Tape Recorders, Tape, and Equipment

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A brief discussion of magnetic tape recorders and the principles under which they operate, together with a description of some of the features of currently available machines and the tape and accessory equipment that is used with them.

MAGNETIC TAPE RECORDING is relatively new on the audio scene, having been introduced in the United States for general use only nine years ago. And while the first machines were fabulously expensive professional machines, models are now available for less than a hundred dollars. Their many advantages have brought the fun of recording right into the home, in addition to making it possible to produce phonograph records more economically and better than ever before. Beyond the audio field, tape is performing yeoman service in computing machines, and we may soon expect to see television pictures that are the result of a stored electrical signal—a method that will displace photography in the TV station to a large extent. Our interest in the tape recorder is limited strictly to its applications in audio, but even those are myriad.

To the non-professional, tape recording offers many advantages—to the professional it undoubtedly offers many more. But while the engineer can become proficient in recording on acetate discs, it is not a process that lends itself to the inexperienced user with any degree of success. On the other hand, even a child can learn to operate the modern tape recorder with consistently satisfactory results which, while undoubtedly not saleable material for wide distribution as LP records, will gladden the hearts and ears of his parents. In addition to the ease with which good results can be obtained, there is practically no cost involved, since the tape can be used over and over again until it wears out physically. Yet when some important material is recorded, it may be stored and played back at will years later, if desired.

The machines themselves are no longer prohibitively expensive, being in the general vicinity of a good television set. Yet the average medium-priced tape recorder will produce tapes which are far superior to many phonograph records of, say, fifteen years ago, with respect to frequency response, distortion, and noise. Since there is no mechanical contact in the playback process as there is with the disc record, noise is largely dependent on the design of the amplifier and the quality of the tape. Furthermore, tape is the most easily adapted medium for stereo recording, since the two tracks that are required are always maintained in the same physical relation—a necessity for satisfactory stereo performance.

Tape Recorder Requirements

For satisfactory performance, a tape recorder should have a minimum of wow and flutter, with the percentage figure being less than 0.5 per cent—a value that is about the maximum listed in the specifications for any machine. For professional use, the figure should be 0.25 per cent or lower. Frequency response should be as wide as the state of the art permits, which means that a range of 50 to 15,000 should be possible at a speed of 7½ inches per second. Distortion should be as low as practicable. Hum and noise should be at least 40 db below the tape overload point, which is usually stated as the point at which distortion is 3 per cent. Because of the proximity of transformers and a.c. motors to the playback head, which by its very nature is sensitive to changes in magnetic fields, hum is likely to become a problem with the lower-priced recorders. Absolute speed should be constant, and should be less than 0.5 per cent off from the correct value.

How It Works

For a short but effective description of the principles of tape recording, we can think of no better condensation than that which appears in the maintenance manual for the Ampex 600 and 612—the former a small portable recorder which is rapidly gaining favor as a high-quality home machine, although it differs from most in many features. We are indebted to Ampex for permission to reproduce the following material which follows.

THE TOOLS OF TAPE RECORDING

At right, from top to bottom: A Presto R-11 recorder, suitable for professional use, but equally satisfactory for the hobbyist whose budget will permit; a more conventional "home" model, the Bell RT-88; Audiotape in 2500-foot rolls suitable for use on the machines which will handle the large reels, but for the smaller models, smaller reels are readily available; an inexpensive splicer, the "Gibson Girl" which makes editing easier; "Scotch" brand leaders provide means for identifying reels of recorded tape; to erase a whole reel at one time, one can use a bulk eraser, such as this one from Amplifier Corporation of America; and finally, tape reels can be stored safely in 8-mm film cans, kept in order in Brumberger storage chests.

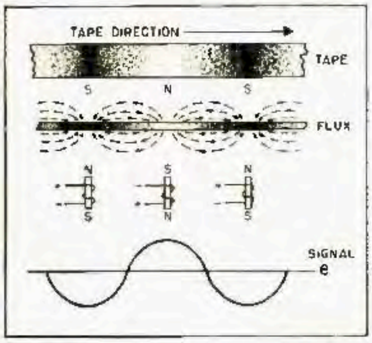

Fig. 1. Tape magnetization.

Principles of Magnetic Recording

If a material capable of being magnetized is placed in the proximity of a magnetic field, the molecules of the material will be oriented according to the direction of the field. Any of several methods may be used to produce the magnetic field, but of most interest in magnetic recording is the field produced by a current flowing through a coil of wire. The current itself may be derived from a transducer. Such a transducer is a microphone which converts the mechanical energy of sound to electric current.

Magnetic recording tape consists of finely divided iron-oxide particles deposited upon a plastic backing. During the recording process, this tape is moved through a magnetic field in which the magnetizing force is alternating and the iron oxide particles are aligned according to the instantaneous direction and magnitude of the field. (See *Fig.* 1.)

The magnetic field is produced in the gap of a recording head, over which the recording tape passes. The recording head is essentially an electromagnet. It consists of an incomplete ring of highly permeable material inserted in a coil of wire. The discontinuity in the ring forms the gap and the ring itself is the core of the electromagnet.[1] The recording head and its gap thus constitute a series magnetic circuit.

Consider the equation $H = B\ \mu$, where H is the magnetizing force (proportional to the current through the coil), B is the magnetic flux density (or flux per unit cross sectional area), and μ is the permeability of the material. In a series magnetic circuit the flux is the same in all parts of the circuit, just as the current is the same in all parts of a series electrical circuit. When the cross sectional area is constant throughout the circuit, B is also constant throughout the circuit. Then it can seen from the above equation that in the case of a core material such as iron with a μ of 50,000 and an air gap with a μ of 1, the magnetizing force across the gap will be 50,000 times that in the iron core.

The magnetization curve of the iron oxide used as the recording medium is similar to that shown as the heavy line in *Fig.* 3. At points near the origin, the curve is extremely non-linear and the signal recorded on the tape would not be directly proportional to the signal applied to the head. This would result in a high degree of distortion upon reproduction. This distortion is greatly reduced by the application of a high-frequency

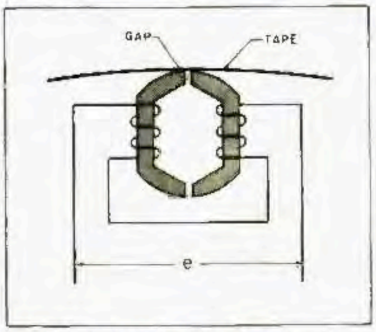

Fig. 2. Recording head diagram.

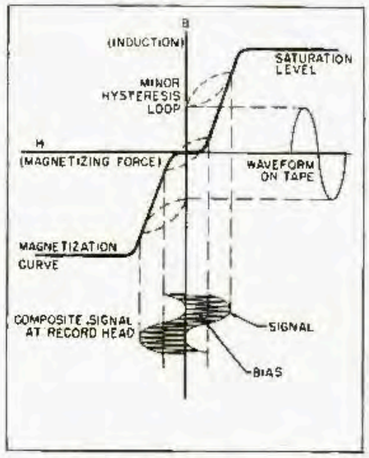

Fig. 3. Recording medium magnetization curve.

constant-amplitude bias signal which is mixed with the signal being recorded. The bias frequency is generally selected to equal five times the upper frequency limit of the recorder to prevent beating between the bias frequency and harmonics of the recorded signal.

While the tape is in the recording gap, the bias causes the magnetization characteristics of the iron oxide to follow the dashed-line loops in *Fig.* 3, known as the *minor hysteresis loops*. As the tape leaves the gap, the influence of the magnetic field created by the bias is reduced to zero and the tape assumes a permanent state of magnetization, known as *remanent induction*, determined by the gap flux at the time the tape leaves the gap and represented by points on the B axis.

After the recording process, there exists on the tape a flux pattern which is proportional in magnitude and direction to the signal recorded on it. If the tape is then moved past the gap of a reproduce (playback) head which is similar in construction to the record head, the magnetic flux of the moving tape will induce a voltage in the coil of the reproduce head. This induced voltage is proportional to the number of turns of wire on the head and the rate of change of flux. This is expressed by the equation $E = N(d\phi/dt)$ where E is the induced voltage (in electromagnetic units), N is the number of turns of wire, and $d\phi/dt$ is the time rate of change of flux.

It is desirable that the gap in the reproduce head be as small as possible so that the gap will intercept less than one wave length of the signal on the tape at the highest frequency to be reproduced. However, as the gap is made smaller, the induced voltage decreases, so there is a practical limit to how small the gap may be made and still maintain an adequate signal-to-noise ratio.

The voltage induced across the reproduce head during playback is computed by the equation $E = B_m\, v \sin \pi w/\lambda$, where E is the induced voltage, B_m is the maximum flux density of the recording material, v is the velocity of the tape across the gap, w is the gap width, and λ is the wavelength of the signal on the tape. From this expression it can be seen that the voltage across the coil increases directly as the velocity increases and as the wavelength decreases (frequency increases). If the tape velocity and gap width are assumed to be constant, the output voltage from the head is directly proportional to the frequency as long as the wavelength on the tape is large compared to the gap width. This results in an output *vs.* frequency characteristic such as shown in curve A of *Fig.* 4. The voltage does not continue to rise indefin-

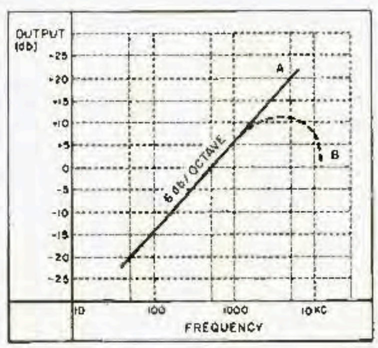

Fig. 4. Playback head characteristics.

[1] Figure 2 shows a typical recording or playback head. Instead of a single gap, however, practically all heads are constructed with two gaps, as shown, to simplify manufacture.

itely, however. As electrical losses in the core material increase and as the wavelength on the tape approaches the same dimensions as the reproduce head gap, the actual output resembles curve B.

In order to provide an over-all frequency response that is flat (see *Fig.* 5), an equalization circuit consisting of a series resistance and capacitance is inserted in one of the early stages of the playback amplifier. This equalizer has a high-frequency droop characteristic (curve B, *Fig.* 5) which is the inverse of the reproduce head characteristic curve (curve A). In order to extend the high-frequency response, additional equalization is included in the record amplifier in the form of a high-frequency boost circuit designed to compensate for the droop in record and playback head characteristics caused by core losses.

Stereophonic Sound

Every person with normal hearing has the faculty for estimating with considerable accuracy the direction from which a sound comes. The sound waves which strike our ears differ slightly in intensity and phase and, from the time we are first capable of understanding direction, these differences are associated with the location of the source. The intensity of a sound is a measure of its energy and, since this energy is dissipated in traveling through a medium, the intensity will lessen as the distance between the sound source and the observer increases. Moreover, since sound is a cyclic variation of air pressure which repeats itself after traveling a distance of one wave length, any two points which differ in distance from the source by any length except an exact integral factor of one wave length will receive the sound at different points in its cycle. This time delay introduces a difference known as *phase difference* and serves along with relative intensity to fix the source of a sound in the listener's mind.

This sense of audio perspective may be represented graphically by *Fig.* 6. Here the sound waves radiate outward from a point source of origin toward an observer. Each individual wave will strike the observer's left ear after traveling a distance of d_1 and after completing three cycles. The same wave will strike the observer's right ear after traveling a distance of d_2 and after completing three and a half cycles. Therefore, for this particular wave, not only will the intensity of the sound be lower at the right ear than at the left, but there will be a difference of half a wave length (or 180 deg.) in phase. Thus each ear hears the same sound in a different manner and years of past experience have conditioned the observer's brain to interpret this difference in terms of direction. This faculty is known as the *binaural* sense.

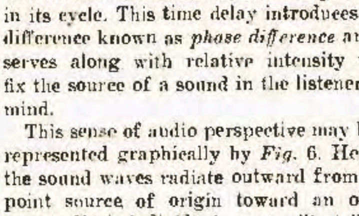

Fig. 5. Flattening effect of playback amplifier.

Consider now the case of a point source of sound recorded in the conventional manner using one microphone. Here the sound waves impinge on the diaphragm of the instrument and generate an electric current which varies in the same manner as the sound waves. In this case, however, the microphone will pick up only a sound with a given intensity which is a function of the original intensity of the source and its distance from the microphone. The microphone is "hearing" with one ear and since "difference" is meaningful only in comparing one quantity with another, both intensity difference and phase difference, the two factors which account for direction, do not exist. Even when the source is not a point source but a combination of a number of sources spread out in various directions in front of the recording microphone, the various intensities and phase angles of all the sounds are still being picked up by only one instrument. Since this instrument is completely lacking in any binaural sense, the intensity of each individual sound is merely recorded in inverse proportion to its distance from the microphone and phase differences for each individual sound completely disappear. The effect of the single point source described above is compounded but unimproved. In either case, when reproduced through a loudspeaker, the system can convey only what the microphone has "heard". The binaural sense of the listener comes into play only when he listens to the output of the speaker and then it only serves to locate for him the position of the speaker.

Fig. 6. Intensity difference and phase difference.

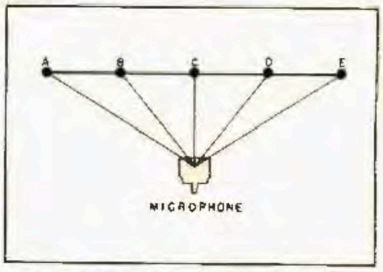

Fig. 7. Moving sound source recorded with one microphone.

Now let us take the case of a moving source of sound recorded conventionally. *Figure* 7 represents graphically the relative intensities of a point source of sound moving from left to right in front of a recording microphone. As the distance between source and microphone decreases, the intensity at the microphone increases. Thus, at point A, the sound has a certain level of intensity. At B the intensity is greater, and at C the intensity is greatest. At D the intensity has decreased to the same level as at B and at E it has decreased to the same level as at A. The microphone has picked up a sound which has risen from a certain level to a maximum level and then descended to its original level. But, from the point of view of a person listening to the reproduced recording, has the sound source crossed the microphone from left to right or from right to left? Or has it approached from a head-on direction, stopped, and then receded along the same line? In each of these cases, the microphone would pick up the same sequence of relative sound intensities. As far as the microphone is concerned, the lateral component of direction is missing. We know by listening to the output from a loudspeaker that the sound has approached us and then receded from us. We have no way of knowing from what direction simply because the microphone has no way of knowing. The result is conventional sound reproduction with no effect of audio perspective whatever.

When once the limitations of single-microphone recording are grasped a natural impulse is to ask why stereophonic sound cannot be produced simply by using more than one microphone. The reason why this will not work can be

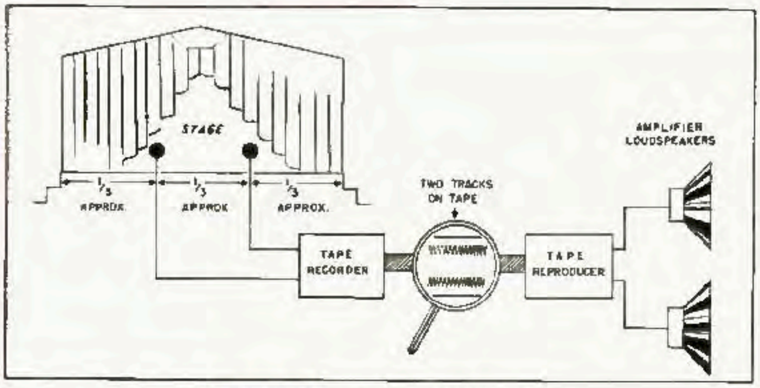

Fig. 8. Two-channel stereophonic system.

seen after a little study. It is true that if two different recording microphones were used, relative sound intensities and phase differences would be picked up. Each microphone would "hear" the same sound in a slightly different manner. But when these sounds are mixed in a one-channel system and fed to one output, the stereophonic effect is lost. The effect is stereophonic only if it is stereophonic to the listener. In this kind of a system, the listener is hearing only one output, whether this output is connected to come from one speaker or many. It is still the same output coming from different locations. The general effect will be fuller than that of a single-microphone system, but a true stereophonic system requires more than the simple addition of one or more microphones.

Let us now see how true stereophonic sound overcomes the narrow limitations of conventional recording. When sound is recorded stereophonically, two or more recording microphones are used. In two-channel stereophonic recording, two microphones are positioned a distance apart equal to approximately one-third the width of the recording room as shown in *Fig.* 8. With this arrangement, each microphone picks up a point source of sound in a different manner, much the same as the observer's ears in *Fig.* 6. Here, both intensity differences and phase differences are recorded. When the input to each microphone is impressed on a separate channel of magnetic tape, these relationships are preserved side by side on parallel tracks of the tape. If, in reproducing, the output from each channel is fed through a separate amplifier and loudspeaker, we will hear two different versions of the same sound being reproduced from two separate sources. As long as the speakers are spaced in the listening room in the same proportions as the microphones were spaced in the recording room, the acoustic characteristics are essentially recreated and the result is stereophonic sound.

When the total sound recorded is a combination of a number of sources (such as an orchestra), each individual sound source except those centered between the two microphones is picked up differently by each microphone. Thus it is possible when listening to the reproduction of this recording through the two loudspeakers to distinguish the location of each individual sound. When listening to a musical recording it is possible to detect the apparent location of the various instruments in the orchestra.

Now let us consider our moving source of sound recorded and reproduced stereophonically. This situation is represented in *Fig.* 9, L and R being the two recording microphones. Because of the difference in distances between A and the two microphones, when the source is at point A, it is picked up with a certain level of intensity at L and with a lower level of intensity at R. This difference in distance also causes each microphone to pick up the sound at a different point in its cycle; that is, phase difference is introduced. As the sound source moves from left to right, it is thus picked up by each microphone with varying intensities and phase relationships depending on the instantaneous position of the sound source on the line AE. In other words, each microphone "hears" the same sound in a different manner as it moves from left to right. When the impressions of both microphones are fed through a two-channel system to two separate loudspeakers, so arranged that the left loudspeaker reproduces the impressions of the left microphone and the right loudspeaker the impressions of the right microphone, the intensity differences and phase relationships of the actual sound are essentially preserved and reproduced in the listening room. Where the original sound was to the left, the reproduced sound will appear to be from the left. Where the original sound was to the right, the reproduced sound will appear to be from the right. And thus at every point along the path AE, the apparent direction of the reproduced sound matches the direction of the original sound. To the listener, there remains no question as to whether the sound source crossed from left to right or from right to left. He can actually hear the sound moving from left to right. Stereophonic sound has introduced a new dimension to sound reproduction.

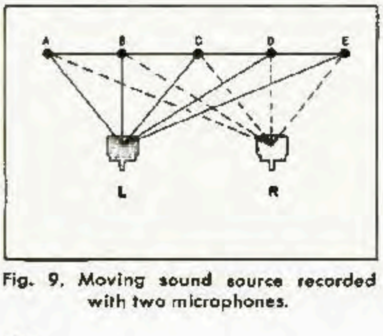

Fig. 9. Moving sound source recorded with two microphones.

Fig. 10. Ampex 612 stereo playback reproducer with matched amplifier-speaker units.

Fig. 11. Concertone 20/20 recorder—a home machine of the professional type.

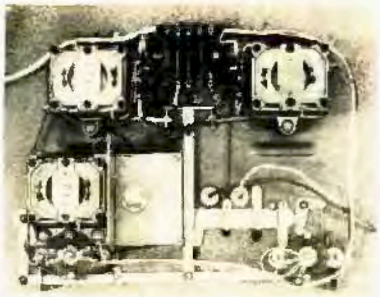

Fig. 12. Fen-Tone Brennell tape deck is kit-type unit for user installation.

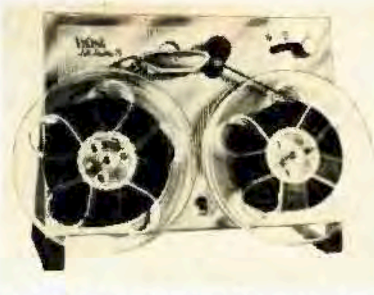

Fig. 13. The Viking "75" tape deck, which is only a playback mechanism.

Recorder Models

Tape recorders come in a variety of housings, from the large professional console type to the pocket models used for specialized applications. Most recorders for home use are built into portable cases, usually with one or more speakers. The serious music lover who envisages no need for recording at a distance from his hi-fi system is likely to be better served with an installation that is essentially permanent—solidly mounted in one of the cabinets housing his equipment. However, most of the portable models have provision for feeding the output of the preamplifier portion of their electronic circuitry to the usual preamp-control unit, and thus to a permanent speaker system. This method gives better quality, in practically every instance, than can be obtained by using the power amplifier in the recorder case to drive the home speaker. Inexpensive speakers mounted in thin plywood boxes can not be expected to provide good quality, as compared to a permanent speaker installation. The one exception to this is the Ampex 620 speaker amplifier, which consists of a heavy-duty 8-inch speaker mounted in a portable case of the same dimensions as the 600 recorder, and an amplifier which is equalized so that the acoustic output from the speaker is essentially flat—for a "flat" input signal—from 65 to 10,000 cps.

Figure 11 shows the Concertone 20/20 model, which is a "home type" machine designed along professional lines—in fact, it is similar in appearance to the Berlant professional recorders. This model can accommodate up to five heads, so that the user can have single-channel dual-track facilities combined with stereo playback and record facilities, for example. One professional application of this machine involves the use of a playback head, which is followed in turn by an erase head, a record head, and another playback head. This permits using the one machine to reproduce a delayed broadcast from the tape, erase the tape and record a program off the network, and monitor it as it is being recorded. With the one machine a radio station can, in effect, have two programs on the same reel of tape. Many other uses would undoubtedly come to mind.

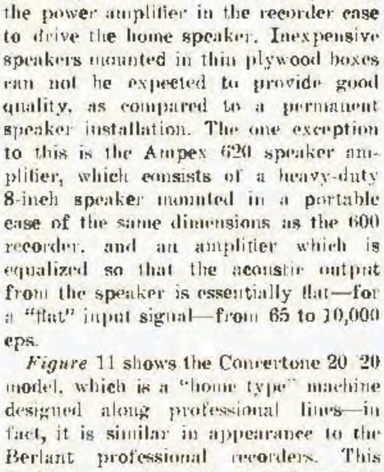

Fig. 14. The EMI broadcast-quality portable recorder.

Figure 12 is the underside view of a tape transport mechanism which is supplied by Fenton Company to be used with an external amplifier which can be built by the user, or one is available ready to use. This model uses three motors—one for the capstan, one for take up, and one for rewind. It operates at three speeds, and is sufficiently flexible that the experimenter can adapt it to many specialized requirements.

Figure 13 is the Viking playback chassis, which reduces to its simplest form the elements of a tape recorder when it is in the playback mode. Thus it ought be called a "tape phonograph" —and sometimes it is. This model is available as shown, mounted on brackets, or in a carrying case, or simply as a chassis for mounting in a cabinet.

Typical Tape Recorder

Basically all tape recorders have the same elements—a means for holding the supply reel and the take-up reel, with a motor to drive the capstan and to rotate the take-up reel; erase, record, and playback heads (the latter two are often combined), an amplifier, and a bias and erase generator. Speakers may or may not be included in the unit, but volume and tone controls usually are, together with necessary facilities for controlling the entire recorder.

Three speeds are commonly in use—15 inches per second (abbreviated *ips*), 7½ ips, and 3¾ ips. For voice recording, such as in conferences, or for dictating, speeds of 1⅞ and 15/16 ips are generally used, but they are of little value for music recording. The best compromise for general use is 7½ ips, which is fast enough for good-quality recording, yet not so prodigal with tape as the still-higher-quality 15 ips. The lowest of the common three speeds—3¾ ips—has very little musical value, and may be considered as a toy.

Records may employ one, two, or three motors, but because of the high cost of fractional horsepower motors, it is usually less costly to use a system of belts, pulleys, idlers, and flywheels than it is to use another motor or two. Similarly, one, two, or three heads may be used—a combined erase, record, and play model in which the erase and record-play coils are wound on different legs of the same core; or an erase head and a combined record-play model; or three separate heads. In some instances a permanent magnet may be used for erasing the tape prior to passing it over the record head, but it is agreed that the high-frequency erase is more effective on a moving tape than a 60-cps field is. The latter is universally used in bulk erasers, which can completely erase a recorded tape in four or five seconds.

Portable Use

While most tape recorders are in portable cases, they are still tied to a 117-volt a.c. outlet, and thus are not truly portable. Some models are built expressly for outside use, such as for recording on-the-spot news events, interviews, and similar types of program material. *Figure* 14 shows a British EMI model which is of sufficiently good quality to be usable for broadcasting. *Figure* 15 shows another type, by Amplifier Corporation of America, that employs a spring motor for the tape drive, and a battery operated amplifier. Many of these are in use by U.S. broadcasting stations. Another model is the Tapak, made by Broadcast Equipment Specialties Co. Some portable units are equipped with battery-powered electric motors instead of the spring motor, and are perfectly satisfactory for the short term usage generally required of them.

Fig. 15. Spring driven motor and battery powered amplifier are used in this Amplifier Corporation of America portable.

Tapes

It may seem superfluous to attempt a discussion of tape, for the average person is of the opinion that all tape is the same, which is not quite true. In the first place, all tapes are not alike, and in the second, even all tapes of the same type are not necessarily the same. Actually, recording tape differs materially in construction, performance, noise level, and output, and each appears to have its particular uses which depend on the final application to which the tape recorder output is to be put.

At the present time, three types of base material are available—paper, acetate, and mylar. Paper is not considered adequate for high-quality recording applications, since the surface coating is not sufficiently smooth to provide a signal-to-noise ratio that is commensurate with present day requirements. Acetate-based tapes have long been the standard, and may continue to be so for some time. They offer reliable performance, high quality, and reproducible characteristics. Mylar tapes, with the higher-strength of the base material, have advantages for many applications, particularly where normal strength must be maintained together with an increase in recording time.

The normal acetate tape, as provided by all the major companies, has a thickness of 1.5 mils, and spools at 1200 ft on a 7-inch reel. This is sufficient for one-half hour of recording time at a speed of 7½ ips on a single-track machine, or for one hour on a dual-track machine. Acetate tape is also available in 1-mil thickness as "Scotch" brand 190, providing a fifty-per cent increase in recording time with only a slight diminution of tape strength. On most machines, the additional flexibility of the 1-mil acetate tape will provide an increase in high-frequency response ranging up to 2 db at 10,000 cps, and only reasonable care must be exercised in its use. Practically all of the companies which produce tape are now marketing a 1-mil mylar tape which gives the additional fifty per cent of recording time per reel, but which is practically equal in strength to the 1.5-mil acetate. For those applications where the maximum recording *time* must be realized, the one-half-mil mylar tape is available, spooling 2400 feet on a 7-inch reel. While this tape is strong enough for use in the average recorder *if it is properly handled*, it must be remembered that it does not have the strength of the more common 1.5-mil acetate tape and requires considerable care in handling. For example, machines which are capable of quick stops without tape spillage may place too much strain on the 0.5-mil tapes, and while they may not break the tape, they are likely to stretch it to the point where it more closely resembles a wire rather than a tape. However, where it is necessary to get the maximum recording time from a given size of reel, the mylar is the only answer short of reducing the speed at which the recording is being made, and this is likely to entail a reduction in frequency response which is not acceptable.

The usual 7-inch reel contains 1200 feet of 1.5-mil tape, with a tuning time of 32 minutes; the same spool of 1.0-mil tape contains 1800 feet of tape, with a running time of 48 minutes; and similarly, 2400 feet of 0.5-mil tape may be spooled on a 7-inch reel with a running time of one hour and four minutes per track. A dual track machine will record twice as long as those figures on the same reel of tape, providing some one is available to turn the reels over at the end of the stated times. Some machines have facilities for reversing automatically without any attention whatever. This can be a doubtful blessing, however, for the reversal—which conceivably takes a certain amount of time—could occur at a critical time in the recording, assuming that the machine were being used to record a broadcast concert, for example.

In effect, then, we learn that while a tape recorder is capable of the highest quality of performance, it also demands some intelligence in its use.

A number of special features are offered by the tape manufacturers. For example, Audio tape is available in several colors, which permits using different colors for each type of recorded material, for example, or to the user's particular demands for identification of the varying subject matters. Reeves Micropolished tapes are claimed to be exceptionally smooth and thus to cause less wear to heads. Irish Ferrosheen tape is also claimed to be highly polished. Scotch brand tapes are also available in a High-Output form where the maximum signal output must be derived from the recording, although no claim is made for appreciably greater signal to noise ratio. Magnetic tape requirements for instrumentation are particularly severe, and most manufacturers make available specially tested tapes for that application.

Packaging differs between the manufacturers: for example, Reeves sound tapes are packaged in five-drawer boxes which are convenient for storage; Audiotape has a box for the 10½-inch reel that facilitates removal from the container and placement on the recorder without the possibility of spillage; Irish has a package which offers a combination of reels of tape, empty reels, and a practical reusable container.

The specifications of commercially available tape recorders which appear on the following two pages have been restricted to the typical home machine. AUDIO is indebted to the manufacturers for this information, and regrets that not all models nor manufacturers are included. The information which is tabulated here is taken from published specifications, and does not represent independent measurements. While every manufacturer was asked to supply information about his products, not all complied with our requests; consequently, some manufacturers are not represented.

Except as noted, all models have a single motor, accommodate up to 7-inch reels, and have erase and record-play heads. The specifications do not indicate whether the erase head is supersonic or permanent magnet, and consequently it is not shown on the charts.

TAPE RECORDER SPECIFICATIONS

Make	Model	Speeds	Input Voltage: Microphone	Input Voltage: Radio etc.	Output: Level, v or dbm	Output: Impedance, Ω	Power Amp: Output, watts	Power Amp: Impedance, Ω	Speakers	Portable Case	Furniture Cabinet	Frequency Response (Max. speed): From	Frequency Response: To, cps	Frequency Response: Down, db	Bias-Erase Osc. Frequency, kc.	Weight	Signal/Noise, db	Wow and Flutter, %	Level Indicator
Ampex[1]	600	B (C)*		0.5	1.25 v	10,000			NO	X		40	15 K	4	100	28	55	0.25	M
	612	B			1.25 v	10,000			NO	X	X	40	15 K*			28	55	0.25	
Ampro	745	B C	.004	.01	0.5 v	100 K	5	3.2	2	X		60	11 K	6	62	25	40	0.35	E
	757	B C	.004	.01	0.5 v	100 K	5	3.2	2		X	60	11 K	6	62	45	40	0.3	E
	758	B C	.004	.01	0.5 v	100 K	5	3.2	2	X		40	15 K		62	34	45	0.3	E
Bell	RT75	B C D					3.5	500/3	1	X		30	12 K			35	60	0.25	IN
	RT86	B C				Hi Z	3.5		1	X		50	10 K			27	60		IN
Berlant[2]	BAX	A B	−55	0.1	6 v/+4	CF/600			NO	X	•	40	15 K	4	55	54	55	0.1	M
Concertone	20/20	A B	−60	.06	6 v/0	CF/600			NO	X	•	40	15 K	4	55	45	55	0.1	M
Columbia	461	B							1	X					50				IN
	462	B C							2	X									M
Crescent	670	B				Hi Z	3	3.2	1	X					50	20		0.5	
	672	B C				Hi Z		3.2	1	X						22		0.5	
	673	B C				Hi Z	3	3.2	2	X		50	10 K			23		0.5	E
Crestwood	304	B C	.002	.020		Hi Z	10		1	X					65	31		0.3	2N
	360	B C	.002	.020		Hi Z	10		2		X	50	12 K		65	42		0.3	2N
	404	B C	.002	.020		CF			*	X	X	30	15 K		65	28		0.3	E*
Crown[3]	Three Speed	ABC(D)*				CF		4,8,16	*	•		30	20 K	4				0.12	M/E
	Prince	ABC				CF						20	18 K	4		38		0.12	M
DeJur	TK820	B C	.0025	.088	0.7	10,000	6		5	X		40	16 K	4	60	45	55	0.1	E
	TM819	B C	.0025	.088					NO	•		40	16 K	4	60	40	55	0.1	E
DuKane	11A200	B C	.004	0.4/1.2*			7.5	8	1	X		50	10 K	3		39	50		E
Federal	37C	B C					3	4	1	X		50	12 K		40	27	43	0.5	IN
	47A	B C				Hi Z	3	4	1	X		50	12 K		40	27	43	0.5	IN
FenTone	Brenell	ABC								•		30	15 K		50			0.2	
	Motek	B (C)*								*		50	10 K	6	50		55		
Mitchell	1425	B C					3	3.2	1	X		65	10 K		50				IN
Pentron	RWN	B C					4		1			50	9 K			23	42		IN
	MP-2	B C				Hi Z				X		50	10.5 K		32		50	0.3	M
	T-90	B C					5		2							27	50	0.3	E
	HF400	B C				Hi Z	10		3							33	50	0.3	M
Presto[4]	SR27	A B			+8 dbm	500	10	15	2	X*		50	15 K		85	77*	55	0.2	M
RCA	7TR3	B C					2		3	X									2N
Revere	1700	B C	.001	0.5			5	3.2	1	X		60	15 K	6	65		50	0.3	2N
	T10	B C	.001	0.5			5	3.2	1	X		60	15 K	6	65		50	0.3	2N
	T11	B	.001	0.5	1.0 v	CF	2.5	3.2		*	•	40	16 K	6	70		50	0.2	2N
Telectro	556	C								X						16			
	220P	B C			1.0 v					•	•	50	15 K				45	0.3	
	220BMP	B C			1.0 v					*	•	50	15 K				45	0.3	
	220	B C								•	•								
Viking	75	B C			5-10 v	CF						40	14 K			9	45	0.2	
V-M	700	B C						8	2	X		60	10 K	10	65	30	45	0.4	IN
Webster	220	B C	.002	0.1			2.5	3.2	2	X		50	10 K					0.3	IN
	224	B C	.002	0.1			2.5	3.2	2		X	50	10 K					0.3	IN
	230	B C	.002	0.1			2.5	3.2	1	X		50	8 K					0.3	IN
	240	B C	.002	0.1			2.5	3.2	1	X		50	7 K			29		0.3	IN
	212	B C	.002	0.1	0.5 v	CF				*	•	50	13 K					0.3	M

[1] Ampex: Model 600 has three heads—erase, record, play—and permits monitoring from tape while recording. Model 612 is playback model only, and may be used for stereo, dual track, or single track.

[2] Berlant and Concertone: Berlant models available in several forms with various features for broadcast and professional use. All models of both Berlant and Concertone accommodate up to 10½" reels, and are usually equipped with separate record and play heads to permit monitoring from tape while recording. Berlant models use hysteresis-synchronous motor for capstan drive.

[3] Crown, Crown Prince: May be had with wide choice of heads so user may monitor from tape while recording. Number of different models available, with varying features, but all are essentially similar in basic design.

[4] Presto: Employs three heads, and permits monitoring from tape while recording. Adapter available to permit use of 10½" reels.

Speeds: A, 15 ips; B, 7½ ips; C, 3¾ ips; D, 1⅞ ips.
Output: Applies to output intended to feed another amplifier. CF is cathode follower.
Frequency Response: Specifications usually state range over which response is within "± n" db. Since response may be considered to be relatively smooth in vicinity of 1000 cps, this portion of the curve may be set at the "+ n" point, and the range taken as the frequencies where the response

TYPE OF EQUALIZATION	REWIND TIME, secs for 1200-foot reel	ADDITIONAL INFORMATION
LC	90	* Conversion kit available
	90	* Plays Std. Tape #5563 within ±2 db. Stereo playback reproducer
RC	120	
RC		Piano key operation
RC		
RC	70	Bass boost on playback, treble boost on record. Piano key operation
LC	30	Three motors. Meter measures, bias, output and record levels. 10½" reels.
LC	30	Up to 5 heads can be installed—single, dual, stereo, erase, etc.—all models.
RC	105	
RC	105	
	90	
	80	
LC	90	Piano key operation
LC	90	
LC	90	* Also has phono input, 0.6 v. Spkr and ampl external.
LC	35	* With adapter. Various plug-in heads available. Three motors.
LC	35	Three motors, electromagnetic braking. Will handle up to 14" reels.
LC	90	* Hys.-sync. motor; reverses without changing reels; relay and solenoid
LC	90	operation; electromagnetic braking. TM-819 is basic chassis model.
	80	* Phono and radio inputs
RC	90	
RC	90	
	45	Chassis only, three motors. Used with external amplifier.
		* With adapter kit. Three motors, electromagnetic braking. Chassis only.
	45	
	70	Consists of TM56 mechanism, P4 ampl.
	70	
	70	
LC	50	Consists of R27 tape transport, A920B amplifier, two cases.
	120	
RC		T800 same with addition of AM radio tuner
RC		T20 same with addition of AM radio tuner
RC		Chassis model; will take up to 10½" reels
		Monaural playback chassis only
		Binaural and monaural playback chassis only
		Playback only, with separate preamp; available for stereo.
	120	
	120	
	120	
	120	
	120	

is at the "− n" point. Thus "± n" db may be interpreted as meaning that the range covers frequencies which are down 2n db from the 1000-cps response. "Down, db" figures are 2n.
Level Indicator: M, vu meter, db meter, or other indicator employing a meter. E, electronic "eye" type of indicator; 1N, one neon lamp, which flashes at or just under maximum recording level; 2N, two neon lamps, one of which flashes at minimum usable level and other flashes at or just under maximum recording level.
Type of Equalization: LC, using inductance and capacitance so as to match tape curve as closely as possible; RC, resistance and capacitance, usually distributed between record and playback.

Accessories—Maintenance & Testing etc.

In the use of tape recorders, various accessories are required. For example, it is necessary to splice tape, to store it, to identify the reels, and to carry it about in a convenient fashion. Enterprising manufacturers have provided useful items to fulfill these requirements.

The simplest splice is made by cutting the two ends of the tapes at a 45-deg. angle, butting them together and applying a short strip of splicing tape, which should also be cut at an angle so as to reduce the "bump" as the splice passes over the heads. The "Gibson Girl" splicer is a convenient device for accomplishing the diagonal splice and trimming the edges of the tape so that no adhesive remains to foul up the heads. The Prestoseal splicer utilizes a controlled heating process to weld the ends of the tape together, thus doing away with the need for splicing tape, which is actually a thin strip of pressure-sensitive tape that uses a minimum of adhesive material so that there is little possibility of any squeezing out the sizes and coming off on the heads.

A similar tape is also available for identifying the reels, being printed with space for date and subject of the recording. The printing is repeated at short intervals, and one section is applied to the side of the reel and the information is written on with ink.

A white leader tape is often used on the ends of reels to permit identification to be written on the end of the tape itself, thus avoiding the possibility of losing the identification by spooling the tape on a different reel than that for which it was intended.

For careful storage of reels, metal cans are available with tight-fitting covers that keep out moisture. These are actually the containers made for 8-mm movie film, but they are of the same size and can be had for either 5- or 7-inch reels. Brumberger, a photo-supply manufacturer, offers sheet metal boxes which hold up to twelve of these cans and provide means for identification, a particularly convenient accessory for one who uses tapes with lectures, for example.

The Cousino magazine is useful when a program must be repeated at intervals, or for a continuous repetition of the same recorded material. These units, shown in *Fig.* 16, provide for as much as fifteen minutes of program material which may be reproduced continuously, or which may be cued by electronic controls actuated by the tape itself—either with a strip of aluminum foil applied to the tape or with a subsonic signal recorded on the tape along with the program material.

While relatively foolproof, the tape recorder does require certain maintenance procedures to ensure optimum performance. The heads should be cleaned occasionally with carbon tetrachloride or with one of the special cleaning solutions provided by some manufacturers. Acetate solutions or lacquer thinners should *not* be used, because they are likely to dissolve the bonding agent in the heads, with resulting degradation of performance.

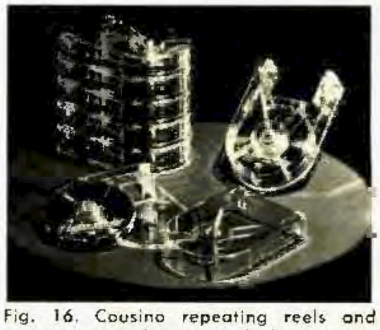

Fig. 16. Cousino repeating reels and magazine-type housings which permit up to a maximum of 30 minutes before repeating.

The head gaps should be aligned at reasonable intervals. Unless adequate maintenance records are kept which should show frequency response over the entire range and permit routine comparisons, it is necessary to make an alignment check by actually realigning the heads. This is done by playing a standard alignment tape and adjusting the azimuth of the playback head for maximum output at a frequency which approaches the maximum frequency of which the recorder is capable. This is usually 10,000 cps for a 7½-ips machine and 15,000 cps for a 15-ips machine. If separate heads are used for recording and playback, the playback head is adjusted first to the standard alignment tape; then a high frequency is applied to the recording amplifier and the record head is adjusted for maximum output from the playback circuit. The operation is relatively simple, but the adjustment is fairly critical, and should be sealed with a small drop of lacquer—or nail polish—each time it is done. Instructions for the alignment process are usually supplied as part of the operating manual.

Aside from cleaning and alignment, little else is required but normal lubrication. The user should make sure that no oil or grease is allowed on belts, pulleys, or any rubber parts, because slippage is almost certain to result in an increase in flutter and wow.

With relatively little maintenance being required, the tape recorder should be capable of giving long and reliable service, for it is a fairly simple machine which must be made to close tolerances and with a high degree of mechanical accuracy. It is undeniably a simple machine to use, and the results have little dependence on the skill of the operator—which is more than can be said about any other recording process. One can only imagine the difficulty that would be encountered by the entire audio and recording industry if it had to return to the days before the tape recorder.