required for a 60-db decrease in the intensity of the sound of a 512-cycle/sec. note; but it will not remain the same for other frequencies. A 1,000 cycle note takes about 5% less time, and higher frequencies are more readily absorbed. See *Fig. 4.*

The curves are drawn through the absorption coefficients, taken from the 25th edition of the *Handbook of Chemistry and Physics* of The Chemical Rubber Pub. Co., of a few commercial acoustic materials at the tone frequencies of 128, 256, 512, 1,024, 2,048, and 4,096 vibrations per second. They show a considerable variation in values and, for the most part, no continuing increase with higher frequency.

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Large rooms have larger reverberation times than similar small rooms, for a sound wave is reflected more times per second in the latter and so is absorbed more quickly by reflecting surfaces. An open window gives a total loss so is rated as unity amongst the coefficients of absorption losses of reflecting surfaces (which coefficients vary from 0.02 for a brick or plastered wall to 0.84 for triple Celotex). But persons and seats in an auditorium, especially where the seats are upholstered, absorb much sound. Seats alone may give 40% of absorption and a capacity audience may increase absorption 50% of the empty absorption.

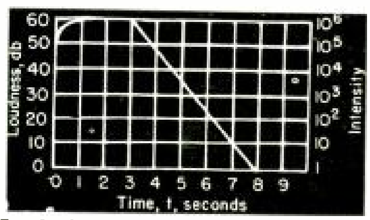


Fig. 2. Logarithmic plot of growth and decay (growth in 1 second, constant 2 seconds, decay in 5 seconds.)

It might be thought that acoustic materials should be chosen so as to make the reverberation time of the room the same for all frequencies. But W. A. MacNair proposes that such is not the case, and that results are best when the loudness at all frequencies decays at the same rate. Then the time of reverberation must be greater at low frequencies than at high.

If low and high pitch tones have equal loudness the low pitch has a lower sensation level and its loudness decreases more rapidly as the sensation levels of both tones decrease at the same rate.

Thus, if the loudness of both tones is to decrease at a same rate the sensation of the lower must decrease more slowly than the high tone. To accomplish this MacNair proposed that the desirable characteristics of an acoustic material would show a variation of absorption coefficients as in *Fig. 5.*

Echo Effects

Echo effects can be avoided by properly shaped surfaces, avoidance of domed ceilings to focus sounds, the application of absorbent materials to surfaces, the hanging of drapes, the splaying of the side walls, and the limitation of flat ceilings to a height of 37 feet. Then, at a velocity of 1120 feet per second, the reflected sound would reach the auditor 1/15th second later than the direct sound and would merge with it. But if ceilings were 40 feet high, the reflected sound would arrive 1/14th second after the direct and an echo could be detected.

The reverberation times, in seconds, for the large symphony halls with capacity audiences vary as follows: Boston 1.93; Chicago 1.90; Detroit 1.44; New York (Carnegie) 1.75; Philadelphia 1.76. The effect of audiences is shown by observations in the Chicago Auditorium: empty 2.93; 1/3rd full 2.51; 2/3rds full 2.19; and with maximum audience of 3,600 persons 1.90 seconds. If the decay of sound is 60 db in 2 seconds it is 90 db in 3 seconds. The reverberation time in a dwelling room may be about 0.6 to 0.9 seconds.

Some authorities declare that echo occurs when the reflected sound occurs 1/17th second after the direct sound (from a surface 33 feet away), and that reflections are troublesome when delayed 1/20th second, or from a surface 28 feet away.

Where a broadcast program is to give a natural, intimate appeal the reverberation time of the studio should not exceed

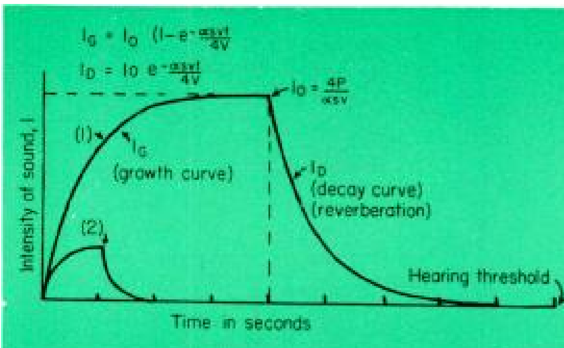
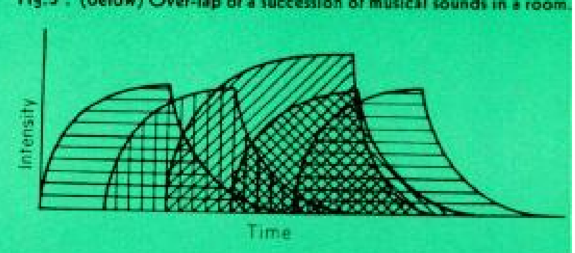


Fig. 1. Growth and decay of sound in room. (1) Poor acoustics of small absorption. (2) Good acoustics of large absorption.

Fig. 3. (below) Over-lap of a succession of musical sounds in a room.



that of the home; and obviously it cannot offer a show to an attendant audience because too large a room is then required. President F. D. Roosevelt's fireside addresses attained that intimate appeal because they were delivered from a room about equivalent in reverberation time to those where they were received by radio.

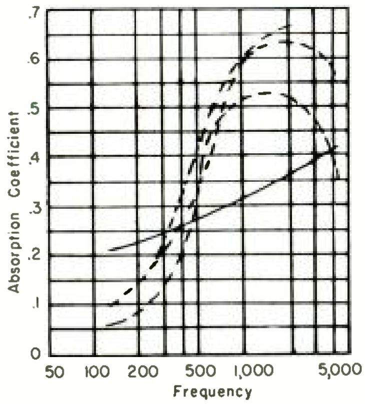


Fig. 4. Various acoustic absorbents.

So the broadcast studios should be chosen in size for the type of the performance. Those of the British Broadcasting Company vary from a volume of 125,000 cubic feet, height of 31 feet, and reverberation time of 1.70 seconds for orchestras, down to a volume of 1,500 cubic feet, height of 8 feet, and reverberation time of 0.28 seconds for talks.

The reverberation time for speech should be lower than that for music, so that speech articulation will be enhanced. A certain amount of reverberative blending of musical sounds is pleasing, if there are no echoes. See *Figs. 3 and 6*.

Calculating Reverberation Time

If smooth, hard plaster walls reflect 97% of a sound whose velocity in air is 1120 feet per second, and if the walls are 28 feet away (a mean free path of 56 feet), there will be 20 reflections per second. At an absorption coefficient of 0.03 there will be 97% of the energy reflected each time. Therefore, to reduce the intensity 60 db the number of reflections "n" which will represent the exponent of the fraction of sound reflected each time. Accordingly, 0.97^n equals 0.000001 or n log 0.97 equals log 0.000001; n equals 6.00000-10, divided by (9.98677-10). Therefore the log of n equals the log (6.00000-10.)—log (9.013228-10.) equals 2.65667; n equals the number whose logarithm is 2.656647, or n equals 453.57.

Therefore, at 20 reflections per second the number of seconds to decay 60 db is 453.57 divided by 20 or equals 22.68 seconds.

Similarly, if the coefficient were 0.95 then n equals 269.36 and the reverberation time is 13.47 seconds; while if the coefficient were 0.50 then n equals 19.93 and the reverberation time equals 0.996 seconds. Such a satisfactory reverberation time as one second is quite possible by the use of drapes and other sound absorbing materials.

The actual time of reverberation (T_r) is a complicated exponential formula which can be simplified as follows by assuming a sound velocity of 1120 feet per second: T_r equals 0.05 V divided by $-S \log_e (1\text{-}a)$ where S equals the total interior area of the room in square feet; V equals the volume of the room in cubic feet; (a) is the average absorption coefficient of the room; and $\log_e$ is the Naperian or Natural logarithm which may be converted to the common logarithm of base 10 by multiplying the former by 0.43429. P equals acoustic power (or sound energy emitted per second.)

This formula is a simplification of Eyring's revision of Jager's formula of "decay," shown in *Fig. 1*. Jager had revised Sabine's formula, leaving out the length of path which the sound traveled, so the viscosity of transmitting medium does not appear in the formulas most generally used.

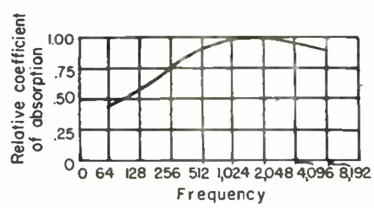


Fig. 5. Proposed absorptive characteristic (MacNair).

In order to get better agreement with experimental values under conditions of great sound absorption, Eyring substituted for the alpha in the exponent of "e" the logarithm to the base "e" of the quantity (one minus alpha). In the above-mentioned simplification I have used "a" to represent alpha.

The relationship between the corresponding values of alpha and the quantity expressed by minus the logarithm, base "e," of one minus alpha is shown in *Fig. 7*.

When "v" equals 1120 ft. per sec., and I_D equals I_o times 10^{-6}, according to the definition of reverberation time, the above-mentioned simplified formula results from substitutions of such values.

But no completely accurate formula is in vogue for sound absorption. However, architectural needs seem to be served reasonably well by those I have given. The errors in determination of coefficients seem equally great as the errors involved in the formula itself.

Furthermore, the energy of the source of sound should be adapted to the size of the room. It should vary for different rooms according to the squares of the cube roots of their volumes.

Articulation

Clarity of speech understanding depends upon transients as well as the lack of reverberation.

The frequency-energy distribution of speech is: below 5,000 cycles 100%; below 3500 cycles 95%; below 2000 cycles 90%; below 1000 cycles 83%; below 500 cycles 60%.

But the understanding of the vowel-consonant combinations in speech, that is articulation, ranks at a lower level probably because of some of the high frequencies in transients: below 5000 cycles 92%; below 3500 cycles 85%; below 3000 cycles 83%; below 2000 cycles 76%; below 1500 cycles 63%; below 1000 cycles 40%; below 500 cycles 5%.

However, articulation is good when the lowest frequencies are absent, as the following shows: above 3500 cycles 3%; above 3000 cycles 9%; above 2500 cycles 19%; above 2000 cycles 39%; above 1500 cycles 69%; above 1000 cycles 85%; above 500 cycles 96%.

The ratings of articulation percentages indicate the understandability of speech but not its naturalness. The latter requires a greater range of frequencies, and its lack probably promotes psychological fatigue.

Overload

A prolific source of distortion is the overloading of electro-mechanical means of recording, amplification, and reproduction, because then there is deviation from the straight line proportionality of response to stimulus.

An overloading of sound volume involves amplitude distortion which is detectable at 3% to 5%, and is very noticeable at 10%. The odd harmonics are more troublesome than the even ones because of the dissonance they engender; and the amount of permissible distortion becomes less as a wider frequency range is reproduced.

We will remember that if sound is reproduced at a lower intensity the lower frequencies are relatively weaker and have less tendency to mask the higher frequencies. Both effects are in the same direction so frequency response must be directly varied with volume level. This is the reason for a "tone-compensated" volume control in some radio receivers and phonographs to obtain a higher quality of reproduction.

To avoid the overloading of an electrical reproducing system the relative intensity of the loudest passages of music is reduced, but the intensity of the weakest passage must be sufficient to be heard above the background noise. This form of distortion is one to which music-lovers are very sensitive. But it can be remedied to a degree by automatic volume expansion, wherein the output of the amplifier has a portion split off and rectified to d.c. so that the d-c output voltage is proportional to the average amplitude of the output during a small fraction of a second. It is then used to control the gain of a second-stage amplifier so that its amplification increases during the loud passages and decreases during the soft ones.

The volume compressor circuit employed in recording increases the amplitude of the second stage when the rectified split from the first stage is smaller, and decreases when it is larger. But this upsets the balance of high- and low-frequency harmonics in complex tones.

The exact phase relations between harmonic components are immaterial unless the phase shift is great enough to produce an appreciable time-delay distortion, such as 0.1 of a second. A variation of plus or minus 180° in the phase of the various harmonics with respect to each other is not detectable by the ear. For the ear has been trained since infancy to accept many forms of distortion, such as sound power variations in small rooms that result from changes in position, or changes in frequency because of interference effects between standing wave trains.

Sound Volume Problems in Broadcast Reception

The problem of recording, broadcasting, and reproducing in homes the full sound power of the original performances becomes more apparent with the realization of its various factors.

To fairly represent music, speech, or usual noises the range of frequencies should be from 40 or 60 cycles to 14,000 or 15,000 cycles; and the acoustic power range above the threshold of hearing should be from 0 to 70 decibels without distortion.

If the volume and power of sound acceptable out-of-doors were transmitted to a room in a home it would be displeasing. This is so because the loudness of sound as perceived by the ear depends not only upon the characteristics of the source but also upon the peculiarities of the surroundings where received: the room size and shape; the materials of construction and the shape and finish of surfaces; the furnishings, including audience, and the position of the reproducing source with respect to the surfaces of the room and the listener.

If a reproducing system were capable of emitting equal sound power for constant input at all frequencies from 30 to 15,000 cycles the results would still be unsatisfactory in the average room of moderate dimensions, and certainly not comparable to attendance at an orchestral concert.

Sound is reflected from the surfaces of the room and it builds up an intensity far exceeding that in the open air, or in a room acoustically "dead." The mean absorption coefficient increases with a rise in frequency, consequently the low tones build up to a greater intensity than the high tones.

When listening to complex sounds, since the tones (particularly those of lower frequency) tend to mask each other, it follows that the tone of a musical instrument when played alone is different from that heard in orchestral work.

If all tones below 1000 cycles are suppressed the ensuing sound causes aural irritation, although the power associated with the upper register is relatively small. The masking effect of the low tones is pleasing; and high pitch tones may mask weak tones of moderate pitch.

Tone Masking

In 1876 A. A. Mayer stated that low pitch sounds completely masked ones of higher pitch, but that the higher will not mask the lower. This does not hold true where the higher are too far removed in pitch, and the low pitch have a very high intensity. Also the high pitch can mask the low if their frequencies are nearly the same, and the "beats" are noticeable.

The explanation of masking may be the non-linear response of the ear which offers to the inner ear subjective harmonics that excite the nerve terminals which would otherwise have received the high tones. On the other hand, the higher tones can produce a nerve stimulation only in the region near their maximum response.

The sound heard in the second ear must have an intensity 50 db higher than that in the first ear, thus allowing for the loss in the bone conduction of the sound, before it forms subjective tones in the first ear.

Studio 3A at broadcast station WNBC.

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N. M. HAYNES*

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[*Continued on page 44*]

Pulse Code Modulation

A new method of multi-channel voice transmission

A NEW communications technique for long-distance telephone transmission was given its first public demonstration Oct. 1st by engineers of Bell Telephone Laboratories where the new art is under development.

Known as PCM, an abbreviation for pulse code modulation, the new technique is entirely different from earlier forms of pulse modulation and promises marked freedom from noise and interference.

A special demonstration program illustrating the remarkably clear transmission which the new system affords was brought over telephone lines from the Bell Telephone Laboratories research buildings at Murray Hill, N. J., where the equipment is installed, to the auditorium of the Engineering Societies Building, 29 West 39th Street, New York City.

There, at a meeting of the New York Section of the Institute of Radio Engineers, several hundred engineers heard the program and an explanation of the new technique. Both speech and music were sent over the new system and reproduced through loudspeakers in the auditorium.

The new technique is expected to find use on broadband transmission hook-ups, including microwave radio relay systems,

R. W. Sears of Bell Labs. holding a special tube which he developed for pulse code modulation transmission.

such as that now being installed to link New York and Boston. Basically it is a method of transmitting the human voice by various patterns or codes of electrical impulses.

A new vacuum tube which electronically converts the human voice into these patterns or codes was also displayed for the first time at the meeting. In a 96-channel laboratory model now under development, such Bell Laboratories' tubes will handle code signals at a speed of 5,376,000 pulses per second.

Although the new system is expected to be used primarily as an adjunct to the telephone network, it can also be used to transmit radio programs, pictures, and teletypewriter signals.

The demonstration was given by L. A. Meacham and Eugene Peterson of the technical staff of Bell Telephone Laboratories, both of whom have been active in the development of the system. The coding tube was described by R. W. Sears, also of the Laboratories technical staff, who designed and developed it for use in the system.

The new method overcomes one of the difficulties of long-distance radio systems, namely, the building up of noise with each of the many amplifications needed for a long-distance radio hook-up. With PCM, special amplifiers reconstruct the signal code during each amplification. Thus, no matter how many amplifiers are used, the PCM signal is received with its original quality.

Pulse modulation, or sampling, transmission in general is expected to be used on broadband communications systems

[*Continued on page 43*]

NAB Recording Standards Meeting

THE NATIONAL ASSOCIATION of Broadcasters' Committee on Recording and Reproducing Standards, quiescent since 1942, met in Atlantic City on September 16 to reorganize for postwar activity. It will be recalled that this Committee, originally organized in 1941, had by 1942 adopted sixteen industry-wide standards for disc recording.

In response to industry requests Royal V. Howard, NAB Director of Engineering, called for a reorganization meeting, held during the NAB Convention. About fifty attended, including a number of foreign delegates to the I.T.C. meetings. R. M. Morris, Chairman of the Executive Committee before the war, agreed to remain active long enough to reorganize the executive and sub-committees. This reorganization was necessitated by the fact that many company representatives had shifted to non-recording work in the postwar era and were no longer available for committee work.

Mr. A. E. Barratt of the BBC discussed the results of a meeting of British magnetic recorder manufacturers and the BBC engineers last May. These preliminary standards are tied to those of the German magnetophon, because of the number of such machines already in use on the Continent. He gave details, which were as follows:

- Tape width = 0.245″ + .005″, − .000″
- Tape thickness, coated = .002″ ± .0001″
- Tape stretch = 1.08 to 1.27% at 250 grams load
- Tape output variation = not over +3 db on any one spool or group of spools
- Spools = center boss of 4″ minimum diameter, with one flange, is recommended. The magnetophon spool, with no side plates, is not satisfactory.
- Tape speed = 77 cm per second
- Speed constancy = ± .5% over long period
  = ± .1% instantaneous variation
- Rewind time = 2½ minutes, for 21-minute spool

The Committee voted to have Mr. Morris organize a new subcommittee, on tape standards.

There was some discussion of disc standards adopted in 1942. Mr. Barratt said that the NAB pre-emphasis characteristic was more extreme than the BBC could use with its present equipment, for the tendency to overload on higher frequencies was too great. They use a curve with 10 to 12 db rise at 8000 cycles.

Mr. Theodore W. Lindenberg felt that judging from the sound of present transcriptions, 100-microsecond pre-emphasis was too much, and tracking distortion was excessive. Mr. Miller said that 35 to 40 microsecond pre-emphasis had been tried, and found good. Perhaps NAB pre-emphasis was set too high; it might be preferable to reduce it, with a resultant increase in surface noise of perhaps 2 db. Two db more surface noise was negligible, beside the benefit from the resulting reduction in tracking distortion. There was considerable discussion of 50, 75, and 100 microsecond pre-emphasis values, and of the resulting cost if each station had to purchase a new equalizer. Mr. Lawrence Ruddell said that the cost would be of negligible importance if better results could thereby be secured. He would favor the change if significant improvement could be shown.

Mr. C. C. Rieskind said that he was using the same crossover frequency for phonograph records as specified in the NAB characteristic. A recent conference of visiting EMI engineers with a group of leading American commercial recording studios had shown crossovers ranging from 250 to 600 cycles in use in this country. A single crossover for all phonograph records would give the stations much more uniform reproduction.

Considering all these remarks, the Committee decided to study both 78 and 33 1/3 rpm recording characteristics. Mr. Howard hoped that the subcommittees could get their work done in time for a full Committee meeting at the IRE Midwinter Meeting in March, 1948.

The meeting then adjourned.

Members Participating

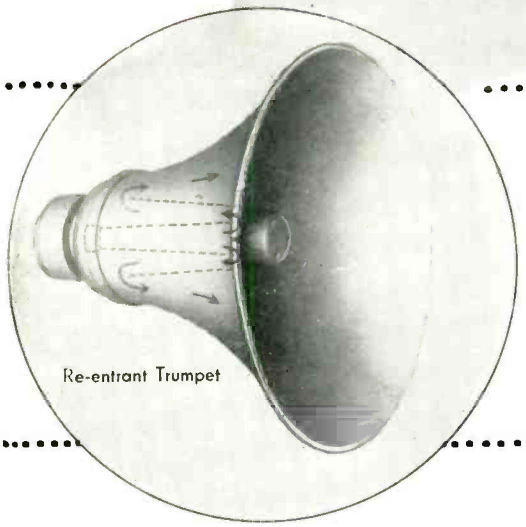
Members participating in the Recording and Reproducing Standards Committee meeting were: F. L. Allman, President and General Manager, Radio Station WSVA, Harrisonburg, Va.; L. J. Anderson, RCA, Camden, N. J.; Ross Beville, Chief Engineer, Radio Station WWDC, Washington, D. C.; Warren L. Braum, Chief Engineer, Radio Station WSVA, Harrisonburg, Va.; Daken K. Broadhead, Manager, Allied Record Manufacturing Company, Hollywood, California; W. J. Brown, Bell Telephone Laboratories, New York City; J. H. Capp, General Electric Company, Syracuse, New York; E. P. Carter, Poinsettia Company, Pitman, N. J.; Robert J. Coar, Coordinator, Joint Senate and House Recording, Washington, D. C.; John D. Colvin, Audio Facilities Engineer, American Broadcasting Company, New York City; A. N. Curtiss, RCA, Camden, N. J.; W. H. Deacy, Jr., Staff Engineer, American Standards Association, New York City; O. B. Hanson, Vice-President and Chief Engineer, National Broadcasting Company, New York City; Fred de Jaager, Empire Broadcasting Corporation, New York City; C. M. Jansky, Jr., Jansky & Bailey, Washington, D. C.; J. G. Lawrence, Radio Division, Western Electric, New York City; C. J. LeBel, Vice-President, Audio Devices, New York City; Theodore Lindenberg, Fairchild Camera and Instrument Corporation, Jamaica, New York; William B. Lodge, Director of General Engineering, Columbia Broadcasting System, New York City; Frank Marx, Director of General Engineering, American Broadcasting Company, New York City; Carl Mayfield and H. P. Meisinger, U. S. Recording Company, Washington, D. C.; R. A. Miller, Bell Telephone Laboratories, Murray Hill, N. J.; George M. Nixon, National Broadcasting Company, New York City; Robert Z. Morrison, National Broadcasting Company, New York City; J. F. Palmquist, Chief Audio Engineer, Radio Corporation of America, Camden, N. J.; R. H. Ranger, President, Rangertone, Inc., Newark, N. J.; Oscar W. B. Reed, Jr., Jansky and Bailey, Washington, D. C.; H. I. Reiskind, Chief Engineer, Record Department, RCA, Camden, N. J.; Arthur F. Rekart, Chief Engineer, Radio Station KXOK, St. Louis, Missouri; H. E. Roys, Advanced Development Engineering Section, RCA, Camden, N. J.; L. A. Ruddell, American Broadcasting Company, New York City; G. J. Saliba, President & Chief Engineer, Presto Recording Corporation, New York City; C. R. Sawyer, ERD Division, Western Electric, New York City; H. F. Scarr, Radio Division, Western Electric, New York City; R. A. Schlegel, WOR Recording Studios, New York City; H. H.

[*Continued on page 44*]

A report on the first postwar meeting of this NAB committee

AUDIO ENGINEERING SUPREMACY

is built into every RACON Sound Reproducer



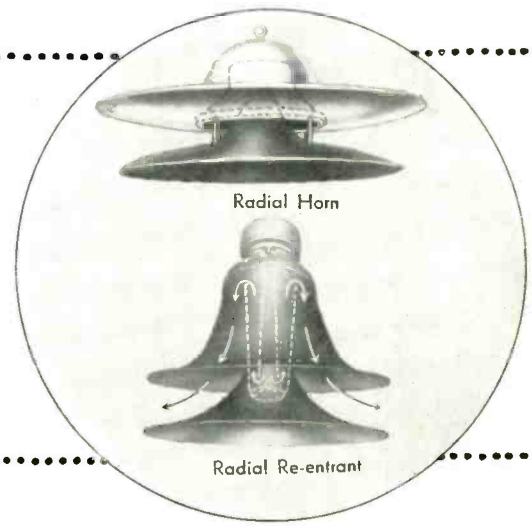
Re-entrant Trumpet

ACOUSTIC & STORMPROOF MATERIAL

Only RACON makes speakers with Racon Acoustic Cloth which is processed by a patented method which gives a non-vibratory wall, thereby increasing the output of the horn without loss due to wall vibration. Supplied as a part of all re-entrant horns, and on all straight horns when so ordered. Stormproof types are guaranteed for life in all kinds of weather and temperature, regardless of climatic conditions.

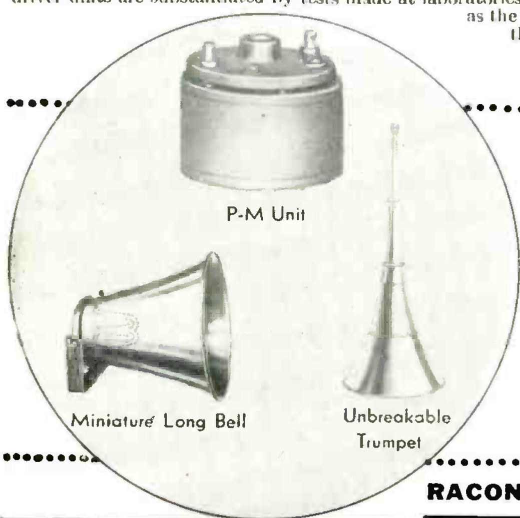
ADVANCED ENGINEERING & DESIGN

RACON'S leadership in sound reproducer engineering has been recognized for almost three decades. RACON driver units have a rated output for peak and continuous performance far in excess of any other brands—continuous operating capacity 30 watts, peak capacity 60 watts. RACON speakers and driving units require less energy input yet they deliver more efficient sound reproduction output. All claims made by RACON as to cutoff frequencies and acoustic lengths of speakers, power handling capacity, efficiency and frequency range of driver units are substantiated by tests made at laboratories recognized as the foremost in the industry.



Radial Horn

Radial Re-entrant



P-M Unit

Miniature Long Bell

Unbreakable Trumpet

COMPLETE LINE TO CHOOSE FROM

There is a RACON driving unit, trumpet or speaker for every conceivable sound application—also the accessories (brackets and housings) that may be required for special purposes. Soundmen know that it pays to choose and use a speaker line that is complete. Yes—RACON makes every kind of sound reproducer from the giant 7 foot length auditorium horn down to the small 4 inch intercom cone speaker—from the super giant P.M. driving unit to the tiny driver for paging horns.

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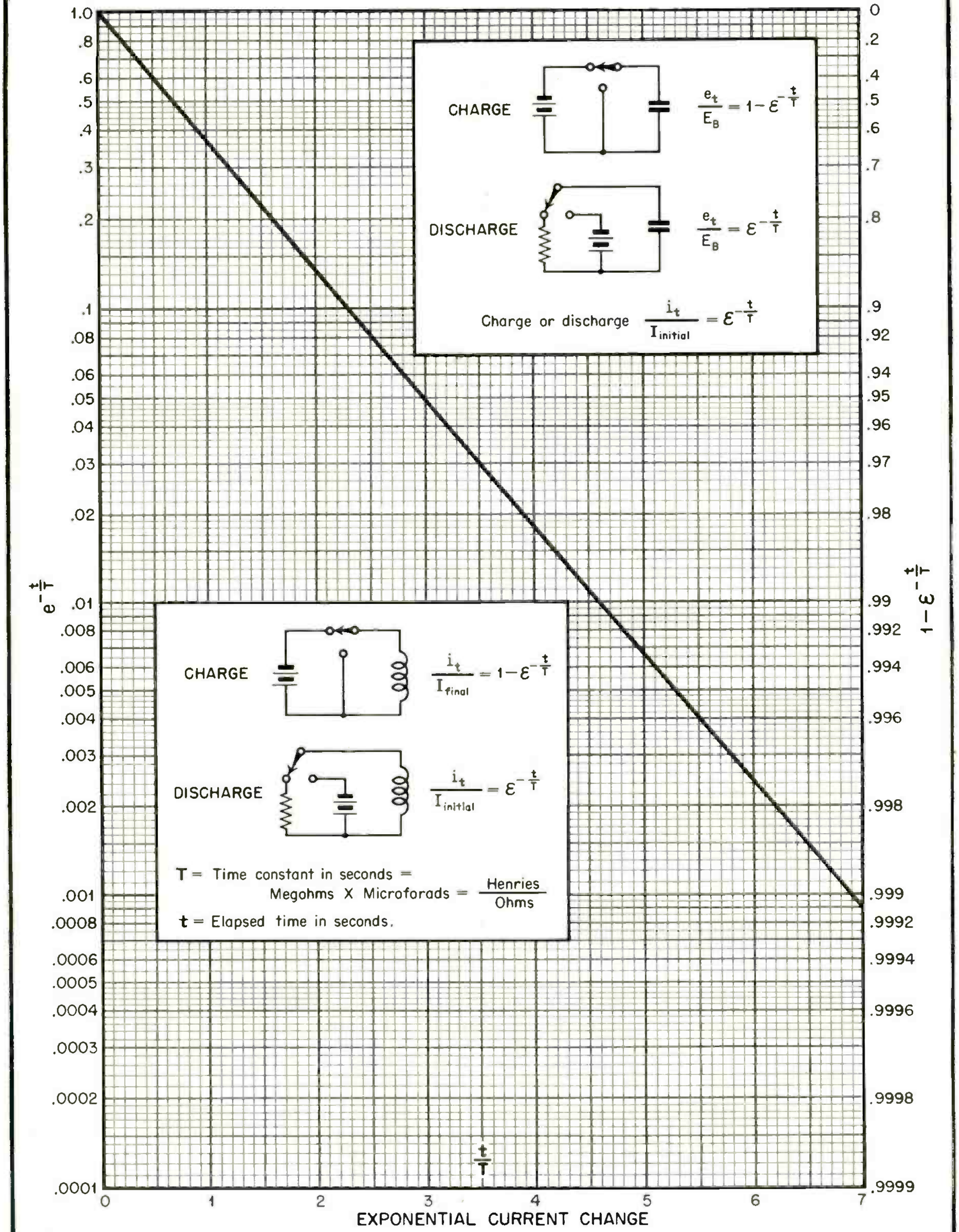
AUDIO DESIGN NOTES

EXPONENTIAL CURRENT CHANGE CHART



Letters

[*From page 3*]

We believe that whatever distortion and loss of highs is noted erratically on phonograph records may be attributed to polishing and excessive use of stampers, and to the retention of fifteen to twenty year old recordings in the catalog to trap the unwary. The date of release is unfortunately no index to the date of recording.

Comparisons such as Mr. Tillson's, abruptly disappeared from the technical scene after Pierce and Hunt's monumental article on tracking distortion in the *Journal of the SMPE* in 1938 had shown that under proper conditions the lateral-cut groove may be tracked with much less distortion than may a vertical-cut groove. This was the only piece of press agentry lateral cut has had in many years but it was very effective. When wide range lateral cutting heads of comparatively low cost became generally available shortly thereafter, public discussion of vertical vs. lateral simply ceased.

"Stylus"

Studies of Reproduction

[*From page 17*]

4. H. Fletcher "Hearing, the Determining Factor for High-Fidelity Transmission." *Proc. I.R.E.*, vol. 30, no. 6, pp. 266; June, 1942.
5. Robert W. Young "Some Problems for Post-war Musical Acoustics." *J. Acous. Soc. Am.*, vol. 16, no. 2, pp. 103; Oct., 1944.
6. N. D. Webster and F. C. McPeak "Experiments in Listening." *Elect.*, vol. 20, no. 4, pp. 90; April 1947.
7. J. Mills "A Fugue in Cycles and Bels." D. Van Nostrand Co.; 1935, pp. 219.
8. D. K. Gannet and I. Kerney "The Discernibility of Changes in Program Band Width." *Bell Sys. Tech. J.*, vol. 23, no. 1, pp. 1; Jan. 1944.
9. James Moir, "Distortion and Acoustic Preferences." *Proc. I.R.E.*, vol. 35, no. 5 p. 495; May 1947.
10. C. J. LeBel, "Psycho-Acoustical Aspects of Listener Preference Tests." AUDIO ENGINEERING, pp. 9; Aug. 1947.

I. T. & T. APPOINTS HATTON

The appointment of William Hatton, a leading engineer in the field of international telephone communications, as Director of Manufacture of the International Telephone and Telegraph Corporation and its worldwide manufacturing and sales affiliate, the International Standard Electric Corporation, was announced today by Colonel Sosthenes Behn, President of I. T. & T. In his new post, Mr. Hatton, who has been associated with I. T. & T. and its affiliated companies since 1919, assumes, in addition to his present duties as Director of Engineering, full responsibility for the System-wide coordination and development of manufacturing methods.

The Magnetophon

[*From page 11*]

conclusive, but are representative of several machines which I ran while in Europe with SHAEF.

In summary, the frequency-response capabilities of the system, the low noise level, the ability to edit, store, and re-use the tapes literally thousands of times without depreciation; the economy of the system in use over conventional methods of disc or film recording, all lend themselves to a further appreciation of the system. Once the economics of the situation have been worked out, I have no doubt but that the Magnetophon, or an Americanized version of magnetic tape recording, will supplant existing methods.

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1. Das Braunbuch: Reichs-Rundfunk G.M.B.H., Berlin 1942-44.
2. Physikalische Wirkungsweise, Das AEG Magnetophon R22 A, *Hochfrequenzie* Reichs-Rundfunk G.M.B.H., Berlin 1941.
3. Das AEG-Magnetophon-Gerat K4: *Allegemeine Elektrizitats Gesellschaft*, Berlin, 1941.
4. Engineering Division Training Manual: British Broadcasting Corp. London, 1942.
5. Department of Commerce, Bureau of Publications, Reports No's. PB-1027, 1028, 1346, 1347, (Bibliofilm Service of Dept. of Agriculture).

NEW PRODUCTS

EQUALIZER

A new, EL-3 equalizer has been developed by Radio-Music Corportion, Port Chester, N. Y. Designed for simplified operation plus finest reproduction without compromise it affords the highest quality tone reproduction possible with both vertical and lateral recordings. The EL-3 Equalizer allows using one arm for vertical only and one arm for lateral only on one turn table or separate tables by connecting both arms to the equalizer. Switching the EL-3 equalizer from vertical equalization to lateral allows changing from one arm to the other . . . at the same time, the correct equalization is thrown in. Both the RMC vertical only and lateral only reproducers can be replaced by the RMC Universal head on either or both. Bulletin EL3-4 sent upon request to manufacturer.

AUDIO METER

Through use of a meter-calibrated speech circuit, the new Deluxe Model 50-E Audiometer of the Audio Development Company provides an entirely new speech test circuit.

Featuring a new dynamic microphone and a meter, this circuit properly controls the level on speech tests so actual speech hearing loss measurements can be made. Such tests are useful in determining recruitment factors, diagnosis and so forth. Results are especially helpful in prescribing medical treatment, recommendation of hearing aids, lip-reading lessons and speech correction studies.

For further information on the Deluxe Model 50-E Audiometer write The Audio Development Co., 2833-13th Ave. South, Minneapolis 7, Minn.

NEW VOLTAGE REGULATOR

Recently developed by the Superior Electric Company is the new Stabiline (Instantaneous Electronic) voltage regulator. A completely electronic device with no moving parts, this new Stabiline Type IE provides the instantaneous correction of line voltage fluctuations with negligible waveform distortion so necessary in all laboratory and industrial voltage regulation applications.

The first model in production is Stabiline Voltage Regulator type IE5101. Extensive tests under all conditions of operation have proved the superiority of performance offered by this new voltage regulator. The output voltage is rigidly held to within ±0.1 volts of any nominal value in the settable output range between 110 to 120 volts for an input line voltage change from 135 to 95 volts. Although the time for recovery varies, depending upon line voltage, load current, load power factor and other conditions, it usually is in the order of 3 to 6 cycles. Performance of the new unit is not affected by any load change from zero to full rating of the unit. It is independent of any load power factor change from a lagging .5 to a leading .9.

One of the most notable features is low waveform distortion. At no time under all adverse conditions does the distortion exceed 3% and for the majority of conditions of operation the waveform distortion is between 1 and 2%. This new unit is not frequency-sensitive and operates equally well for any frequency variation up to ±10% of the designed operating frequency. Type IE5101 will maintain a constant voltage to any load up to 1 kva.

Further information may be obtained by writing to 5137 Laurel St., Bristol, Conn.

AUDIO EQUIPMENT

Bardwell & McAllister, Inc., Hollywood, announced a series of new products in the Electronics field: a line of commercial amplifiers, public address systems, and sound and recording equipment for the motion picture industry.

This firm is known through their line of photographic lighting equipment, particularly for motion picture studios, and the new products are an outgrowth of research projects in the field of electronics which they carried on during the war for the Government. Many unusual features of the new units are the result of their findings and developments during their activity as part of the war effort. All the amplification systems entail unit construction which permits enlargement or modification of a unit to meet the buyers' needs.

This audio equipment is designed and manufactured to studio quality specifications. Every piece of equipment is so designed that the individual component parts are never operated at more than 75% of their rating. This insures long, trouble-free operation.

A specialized department for the research, development and manufacture of audio equipment to customer specifications has also been established.

A new 1947 catalog is available to anyone desirous of further information. Address inquiries to Bardwell & McAlister, Inc., P. O. Box 1310, Hollywood 28, California.

CONSTANT VOLTAGE SELENIUM RECTIFIER

A selenium rectifier that maintains constant voltage regardless of the changing amounts of current drawn from it has just been marketed by a Chicago electrical concern.

This rectifier was constructed to handle large gangs of low voltage d-c magnets in varying loads of from zero to 20 amperes with no appreciable variance in voltage. The d-c voltage control will maintain or increase the starting voltage until the full amperage has been drawn from the rectifier, in contrast to the ordinary rectifier in which the voltage drops as the current is increased.

Originally the product was designed for use in the electrical systems of pipe organs Now, however, the manufacturer believes that this rectifier has wider possibilities and that its use in industry is practically unlimited.

The rectifier itself is a full-wave bridge type suitable for any a-c frequency and a line voltage of 115 to 230. The pulsating d.c. is filtered about 25%, but a smoother current can be supplied if necessary. The rectifier occupies about a cubic foot of space.

For further data, write Austin W. La Marche, of the La Marche Manufacturing Company, 6525 Olmstead Avenue, Chicago 31, Ill.

PICKUP ADAPTER

Technical Products International, 453 West 47th St., New York City 19, announces the development of the new Vibromaster type M Adapter. It adapts the Western Electric 5A arm to accommodate General Electric variable reluctance or Pickering 120M cartridges. The adapter is interchangeable with 9A heads and provides correct balance when used with the 5A arm and either cartridge described above. No soldering is necessary for atachment to cartridge lugs.

JACK STRIPS

Audio Equipment Sales, 923 Eighth Ave., New York 19, N. Y., has announced a new line of jack strips designed to fit the customers' requirements to an exactness not heretofore available in a standard line. While a number of types will be furnished in accordance with already existing types, special arrangements and spacings will be obtainable in small quantities without the expense of dies. These strips are individually machined from XT Bakelite or from anodized dural, and are supplied with or without designation strip holders.

Standard spacings do not always fulfill the requirements of special installations, and many users are unable to obtain accurately built jack strips that are exactly to specification. With the addition of these custom-built designs to the standard line, without price penalties, any desired jack arrangement can be had with the assurance that the strips will fit existing racks, and that the jacks will fit the strips, since the company specializes exclusively in audio equipment.

[*Continued on page 47*]

Program

Rochester Fall Meeting

of members of the
R.M.A. ENGINEERING DEPARTMENT AND THE INSTITUTE OF RADIO ENGINEERS
Sheraton Hotel, Rochester, N. Y.
November 17, 18 and 19, 1947

Monday, November 17

8:30 A.M.—Registration
Inspection of Exhibits

9:30 A.M.—Technical Session
Chairman—A. E. Newlon
V-H-F Direction Finder for Airport Use, A. G. Richardson
Federal Telecommunication Laboratories
R-F Inductance Meter with Direct Reading Linear Scale, Harold A. Wheeler, Wheeler Laboratories Inc.
Design and Layout of Radio Receivers and the Maintenance Man, A. C. W. Saunders, Saunders Radio & Electronics School

12:30 P.M.—Group Luncheon
Committee Luncheon Meetings

2:00 P.M.—Technical Session
Chairman—B. S. Ellefson
Use of Miniature Tubes in AC/DC Receivers for AM and FM, R. F. Dunn, Radio Corporation of America
Two Signal Performance of Some F-M Receiver Systems, B. D. Loughlin and D. E. Foster, Hazeltine Electronics Corp.

4:00 P.M.—Inspection of Exhibits
Committee Meetings

6:30 P.M.—Group Dinner

7:30 P.M.—Inspection of Exhibits

8:15 P.M.—General Session
Chairman—George R. Town
Engineering Responsibilities in Today's Economy, E. F. Carter, Sylvania Electric Products Inc.

9:15 P.M.—Stag Party
Courtesy of American Lava Corporation

Tuesday, November 18

9:00 A.M.—Registration
Inspection of Exhibits

9:30 P.M.—Technical Session
Chairman—L. C. F. Horle
Avenues of Improvement in Present-Day Television, Donald G. Fink, McGraw-Hill Publishing Company, Inc.
Standardization of Transient Response of Television Transmitters and Receivers, R. D. Kell and G. L. Fredendall, RCA Laboratories
Psychoacoustic Factors in Radio Receiver Loudspeaker Selection, Hugh S. Knowles, Jensen Manufacturing Company

12:30 P.M.—Group Luncheon
Committee Luncheon Meetings

2:00 P.M.—Technical Session
Chairman—Clinton B. DeSoto
Spectral Energy Distribution of Cathode Ray Phosphors, R. M. Bowie and A. E. Martin, Sylvania Electric Products Inc.
Quality Control in Receiving Tube Manufacture, J. A. Davies, General Electric Co.

4:00 P.M.—Inspection of Exhibits
Committee Meetings

6:15 P.M.—Cocktail Party
Courtesy of Stackpole Carbon Company

7:00 P.M.—Fall Meeting Dinner (Stag)
Toastmaster—Ralph A. Hackbusch
Speaker—Fred S. Barton
Subject—The British Radio Industry Today

Wednesday, November 19

9:00 A.M.—Registration
Inspection of Exhibits

9:30 A.M.—Technical Session
Chairman—B. E. Shackelford
Metallized Film Coaxial Attenuators, John W. E. Griensmann, Polytechnic Institute of Brooklyn.
I-F Selectivity Considerations in F-M Receivers, R. B. Dome, General Electric Dome, General Electric Company.
A New Television Projection System, William E. Bradley, Philco Corporation.

12:30 P.M.—Group Luncheon
Committee Luncheon Meetings

2:00 P.M.—Technical Session
Chairman—R. M. Wise
The Organization of the Work of the I.R.E. Technical Committees, L. G. Cumming, Institute of Radio Engineers.
V-H-F Bridge for Impedance Measurements Between 20 and 140 Megacycles. Robert A. Soderman, General Radio Company.

4:00 P.M.—Committee Meetings

6:30 P.M.—Group Dinner

8:15 P.M.—Photographic Session
Chairman—A. L. Schoen
The Problem of Amateur Color Photography, Ralph M. Evans, Eastman Kodak Company.

TECHNICANA

FEEDBACK EQUALIZER

● A single-tube amplifier circuit claimed to furnish sufficient equalization for magnetic phonograph pickups together with an appreciable amount of amplification is described by J. Ellis in *Wireless World* for September, 1947. The circuit, shown in *Fig. 1* employs a single pentode with feedback to provide the desired frequency response.

Variation of the setting of *R1* changes the transition frequency by selecting desired proportions of the original signal and of the amplified signal with the boost on the low frequencies. If no volume control is required at *R2*, the arm of *R1* may be connected directly to the grid of the following stage, provided there is a d-c path to ground through the input device.

PIANO TONE DECAY

● A comparison between the Decay Rates of Piano Tones in two conventional pianos—upright and baby grand—and an electronic instrument is described by Daniel W. Martin in the *J. Acous. Soc. Am.* for July, 1947. These measurements were made by the use of a high-speed level recorder, and the results presented on the basis of the time required for the sound level to decrease 60 db from the original tone, a criterion with which acoustical engineers are familiar.

Two rates were found to exist, the first being considerably more rapid than the second. In addition, the rates differed between octaves. The two conventional pianos had initial decay times which were closely comparable, while the secondary decay time for the upright was less in the lower octaves than for the baby grand.

The electronic piano—consisting of a spinet type with the sounding board removed and an electronic pickup device attached—was found to have a decay time approximately three times that of the conventional instruments. With the electronic equipment turned off, it was found that the sound output from the electronic piano was reduced by 14 db by the removal of the sounding board, and the rate of decay was approximately halved. While the volume of the original tone had a considerable effect upon the rate of decay with conventional pianos, the decay time of the electronic piano has practically no relation to the amplitude of the original tone.

PROPOSED "WOW" STANDARDS

● The Sound Committee of the SMPE reports its draft of the proposed standards relative to "flutter" or "wow" in the August *J. Soc. Mot. Pict. Eng.* The proposal defines Flutter Rate as the number of excursions of frequency per second in a tone which has flutter, and Per Cent Flutter as the ratio, expressed as a percentage, of rms deviation in frequency of a tone to the average frequency, as measured by an instrument which responds uniformly to all flutter rates up to 200 cps.

The standard flutter-test frequency for 35 mm film and for disks is specified as 3,000 cps ± 15 cps, and the flutter index is a measure of the relative perceptibility of frequency-modulated tones. This index can be used as a specification of flutter content, and used as a means for identifying the amount of perceptible flutter in a given listening position. For example, the value of the flutter index for a small

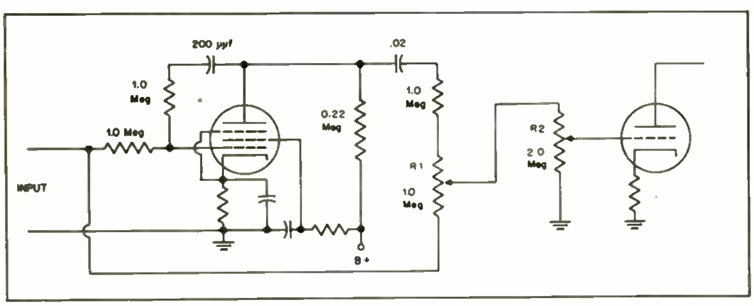


Fig. 1

auditorium is approximately 0.024 for all rates from about 5 to 100 per second. These standards, if adopted, should provide a yardstick by which flutter or wow in disk and film reproducing equipment may be evaluated.

VARYING-LOAD DISTORTION

● The question of distortion in pentode amplifiers operating in the varying load presented by loudspeakers is discussed by F. Langford-Smith in *Radiotronics* (Australia) for May-June, 1947, in the second part of his article on the design of high-fidelity amplifiers. It is an accepted fact that the load impedance may vary over a ratio of 10:1 when inverse feedback is not used.

A study of the curves for a typical beam tetrode with the plate characteristics plotted for a negative feedback factor of $\beta = 0.1$ shows that they are similar to those of a triode, giving similar intercepts on the loadline.

The principal difference between triode curves and those of the beam tube is that the grid current curve of the latter limits the grid voltage swing of the grids. A typical set of curves is shown in *Fig. 2*, plotted for a 6L6. It will be noted on this curve that the grid current point does not correspond to the zero grid voltage condition. The normal load curve, *R*, has intercepts on the various grid voltage curves that are approximately equal. However, as the load resistance is decreased, the grid current flow commences before the voltage reaches zero, causing a flat top on the output waveform. This may be avoided by reducing the maximum grid voltage swings, with the following table indicating probable operating conditions for various loads, both above and below normal.

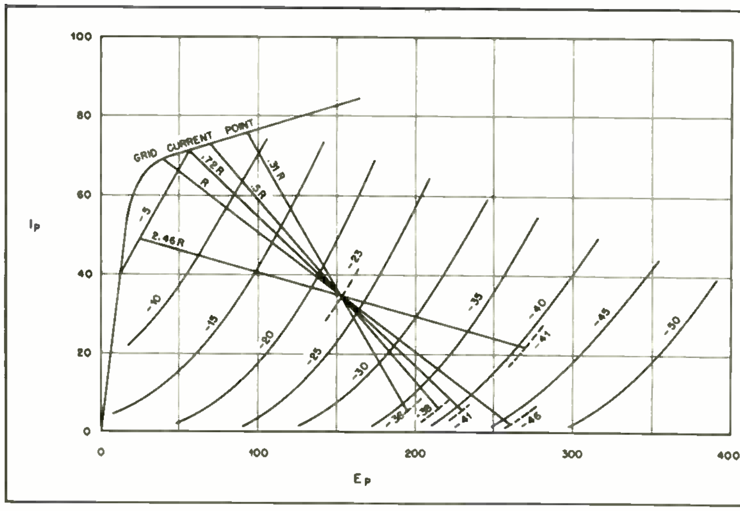


Fig. 2

Load	Peak e_c	% Dist.
∞	15.5	1.5
2.46R	18	0
R	23	5.0
.72R	18	11.5

And for lower values of load resistance,

[*Continued on page 47*]

How to Avoid Saving Money

by DANNY KAYE

To avoid saving money, the first thing is to cut off all your pockets. (Or throw away your purse and keep your lipstick in your snood.) Thus you will have to carry your money in your hand. Which will insure that you—1. spend it, 2. lose it, 3. get it taken from you—*quicker!*

Also to be avoided like crazy are piggy banks and sugar bowls. Keep these out of your home! The kiddies in particular are victimized by such devices, often saving quite a bale of moolah. Be stern even if the little ones cry—remember what money could do for them! And be sure to avoid budgets. It is best to draw your pay and walk down Main Street buying anything you don't particularly hate.

Above all, don't buy any U. S. Savings Bonds—or it's *impossible* not to save money! These gilt-edged documents pay fat interest—4 dollars for 3 after only 10 years! There is even an insidiously easy scheme called the Payroll Savings Plan by which you buy bonds *automatically*. Before you catch on, you have closets full of bonds. You may even find yourself embarrassed by a regular income! Get-gat-gittle!

Danny Kaye

IF YOU MUST SAVE

SAVE THE EASY WAY...

BUY YOUR BONDS THROUGH PAYROLL SAVINGS

Contributed by this magazine in co-operation with the Magazine Publishers of America as a public service.

Ultrasonics in Solids

[from page 24]

There is no limit, however, to how much we can push a load, except the power of our generator of accelerating force. Since practically all loads are elastic, we can set up our oscillation in the load by timed pushes. The few exceptions to an elastic load in practice might include powdered material, where the "Q", as the radio man says, is very low.

Thus any phenomenon that exhibits intermittent pushing effect is a potential ultrasonic generator, provided that the effect can be speeded up to give us say 24,000 pushes a second or so. A boy running a stick along a picket fence might have some difficulty in reaching the velocity requirements.

Centrifugal Pump Action

An interesting high-power effect can be observed in the action of a centrifugal pump. A ten-inch rotor at 3,600 r.p.m. can use up to two hundred h.p. in the driving motor, so we can look for great energy concentrations. Let us examine an idealized one in *Fig. 1*. Water, with some initial velocity V_i is fed into the rotor in the center, and by centrifugal force ejected around the periphery in a series of streams *S*.

Looking at *Fig. 2*, we see it will acquire additional velocity V_r in a radial direction, and also will have the peripheral velocity of rotation added to it at right angles, shown as V_t, as it appears as a tangential component. In practice the tangential is probably the highest velocity component, and since the kinetic energy in the stream is as the velocity squared, its energy contribution is very great.

In *Fig. 2*, we have straightened out the stream *S* for simplification, and show it ready to impinge on the solid block "*A*," say, of steel. *Fig. 2A* shows that the stream will give up its energy in its own thickness *T*, and since this dimension is quite small, the kinetic energy will be transferred at a very rapid rate. This will produce a single push on the load. Since we cannot well rev up much beyond 300 r.p.s., or 18,000 r.p.m., we must have many such streams hit our target in succession in each revolution. At 14,000 r.p.m. we need 100 jets to give us a striking rate of 24 kc.

If we make these streams of large cross-section, we rapidly run into extreme powers. This is somewhat the same thing as the fuel pump in the German *V2* rocket—about a 12-inch rotor running 14,000 and absorbing some 4,000 h.p.

Calculating on a basis of a water stream of ¼" cross-section, and round, let us give it a total radial velocity of 100 feet per second, and a peripheral or tangential velocity of 300 feet per second. Each stream then represents 5.5 h.p. of kinetic energy, and a hundred such streams of course, 550 h.p. We can use a much larger disc at much slower r.p.m., of course, than the rocket pump.

Such a water stream colliding with the solid block of *Fig. 2* would generate pressures of 37,000 psi. This power density would have to be cut down, unless we wanted to erode the steel piece "*A*" at a rapid rate.

Just for curiosity we calculated such a condition with 1,000 fps velocity and mercury for the liquid, 100 streams of ¼-inch diameter. The power was 65,000 h.p. and the pressure on the block about 5 million pounds per square inch. This would cut up armor plate.

One great advantage for this type generator is that it offers an ideal load for a turbine of any type, that naturally operate at high r.p.m. and constant torque.

The twin disadvantages are too high power density, and great inefficiency in the form shown, where the energy is absorbed by one target only. It is obvious that 100 targets would be provided, however, and in following articles we will discuss the general attack on altering too high power densities to a lower value which can be well handled by commercial materials. This copious use of water or other liquid leads us to the problem of "drowning" such apparatus by inability to draw away the liquids at a sufficiently high rate. This we shall also discuss later.

This type generator certainly is a step toward high power ultrasonics—in fact it is almost embarrassingly too much power. To the engineer who has been playing with 100-watt crystals for years, it might be a pleasure to be faced with the difficulty reversed—namely, something that must have its power and power density minimized in design.

Record Revue

[*from page 29*]

fessional equipment. The alternative seems obvious: "We'll stick to our own stuff, and take away those 'high fidelity' records!"

The consequence: a wall of resistance from dealers and public alike against improvement in records. The old twin arguments that have bedeviled f-m radio for all these years, are trotted out. "The public is satisfied and doesn't want higher fidelity" (*it hasn't tried it yet*), and, "Anyway, you can't make sets good enough for it." And now a new and sinister note. "We don't want 'high fidelity' records because they tell us (who?) that on our machines they'll sound worse than the ordinary ones."

Now it is just possible, I suppose, that on a few really terrible machines a wide range record may sound relatively worse than one of the old-timers. But it's a fact that very, very few do. That argument is a fallacy. In my experience, what counts on a cheap machine is not range, but curve. Records with a built-up high end sound relatively well, whether they get up to 5000 or 10,000 cycles; those recorded "flat" sound muffled and dull, again whether "high fidelity" or not. I am sure any dealer can find if he tries for himself that the best new records will never sound worse than the old ones, merely because of their "fidelity."

In other words, here is simply a confusion between range and recording curve, not a complex matter by any means—yet this very argument, typical of too many others, is, right now, actually endangering the business life of companies that are making and advertising improved records. Sound man—step in! Or would you prefer to have these recording companies revert to "poor" records, to satisfy their dealers' feelings?

The worst of all this is the bland assumption that existing commercial machines will not be improved, and hence *better records are a waste of money*. This is the eternal fallacy of minute-by-minute retail merchandising. Take the public's pulse (test it, too) and give it what it wants. What it wants now it will want tomorrow.

We had the model T Ford and it sold millions because the public wanted it. It is gone. We had acoustical records and they too sold in prodigious quantities. They too have gone; and mind well, the electrical record, vastly improved, higher fidelity, appeared on the market *before there was a commercial electric phonograph to play it*. By today's unhappy argument, the orthophonic record should have been suppressed because the existing machines could not match its quality, and because the public had been well satisfied (look at sales) with existing records. We have seen a thousand examples of the expensive, the professional, the luxury-for-the-few turning into the cheap article for the many.

How absurd it is then, when you come down to it, to find the pioneers of today in better commercial record production fighting against the temptation to give up their better standards and follow the backward line of popular prejudice. It is up to the sound man, who can see the matter in perspective, who can sort out the fallacies, the prejudices, the misconceptions from the genuine problems that obviously exist, to help those who help fight his battles. It is up to him to hail every real improvement in the low price field, whether in records or equipment, even if it may mean little in strictly professional terms. And above all it is up to the informed engineers to keep the possibility of commercial progress alive, to keep the public aware that great improvements *are* possible and probable. And at a price too.

Let the sound man marvel at the GE cartridge and the Pickering, at the Pilotuner—splendid proof for anyone to see that improvements beyond our wildest prewar dreams are already available in the lowest price ranges. Let him think twice, too, before he sniffs at that $15 "high fidelity" speaker. For though it may be far from ideal, that speaker nevertheless (tell the dealers!) can cope very nicely with all there is to be had on a new "high fidelity" record. These improvements are bound to be general before long and those who buy good records now are just that far ahead of the game. Tell the dealers that, too, and tell the public. Give a helping hand to our friends, the high-fidelity record makers!

RECOMMENDED RECORDS

Here are some recent recordings of outstanding interest technically:

Richard Strauss, Le Bourgeois Gentilhomme. (Incidental music). (1912). Pittsburgh Symphony Orchestra. Fritz Reiner. . Columbia M693

One of the finest shellac records for high fidelity demonstration I have ever heard. Very wide range, beautiful liveness, excellent surfaces. But the music has much to do with it; this is gay, dance-like music, in short movements, mostly one side, the orchestration is perfect for microphone use—a biggish orchestra but constantly broken up into solos of all sorts and solo groups, with wonderful tone color contrast. Try side 3—filter to 4000 cps and the solo violinist disappears like magic, open 'er up and he's there again!

Glazounoff, Raymonda Ballet Music. Boston "Pops," Arthur Fiedler............ Victor M1133

Strange that the Boston "Pops" (alias the Boston Symphony) should seem to record better than the Boston Symphony, but it works that way. May be in part the music itself—it's lighter, easier to record in general—and partly style of playing. But there still is an apparent difference in recording technique. This seems to have wider range than recent BSO recordings; a fine over-all type live recording of light-weight, big-sounding ballet music.

Grofe, Mississippi Suite. Andre Kostelanetz and His Orchestra. Columbia MX284.

(One of Columbia's new box-packaged sets, which I dislike thoroughly!) This is wide range all right, but with a strange convention-hall sort of liveness, quite unlike most of Columbia's classical or popular jobs. Interesting to try to analyze what's wrong here.

Note: The first Keynote "Manuscript" records (see AUDIO ENGINEERING, August) are now out, with a new type material, part vinyl. Surface on the Stravinsky Dumbarton Oaks Concerto is about equal to finest shellac, with an even, low hiss, very few imperfections, no vinylite "ticks"; the Vivaldi Concerto (single record) seems to have suffered in its material; more scratch, some unevenness. Material is heavier, more rigid than average plastic record, still flexible. Not the perfect surface yet, but a good step forward. Records sell at only 25c more than regular shellacs.

Bartok Memorial Album. Piano music played and announced by the composer.... Vox 625 (2 plastic)

An interesting album—this was recorded some time ago, "instantaneous," for broadcast on a Hungarian radio station and was never envisioned as a commercial recording. Yet, aside from a few overloaded peaks, it is excellent piano recording. Made under supervision of Bartok's son, Peter, now a sound man in N. Y. Music is series of short folk song settings for piano students, often used by teachers in this country. Good surface.

Pulse Code Modulation

[from page 31]

on which many conversations can be carried simultaneously. Such transmission is so named because the continuous speech wave is sampled very briefly and rapidly and only information regarding these samples is transmitted. For a standard telephone circuit 3000 to 4000 cycles in width, samples taken at the rate of 8000 per second are adequate. Just these brief samples are sufficient to reconstruct the original wave with high fidelity.

Since information regarding the sample can be sent very quickly—in roughly a millionth of a second—the system can carry not just one but many different telephone conversations, each of which is sampled in turn and then reassembled at the receiving end. Thus, a transmission system of this type actually carries a sample from one conversation, then from another and so forth, repeating the sampling cycle through as many conversations as are being transmitted.

Several pulse methods have been available by which information regarding the sample can be transmitted. One method, known as PAM for pulse amplitude modulation, sends a sample amplitude directly. Another, known as PPM for pulse position modulation (and also as PTM for pulse time modulation), varies the time with respect to a reference time at which pulses of uniform amplitude and duration are sent. This conveys variations in amplitude. Still another, known as PWM or PLM, for pulse width or length modulation, conveys amplitude by the length of time the pulse lasts.

Method of Operation

PCM accomplishes this by using a set of patterns or codes, each one of which conveys specific information about the sample which it represents. Each of these patterns consists of an arrangement of electrical pulses which always contains a definite and constant number of pulses. These pulses are either "on" or "off," that is, present or absent. Thus, as long as these groups of simple on-off pulses are received properly, speech sent over PCM is reproduced perfectly.

The more code-patterns there are available, the more faithfully the voice wave can be reconstructed at the receiving end. Experiments have shown that patterns or code-groups using six or seven pulses assure high quality transmission. The system demonstrated employs code-groups of seven pulses. By using different combinations of these seven pulses, 128 separate codes are available. During the demonstration the improvement of quality with the addition of pulses was shown by transmitting first with only a one-pulse system and then adding others one at a time.

All the 128 codes available in the seven pulse code-group are perforated in appropriate order in a special plate inside the tube. This plate is so placed that a beam of electrons can sweep across the seven elements of any one code-group. Which one it actually sweeps across is determined by the position of the beam, and this in turn is determined by the amplitude of the signal at the time of sampling.

If the beam goes through a hole in the perforated plate, the pulse is an on-pulse; if the beam is blocked because there is no perforation at that point, it is an off-pulse. The irregular, machine-gun-like pattern of on and off pulses carries the information concerning the amplitude sample to the receiving station.

DAVEN BULLETIN

The Daven Company of 191 Central Avenue, Newark, N. J. announces the publication of a new bulletin of technical data. This folder presents information widely used in the design of sound equipment in a brief, simple form.

The contents include a table showing Impedance vs. Decibel Loss, with values calculated for impedance mismatch, minimum "T" loss, and bridging pad loss. Also included are data on mixer circuits showing circuit diagrams and applications.

These bulletins are available from the manufacturer on request at no cost. Please use company stationery when writing for your copy.

NAB Recording Standards

[from page 32]

Scott, H. H. Scott, Inc., Cambridge, Mass.; Alex Sherwood, Standard Radio Transcriptions, New York City; K. R. Smith, Vice-President, Muzak Corp., New York City; H. F. Tank, Radio Station WWJ, Detroit, Mich.; O. W. Towner, Chief Engineer, Radio Station WHAS, Louisville, Ky.; L. Vieth, Bell Telephone Laboratories, New York City; A. E. Barrett, BBC, New York City; Angles d'Auriac, International Broadcast Organization, Brussels; Roy Cahoon, Canadian Broadcasting Corp., Montreal, Canada; W. T. C. Dowding, Engineer, Toronto Studios, RCA Victor, Toronto, Canada; Raul Lopes Duarte, Chief Engineer, National Portuguese Broadcasting System; L. D. Headley, Mgr., Radio-Recording Division, RCA Victor, Toronto, Canada; W. Hilarius, Chief Engineer, South African Broadcasting Co.; Ing. Raoul Karman, RHC Network, Havana, Cuba; Leonid A. Kopytin, Department Chief Engineer, Ministry for Postal and Electrical Communications, USSR, Moscow, Russia; and M. L. Sastry, Station Engineer, All India Radio.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AND MARCH 3, 1933

of AUDIO ENGINEERING, published monthly at Pittsfield, Massachusetts, for October 1, 1947.

State of New York } ss.:
County of New York }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Sanford R. Cowan, who, having been duly sworn according to law, deposes and says that he is the Publisher of AUDIO ENGINEERING, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business manager are: Publisher, Sanford R. Cowan, 1620 Ocean Ave., Brooklyn 30, N. Y.; Editor, John H. Potts, 1737 York Avenue, New York, N. Y.; Managing Editor, C. G. McProud, 90 Bank St., New York 14, N. Y.; Business Manager, S. R. Cowan, 1620 Ocean Ave., Brooklyn 30, N. Y.

2. That the owners are: Radio Magazines, Inc., 342 Madison Ave., New York 17, N. Y.; John H. Potts, 1737 York Avenue, New York, N. Y.; and Sanford R. Cowan, 1620 Ocean Ave., Brooklyn 30, N. Y.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities, are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company, but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock, and securities in a capacity other than that of a bona fide owner: and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

(Signed) SANFORD R. COWAN, Publisher.

Sworn to and subscribed before me, this 18th day of September, 1947.

(Seal). HARRY N. REIZES, Notary Public.

In the State of New York, Residing in Kings County Kings Co. Clk's No. 634, Reg. No. 612-R-9; N. Y. Co. Clk's No. 779, Reg. No...... Term Expires March 30, 1949

Magnetic Recording

[from page 31]

U. S. Signal Corps: "Magnetic Sound Recorders, Magnetophone and Tonschreiber (1945) Technical Report No. PB 3586, Dept. of Commerce, Wash. 25, D. C.

1946 Menard, James C.: "High Frequency Metaphone Magnetic Sound Recorders" Technical Report No. PB 12659, (Jan. 1946), Dept. of Commerce, Wash. 25, D. C.

Harcourt, Wm. M.: "Agfa Colour," Technical Report No. PB 25659, (Jan. 1946) Dept. of Commerce, Wash. 25, D. C.

Wooldridge, D. E.: "Signals and Noise Levels in Magnetic Tape Recording," *A.I.E.E.* Trans vol. 65, (June 1946), p. 343.

Camras, Marvin: "Theoretical Response from A Magnetic-Wire Record," *Proc. I.R.E. and Waves and Electrons*, 34, 8. (Aug. 1946), p. 597.

1947 Begun, S. J.: "Recent Developments in the Field of Magnetic Recording," *J. Soc. Mot. Pict. Eng.*, 48, 1. (Jan. 1947), p. 1.

Camras, Marvin: "Magnetic Sound for Motion Pictures," *J. Soc. Mot. Pict. Eng.*, 48, 1. (Jan. 1947), p. 14.

Tinkham, R. J. and Boyers, J. S.: "A Magnetic Sound Recorder of Advanced Design," *J. Soc. Mot. Pict. Eng.*, 48, 1. (Jan. 1947), p. 29.

Robin, H. L.: "Magnetophone, Type K-7," Technical Report No. PB 60743 (Jan. 1947) Dept. of Commerce, Wash. 25, D. C.

Research Council: "Discussion of Magnetic Recording" *J. Soc. Mot. Pict. Eng.*, 48, 1. (Jan. 1947), p. 50.

Howell, H. A.: "Magnetic Sound Recording on Coated Paper Tape," *J. Soc. Mot. Pict. Eng.* 48, 1. (Jan. 1947), p. 36.

Miller, W. C.: "Magnetic Recording for Motion Picture Studios," *J. Soc. Mot. Pict. Eng.* 48, 1. (Jan. 1947), p. 57.

Chinn, Howard A.: "Magnetic Tape Recorders in Broadcasting," AUDIO ENGINEERING, 31, 5. (May, 1947), p. 10.

Holmes, Lynn C.: "Some Factors Influencing the Choice of a Medium for Magnetic Recording," *Jour. Acous. Soc. Amer.*, 19, 3. (May 1947), p. 395.

O'Brien, Richard S.: "Adapting Paper Tape Recorders for Broadcasting," Audio Engineering, 31, 6. (June 1947), p. 10.
Williams, A. L. W.: "Rotatable Magnetic Reproducing Means," U. S. Patent No. 2,424,295, (Granted July 22, 1947).
Nygaard, H.: "Continuous Magnetic Recording System," U. S. Patent No. 2,424,498. (Granted July 1947).
Begun, S. J.: "Magnetic Recording-Reproducing Means and Systems," U. S. Patent No. 2,424,218. (Granted July 1947).
Ranger, R. H.: "Design of Magnetic Tape Recorders," *Tele-Tech*, 6, 8. (Aug. 1947), p. 56.
Kornei, Otto: "Frequency Response of Magnetic Recording," *Electronics*, 20, 8. (Aug. 1947), p. 124.
Indiana Steel Products Co.: "Hyflux Magnetic Recording Tape," Engineering Bulletin No. EBT101, (1947), Indiana Steel Products Co., Chicago 2, Ill.

Space-Charge-Grid Tubes

[*from page 21*]

former. This reduces the transformer cost, and also reduces losses in the secondary winding, and leakage inductance. A primary inductance of 10 henries is sufficient for response to within 1 db down to 30 cps.

The input-output curves for the three types of tubes were also compared, and the space-charge tube was better in this respect. The 6V6 curves depart from linearity about 10 db below the maximum output point, while the space-charge tubes were linear up to 3 db below the maximum output. The triodes were intermediate to these two values.

The aural demonstrations accompanying Mr. Pickering's talk were conclusive proof of the advantages of the space-charge tubes. Using a modified Klipsch speaker system, the low-frequency response was notably freer from hangover and from distortion in the higher frequencies. However, when reproduced through a good quality 12-in. speaker mounted in a conventional bass reflex cabinet of about 3 cu. ft. volume, the hangover effects of the 6V6 amplifier were particularly objectionable, and the performance of the space-charge tubes was seen to be definitely superior to that of the beam power tubes. In all particulars, the performance of the space-charge tubes was equal to or better than that of the triodes.

Unfortunately, these tubes are not yet in production. The response to the paper and the obvious advantages of the new tubes will govern the future steps of the designers. Your reporter has already placed an order for a pair of them as soon as they become available. It is contemplated that these tubes will be made in two power capacities, one being in the range of the 6V6 while the other will correspond roughly to the capacity of the 6L6.

Musical Acoustics

[*from page 28*]

of the musical instruments, just as does seasoning on food.

It is to be hoped that in the future listener reaction surveys will present to a greater extent a completely accurate indication of how faithful an image of the prototype of live music the listener has heard, what distortions of harmonics or transients occurred from the system of pick-up, amplification, and reproduction, or from the characteristics of the rooms where recorded or reproduced in comparison with concert halls, or the home.

In amplication of my remarks in Part IV of Musical Acoustics about the esthetic characteristics associated with the various key-scales the following is quoted from "Music and Musicians," a book by Albert Lavignac, Professor of Harmony in the Paris Conservatory, 1899 ed'n, p. 365.

"It is not by chance that Beethoven selected the key of E flat for the Heroic Symphony, and that of F for the Pastoral; it was in obedience to that mysterious law which assigns to each key a peculiar aspect, a special color." "Each person will regard this aspect according to his own personal temperament—but, to my own mind, these are the preponderating shades of the different keys, major and minor:

Major Key	Characteristics
$F^{\sharp}$	rugged
B	energetic
E	radiant, warm, joyous
A	frank, sonorous
D	gay, brilliant, alert
G	rural, merry
C	simple, naive, frank, or flat and commonplace
F	pastoral, rustic
$B^{\flat}$	noble, elegant, graceful
$E^{\flat}$	sonorous, vigorous, chivalrous
$A^{\flat}$	gentle, caressing, or pompous
$D^{\flat}$	charming, suave, placid
$G^{\flat}$	gentle and calm
Minor Key	
$G^{\sharp}$	very sombre
$C^{\sharp}$	brutal, sinister, or very sombre
$F^{\sharp}$	rough, or light, aerial
B	savage, or sombre but vigorous
E	sad, agitated
A	simple, naive, sad, rustic
D	serious, concentrated
G	melancholy, shy
C	gloomy, dramatic, violent
F	morose, surly, or energetic
$B^{\flat}$	funereal, or mysterious
$E^{\flat}$	profoundly sad
$A^{\flat}$	doleful, anxious"

Gevaert, in the first edition of his book on orchestration, Ghent, 1863, page 189, has given a somewhat similar table not seen by Lavignac; and in the following bibliography are some other supporters of this thesis.

"The Power of Sound," E. Gurney, 1880, London, p. 319.

"Color-Music," A. B. Klein, 1930, Appendix II, p. 241, quoting Krehbiel.

"Psychology of Music," Max Schoen, 1940, p. 70.

"Key Quality," W. W. Roberts in mag. "Music & Letters," London, Jan. 1930.

"The Individuality of Keys," P. E. Vernon in mag. "Musical Times," London, April, 1942.

In the time of Aristotle what we now call "key-scales" in music corresponded to "modes"; and Aristotle believed they gave expression to different feelings for the following is quoted from his politics:

"In poetry and music there are limitations of manners; and this is evident, for different harmonies differ from each other so much by nature that those who hear them are differently affected, and are not in the same disposition of mind when one is performed as when another is; the one, for instance, occasions grief and contracts the soul, as the Mixolydian (mode or Key); others soften the mind, and as it were dissolve the heart; others fix it in a firm and settled state, such is the power of the Doric (mode of) music only; only the Phrygian (mode) fills the soul with enthusiasm, as has been well described by those who have written philosophically upon this part of education; for they bring examples of what they advance from the things themselves."

The composer Beethoven assuredly associated definite esthetic effects with different keys because he applied similar terminology to his conversational language, called the key of A flat "barbaresco," that of B minor "the black key," and D flat as "always maestoso."

The composer J. P. Rameau, almost a contemporary of Bach and Handel, assigned various esthetic qualities to the simpler keys.

The music critic H. E. Krehbiel wrote in the *N. Y. Tribune*: "the choice of keys for certain works of different character is certainly not all a matter of haphazard. In instrumental compositions, no doubt, the choice depends to a larger extent upon the mechanism of the medium chosen. This fact has been frequently overlooked by psychologists who are not familiar with practiced music. There is a very obvious reason why a composition should sound very different on a violin in a key in which the tones of the open strings do not form a part of the key-scale, and one in which the open strings may be fully used. So the difference in the mechanism of the pianoforte as applied to the white and black keys (the difference in leverage works differences in the character of the tones, despite the efforts of manufacturers to minimize it). 'Flat Keys,' as they are called, are supposed to be richer and more sombre than 'sharp keys'!"

Correction

In Part IV in the September issue there are two errors. On page 44, first column, 12th line should read 10^{-23}. 21st line the V should be deleted from under the radical.

Technicana

[*from page 39*]

the distortion goes much higher. This shows that there is less interdependence on the load when the variation is upward, provided the signal is not increased to the assumed maximum possible value. A reduction of applied signal to 70 per cent of the normal maximum causes a reduction in power output to 50 per cent of maximum, but distortion is held to lower values.

None of these figures takes into consideration the distortion caused by other factors than the curvature of the tube characteristics.

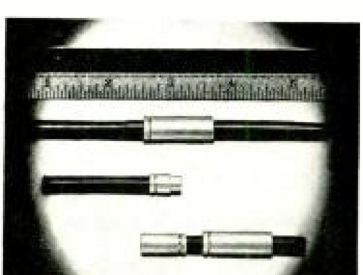
New Products

[*from page 36*]

MINIATURE CONNECTOR

A new low-priced miniature connector with an overall diameter of 23/64 inches and an overall length of 1¼ inches when mated is designed for either RG 58/U or RG 59/U cable.

It is small in size and light in weight and has a voltage rating of 500 volts peak. It is solderless and requires minimum cable preparation. No special tools are required for assembly. The separation force of the quick disconnect lock more than satisfies normal requirements. A panel mounting plate is optional.



This connector is manufactured by H. H. Buggie & Company, 2145 Madison Avenue, Toledo 1, Ohio.

AUDIO CABINET RACK

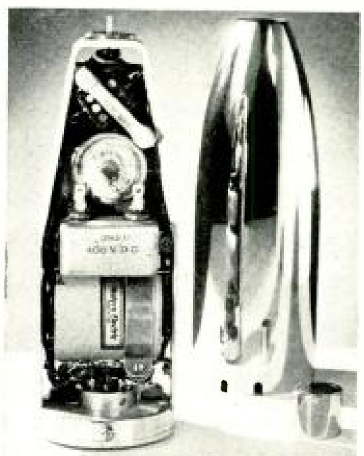
A new audio cabinet rack, designed for mounting audio facilities equipment, measuring apparatus, and other associated panel-mounted equipment in broadcast station control rooms and transmitter installations has been developed by the Transmitter Division of General Electric Company's Electronics Department at Syracuse, N. Y.

The new rack, Type FA-8-A, is 20⅝ inches wide and 83⅛ inches high. It is 15⅜ inches deep and provides a 19 inch wide by 77-inch high panel mounting space with 14 inch clearance behind the panels.

Further details on the newly-announced audio cabinet rack for broadcast applications are available on request to the G-E Electronics Department, Transmitter Division, Electronics Park, Syracuse, N. Y.

640AA MICROPHONE

The Western Electric RA-1095 amplifier has its bright chromium-finished spun metal housing removed to expose the components of the single stage amplifier circuit. The tiny 640 type microphone at the right can be screwed securely in place in the pointed end of the amplifier housing. This combination provides free field response characteristics suitable for the highest quality f-m or a-m program transmission requirements.



3-POSITION RELAY

As an improved output device for relay-terminated control circuits and servo-mechanisms, Sigma Instruments, Inc., offers a new 3-position or null indicating polarized relay. This unit combines a high order of sensitivity and speed with a flexible contact structure of up to a maximum of four normally open circuits for each polarity (total of eight) having power handling capacity comparable with light to medium duty switching relays.

When the coil is provided with two opposed windings for use in a push-pull output circuit, minimum differential power requirements are approximately .005 watt per contact pole, and operation is entirely unaffected by variations in "stand-by" current. With a single-wound coil, about .0025 watt is needed per contact pole.

The armature, which is almost exactly balanced, has "snap-action" centering or detent, and does not move gradually with increasing coil current. About 25 grams of force at the contacts are available from an input of .005 watt, and a similar amount for holding the central or null position, with input balanced or zero. The magnetic circuit being polarized, these forces increase directly with current up to nearly 200 grams.

Additional information may be obtained by writing to Sigma Instruments, Inc., 70 Ceylon St., Boston 21, Mass.

Acoustic Room Design

[*from page 13*]

circular sections will obviously be somewhat more expensive than splays built on circular arcs, because the "laying-out" of the wood forms over which the plywood is to be bent can be less readily prepared. However, if the designer provides cardboard templates, this "laying-out" process could be made quite easy; of course, the time consumed by the designer in preparing the templates must be taken into consideration. Even so, however, when the total building cost of a studio is considered, these "extras" of templates, plywood board wastes, frequently amount to very little, while the appearance of the studio may be vastly enhanced. *Fig. 6* shows a row of splays employing non-circular cross-sections, and the "streamlining" effect is at once apparent.

Fig. 7 shows a "schematic" treatment of a music studio band shell employing non-circular splays, with intervals of sound-absorbent treatment. The arrows indicate the efflux" of the sound from the shell, the short-radii sections of the splays contributing less to the total amount of re-radiated sound than the splay sections having the longer radii. It should be noted that this treatment is "schematic," and not necessarily the best for the width of the studio; the exact size, curvature, and orientation of the splays will to a great extent depend on the type and size of orchestra usually accommodated by the studio, as well as the purpose for which the room is intended (broadcast, film recording, etc.)

Book Review

Mathematics for Radio Engineers, by Leonard Mautner, 326 pp. $5.00. Pitman Publishing Corp., 2 W. 45th St., New York, N. Y.

This volume presents all of the standard mathematical methods with sufficient detail to enable the average engineer to apply them to the solution of audio and radio problems. While most texts on mathematics offer the same information, they are broader in scope, and the application to specific examples in circuit analysis are often obscure.

With a definite slant toward radio, this text is of especial value to those who normally solve circuit problems by empirical methods. Beginning with a review of simple algebra, it proceeds through logarithms, trigonometry, complex algebra, hyperbolic functions, determinants, differential equations, and Fourier Series. The problems following each chapter all deal with electrical circuits, and answers are provided for checking results.

This is an excellent reference work for all—from engineering student to graduate engineer.

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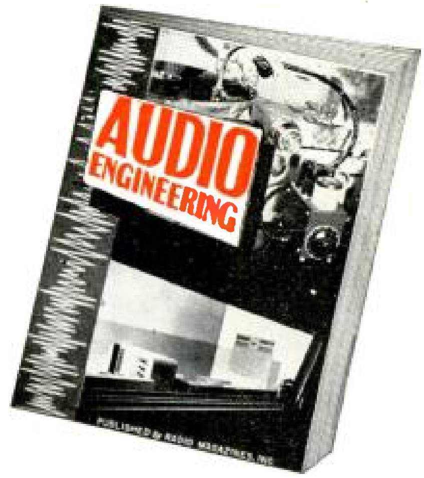

Each issue covers 5 or more of these subjects

1—Broadcasting

2—Transmitter and receiver manufacturing

3—Sound-on-film equipment

4—Recording (disc, wire and tape)

5—Public address

6—Industrial sound equipment and applications

7—Acoustic treatment of studios, rooms, auditoriums, etc.

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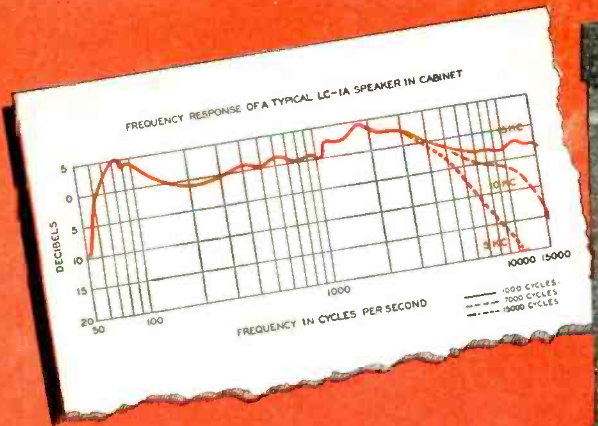


At last!

True FM response

...with the new RCA LC-1A Duo-Cone Speaker

The RCA LC-1A full-range, duo-cone Broadcast Monitoring Speaker, with cabinet. Speaker mechanism only, is type MI-11411.

The RCA LC-1A speaker is expressly designed for monitoring FM programs and high-fidelity recordings in broadcast stations. Its response is exceptionally free from distortion—over the full FM range. Read these highlights:

Uniform response, 50 to 15,000 cycles. Audio measurements prove RCA's new speaker free from resonant peaks, harmonic and transient distortion . . . *at all usable volume levels.*

120 degrees radiation at 15,000 cycles! The LC-1A is unique in its ability to project a wide cone of radiation through a constant angle of 120 degrees. And frequency response is uniform throughout! Advantages: It eliminates the familiar sharp peak of high-frequency response usually present in other systems. And exact location of the LC-1A in control or listening rooms *is not critical.*

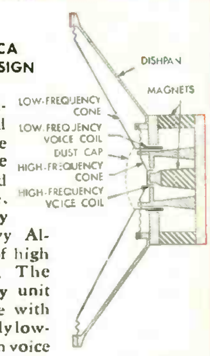
Remarkably smooth crossover-response. Both cones are mounted on the same axis and have the same flare angle to place their surfaces in line. Thus the possibility of undesirable interference between H-F and L-F units over the crossover range is eliminated.

Controlled "roll-off" at 5 and 10 kc. Because of the LC-1A's exceptional high-frequency response, the surface noise and high-frequency distortion present in many recordings is accentuated. Therefore, a panel-mounted switch is provided to control and restrict the LC-1A's high-frequency range for this type of program material (see response curve).

Two fine bass-reflex cabinets (optional) are designed to match the LC-1A speaker. One is finished in the familiar RCA two-tone gray for control-room use. The other . . . in bleached walnut, is suitable for executive offices and modern surroundings.

For prices and further details on the LC-1A speaker . . . now in production, write 115-J

DETAILS OF RCA DUO-CONE DESIGN



Two individually actuated cones are mounted on the same axis and flare angle, with a specially designed heavy Alnico magnet of high flux density. The high-frequency unit is a 2⅜" cone with an exceptionally low-mass aluminum voice coil. This cone follows out the shallow angle of the larger cone to radiate a pattern at full power over an area of 120 degrees at 15,000 cycles! The low-frequency unit has a massive 15" diaphragm with a high-mass voice coil of large diameter. Its resonant frequency, only 35 cycles . . . with true bass response at all volume levels.

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