Mass Production Tape Recording

The final technical obstacle in the way of mass production of recorded music on tape now has been overcome. A machine has been perfected by Minnesota Mining and Manufacturing Company, St. Paul, that can simultaneously reproduce 48, hour-long tape recordings indistinguishable from the master transcription in one hour, according to an announcement by W. L. McKnight, president of the firm.

These pre-recorded reels of tape will be designed to compete with disc records for use in the home, in broadcasting, in schools and theatres. Since many sound engineers contend that magnetic sound tape has better fidelity than any other known sound recording medium, it is to be expected that recorded music on tape may enjoy a competitive advantage over disc recordings, whether of the 78, 45, or 33-1/3 rpm variety. Tape recording machines for home use have been available for some time.

Minnesota Mining and Manufacturing Company describe the new machine as "a high fidelity multiple recorder capable of making tape recordings which are indistinguishable from the master transcription." Reproduction is accomplished by an electrical duplicating process in which the signals from a master copy are picked up by a playback head, amplified and fed electrically into a number of re-recording heads. The master tape and the tapes to be copied are all run side by side on a common capstan. Thus exact speed relation is maintained at all times.

Recording tape is currently available only in the unrecorded form, which is used by the major broadcasting networks as well as in homes, offices and schools for making private transcriptions. Announcement of the multiple recorder, however, opens the way for mass production of pre-recorded music and promises to affect the whole field of sound recording. Perfection of the multiple tape recorder follows hard upon the introduction of 45 and 33-1/3 r.p.m. disc records and machines by Victor and Columbia respectively.

The single mass production recorder built to date has been offered for lease by Minnesota Mining and Manufacturing Company, its producer.

[Continued on page 47]

EDWARD TATNALL CANBY*

OUR EDITOR has brought up a point concerning electronic musical instruments where I was technically in error, though the point I had to make was unaffected. In the February article I spoke of "pure" tones to be heard on an electric organ; it seems that according to engineering standards of measurement the fundamental tones produced by such devices are not pure, that indeed a pure tone is very difficult to achieve. What a pure tone is, then, is a matter of engineering vs. musical terminology. From a musical viewpoint, any tone that comes even fairly close to a continuous sine wave form is for all intents and purposes "pure"—by which we musicians mean, of course, something highly uncomplimentary. A continuous "pure" tone in music is a dead duck.[1] It's lifeless, featureless, without character, unfit for musical purposes altogether—just a noise. I'd say the principal musical difficulty with the electronic musical instrument is still that of oversimplification of the wave forms. You will find that the continuing distrust of such instruments (often a highly unreasonable blanket distrust that includes various instruments that work on utterly different principles) is, nevertheless, basically a feeling that the gadgets just aren't musically "natural," and this feeling must be reckoned with.

And by "natural," I hastily add, we do not mean that your electronic sound must be a good imitation of some specific natural sound. The advantage of the electronic sound is that it can introduce all sorts of new qualities. Few musicians would quibble about this—unless provoked by manufacturers who insist upon using such terms as "electronic clarinet." We are entirely ready to recognize the musical value of new tone color combinations whatever names may be assigned to them; silly, fanciful, inspirational, or what.

But whether your newly created electronic sound comes forth like a cello or an oboe, a new-born babe with asthma or a honking goose (a goose is straight-bore, producing only the odd overtones) the musician will give ear and instantly make up his mind on one vital point—whether the tone is *alive* or *dead*; musically natural or unnatural. Being no engineer, your musician will seldom be able to explain what he means. Being only human, he will give you lots of reasons for his energetic (and probably correct) opinions that will make no engineering sense, for the most part. (Note the singing teacher who insists that her pupils generate their tone somewhere in space a few feet in front of the forehead! Cockeyed, but pragmatic; it works, because with such conceptions singers actually do learn to produce good sounds.) Explanations in physical terms of these things are up to the engineers to make. And in every case the musician, however false his physics may be, has a basically sound idea, needing only the delicate physical interpretation that will reproduce it in electrical terms. What an astonishingly difficult and challenging area this fringe-area is, between the arts and the sciences, between objective scientific analysis and the far quicker, more penetrating human intuition! In the end, as we all have to admit, it's usually "hunch," that solves the most baffling problems, when the "hunch" is well backed by competent engineering training.

What t h e n, is an "alive" musical tone? How can it be synthesized? This column has touched on the matter before, but look at it this way. To be musical a tone must be complex, irregular, and that in many different ways. It must avoid all sorts of too-regular mathematical patterns that will kill its musical effect. A paradox, since most of us have supposed that pitch and rhythm in music were at least reasonably fixed quanitities, not to mention tone color. But no. Life, in tone, is highly delicate; it succumbs instantly to an overdose of regularity. Yes, there must be a sense of pitch, a fundamental tone that is interpretable to the ear in a very exact sense. But even this is seldom mathematically exact. A tone that is interpretable to the ear as an excellent musical "A" may be far removed from a pure 440 tone. Almost all musical tone, for example, includes the baffling feature of the vibrato. It is frequency modulated. Take a lady opera singer producing a walloping A and play her 78 rpm record at 33. You will be astonished at what the ear has managed in its own strange way to interpret as a pitch of 440! The vibrato may waver up and down so enormously that, at 33, the ear recognizes no fixed pitch whatever but only a sort of rapid-action fire siren. A graph of the sound would be even more baffling. Yet this isn't all—for even the vibrato's own frequency must not be fixed, if the tone is to be musical—as electric organ builders know to their own distress. The vibrato is *almost* regular, but never exactly so—make it mathematically regular, and instantly the tone is dead.

Moreover, the amplitude of your vibrato must not be exactly regular. Amplitude too must vary minutely from instant to instant as the musical tone continues. Fix the amplitude mathematically and your tone is dead. Listen again to your lady singer and note how much the varying amplitude has to do with the musical sense of what she is singing—some passages being almost "flat," others being highly modulated with vibrato. So too with an oboe, a violin, even a trumpet. Only a few instruments dispense with the vibrato: the piano of course and its relatives; to a considerable extent, the clarinet.

But vibrato is merely one factor that must avoid the mathematically regular. Even more vital is the tone-color problem. Engineers tend to take an *average* tone color for, say, a clarinet, and assume that this is that instrument's official tone color. There is scarcely any instrument which produces a constant overtone pattern for more than a fraction of a second at a time; one of the main sources of musical "life" is the dynamically changing tone color of nearly all instruments as they (*a*) change pitch and (*b*) change intensity and (*c*) change methods of tone production. Perhaps the natural pipe-organ is the only instrument with a fixed overtone pattern that actually persists measurably.

All of which no doubt leaves most engineers exasperated—if music is as touchy as all this, what in Heaven's name is the use of trying to please a musician! And yet this *is* music and always will be. Exasperated or no, these are the actual problems that a sound engineer faces in any electronic musical instrument design and they cannot be dodged, only compromised with. When you come down to it (and this a fine reason for this column's discussion of the problem) the same sort of thing is true for the recorded art. If you are going to reproduce *musical* sound in a natural-sounding way you must meet the challenge of the musical ear. Your success as a sound man, given sound training, will depend on it, too.

Any electric organ designer knows that problems of naturalness go far beyond what I have suggested here. One must get the tone under way with the proper "ping" (the musical ear will take nothing else) and one must get it properly stopped, too. Can't just turn it on and off. One must see that the tone "speaks" a bit late in the keyboard-type instrument; the musician won't like an instantaneous action. Unnatural. Theoretically, as volume increases tone color should become more brilliant. Natural music works that way. And so on. These problems bedevil sound engineers and in practice they are bound to involve very great compromises all along the line, depending, of course, on the cash available to put into refinements. Theoretically anything is possible. Practically, the most ingenious compromise wins out musically. Far too often in today's electronic musical instrument some regularity gets in that "kills" the tone as far as

[*Continued on page 33*]

**279 W. 4th St., New York 14, N. Y.*

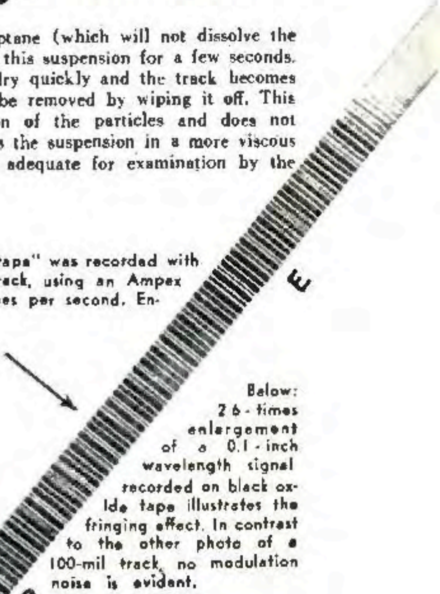
1 The flute, as engineers know, can give an almost pure sine wave tone. But note well that such a tone is hardly what one hears in flute music. A flute player making actual music produces the same multiple varieties of irregularity that are described later in this article. There must be the ictus of the initial accent, a brilliance in loud passages (harmonic tone color) contrasting with less brilliance in soft passages, a vibrato that is among the most noticeable (and most irregular) in any musical instrument, a breath-sound that is normal part of the music (and is not a sine wave)—all this and more, in addition to rhythm, phrasing, etc. A mechanically played flute, actuated by a constant stream of compressed air, may produce a sine-wave—but the sound will be noise, not music. No electronic sine wave "beep" has yet been compared to flute music, that I know of!

The beat note resulting from a high level recording of the two frequencies, 200 and 230 cps, is seen in this five times enlargement.

Making Magnetic Recordings Visible

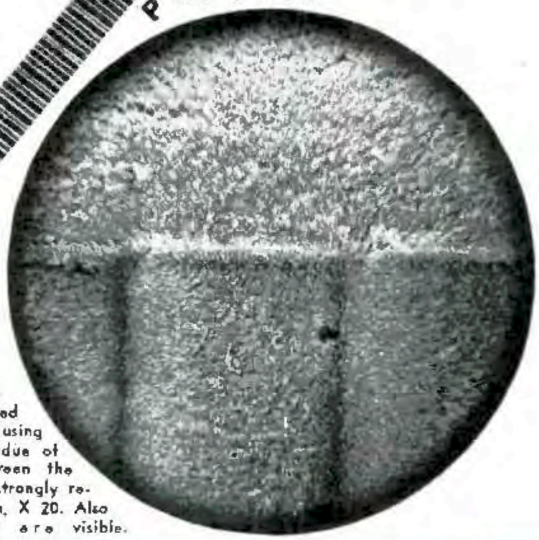
The technique used in making visible the sound tracks shown on this page was described in an article entitled, "Alignment of Magnetic Recording Heads" by B. F. Murphey and H. K. Smith in the January 1949 issue of AUDIO ENGINEERING. For some purposes, where several inches or feet of tape are to be visibly examined (as for editing), Mr. Robert Herr of Minnesota Mining & Mfg. Co., who has supplied these pictures, reports a more convenient and less messy method. The carbonyl iron is suspended by shaking in a volatile liquid, such as heptane (which will not dissolve the tape) and the tape is dipped in this suspension for a few seconds. Upon removal, the liquid will dry quickly and the track becomes visible. The carbonyl iron may be removed by wiping it off. This method allows some flocculation of the particles and does not yield quite so good resolution as the suspension in a more viscous medium, but it is simpler and adequate for examination by the naked eye.

Above: A constant tone modulated by a vibrating head is shown here. Magnification X 60.



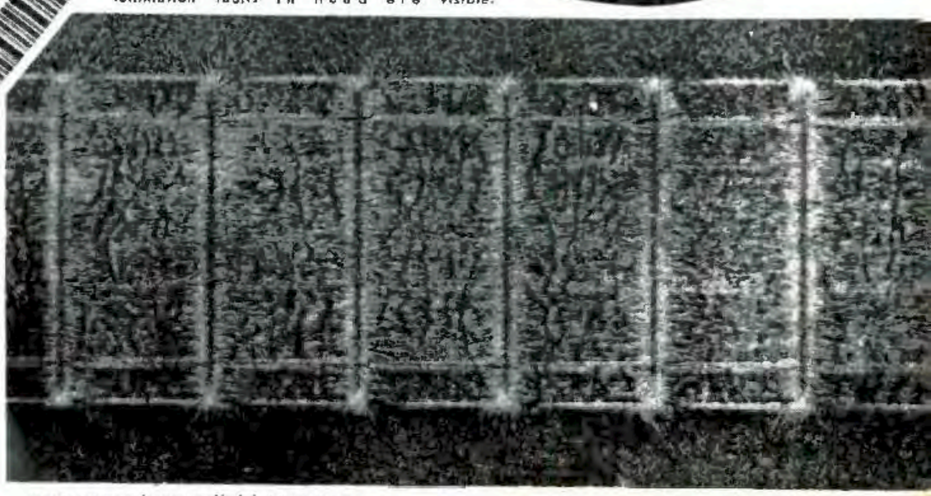
Below: The word "tape" was recorded with a full width ¼" track, using an Ampex machine at 30 inches per second. Enlargement, X 1¼.

Below: 26-times enlargement of a 0.1-inch wavelength signal recorded on black oxide tape illustrates the fringing effect. In contrast to the other photo of a 100-mil track, no modulation noise is evident.



Below: A 0.1-inch wave length recorded on a 0.1 inch track using noisy tape shows residue of modulation noise between the prominent poles of this strongly recorded signal. Magnification, X 20. Also lamination faults in head are visible.

Above: Music recorded on oxide-coated 35 mm film is illustrated by this photo. Ready means for editing and track location is provided by making the track visible. No enlargement.



Experimental Ultrasonics

S. YOUNG WHITE*

Part II—A description of some of the problems of instrumentation for experimental work in the realm of ultrasonic frequencies.

About the minimum amount of equipment required in the investigation of ultrasonics is a source of ultrasonic power, such as the Hartmann generator, a microphone or pick-up, and an indicating device such as a receiver or oscilloscope. Of course, other indicators can be used, such as pigeons or insects, which have positive reactions of various kinds to certain frequencies and amplitudes, but the lack of some measurement devices is rather a handicap.

One great difficulty in attempting to turn out a standard line of ultrasonic apparatus is the very complexity of the requirements. A biologist might wish to investigate the effect of ultrasonic stimulation on cancer, and a cathode-ray tube production man may wish to use the well-known dust precipitation effect to more rapidly coat his screen with phosphorus. In these cases both the generators and observation instrumentation would be quite different. Also, the biologist would be rather unskilled in using apparatus of this nature.

In this article we shall discuss some design features of rather small pick-up devices, such as would be used in a probe. It is almost universally true that all these receiving probes can just as well be used as low-power transmitters, so it would be a great advantage always to design them for both functions. It is also desirable to make them immersion-proof, if possible, so they can be used in liquids as well as air or other gases. Most of them have a natural temperature limitation of some kind, also, and we wish to extend this to its highest limit possible.

Another requirement is small size. These are to be used in sonic fields of small wave-length, and in general we wish them to disturb the field as little as possible. Of course, if we work up around the megacycle region, the physical size must be many wavelengths in dimension for practical apparatus for general use, although special microscopic devices can be made if the requirement justifies the expenditure.

*℅ Radio Magazines, Inc., 342 Madison Avenue, New York 17, N. Y.

Test chamber used with two transducers for experiments with transmission through various media. One of the transducers of Fig. 1 is shown separately.

Shielding against powerful electromagnetic or electrostatic fields is often necessary. As a rule, 60-cycle hum pickup is small, but can be troublesome if not kept in mind. A particularly difficult case is when two magnetostrictive probes are used close together as transmitter and receiver. Very often the flux leakage from the transmitter will directly excite the receiving unit and the supersonic coupling through the medium will be masked.

It is a great advantage to design a series of units interconnected with modern, 52-ohm concentric cable. It has a nice line of fittings available for all purposes, provides good shielding, is low-loss at all frequencies we may wish to use, and is very neat and durable. Unfortunately, about the only type unit that can readily be made to match this low impedance is a magnetostrictive one. All the piezoelectrics suffer severely from the high capacitance, and sometimes it is necessary to go to troublesome or expensive steps to overcome this.

A real hardship in designing a line of units is the wide frequency range we generally wish to cover in general experimentation. A final commercial installation can often be designed to operate at one frequency only. Before we can determine this optimum frequency it may be necessary to investigate an enormous range of many octaves. In working with small particles in water it is usually interesting to investigate the entire spectrum from 10 kc to nearly 10 mc. This is a real test of the designer.

It is the purpose of this table to give a rather rough idea of the frequency limits of various transducers we may wish to use. The range designated as "natural" shows the frequency limits within which no unusual difficulty is had in normal design. The "extreme" range shows maximum performance ever observed by several experimenters. It may be only a single sharp peak shown in some unusual mode of oscillation.

Significance of the Resonant Peak

In general terms, we can operate our devices at resonance or off resonance by any desired amount. Since

TABLE 1

Device	Natural Range	Unloaded Q	Extreme Range	Max. Temp. (F)
Rochelle Bimorph	0 to 30 kc		0-2 mc	120
Rochelle single	0 to 300 kc	20,000	0-3 mc	120
PN	0- 200 (piston)		0-3 mc	250
Magnetostriction	10- 100 kc	30,000	200 kc	250
Rubber electrostatic	10- 500 kc		2 mc	150
Quartz	50- 7,000 kc	10,000	Very high	1,000

many show unloaded Q values that are very high, we can mount them so that high Q is maintained, or load them down to almost any extent.

The chief argument for high Q is the great output obtained at that resonant peak, a very strong argument indeed. The price one pays for it is high, however.

If the units are operated in pairs, one being the loudspeaker and the other the microphone, this resonance rise is squared, and the output is very favorable. The frequency stability on the transmitting signal source must be very great indeed, and in general is hardly practical. If we use a precision frequency standard for the signal to drive the transmitting transducer, it will not follow the transducer peak in many cases, as the transducer is out on the firing line, subjected to variations in temperature, vibration, pressure changes and the like while the standard crystal is locked up in a temperature oven. Also, in the field standing waves with ratios of ten to a hundred are rather common, and these change due to local conditions.

This severely limits the use of the high-Q transducer. So in practice a load sufficient to bring the Q down to as low as ten or thereabouts is often employed. Even at this low Q standing waves are severe, and frequency modulation must be employed to break them up.

This loading does not seriously affect the off-frequency operation of the devices, but of course operation off frequency severely cuts down the signal. A typical example is a pair of one-quarter inch cubes of PN crystal suitable for stable operation in a water supply which might have particles in it. At 200 kc operation, resonance for both units, an input of 200 volts of signal on one will give perhaps 2 volts on the receiving crystal, while off resonance at say 150 kc the combination might give an output of 5 millivolts or so.

Diaphragm Design

The only transducer diaphragm easy to design is the magnetostriction type. It is inherently rugged and needs little protection from gas or liquids. A simple metal disk silver-soldered on the end of the nickel rod, gives almost any desired acoustic impedance match.

PN and Rochelle crystals are very fragile and must be protected from shock and damage if used as contact microphones. PN instantly melts if one drop of water comes in contact with it, but Rochelle salt often can be given a protective coating to prevent this. Quartz has high resistance and moisture must be kept out to preserve the insulation of the assembly. A 7-mc quartz crystal, of the X-cut type is about 20 mils thick, and is quite fragile.

So we have our choice of rubber (plastic) diaphragms, or solid metal. The rubber must be quite thin and offers little protection from sharp points. However, diaphragms made from thin rubber, nylon, or Teflon of a thickness of only two mils or so are very easy to handle, as below 200 kc or so they have little effect on the transmission of ultrasonics through them. To provide clean-cut effects, they must be placed under tension in some way, and the mounting made waterproof by some means.

Standardized Shell For All Frequencies

Figure 1 and the photograph show an earnest attempt to design a universal shell of wide application in ultrasonic commercial and experimental work. In most cases it has a metal diaphragm. This was designed to operate through the spectrum from 10 kc to 7 mc, using practically any type of transducer from magnetostriction to X-cut quartz.

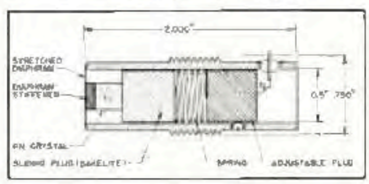


Fig. 1. Universal shell design for transducer suitable for wide range of ultrasonic frequencies.

An accurate half-inch bore dimension was used with a thick wall so that set-screws and glass-bead lead-throughs could be used. A three-quarter inch thread was formed on the center section and this made the tube outside diameter 0.690 inch, as this cleared the root diameter of the thread. This thread was made rather fine, 24 threads/inch, as very often we want fine adjustment of the position of the diaphragm in our tests. The shell was usually made of monel, because it is an attractive material unaffected by many liquids. Sometimes it was hard chrome-plated, or gold plating was called for. A length of 2 inches worked out well.

The series of diaphragms gave us the most trouble to design. If we use quartz or PN crystals, they are mechanically dead flat, and the diaphragm is often used under at least city water pressure, which might reach 60 pounds/square inch at times.

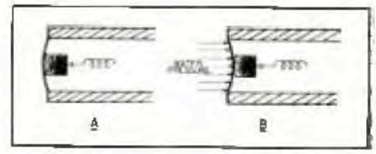


Fig. 2.(B) When used under pressure, diaphragm is pushed inward, providing contact on only a portion of the crystal surface. (A)Pressure behind the crystal bulges diaphragm outward, provides contact only on corners.

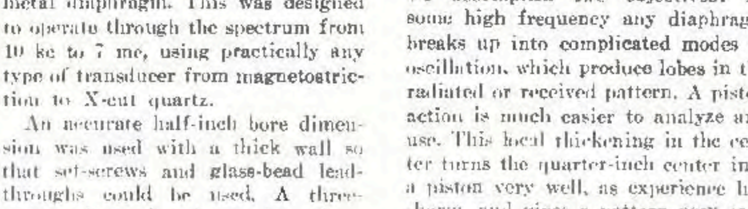
This bulges the diaphragm inwards, as shown in *Fig. 2B*, and the crystal would only touch in the center of its working face. In general, we need some pressure driving the crystal against the diaphragm to obtain intimate contact, and with no pressure on the outside of the diaphragm a reverse bulge takes place, as in *Fig. 2A*, and the crystal touches on the corners only.

By soldering a one-quarter inch button to the center of the diaphragm, we accomplish two objectives: At some high frequency any diaphragm breaks up into complicated modes of oscillation, which produce lobes in the radiated or received pattern. A piston action is much easier to analyze and use. This local thickening in the center turns the quarter-inch center into a piston very well, as experience has shown, and gives a pattern very easy to use.

In practice, some care must be used in making and mounting this center button. Since it will often be used with a precision finished transducer element, it must be dead flat and squarely mounted. If slightly cocked, the pattern put out is hard to analyze, and results are undisciplined.

[*Continued on page 33*]

Transducer probe for use in air. Details of the interior of the crystal mounting are shown in Fig. 3.



The Cutting Sylus Problem In Microgroove Recording

"Stylus"

A discussion of the effect of burnishing-facet dimensions on frequency response.

THE CURRENT INTEREST in new methods of sound recording has made many an engineer re-examine more critically the faults of older systems. Modern disc recordists have become increasingly conscious of diameter effects, and particularly of loss of high-frequency response at smaller diameters. This loss occurs in two parts: First, a loss in *recording* due to the cutting stylus shape; and secondly, a loss in *reproduction* due to the reproducing stylus failing to follow the finer groove convolutions faithfully (tracing loss). Reproducing loss can be reduced by using a smaller stylus tip, within reason. In the case of lacquer, it can be reduced by using a harder lacquer, again within reason.

Only recently has there been much interest in minimizing recording loss. It is not generally realized that commonly used lacquer-cutting styli polish the groove walls by a burnishing action after cutting. This effect is comparable to the use of a dulled cutting tool in making a polished cut in brass.

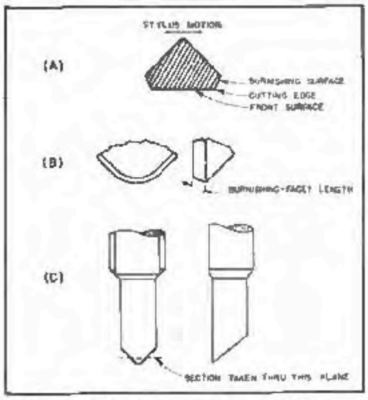


Fig. 1. (A) General view of lacquer cutting stylus. (B) Magnified view of cutting stylus tip. (C) Magnified cross section of tip.

As the polishing action is made more effective by increased burnishing-surface length, the high frequency response deteriorates. A glance at *Fig.* 1 will illustrate why. Effectively, there are flats on the sides of the stylus, which impede lateral motion.

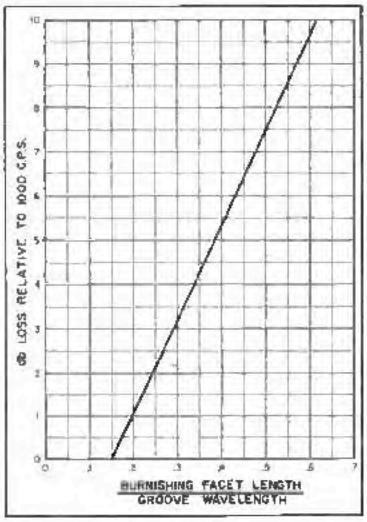


Fig. 2. Generalized effect of burnishing facet length.

The shape of the stylus and the nature of recording lacquer are such that it is not feasible to derive a solution by theoretical means, and so laboratory methods must be used. The only quantitative study of this phenomenon, which has been published, is that of LeBel[1] in 1942. While the original study was made with a standard-size groove, we believe that its conclusions may be applied to the microgroove without too much error. Every cutting stylus has a certain amount of personality of its own anyhow, and the variability so produced is superimposed on the general trend.

We have used the generalized solution given by the above reference—a graph showing the relation between the fraction: burnish length/wavelength, and the attenuation in recording. We have taken the liberty of continuing the main trend for a db further than the reference has, for reasons that will be evident on inspection of his data. This slightly modified graph appears as *Fig.* 2.

The tests on which this curve is based were run at a stylus velocity of 1½ inches, and checked at 2⅝ inches per second. Visual inspection of *Fig.* 1(A) will suggest that the loss might increase at very high peak velocities, but the velocities indicated include the range of velocities normally expected.

The LeBel study was made in terms of *tip* burnish length, which is the easiest to measure accurately. The

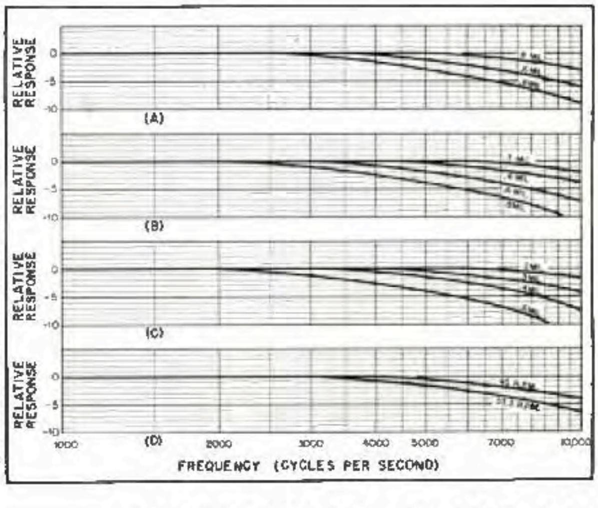


Fig. 3. (A) Frequency response of recording stylus at 8 inch diameter, 33.3 rpm. (B) Frequency response of recording stylus at 7 inch diameter, 33.3 rpm. (C) Frequency response of recording stylus at 5 inch diameter, 33.3 rpm. (D) Comparison of response at 33.3 and 45 rpm, .4 mil burnishing facet, 5 inch diameter.

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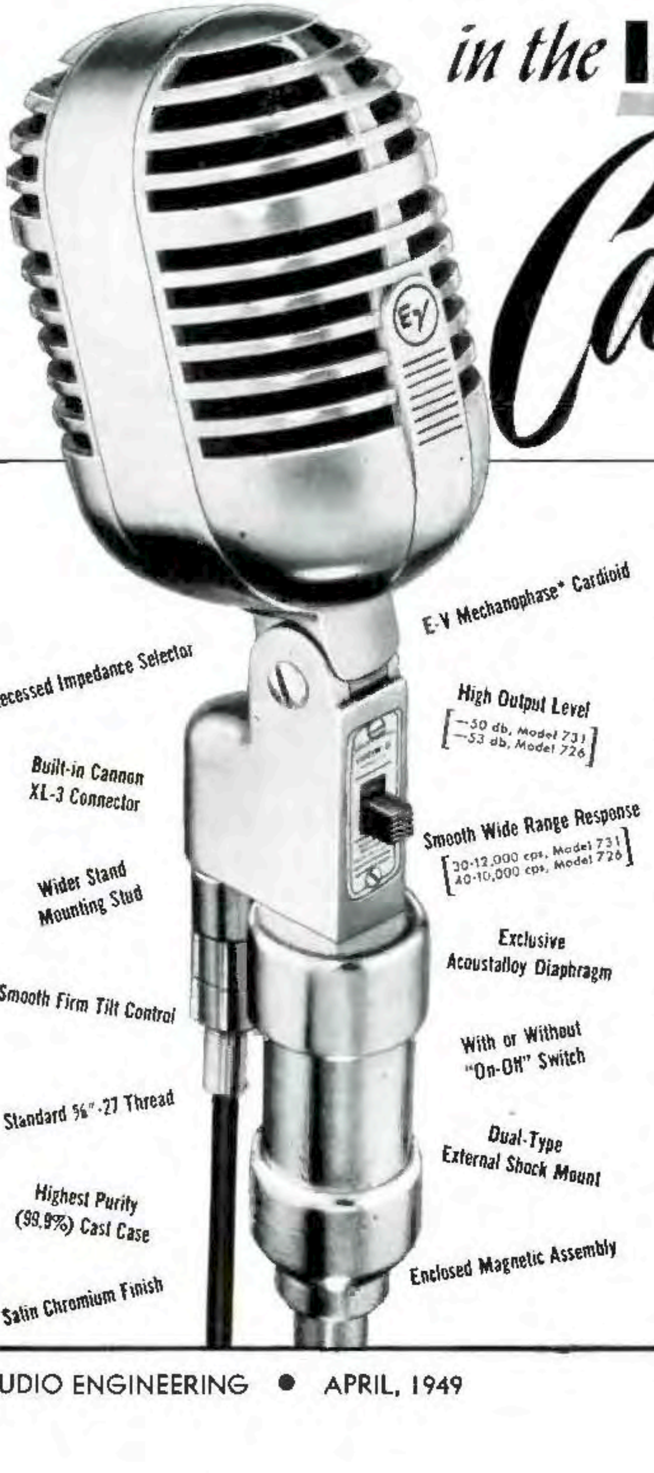

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length at the sides may be slightly less, with the decrease somewhat under the control of the lapidary.

The following formula is too obvious to require derivation:

$$\frac{\text{Burnish length}}{\text{Groove wavelength}} = \frac{f\,l}{\pi D n}$$

where f = frequency in cps
l = burnish length, inches
D = recording diameter, inches
n = speed in rps

A glance will show that the fraction increases with frequency and burnish length, and decreases with an increase of speed or diameter. From this formula the graphs of *Fig.* 3 were computed.

A condition typical of standard high-quality 16-inch transcription recording is shown in *Fig.* 3(A). By the use of 136 or 144 pitch, the inner diameter is limited to 8 inches.

At (B) we have a condition occurring in many broadcast stations which have continued to record transcriptions with the pitch of ten years ago. This results in an inner diameter of 7 inches. The injurious effect of a given burnish is measurably greater, as can be seen by looking at the 10 kc response. Incidentally, this is fairly close to the outer recording diameter of a 7-inch microgroove disc.

Conclusions

Finally, we go in to the innermost diameter of a microgroove record—about 5 inches—at (C). A very small burnish is necessary, else the high frequency loss rises rapidly.

Just for comparison, at (D) we have plotted the response of a .4 mil burnish at 5 inches diameter at 33.3 and 45 rpm. The higher speed eases response problems, by 3 db at 10 kc in this case. This saving taken alone would not be significant, but similar savings accrue at other stages in the recording process, making a significant total.

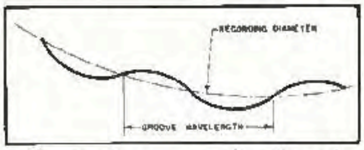


Fig. 4. Groove wavelength and recording diameter.

With current interest in higher fidelity, it is evident that burnish length will have to be limited. The high quality transcription recordist and the microgroove specialist will both have to use care.

Transcription work will have to use a burnish of not over a half mil, approximately. It is not difficult to make such a stylus satisfactorily quiet. A great many 10- and 12-inch microgroove discs are recorded in to only a 7-inch diameter, and a similar stylus will often suffice. On the other hand, the recordist working with 7-inch microgroove discs will be faced with a real problem. Compelled to use a burnish of about a quarter mil, he may have difficulty in getting a quiet groove unless he uses a higher cost stylus. It is a good deal harder to get a quiet groove when using a small burnish, and the lapidary may have to be much more careful than he is with a half-mil burnish.

In spite of all these precautions, not every stylus will have equally good frequency response, and it may be desirable for the recordist working at less than 6-inch diameter to check each stylus individually, using the poorer points for less critical work.

It should also be recognized that small-burnish styli of the best quality are not all equally quiet. Some are satisfactory all the way in to 5 inches, while others start to become noisy at the 6-inch diameter. It is highly desirable to segregate the latter for use at the larger diameters only. Again we may say that each stylus has a personality of its own.

One may object that this is a lot of work. True, unfortunately, for the secret of good recording quality has always been meticulous care, and we see no chance of the future remedying the situation.

Reference

1. C. J. LeBel, Properties of the Dulled Lacquer Cutting Stylus, *J. Acous. Soc. Am.*, Vol. 13, No. 3, pp 265—273, January 1942.

Report on 1948 Convention of Speech Assn. of America

THE problems and limitations of bone conduction audiometry were discussed at the 1948 convention of the American Speech and Hearing Association by the well-known authority on hearing measurement, Dr. Scott Reger of the State University of Iowa. His paper, "Factors Influencing the Accuracy and Interpretation of Bone Conduction Hearing Tests," was presented in Washington, D. C., on Dec. 28th.

He first touched on the inherent inaccuracy of measurement of bone conduction and air conduction hearing thresholds by the use of tuning forks as described by Weber, Rinne, and Schwabach. These methods would be valid only if controlled by elaborate instrumentation. While the modern audiometer is superior to the tuning fork, he criticized the naive assumption that the audiometer is a precision instrument. Measurements made with a perfect audiometer under ideal test conditions are only as accurate as the audiologist's testing skill and knowledge about the limitations of his instrument and testing technique.

It is necessary to hold the audiometer's bone conduction vibrator against the skull with constant pressure, because the pressure governs the mechanical coupling between vibrator and head. Also, with some types of magnetic vibrators, the distance between armature and pole pieces (and hence the output) is affected by pressure. He used a pressure of 1000 grams, controlled by a special headband structure.

To measure the resulting vibrations of the skull, he used a crystal-type contact microphone held against the frontal eminence of the forehead by a heavy rubber band. This made possible a study of the vibration waveform, and of the vibrator linearity.

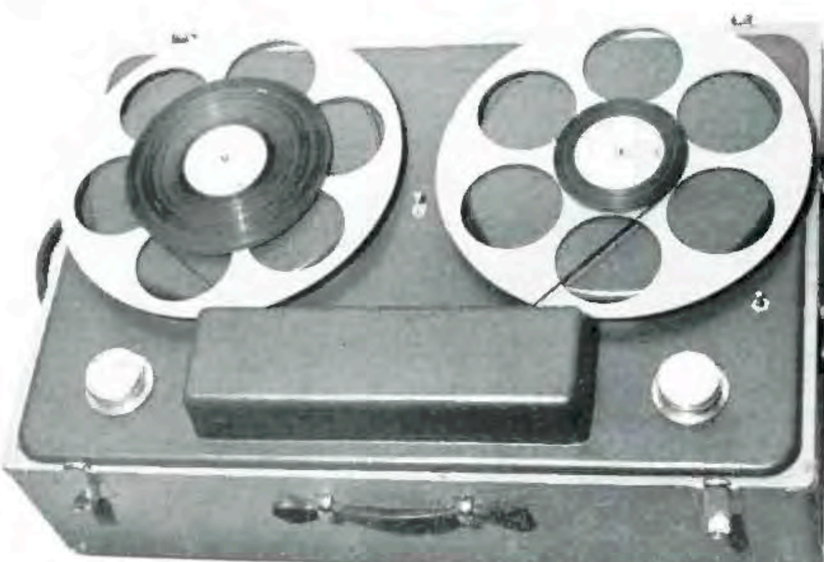
In testing a vibrator it is necessary to determine the difference between the bone conduction threshold of a given unit, and the air conduction threshold produced by the same vibrator due to leakage. The differential should be at least 15 db.

He then discussed the application of bone and air conduction measurements to the localization of ear pathology. This was then used to explain why some untrained individuals have acceptable speech even though hard-of-hearing from childhood, while others do not. Children with middle-ear impairment may hear their own voices very well by bone conduction, even though their air conduction hearing of other people is inadequate. They will tend to have normal speech development, while those with an inner ear lesion, and hence impaired bone conduction, from childhood may be in serious need of speech training. Except in extreme cases, this will be of help.

Recording Equipment

A symposium of interest to recording equipment designers was held on the morning of December 30, presenting the following subjects and speakers.

[*Continued on page 36*]



NEW PRODUCTS

NEW JACK

A new, improved ADC jack for jack panels and numerous similar uses is being produced and distributed by Audio Development Co., 2833 Thirteenth Ave. So., Minneapolis 7, Minn.

The frame of the new ADC jack is made of nickel plated, heavy gauge steel,

and is die-formed and press-welded for utmost rigidity and dimensional accuracy. The brass sleeve is nickel plated. To meet the high corrosion resistance requirements called for, silver alloy contacts and nickel silver springs were specified in the new design.

Dimensions of the new jack are standard, and like earlier types of ADC jacks it is interchangeable with any standard telephone type jack using a ¼" plug.

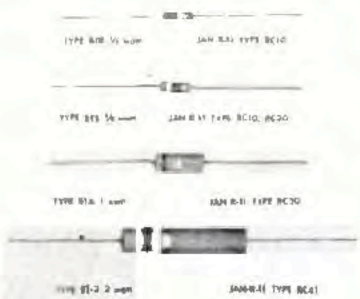
ALL-TRIODE AMPLIFIER

A high-fidelity, medium power, all-triode amplifier is announced by the Browning Laboratories, Inc., of Winchester, Mass. as a companion unit to their recently released RJ-20 high-fidelity FM-AM Tuner. Designated as Model AA-20, the new amplifier features all triode voltage gain and power stages for response within 1 db. from 10 to 17,000 cycles with less than 1½% harmonic distortion at 14 of the rated 15 watts output. Hum level is 65 db below maximum rated output. Extremely high quality pushpull input and output transformers are used and voice coils from 1.2 to 30 ohms can be matched by tap selection. The output stage is pushpull 6B4G's driven by two triode sections of a 6SN7 in cascade with separate bias rectifier. Convenience receptacle provides voltages for operating noise suppressors or preamplifiers for reluctance pickups. Use of the AA-20 is recommended with the Model RJ-20 Tuner for high fidelity installations.

NEW RESISTOR

● A positive advance in the field of electrical resistance has been established by the Engineering and Research Departments of International Resistance Co. After years of wartime and postwar exploration and development, a new insulated fixed composition resistor has been produced that challenges performance standards for that type resistance unit.

This new resistor, designated by IRC as the Advanced Type BT, is being produced in 1/3, 1/2, 1 and 2 watt ratings—equivalent to JAN Types RC10, RC20, RC30 and RC41. It meets joint Army-Navy requirements under JAN-R-11 specifications.



Production experience by IRC on this advanced resistor currently totals over 70 million units.

This family of tiny resistors (type BTR resistor body measures 3/32" x 13/32") is furnished in ± 5%, 10% 20% tolerances in RMA resistance ranges. Temperature coefficient varies from 0.02% per °C. for low ranges to 0.14% per °C. for high ranges. Depending on the size of the resistor, voltage coefficient varies between 0.0% and 0.27% per volt. Noise level is inherently uniform and low. The element, constructed to IRC's filament principle, is housed in phenolic resin; High pressure molding of the housing provides maximum security against humidity damage and moisture penetration, and enables this new resistor to withstand the most severe salt water immersion tests.

For short periods, overloads of 50% to 100% may be applied without damage to the Advanced BT, and 5 second overloads of 2.5 times rated load result in only negligible resistance changes. Frequency characteristics and other performance data are given in Technical Bulletin B-1. Copies may be obtained from International Resistance Co., 401 N. Broad St., Phila. 8, Pa.

EQUALIZER-AMPLIFIER

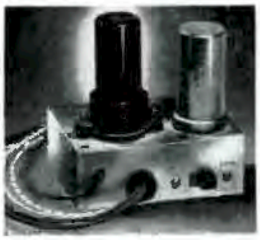
A new Equalizer-Amplifier, the Model EA-3, for use in conjunction with Astatic Corporation's highly touted Magneto-Induction Pickup Cartridge, brings to a total of three such accessory units produced by this pioneer Conneaut, Ohio, sound equipment manufacturer.

Astatic invaded less than a year ago the magnetic type cartridge field, with announcement of its revolutionary Magneto-Induction Pickup, after years of adhering solely to the development and production of crystal devices. Radical reversal of engineering precedent and drastic simplification, embodied in the Magneto-Induction unit, eliminate need for delicate handling and common sources of trouble with magnetic type cartridges, the firm

PROFESSIONAL DIRECTORY

claims. The result is peak fidelity of reproduction that is not diminished by consistent service or adverse climatic conditions.

With the advent of the new long-playing records, the Magneto-Induction Cartridge was one of the first adapted by Astatic to the new requirements. It is



thus available in models for both standard 78 RPM and long-playing microgroove platters.

The Magneto-Induction Pickup has enjoyed steadily mounting acceptance since its introduction. It is felt that availability of a third type of Equalizer-Amplifier, which lends itself most advantageously to many applications, will stimulate still further the rate with which the cartridge itself is being adopted by the trade.

WIDE-RANGE CAPACITANCE TEST BRIDGE

The General Radio Type 1611-A Capacitance Test Bridge measures capacitance over the extremely wide range of 1 $\mu\mu$f to 10,000 μf, a total spread of 10 billion to one. Over this entire range an accuracy of $\pm(1\% + 1\ \mu\mu f)$ is maintained. The dissipation factor range is 0 to 60%. The frequency of the test voltage is 60 cycles.

The bridge is useful for measuring all types of capacitors, and the dielectric constant and dissipation factor of both solid and liquid insulating materials. It is also suitable for the shop testing of bushings and insulators in the electric power industry. Facilities are provided for introducing a polarizing voltage for the measurement of electrolytic capacitors.

A feature of the bridge is a unique zero-compensating circuit that balances out the initial capacitance and dissipation factor at zero setting of the dials.

The bridge is completely self-contained, including visual null detector, and operates from the 60-cycle power line. The case is of the airplane-luggage type, with handle for carrying. Over-all dimensions are 14½ x 16 x 10 inches, and net weight is 30½ pounds.

BROADCAST EQUIPMENT BROCHURE

Three new brochures describing RCA's finest AM broadcast transmitter and new AM-FM and television studio audio equipment are now available to those requesting them on broadcast station letterhead addressed to RCA field offices or to the Broadcast Equipment Section of RCA Victor, Camden, N. J., it has been announced by the RCA Engineering Products Department.

AM BROADCAST TRANSMITTER (Form 2J-4367) fully describes the BTA-50F1, latest model in RCA's series of 50,000-watt AM broadcast transmitters. The new power-saving triodes and other design features which can cut broadcasting costs up to $12,000 a year are presented in detail in the 24-page booklet.

BROADCAST TWO-STUDIO CONSOLETTE (Form 2J-4604) provides detailed information on the broadcast two-studio consolette (Type 76C). This 20-page brochure furnishes complete operating data and specifications, as well as simplified line drawings.

CONSOLETTE SWITCHING SYSTEMS (Form 2J-4622) presents 16 pages of complete information on the latest consolette-type switching systems, Models BCS-1A, -2A, and -3A, for AM-FM and TV networks. Elaborate or simple switching problems for controlling up to 15 studios are outlined in detail in this brochure.

SOS CINEMA CATALOG

A new 64 page catalog covering every phase of motion picture theatre operation has been issued by the S. O. S. Cinema Supply Corp. Over 100 illustrations distributed throughout the book alongside the text make it simple to order the wanted part.

Sections are devoted to equipment for auditorium, booth, drive-in theatres, electrical installations, lobby, boxoffice, photography, portable and home movies, projection lighting, 16 and 35 mm projection, public address systems, theatre sound, stage, studio, recording and laboratory.

This 1949 edition is claimed to be the most complete listing ever issued in the trade and bears out the S. O. S. tradition as the "Department Store for the Motion Picture Industry."

— *News* —

NEW AUDIO CONSULTING FIRM

Audio Research Associates, 608 Fifth Avenue, New York, has recently been organized with J. H. Beaumont as general manager and L. S. Goodfriend as chief engineer. The services furnished by the new firm include anything from changing a tube in an amplifier to the complete design of a theatrically equipped auditorium, including the lighting, sound control, acoustical treatment, and general overall problems.

The staff includes a number of leading specialists in the fields of audio facilities, the theatre, architectural acoustics, recording and reproducing systems, hearing aids, residence radio systems, psycho-acoustics, patents, technical manuals, and psychological problems. Their work includes consulting, design, preparation of specifications, fabrication, installation, and operation.

* * *

ERRATA

George W. Curran, whose excellent article on the "Use of the Transmission Measuring Set" appeared in the February issue, has mentioned a few errors in typography, all on page 28. The first word on the page should be "Choose" instead of "constant." Paragraph *f* in the second column should read "The gain of the X-amplifier at the reference frequency will then be equal to the amount it was necessary to change the GS loss in (e)." The second paragraph in the third column should read, "The auxiliary amplifier will not be needed if the AF oscillator can deliver a level at the output of the branch pad equal to the rated output of the X-amplifier."

RECORD REVUE

(from page 22)

music is concerned. And I repeat, your musician is on absolutely solid ground when he objects. After all, are you designing an electronic instrument or a musical one?) Some too-pure wave form is generated that, though perhaps highly impure technically, measured for distortion, is nevertheless too *simple*, too fixed in its pattern for the musical ear to take as the basis for musical performance.

The type of electric organ in which sliders are pulled out to add each of the overtones of a "pure" fundamental is to some extent a victim of this too-simple pattern. The fundamentals generated by this machine are incredibly dead to any musical ear, even if something less than pure by distortion measurement. Even with a maximum of tone coloration added, via the sliders, the compound tone generated is still, to most musicians, relatively dead and unmusical. That is a widespread opinion. Hence, for the purposes of my February argument on tone color vs. harmony and counterpoint, we may consider the basic tone of this type of instrument as pure—far too pure.

* * * *

All of which leads to brief mention of an electronic keyboard instrument now under development by a well-known sound engineer who shall be nameless, which I played at length last week. Good. Remarkably alive, though it is designed for the simplest uses at a low (home instrument) price. The answer to this good musical quality would seem to be (*a*) specifically, tone color directly generated along with the fundamental, as harmonic "distortion" (or so I understand it); (*b*) more generally, a rather nice appreciation of the importance of all these semi-psychological laws for musical-sounding tone, plus a common-sense, ingenious application of them within the limited means available.

Vital items were, for instance, to my ear, the excellently contrived initial *ictus*, the "speaking" of the sound; similarly, the well-calculated decay rate when the key is lifted. Neither is *consciously* noticeable, nor should be; the net effect, though, is a sense of rightness, of appropriately musical sound. A fairly simple matter of electronic principle—except for the decision as to values; and that is where it takes what this designing outfit seems to have, a sense for music and the ability to interpret that sense directly into *mfds*. Another item I found pleasing musically was the longer time required for the keys to "speak" in the low registers, as compared to the upper, an excellent and thoroughly musical idea. The lowest tones were so realistically delayed and came in with such a fine "blat" that one would swear a heavy reed was speaking. That's the kind of thing a musician can understand.

Musical Tone — Dead or Alive

Between the misprint and the correction in a monthly magazine there's a long wait—here's a bit of verbal untangling that goes back to the February issue. What came out takes the prize for insanity among our supposedly sane contributors. Naturally all our readers keep back issues of AUDIO ENGINEERING. Kindly turn to p. 30 of the February issue and look at paragraph two. Note that the second line ("*that changes inde cribably. . .*") also appears farther on. 21 lines up from the bottom, where it belongs. The proper line was omitted, this one installed in its place, making for a fine Department of Utter Confusion![2] Correct reading:

"*This peculiar relationship between tone-color and harmony-melody is one of the fascinations of sound as we hear it, ...*" etc. It was a humorous accident that this very sentence concluded with the remark that it was this kind of thing that left engineers gasping like fish out of water. Some of you must have gasped several times.

RECORD REVUE

Beethoven, *Trio in D*, opus 70 ("Ghost" Trio).

Busch-Serkin Trio.

Columbia MM 804 (3)

Beethoven, Violin Sonata #5 ("Spring" Sonata) opus 24.

Jascha Heifetz, Emanuel Bay.

RCA Victor DM 1283 (2)

An interesting technical example of the difference between good recording and good microphoning—this has the former but is lacking in the latter. The usual excellent tonal range applies here, with what at first might seem to be an unusually strong pre-emphasis of the high end, that is more likely (as one begins to discover in this field) a purely acoustical difference that brings the highs more strongly than usual to the mike. (But note well that whether it is actually pre-emphasis or merely a matter of acoustics, the net result is the same in the listening; with this record you will find it desirable to roll off the highs and you can ascribe your own best guess as to the reason, if you don't subscribe to mine!) On the other hand the microphone-acoustic factor is not up to par here, in common with a number of Columbia chamber recordings, probably all made at about the same period and being issued irregularly. The general effect is too dead, even for a group of only three instruments. But more unpleasant is the seeming closeness of the two stringed instruments, violin and cello, which have an overly sharp and dry sound; the piano, on the other hand, is relatively off-mike, with a good sound on its own but one that doesn't mix well with the close sharpness of the strings. In some situations this perspective effect might be very useful; unfortunately the piano is notoriously hard to blend with strings at best and this only makes the musical split here a bit wider. . . However, this is still a good enough job for any listening—I'm splitting hairs for the technical-minded. Musically, Rudolph Serkin does some extraordinarily powerful piano playing, as always, and carries this performance along towards being one of the best Beethoven items for a good while.

The "Spring" Sonata, a similar musical combination, is somewhat the reverse. Though it has good tonal range, I suspect that the above Columbias have a bit more. On the other hand, RCA's acoustics and mike pickup are brilliant, both technically and with a brilliant sound. There is a trace too much violin here and there (Heifetz being the big name) but mostly the volume balance is excellent. The perspective balance is even better and considerably superior to that of the Columbia recording—here the violin and piano blend, in the general acoustical brilliance, as well as they ever can in real life. This album is a continuation of an earlier Heifetz-Bay sonata album, DM 1254.

Mozart, Piano Sonata in F, K. 332.

Vladimir Horowitz

RCA Victor DM 1284 (2)

Kabalevsky, Piano Sonata #3.

Vladimir Horowitz

RCA Victor DM 1283 (2)

Debussy, Serenade for the Doll; Poulenc, Presto; Prokofieff, Toccata, op. 10.

Vladimir Horowitz

RCA Victor 12-0428 (1)

Highly diverse samples—they couldn't be more different—of Horowitz' astonishing facility at the piano. These are, together with numerous other Horowitz recordings, the finest piano offerings Victor has made to date, and you couldn't do better than to sample this wide range of music, all canned under similar conditions, to see what Victor has to offer in the way of piano recording technique. Always a big, concert hall sound, very live, with plenty of brilliance in the piano tone. But these are the records we will most look forward to hearing on the new 45 plastic, since hiss and scratch interfere prominently in all of the softer passages. (Victor allows them to fall to very low levels.)

The Mozart sonata is a model of good playing, making what is usually played as a finger exercise into the real music that it ought to be. Kabalevsky's sonata is a harsh and, I find, rather crude bit of semi-modernism; Horowitz plays it just as harshly as he plays the Mozart with delicacy. The Prokofieff Toccata is harsh but less so and with more good sense to it, a very strong rhythm, fiery, breathtaking performance. The Debussy is lightly humorous, misty, scratchy (i.e., the shellac is

2 (Ed. note: This is what sometimes happens when a compositor reassembles type after making a correction. The editors don't get a chance to check it again.)

scratchy); Poulenc's *Presto* is fast, lightweight, over almost before it gets underway.

Britten, The Rape of Lucretia. (Slightly abridged)
Peter Pears, Joan Cross, N. Lumsen, etc., Chamber Orch.
RCA Victor DM 1288 (8)

This is the newest opera sensation from this leading British composer, in a performance supervised by Britten himself, an English cast that is ideally suited to this music, so utterly different from "modern" American music. This is a Roman tragedy set in a classic style, severe, simple, with small orchestra, no big noises, beautifully restrained singing: the whole thing builds by understatement and atmosphere that gets over even on non-long-playing records and is, I find, very moving and mightily impressive. Most of the words are intelligible as sung; the notes in the album give the story. The music is not at all dissonant; rather it is modal, the nearest equivalent being perhaps Vaughan-Williams.

A moot point technically: was this originally one of the famous E.M.I. wide range recordings? If so, then once more, as has been noticeable before, the Victor pressings do not show it. The recording is very fine, but the highs are certainly far from exceptional and I'd say they are definitely weak. Again, it may be a matter of acoustics, but I doubt it, in view of similar effects on other Victor-pressed E.M.I. imports. Has anyone directly compared a British pressing with a Victor pressing of a recent, postwar recording? Does Victor perhaps treat the masters to a bit of polishing? If not, then what?

Mozart, Symphony #39 in E flat, K. 543.
Cleveland Orchestra, George Szell.
Haydn, Symphony #88 in G.
Philadelphia Orchestra, Ormandy
Columbia LP: 4109 (1)

Two first rate symphonies in this style, here recorded with excellent acoustics, performance and engineering; both are on the single LP record and (for my taste at least) a good combination. The two are also available in separate standard albums, 3 records to each. There is considerable difference in liveness between the two recordings; the Philadelphia job is big, brilliant, the Cleveland one somewhat less live, with a closer feeling. Impossible to know whether this is purely an engineering difference or whether it is actually a matter of musical interpretation. My guess might be that Szell, in the Mozart, purposely used a somewhat smaller orchestra as is proper, and perhaps even preferred the less live, more intimate pickup, which also is proper for the music.

Chopin, Andante Spianato and Grande Polonaise Brillante, Op. 22
Claudio Arrau, piano; Little Orch. Society, Scherman.
Columbia MX 307 (2)

This early work of Chopin's is somewhat of a freak—the first part, the *Andante Spianato*, is for piano alone, but the second part suddenly sprouts an orchestral accompaniment. Since the two parts are more or less continuous, this poses a nice recording problem, and the results here are unexpectedly happy. Most of Columbia's piano solo recording has been of the close-up, rather dead variety. Here we have a whole piece where the piano is necessarily set up in the midst of an orchestra in a largish hall or studio. I like it, and recommend that Columbia try more of the same. A nice, liquid, unpercussive tone, perfectly suited to Chopin and actually much better than the hard, brassy, triumphant Chopin that Victor's artists often give us. The Orchestra—when it enters—is not of much importance, as always with Chopin, but its background efforts set the piano off well. The *Polonaise* is mostly icing of the most glittering sort, played perfectly and just a bit icily by Arrau.

Auber, Overtures.
Boston "Pop" Orch. Fiedler.
RCA Victor DM 1274 (4)

A fine batch of rip-roaring, sentimental, dignified orchestral overtures in a real old fashioned style. A good album to have around for general test purposes, as well as casual listening. Big, pompous orchestra, nice melodies, climaxes, etc. None of it vitally important as music—but so what!

SPEECH ASSOCIATION

[from page 28]

Recording in the Speech Laboratory, by *Giles Wilkeson Gray*
Recording in the Speech Clinic, by *B. A. Anderson*
Recording in the Speech Classroom, by *Wayne C. Eubank*
An Engineer Looks at the Problems of Speech Recording, by *C. J. LeBel*

Professors Gray, Anderson, and Eubank emphasized the wide use of recording in speech work, and the need for high audio quality. As a teaching device, a recorder is useless unless it can exhibit a speech defect clearly to the student. A machine whose frequency range is inadequate or whose distortion is excessive cannot be used to illustrate poor diction, for example. The problem is accentuated by the fact that the speech sounds are presented alone, not in context. It is therefore highly desirable to have a frequency range of 50 to 10,000 cycles reproduced uniformly. A large proportion of the recording machines presently offered to schools for speech work are unsatisfactory. Professor Eubank noted that while tape reusability made it preferable for much routine work, it was easier, cheaper, and more compact to store material on lacquer discs.

Mr. LeBel pointed out that their complaints pertained to inexpensive home-type machines. The engineer working on inexpensive equipment has never had to achieve faithful reproduction, a moderately pleasing result being his normal goal. It is out of the question to get a 10-kc range for $135 as one of the speakers requested, for whereas a home recorder manufacturer may sell several hundred thousand units per year, a professional design will be fortunate if it sells at the rate of one thousand in the same period. Mr. LeBel showed that while magnetic recording media had the advantage of reusability, magnetic recording equipment had maintenance problems not needed by disc equipment. These problems are head wear, head alignment, and bias variation with time.

In the resulting discussion it developed that while the schools had paid several hundred to several thousand dollars for each disc recording unit, and had no complaint about their performance, they were very unhappy about the sound quality and/or durability of home wire and tape machines. It was pointed out that they were calling for professional quality, and could expect to get it only at professional prices.

Educators may not be able to toss around electroacoustical terms as glibly as the average engineer, but they appear to have better trained ears than the average home recorder designer. It would be profitable for sales departments to drop the idea that any old piece of junk is just the thing to sell to schools. This idea was the vogue in the disc recorder field until the educators learned their lesson. Apparently we are now about midway in a similar cycle in magnetic recorders, and the disillusionment stage has already begun.

N. A. B. CONVENTION

[from page 15]

meetings cover training of personnel, advances in facsimile, and a report on UHF television. An FCC-Industry Roundtable is scheduled for 10:45 a.m., with Royal V. Howard of NAB as moderator.

Two interesting affairs are scheduled simultaneously for Saturday afternoon—a tour of ABC and NBC television stations, and an open meeting of the NAB Recording and Reproducing Standards Committee in which all members and interested parties are invited to participate.

RMA-IRE SPRING MEETING

● Two audio papers are scheduled for the RMA-IRE Spring Meeting, to be held at the Benjamin Franklin Hotel in Philadelphia on April 25, 26, and 27. Both are spotted for the 9:30 a.m. session Wednesday, and are:

- Audio Power Amplifier with Positive and Negative Feedback, John M. Miller, Jr., Bendix Radio.
- Longitudinal Interference in Audio Circuits, H. W. Augustadt, Bell Telephone Laboratories.

These papers should be of especial interest to the broadcast engineer, particularly those who are involved in system design.

EXPERIMENTAL ULTRASONICS

[from page 25]

Stretching The Diaphragm

The diaphragm material can be nickel, monel, German silver and so on. For any reasonable predictability of results, it must be stretched. This proved rather difficult. Welding around the rim did not work out too well, as the joint was required to be waterproof under 100 lb of pressure, and welding often left small gaps. It was finally soldered in a jig that kept the diaphragm under tension during the soldering operation. A jig was

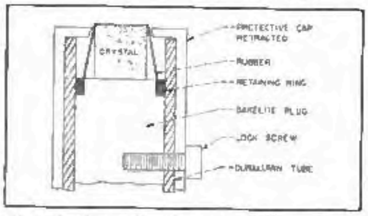


Fig. 3. Details of end of transducer probe suitable for use in air or gases.

constructed that could be placed in a furnace and brought to 400°. After precision tinning both the diaphragm and the shell, as well as the button, the assembly was slowly brought up to heat and a ring of solder flowed around the joint. Slow cooling gave us a stable assembly, and the diaphragm was turned off flush.

A diaphragm thickness between 4 and 6 mils proved practicable. The button thickness did not prove critical in the sense that a thickness of a quarter or half wave showed up in greatly increased output. The thicker the button, the less the output, in general. For stiffening, a thickness of 6 mils proved adequate.

Crystal Mounting

In general, a sliding reaction type mounting was used. If we assume the diaphragm will be bulged inward by external pressure, then we attempt to spring mount the crystal so it can move longitudinally with the slow displacement of the diaphragm. This works out well if good sliding fits are made.

Loading the crystal with a lead block did little good above 50 kc or so, a small mass sliding bakelite plug being sufficient to back the crystal.

Characteristics of Various Crystals as Mounted

In general, the Rochelle bimorph of either bender or twister type, such as are used in phonograph pickups, gives great output in isolated peaked responses, with no uniformity of output at all. Its modes of oscillation above 10 kc are so complicated as to defy analysis. If you just wish to know that some supersonic energy is in the medium, the bimorph will often be a guide with occasional flashes of output up to several megacycles, but for quantitative work it is useless.

Quartz has little response off resonance, especially when we attempt to drive one quartz with another through some medium. So in general, they are useful well above a megacycle, where other devices are unusable, and then we must frequency modulate the transmitter quartz crystal for practical applications. The combination then works rather well. With a swept band of 100 kc or so at 5 mc, and 200 volts input, the receiving unit will pick up about a millivolt of signal. Quartz must also be used when the temperature is much above 250° F.

A word of warning—practically all wartime quartz was shear cut, so do not attempt to use it under penalty of extremely complicated radiation patterns, useless for any practical purpose.

Primary ammonium tartrate crystals (PN) are about the most promising. They can be used at boiling water temperature. They readily come up to an inch in length in pure piston action, cut with a natural period of about 50 kc, are fairly sensitive and have low noise level. They have too low a capacitance to be ideal. A half-inch cube has about 0.8 $\mu\mu f$ capacitance, so they suffer from the shunt capacitance of a long lead or a vacuum tube voltmeter or oscilloscope.

Since they very readily dissolve in water, any mounting must be waterproof. Any handling with the fingers should be avoided, as they are gradually eroded by finger sweat. They are quite soft, about like a cube of sugar in hardness, so they are easily damaged by a blow, or a sharp-pointed instrument.

Another controlling difficulty in making a stable permanent mounting of the PN is the fact that no pressure can be used except on the working faces. These come marked with a little black dot, and the crystal must be wholly supported by simple direct pressure on these faces only. Otherwise its sensitivity and resonant period will be seriously and erratically affected.

The writer has used these mostly in the form of cubes. Samples are furnished to very exact dimensions, and dead square.

When mounted in the shell of *Fig. 1*, they are very stable and uniform. Care must be taken that no sharp blow on the diaphragm crushes the crystal but a reasonable amount of care will prevent this. However, the metallic diaphragm lowers the sensitivity very much when used in air or a gas, so the mounting shown in *Fig. 3* was developed.

This mounting as a probe has several advantages. The stretched rubber of a thickness of about 0.3 thousandths damps the crystal somewhat, but an absolute minimum. It has no characteristics of its own to speak of as a diaphragm. However, it does not do a very good job of protecting the crystal, and when used as a contact microphone considerable care is required not to damage the crystal. When used on the body there is little danger, but when working around metal parts that have sharp edges, great care must be used. The sliding protective metal sleeve should be only retracted when the crystal is actually in use.

When used with a high-intensity source, such as the Hartmann generator, this unit gives out a volt or two to drive an oscilloscope, if within two inches of the generator, and in the maximum field. It will give the same with the parabolic reflector ten feet away, sharply focused on the face of the crystal. However, this is only true with about two leads about two feet long and separated. If a six-foot concentric cable is used the signal drops rapidly for each foot of cable. For serious work a cathode follower stage right at the crystal and impedance matching itno the 52-ohm line is required.

Unit Used as Transmitter

Any PN crystal will take 200 volts of drive. If you wish to operate over a wide band of frequencies this offers some problems.

Suitable oscillators should cover the spectrum from ten to a few hundred kc or higher. The output must, of course, be stepped up in voltage by some means.

One means is a tuned circuit right at the crystal. Due to its very small capacitance, this is rather easy to do. Somewhat more difficult is designing a wide-band transformer to step up the 52-ohm line to match the crystal. Another answer is a driver tube at the crystal, choke-coupled to it.

A warning on using the crystal as a self-frequency determining oscillator. By the time the crystal is loaded with a diaphragm and damped by the mounting, it is seldom possible to have it develop sufficient reactance to act as a normal oscillating crystal. This is especially true if it is immersed in water, where the Q often falls to ten or less. The writer made a determined but unsuccessful effort to lock such a crystal to an unstable oscillator.

Working Units in Pairs

Two similar units work well in either air or water. For a first experiment, have them face to face and join them with a drop of water. The signal transmission will be very good.

If they are used with only air in between, very high values of standing-wave ratios will be noted as they are moved apart. These may be 40 db or so. These are obtained only when they are dead parallel and dead concentric on the same axis.

If used in a test chamber, as shown in photograph, some interesting effects can be observed. If we gradually fill the chamber with water, reflection from the underside of the water will be almost 100% and wave cancellation will occur, and by careful filling drop by drop a range of signals of 60 db or more will be had. This means that a test cell such as this must be a complete housing with no water surface on top. So the filling orifice must be closed by a plug whose inner wall is flush with the inner wall of the tube. With a suitable selective receiver, almost any of these units will pick up the ticking of a watch up to 200 kc or so, even through several hundred feet of wire. Some interesting work might be done on machinery noise, especially high-speed machinery. Most of the analyzing now done acoustically cuts off at rather low frequencies.

It is somewhat of a shock to find that the ordinary telephone receiver, when overloaded by loud speech, gives out detectable energy up to 100 kc at least. We might investigate direct pickup of noise above 20 kc from a phonograph needle tip. The noise spectrum direct from a grinding wheel may tell us how many of the cutting particles are engaging the work, and might be used as a feed control. We know it will be difficult for a reader of AUDIO ENGINEERING to locate a cockroach to chivvy with ultrasonics, but if he is given his dinner on the diaphragm of one of these units the noises are very unusual.

In the next article of this series we will discuss the design of suitable receivers, tuned voltmeters, and the like. It is obvious to select a communications type receiver for frequencies above 550 kc or so, but many of them are too sharply selective for some uses. The range from 10 kc to 550 kc requires very special design indeed.

MEASURING PROCEDURES FOR MAGNETIC RECORDING

[from page 19]

um, the magnetic heads, the bias level, the signal level, the amplifiers, and the speed of the medium. The last four items can be specified within reasonable limits. However, it seems to be impossible at the present time to specify a standard medium, or standard recording and reproducing heads. This being the case, the frequency responses of different media may only be compared directly when these responses are made using the same or exactly equivalent magnetic heads. Needless to say, the testing procedure must follow certain standard specifications. It is the purpose of this section to state and explain these standard specifications.

I. Speed of the Medium

a. *Magnetic Wire.* For magnetic recording wire, the speed of the medium for frequency-response measurements shall be two feet per second ± 2%.

b. *Magnetic Tape.* For magnetic coated recording tape, the speed of the medium for frequency-response measurements shall be 7.5 inches per second ± 2%.

II. Signal Level

The recording signal level shall be set at the *Standard Recording Level.* In a given magnetic recording system, the standard recording level is the value of audio current in the recording head such that the resulting remanent induction in the recording medium produces an open-circuit voltage at the terminals of the reproducing head which is approximately 12 db. lower than the *Saturated Signal Output*, provided that the frequency is the *Frequency of Maximum Response* and that the bias is set at the value of *Operating Bias Current*.

Saturated Signal Output

The saturated signal output is the maximum voltage which appears at the terminal of the reproducing head when the field intensity in the gap of the recording head is of such magnitude that a further increase does not result in an increased reproduced signal measured at the frequency of maximum response and at the operating bias current.

Peak Recording Level

The peak recording level shall be that value of input which results in 10% total harmonic distortion at 400 cycles, as determined in accordance with distortion measurement procedure.

Operating Recording Level

The operating recording level shall be such that modulation peaks do not exceed the peak recording level.

Frequency of Maximum Response

The frequency of maximum response is that frequency of recorded magnetic signal which produces a maximum open-circuit output voltage at the terminals of the reproducing head when a constant-current recording signal at the standard recording level is used in the recording head.

III. Operating Bias Current

The operating bias current shall be that value which results in maximum output at a frequency of 200 cycles at the standard recording level. The exact value shall be the algebraic mean of a higher and lower biasing current which results in a 1 db. decrease from the output of maximum response.

IV. Amplifiers

a. *Recording Amplifier*. The recording amplifier shall be designed and connected to the recording head in such a manner that the signal current in the head for constant voltage supplied to the amplifier input does not vary more than ± 1 db. over any specified useful bandwidth of the recording system.

b. *Playback or Reproducing Amplifier*. The frequency response of the playback amplifier shall be flat in terms of voltage output within ± 1 db. over any specified useful bandwidth of the recording system.

It should be pointed out that when high-impedance magnetic heads are used, resonant effects may give an erroneous impression as to the unequalized frequency response of a magnetic recording system. In the recording head, the resonant effect may result in a gap field strength which is considerably higher at the resonant frequency than at other frequencies. In the playback head, the resonant effect may account for as much as 6 or 8 db. higher response at the resonant frequency. This may be a desirable method of obtaining post-emphasis characteristics of a magnetic recording system but does not tend to improve the signal-to-noise ratio of the system.

In making frequency-response measurements of the medium, it is therefore recommended that

(a) Signal level be that specified as Standard Recording Level;
(b) Bias be that specified as Operating Bias Current;
(c) Amplifiers meet the requirements as specified in Section IV;
(d) Measurements should extend either side of the frequency of maximum response until noise becomes the

limiting factor or the output is 20 db below that obtained at the frequency of maximum response.

In making overall frequency-response measurements of a magnetic recording system, the same conditions as above shall apply, except the amplifiers shall be those used in the system.

2. DISTORTION

In measuring the distortion of a magnetic system, or any system where a moving medium is involved, certain precautions must be observed in order to obtain a true distortion evaluation. Variations in speed of the medium may cause frequency and phase shifts which exceed the limitations of the measuring equipment. This is especially true if the equipment is of the type where the fundamental is filtered out by means of a sharply tuned filter and the residue measured, or where the individual harmonics are selected and transmitted through a band-pass filter of only a few cycles in width. It is believed that the band pass of the filter should be broad enough to permit frequency changes of the order of at least plus and minus 5 percent. If harmonic distortion measurements at only one frequency are contemplated, it is suggested that 400 cycles be chosen as the frequency, since distortion measuring equipment which fulfills the requirements stated above exists.

Harmonics above the fifth may not be too significant, and if such is the case, the playback system need only be compensated so that the overall response is flat within one db from at least 400 to 2000 cycles. When making distortion measurements, the recording current should be held constant as recommended for frequency-response measurements. In order to minimize the high-frequency noise, so that is is not an appreciable part of the distortion reading, it may be desirable to permit the high-frequency end to roll off above 2000 cycles.

Obviously distortion measurements may be made at any recording level, and many measurements should be made at different recording levels and with various amounts of biasing current in studying the characteristics of the system. Such a study permits a more accurate determination of the normal recording level and operating bias.

The recording level is usually not too important from the viewpoint of the audio power, as the actual power required is very low and more power, if needed, can easily be obtained. Output voltage from the magnetic head, on the other hand, is low and requires considerable amplification, so that it may be of greater significance when comparing media. It is, therefore, suggested that when making distortion measurements both input and output levels be given.

It is therefore recommended that total harmonic distortion measurements be made

(a) At 400 cycles (measurements at other frequencies may be made and so indicated, but figures of the 400-cycle distortion values should always be included);
(b) With a system which is flat within one db from 400 to at least 2000 cycles;
(c) Using the value of biasing current as defined by Operating Bias Current;
(d) With inputs 6 and 12 db below the peak recording level.

3. NOISE

a. *System*

In order to specify noise in a manner that shows the capability of the equipment, two measurements are recommended: First, a "high-frequency" measurement which excludes hum and other low-frequency noises and evaluates the effectiveness of the Erase, the result of the addition of Bias (used during recording), and the high-frequency noise present in the system; the second method includes the entire frequency spectrum covered by the system and is therefore an "over-all" measurement.

For the high-frequency measurement, a 250-cycle high-pass filter should be used to minimize hum and other low-frequency noises. The equipment noise, with the medium not running, should be at least 10 db below the value measured with the medium moving, in order to obtain reasonable accuracy of system noise measurements. If this is not the case, both measurements, "equipment" and "system high frequency," should be stated.

Since the measurement is usually one of comparison, it is recommended that the comparison be with the reproduced output obtained with the peak recording level as defined previously, and the noise be stated as so many db below this value. The frequency range covered by the system is significant in noise measurements, and it is recommended that the playback system be at least equalized flat within one db between 200 and 2000 cycles. The specified range should be expressed as extending to the frequency at which the output drops 15 db below the flat response portion. For high-frequency noise measurements, the 250-cycle high-pass filter will, of course, determine the low-frequency cutoff, and the range would be specified as being from 250 cycles to some frequency where the output is 15 db below the flat response portion.

For an over-all noise measurement of the system which includes low-frequency noise, such as hum, the 250-cycle high-pass filter should be removed and the noise measured as before. The frequency range should be stated as extending from some low frequency, which is 15 db below the flat response level, to a high frequency, which is also 15 db down.

It should be noted that noise measurements require about the same equalization as distortion measurements, and it may, therefore, be possible to use the same equipment by including a 250-cycle high-pass filter, since the distortion meter of the type available is also designed for noise measurements.

In making both the overall and high-frequency noise measurements, the medium should be erased and bias applied as normally done in recording, but without signal.

It is therefore recommended that when making noise measurements pertaining to the system

(a) The medium should be erased and bias applied as is normally done in recording.
(b) The playback system be compensated flat within one db from 200 to at least 2000 cycles.
(c) The reference signal be 400 cycles recorded at the peak recording level and the noise expressed in db below this level.
(d) A high-pass filter cutting off frequencies below 250 cycles be used.
(e) The frequency range be stated as from 250 cycles to the frequency at which the response is down 15 db from the flat response portion.

Note: If the equipment noise (medium not moving) is not 10 db or more below the system noise, both values should be stated. When making noise measurements of the overall system, which would include "hum," the procedure outlined for system noise should be followed, except that

(a) The 250-cycle high-pass filter not be used.

(b) The frequency range be stated as extending from the low frequency which is 15 db below the flat response level to the high frequency which is also 15 db below.

b. *Medium*

Where a noise measurement which properly evaluates the capabilities of a medium is wanted, great care must be taken in erasing the medium prior to the noise measurements. It has been found that asymmetry of wave shape of erase and bias of the high-frequency supplier affects the resulting noise. Therefore, to avoid possible errors due to such an effect, it is recommended complete erasure be obtained by the use of a strong low-frequency (60-cycle) magnetic field (solenoid coil structure), having gradual decreasing strength where the medium leaves the field. Neither high-frequency erase or biasing fields should be applied after the low-frequency erase, and every effort should be made to completely demagnetize the reproducing head or any other magnetic material which may be in contact (or sufficiently close to cause magnetization of the medium), before measurement. The reference signal of 400 cycles should be recorded on a separate section of the medium or the reference level established immediately prior to the low-frequency erase. Since equipment hum should not be chargeable to medium noise, a 250-cycle high-pass filter should be used during measurements.

It is therefore recommended that when making noise measurements pertaining to the medium

(a) The playback system be compensated flat within one db from 200 to at least 2000 cycles.

(b) The reference signal of 400 cycles be recorded at the peak recording level and the noise expressed in db below this value.

(c) A high-pass filter cutting off frequencies below 250 cycles be used.

(d) The medium be erased completely, using a strong low-frequency field if necessary.

(e) The frequency range be stated as from the cutoff of the filter, 250 cycles, to the frequency at which the response is down 15 db from the flat response portion.

Note: If the equipment noise (medium not moving) is not 10 db or more below the system noise (medium moving), high values of noise should be given.

Submitted by:
Dr. S. J. Begun, Chairman
Mr. L. C. Holmes
Mr. H. E. Roys

DISC RECORDING

[*from page 13*]

ful copy. Also, when making recordings purposely for dubbing, lower levels are used in order to take advantage of the reduced cutter distortion, and care is taken to work at the outside radii as much as possible. By careful attention to response and distortion, it has proven possible to rerecord speech program as many as five times with very little deterioration of quality. The accuracy of the complementary NAB pre-emphasis and deemphasis networks allows the faithful preservation of the original response of any phonograph record or transcription recorded at outside sources. Good advantage is taken of this factor when dubbing flip sides of phongraph albums used in daily symphony programs. To keep the radius losses at 78 rpm from doubling during this procedure, additional equalization is available during the last minute of travel by moving the radius-equalizer control switch from "off" to "low-fixed." By addition of the "off," "low-fixed" and "high-fixed" positions to the three basic curves, nine curves are available.

Although such a system of equalization is not applicable to all conditions of recording, it has proven remarkably practical for speech, for all network recording, and for most music. The tracing distortion generated by this system does not become severe until the last equalization step is reached, and even that is tolerable when played with a good magnetic pickup capable of rejection o fall vertical components. The segues and overlaps of the sections of a half-hour show are unnoticeable even on better-than-average home radios.

Photographs by Rueben Lawson, Jr.

— Letters —

[*from page 6*]

as a reader of at least 13 radio magazines every month, I can testify that he is the first to do it.

The Columbia-Victor controversy is so confused and befuddled by corporate names, reputations, advertising, and quasi-engineering considerations that just about everyone in the technical world has got to the point of holding his head in his hands trying to stave off apoplexy. Magazines and newspapers have skirted the subject, adding to the confusion by playing up the befuddlement of all concerned. Canby's comments are the first honest, objective, intelligent ones to appear.

The comments are objective because —paradoxically—they are subjective. Everyone has so far forgotten that the only purpose of any record is to enable someone to listen to music! And music is designed for and produces purely *subjective* reactions. The only objective view that can be valid must be based on a subjective reaction.

The tremendous, unbelievable, vital fact about LP's is that you can actually forget you are listening to a record! For someone who has been a record addict for years, elimination of the high-pitched surface hiss, the mental picture of the needle traversing a fast-moving disc, and all the other nerve-shattering disadvantages Mr. Canby mentions is like finding a diamond on the street. You can listen to the music—and not worry. I have bought about 15 LP's since September and will never buy another 78. I have even duplicated some of the music I already had on 78's and the difference makes the LP music sound and feel like a new, unfamiliar composition.

No matter how good Victor's disc sounds (and they do sound good—I've tried them) no one can convince me that Beethoven scored a pause in the orchestration every 4½ minutes. As long as the pause is there, it isn't Beethoven—it's a "canned" imitation.

I regret to say that I don't like the new cover design as well as the old. The magazine, however, is definitely keeping up its standard.

Richard H. Dorf
255 W. 48th St.,
New York City

PRODUCTION TAPE RECORDING

[*from page 21*]

Details concerning the manufacture of additional such machines have not been completed.

With the new machine, tape can be recorded with a single magnetic pattern in the center, or with a double pattern of two magnetic paths side-by-side on the tape.

One path plays as the reel unwinds forward, the other path functioning when the tape reverses, which is accomplished automatically in a fraction of a second. The double pattern affords twice the playing time with the same amount of tape.

The new multiple recording machine is designed so that it can record either the single or double pattern type of tape. It can record both paths on the double pattern tape simultaneously. In addition, it can be adjusted by switch control for recording different length reels, and for different speeds.

Reels having 600 feet of tape, double pattern, and a playing speed of 3¾ inches per second can be turned out at the rate of 48 per hour, each reel having a full hour's playing time.

Reels with 1,200 feet of tape, double pattern, and a playing speed of 7½ inches per second can be turned out at the rate of 32 per hour, each reel having one hour of transcribed material.

In addition, 1,200-foot tape reels designed for playing speeds of 15 and 30 inches per second can be produced, it was announced. Master transcriptions from which the tape records are made, can be played at varying speeds, to fit the requirements of the job.

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