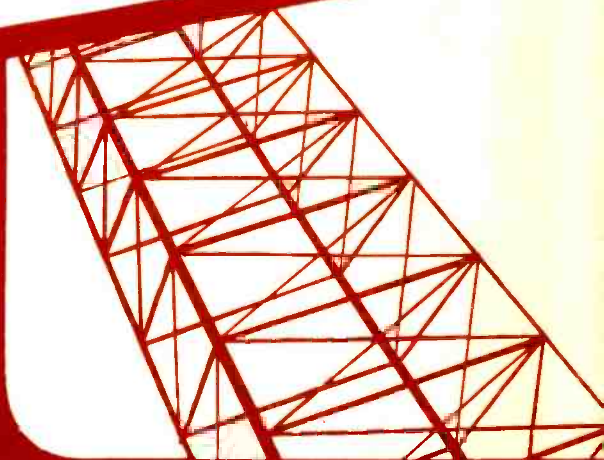
Sound Recording

Lesson RRT-6



DE FOREST'S RADIO TELEVISION ELECTRONICS TRAINING, INC.

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RRT-6

Radio Reception and Transmission

LESSON RRT-6

SOUND RECORDING

CHRONOLOGICAL HISTORY OF RADIO AND TELEVISION DEVELOPMENTS

1875—Elihu Thompson, an American, operated the first wireless set in history.

1883—Edison made first electronic observation by noting that an electric current can pass through a vacuum—now known as the Edison Effect, and the basis of all thermionic tube operation.

1884—Lord Kelvin announced his electronic theory of matter, laying the ground work for our modern electron theory.

1884—Paul Nepkow introduced his rotating scanning disk containing a series of holes in a spiral order — thus advancing television another step.

1884—Edward Branly, a Frenchman, invented the coherer, the first available detector for wireless waves—an incidental observation while experimenting on the conductivity of loosely packed iron filings.

DE FOREST'S TRAINING, INC.

2533 N. ASHLAND AVE., CHICAGO 14, ILLINOIS

RADIO RECEPTION AND TRANSMISSION

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SOUND RECORDING

INDEX

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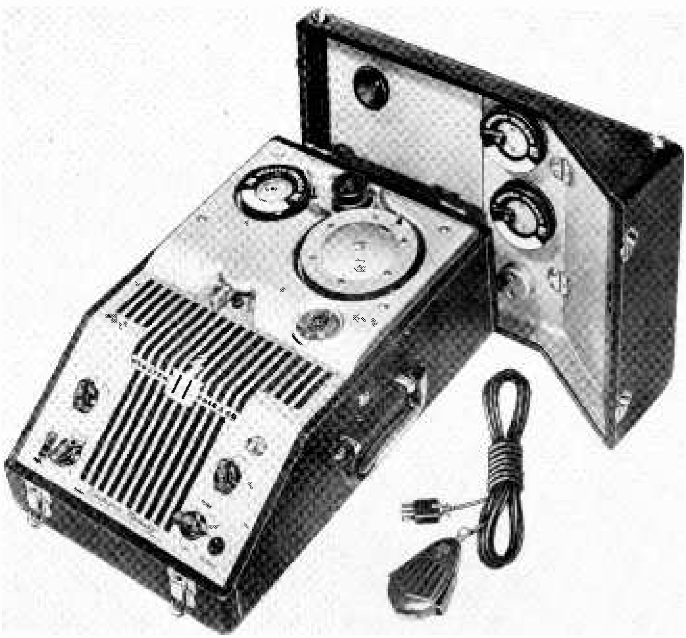
LOST

Between Sunrise and Sunset, two precious hours set with Golden Opportunities.
No reward offered—They are gone forever.

SOUND RECORDING

Many modern models of broadcast radio receivers include a turntable and pickup to provide for the reproduction of recorded voice and music through the audio amplifier and speaker of the receiver. Also quite common are automatic record changers which operate to play ten or twelve records in sequence without any attention by the listener. Units of this type will be described in a following lesson but, at this time we want to explain the methods by which the sound is recorded.

At present, there are three distinct methods in common use. 1, Cutting a spiral groove in a disk or cylinder, 2, Magnetizing a steel wire or tape coated with magnetic material and 3, Photographing a sound track on motion picture film. As the photographic sound track applies almost exclusively to motion pictures, only the first two methods will be described in this lesson.



Portable wire recorder and playback un t, provided with plug-in hand microphone.
Courtesy Webster-Chicago Corporation

As shown in Figure 1, the basic recording equipment is similar to that of the ordinary electric phonograph but the direction of the signal is reversed. Here, the sound enters the microphone which converts it to corresponding electrical energy that is amplified sufficiently to drive the cutting head placed on a revolving blank record. The cutting head converts the electrical energy into corresponding mechanical movements of the cutting stylus which cuts the groove in the surface of the record blank.

To form a continuous or spiral groove, the cutting head is moved slowly from the outer edge toward the center, or in some cases from the center toward the outer edge, as the record blank revolves with the turntable. The exact shape of the groove is determined by the movements of the needle caused by the electrical energy and thus the groove becomes a record of the original sound picked up by the microphone.

Besides the basic elements shown in Figure 1, a complete recording set-up usually includes a phono pickup and a speaker, with a switch arrangement that permits connecting the proper components to the amplifier, depending upon whether it is desired to record or to reproduce.

The amplifier has good response over a wide frequency range, and contains input channels for more than one microphone, also an input terminal to which the audio output of a radio can be introduced. It incorporates a good tone control circuit, and has an output of from ten to fifteen watts. To monitor the amplifier, an a-c voltmeter which is marked plainly as to the maximum level that may be applied safely to the cutting head, is permanently connected to the amplifier output.

The type of microphone depends upon the kind of sound to be recorded. For speech, the crystal and dynamic microphones are preferable, while the velocity and cardioid types are better for music.

The turntable drive motor must have sufficient power to prevent slow down under the load of the cutting head and the turntable itself should be fairly heavy so that its flywheel effect will tend to maintain a constant speed. When the speed of a turntable varies during each revolution of recording, the reproduced sound will have a recurring change in pitch called a "wow". To prevent such wows, large 16 inch recording turntables are made of cast iron and usually weigh up to 20 pounds.

As mentioned above, in order to cut a spiral groove of gradually changing radius, a method of moving the cutting head across the record blank is needed. These arrangements are of two kinds, the simplest and least expensive having the general appearance of the phonograph pickup arm with the movement accomplished by means of a worm, geared to the drive motor and also to the cutting head or arm. The speed at which these gears cause the cutter to move across the record determines the pitch of the spiral groove, and thus the number of grooves or lines per inch. Some recorders cut as many as 136 lines per inch, others as few as 80, but usually the number of lines per inch is between 90 and 120.

For the popular records, the turntable speed is 78 revolutions per minute, (rpm) while for the larger commercial transcriptions and long playing, (LP) records, the turntable speed is 33⅓ rpm.

Recorder for 12-inch disks. Both the cutting arm and pickup arm can be seen. The pickup arm can be used also for 16-inch transcriptions.

Courtesy Rek-O-Kut Company, Inc.

More recently another type of record has been announced to operate at a turntable speed of 45 rpm.

In order that best recording be accomplished, it is desirable that the face of the cutting stylus be directly in line with the radius of the record at all times. However, this requirement is actually realized at only one point on the record when the swinging-arm phono pickup type of mechanism is employed; and at all other points along the radius of the record, there is a slight angle between this radius and the face of the cutting stylus.

To correct this condition, a straight-across motion of the cutting head is provided with the more elaborate carriage type of assembly, such as that illustrated in Figure 2. The drive flange, lower left in the figure, is placed on the center of the record blank so that its drive pins fit into corresponding holes in the record. As the latter rotates with the turntable, the drive flange is likewise rotated, and the worm gear turns the drive screw, making the carriage move along the support rods. The vertical position of the cutting head is set by means of the weight adjusting nut so that the stylus cuts the desired depth of groove into the record.

MAGNETIC CUTTING HEADS

As mentioned above, the device in which the electrical output of the amplifier is converted to corresponding mechanical energy, is called the cutting head. There are two types of cutting heads in general use, the magnetic and the crystal, both of which accomplish the same purpose though differing greatly in their principle of operation.

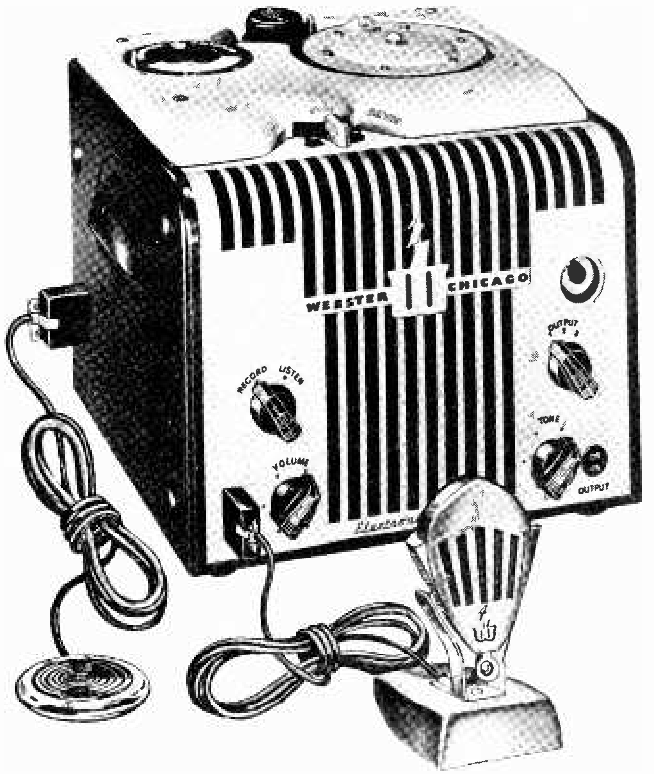
The general construction of the magnetic type of cutter is illustrated in the drawing of Figure 3 that shows the armature mounted on a pivot and situated between the pole pieces of a permanent magnet. The coil which carries the a-f output from the amplifier, is placed around the armature which serves as the coil core. Thus, the magnetic flux in the armature will vary in strength and reverse polarity with the amplitude and frequency of the amplifier output.

Referring again to Figure 3, the magnetic circuit of the permanent magnet is arranged to provide two "N" and two "S" poles, one pair opposite the upper end of the armature and the other pair opposite the lower end of the armature. When the current in the coil causes the upper end of the armature to have an "N" magnetic polarity, it is repelled by the upper "N" and attracted by the upper "S" pole of the permanent magnet. At the same time, the lower "S" end of the armature is attracted by the lower "N" pole and repelled by the lower "S" pole of the permanent magnet. Due to the centrally located pivot, the armature swings and the movement is transmitted to the cutting stylus which mechanically, is an extension of the armature. As the current in the coil reverses direction, the magnetic action is reversed also and the armature swings in the opposite direction.

The distance the armature moves is proportional to the amplitude of the current in the coil while the rate at which it swings is the same as the frequency of the coil current. Imbedded in the revolving record blank, these movements of the stylus produce a wavy groove, the variations of which correspond in frequency, amplitude and waveform to the sound waves striking the microphone.

Polyphonic Sound wire recorder equipped with desk stand microphone. Note the volume and tone controls for regulating the reproduction output.
Courtesy Electronic Sound Engineering Company

Due to the rotation of the record blank and movement of the cutting head, with no current in the coil, the stylus will cut a uniform spiral groove. With a-f current in the coil, the movement of the armature causes "wavy" grooves as indicated in Figure 3. For simplicity, the grooves are shown narrower than the uncut "land" area between them but, in actual practice, the groove width is usually greater than that of the land by a ratio of about 3:2.



Electronic Memory wire recorder with desk microphone and foot-control button for press-to-talk and press-to-listen control. It is designed particularly for business correspondence dictation.

Courtesy Webster-Chicago Corporation

Since the armature of Figure 3 possesses a certain mass, its inertia tends to make it swing further in each direction than it would due to the pull of the magnetic field alone. To prevent such action, a means of mechanical damping must be employed. In the simpler units, the damping devices consist of pads made of some pliable material such as soft rubber. In the more expensive commercial cutters, the upper end of the armature is extended into an oil chamber, and damping results when the armature moves against the oil.

Most magnetic cutters are high-quality, wide range units. However, the capabilities of a particular make as regards frequency range, sensitivity, and other refinements, depend largely upon the type of construction and the finished workmanship of the unit. There are inexpensive magnetic cutters designed primarily for home recording, as well as expensive units for professional use. However, providing that special attention is given to the mounting, and that the associated equipment is well designed, many inexpensive magnetic cutters are quite capable of producing high-fidelity recordings. They are very rugged and stable, giving long and satisfactory service under all climatic conditions. They are not readily damaged by electrical overloads, and the cutting level as well as the frequency response characteristics are independent of temperature over a wide range.

Some high-fidelity recording heads, designed for professional applications, are capable of maintaining an ideal frequency response, with only slight variations, over a range of from 50 to 10,000 cycles. With these professional type heads, the frequency response and sensitivity vary slightly with temperature, and to obtain the most uniform results recorders in which they are used should be operated in temperature controlled rooms.

CRYSTAL CUTTING HEADS

As you learned previously, certain crystalline substances possess the property known as piezo electricity, that is, when they are stressed mechanically, an electric potential is produced; also, if a voltage is applied to them, the crystals become distorted mechanically. In the case of crystal microphones and phono pickups, the action of the crystal can be compared to that of a generator because it converts mechanical motion into electricity; whereas with crystal headphones and record cutters, the action is like that of a motor because in these units electric energy is converted to mechanical motion.

Crystals of the type called Rochelle Salts, which have greater piezo electric properties than any other known substance, are grown in large bars about two feet in length. These bars are first cut into slabs and finally into the small plates used in the various crystal operated devices. When a potential is applied, these crystal plates tend to expand in one dimension and at the same time to contract in a direction at right angles to the first. Furthermore, if the crystal plates have been cut so that their sides are at an angle to the directions of expansion and contraction, then the arrangement of Figure 4A will be produced.

When a d-c voltage is applied across the opposite faces of this plate, it will expand in a direction shown by the arrows between corners 1 and 3, while at the same time it contracts in the direction shown by the arrows between corners 2 and 4. If the polarity of the voltage is reversed, the plate will contract between corners 1 and 3 and expand between corners 2 and 4. If an a-c voltage is applied, the crystal will alternately expand and contract in each direction.

In practical applications, two such crystal plates are cemented together to form a unit known as a bimorph element. This is illustrated in the simplified sketch of a crystal cutter in Figure 4B. Here the plates of the element are oriented so that corner 1 of plate a is adjacent to corner 2 of plate b, etc. With the a-f amplifier output connected as shown, the outside faces of both plates are at equal a-c potential of one polarity while both inside faces are at equal potential but of the opposite polarity.

Due to this arrangement, during that part of the a-f input cycle that plate a is expanding between corners 1 and 3, plate b will be contracting between corners 2 and 4. At the same time, plate a will contract between corners 2 and 4 and plate b will expand between corners 1 and 3.

As a result of this action, the upper edge of the front end of the bimorph element will move in the direction of arrow X, while the lower edge will move in the direction of arrow X^1. Likewise, when the a-c voltage changes polarity, the resulting crystal expansion and contraction will cause the upper front edge of the element to move in the direction of arrow Y, and the lower edge to move in the direction of arrow Y^1. Thus, these twisting movements of the crystal element impart an oscillating circular motion to the attached shaft. The shaft is bent at right angles at its outer end and the resulting side-to-side chuck motion causes the stylus to cut record groove variations which correspond in frequency and amplitude to the a-f voltage applied to the crystal. Because of the twisting motion it develops, a bimorph element, oriented as shown in Figure 4B, is also given the name "twister element".

A well designed crystal cutter is capable of producing excellent records. It is practically free from harmonic distortion and has a wide and uniform frequency response. Because of its high efficiency, the driving amplifier requires a comparatively low power output. The amplitude and frequency response are almost completely independent of the depth of the cut and of variations in hardness of the record materials.

Rochelle salt crystals have their greatest piezo electric activities at normal room temperature, 72° Fahrenheit; but will also operate safely over a range from −40° to +130° Fahrenheit. However, if exposed to temperatures higher than 130° Fahrenheit, they lose their piezo electric properties permanently.

RECORD BLANKS

Several types of record blanks are available, the most popular of which, called the acetate blank, consists of a metal base with a special type of baked lacquer coating or surface. This recording surface is soft enough to be cut with a stylus, yet is hard enough to withstand the wear of repeated playings. Though every playing wears away the grooves to some extent, when properly handled, this type of record may

Wire recorder showing the microphone at left and foot control at right. The pickup arm can be used for reproducing 10, 12, and 16-inch records.

Courtesy Wire Recorder Corporation of America be played several hundred times before the reproduced sound becomes unsatisfactory.

A second type of blank consists of a solid aluminum disk. This type is less expensive than the coated disk, but is not as good. A number of types of pressed paper recording blanks are also available, but because they can be played back only a few times, they are the least popular of all.

As mentioned before, one requirement of a good recording blank is that it be hard enough to maintain its condition after numerous play-backs, yet the material of which it is made must be such that it will cut smoothly and not tear as the cutting stylus plows through.

Furthermore, the record material must cut easily even during the most rapid vibrations of the stylus, and to prevent rapid wear or dulling of the cutter its ingredients must not be harsh or abrasive. Also, it must develop as little surface noise as possible. Because it is superior in these various factors, the coated blank is preferred over the aluminum and the pressed paper type disks.

Federal Little Pro 12-inch disk recorder, combined with an electric phonograph, superheterodyne radio receiver, and public address system.
Courtesy Federal Recorder Company

In commercial practice where a great many copies or pressings are to be made, the original record is made of a very fine and uniform grade of wax or special soap material. These waxes are about an inch or inch and a half thick with the upper surface turned to an absolutely flat, mirror like finish. Soft wax is used for this purpose because it offers practically no resistance to the side motions of the cutter, and thus readily reproduces the higher frequencies.

After the record has been cut, it can be listened to or played back by using a very light needle made especially for the purpose. However, this a poor policy as it has a tendency to cut off the high notes. Instead, the usual practice is to dust the wax carefully with a fine powder which makes the surface electrically conductive. Then it is placed in a bath and copper-plated on the cut side.

The plating follows all the variations of the grooves, and when taken from the wax, it has raised lines instead of grooves. Thus, the copper plate really is a negative and is called the "master". This master is then put into a press with a dough-like mixture and is placed under extremely high pressure and heat. The result is a pressing, much like the usual record, which can be played to check the master.

The original wax record is spoiled when the copper plate master is removed, therefore, to preserve the master it is electroplated, this plating being called a "mother". Being made from the master, the mother has its lines indented like a finished record and therefore cannot be used for stamping other records.

The mother is then electroplated to obtain a negative like the master, but this one, called a stamper, is used in the press for making the final records. However, if many duplicate records are required, several stampers are made because they wear in use and then the duplicate stamped records are not clear and sharp. The master is filed for future reference, orders, or emergencies in case the mother or stampers should be damaged.

Record blanks are available in sizes ranging from 6 to 16 inches in diameter, the 6, 8, 10 and 12 inch sizes being employed for home recording and for commercial pressings, while 16 inch disks are used for high fidelity recording in transcription work.

CUTTING STYLI

The four basic types of cutting styli in present use are the steel, alloy, sapphire, and diamond-chip. Since the tip of the stylus is the only part that does the actual cutting, it is the only portion which need be of hardened material. The stylus cuts a groove about .003 inch in depth and, therefore, not only must its cutting edge be extremely sharp and free from imperfections, but the sides of the tip must be polished to a very smooth surface. If this is the case, the finished groove will have a shiny appearance therefore a dull finish on the sides and bottom of the cut groove indicates that the stylus is worn and should be sharpened or replaced.

The most inexpensive cutting stylus is made of hardened carbon steel which has its tip ground to a V shape. Being of tough material, there is little danger of it breaking or chipping upon being dropped accidentally. Though the steel is very hard, the amount of friction developed in cutting a record is considerable, and while these styli possess a very sharp, keen cutting edge during the first few seconds of use, they dull rather quickly and the recording becomes quite noisy.

Steel styli cannot be resharpened, and since their useful life is only from about 30 to 60 minutes, they must be discarded at the end of this time. Their frequency response is sufficiently good for applications where high tone quality is not a requirement, but they are not capable of recording the high notes obtainable with the other types of styli.

The alloy types of styli are made with a brass or dural shank, and only the tip is of the hard cutting alloy. Instead of a sharp V shape, these tips are rounded somewhat, to make a smoother cut which produces less surface noise (needle scratch) than is obtained with a steel stylus. Different alloys are used for the cutting tip of the various makes on the market, and one of these, known as a "stellite", is tipped with a metal having that name. The stellite cutter has a useful life of about two hours cutting time and may be resharpened for about one-half the cost of a new unit. Not all makes of alloy type styli can be resharpened, and when this is possible, it is stated in the particular manufacturer's literature. There is practically no danger of chipping the alloy type stylus by dropping.

A stylus producing a better frequency response and less surface noise than those described above, is one which contains a sapphire insert for a tip. This tip may be made from the genuine gem or from synthetic sapphire (aluminum oxide). The former has a somewhat longer cutting life and is slightly more expensive. Both genuine and synthetic sapphire styli are very hard, take a high polish, and, therefore, have a low coefficient of friction. They may be resharpened many times at a fraction of their original cost, and after each sharpening will cut satisfactorily for about 15 hours.

By far the best available stylus employs a diamond-chip insert as the cutting edge. The diamond is the hardest of all known substances, and therefore the life of this type of stylus is almost indefinite. It is the most expensive of the cutting tools, but produces top quality recordings and will cut thousands of blanks before becoming dulled.

Portable disk recorder for use with microphone or other external sound source.
Courtesy Emerson Radio & Phonograph Corporation

The sapphire is quite brittle and hence is rather fragile, which is a disadvantage in that it can be chipped easily and when chipped it must be discarded. Even though the chip is so small as to be invisible to the naked eye, it can easily cause the recording to be spoiled if the stylus is used again for cutting. Therefore, this type must be handled with great care because, even if dropped accidentally onto a record, the tip may be ruined.

RECORDING PROCESSES

In the cutters of Figures 3 and 4 the stylus moves from side to side so that transverse waves are produced as the groove is cut but the depth of the cut remains constant. This method of recording, used almost universally, is known as lateral cutting. Another system, called hill-and-dale, produces a groove which has no lateral excursions, but which varies in depth in accordance with the modulating audio-frequency variations. This arrangement has the advantage in that the amplitude or level of the recorded sound is not limited by the space or land area between grooves. Although it permits the cutting of more lines per inch, it requires the use of special recording equipment, therefore most commercial recordings are of the lateral cut type.

Record grooves may be cut in either of two directions: from the outside toward the center, termed the "outside-in" method, an example of which is seen on all commercial recordings for use on phonographs; or from the center toward the outer edge of the blank, known as "inside-out" recording. Since the material cut from the record groove, called the "chip" or "scrap", normally tends to fall toward the center or inside of a record, the inside-out method of cutting permits the recording to be made without the operator having to give his constant attention to the chip. That is, the stylus moves away from the chip instead of into it, and is therefore less likely to become fouled in the thread-like shaving. However, it is seldom possible to estimate the exact amount of record space which a given amount of recorded material will require, and for this reason, the inside-out method frequently results in either a waste of record space, or else the cutter reaches the edge of the disk before the recording is completed. Thus for the phonograph records, the outside-in system of cutting is in practically universal use.

Two turntable speeds have been adopted as standard in modern recording practice. One of these is 33⅓ rpm and the other, known as 78 rpm, is actually 78.26 rpm. A great advantage of the lower speed, of course, is that everything else being equal, much more material can be recorded per disk than at 78 rpm. For example, under like conditions the approximate playing time of a 12 inch record is 4 minutes at 78 rpm and about 8 minutes at 33⅓ rpm. At both speeds, however, there is a definite limit to the amount of disk area which can be used for high quality recording, less area being available when 33⅓ rpm is employed than when 78 rpm is used.

The reason for this condition can be seen in Figure 5 where the groove variations produced by a 21 cps audio note are shown, their amplitude being greatly exaggerated for simplicity in the explanation. With a record speed of 78 rpm (1.3 revolutions per second) about 16 complete cycles (21 ÷ 1.3) will be cut during each revolution of the disk. Thus, a quarter section of the disk will contain approximately 4 cycles as drawn. Assuming a 16 inch disk, the outer groove, a, cut at an average radius of 7¾ inches from the center of the record, has a length of about 12⅛ inches, and the variations are extended smoothly over this entire distance. On the other hand, the groove, b, with a 4 inch radius, is only about 6¼ inches long, yet the same number of variations must be squeezed into this short distance, resulting in the groove having shorter and sharper curves.

Magnetic tape recorder showing the two winding reels on the top, and the operating controls on the front panel. A desk stand microphone with on-off switch.
Courtesy Webster Electric Company, Racine, Wis.

In other words, the speed of the disk travel under the cutting stylus depends not only upon the turntable speed, but also upon the distance from the center of the record to the point at which the cutting is taking place, being greatest at the outer edge. Thus, as the cutter nears the center of the disk, more and more crowding of the groove cycles is produced. As will be shown, at a given distance from the center of a record, the crowding is more severe in the case of the 33⅓ rpm turntable speed than at 78 rpm.

Magnetic tape recorder with input microphone. Two sound tracks are impressed on the tape —hence the commercial trade name Twin-Trax.
Courtesy Amplifier Corporation of America

For example, with a turntable speed of 78 rpm, the speed of the disk under the cutter at a distance of 5½ inches from the center is about 45 inches per second. The groove wavelength produced at this point by a 100 cps audio note is 45 ÷ 100 = 0.45 inch long. Since 1 mil equals .001 of an inch, this may be expressed as a wavelength of 450 mils. At 33⅓ rpm the cutter-disk speed at the 5½ inch radius point is only about 19 inches per second, and the wavelength of a 100 cps audio note is about 190 mils.

At this same radius point, a 500 cps note will have a 90 mil wavelength at 78 rpm, and at 33⅓ rpm its wavelength will be only 38 mils. Also, at 78 rpm a 3000 cps note will produce a 15 mil groove wavelength, while at 33⅓ rpm the wavelength will be about 6.4 mils long.

At the point it touches the record groove, the reproducing needle is approximately 4 mils in diameter, and consequently, when the wavelength of the record groove variations approaches this value, it becomes extremely hard, and finally impossible, for the needle to follow them. For this reason, there is a tendency for the output of the phono pickup to fall off whenever conditions are such that the groove wavelength is equal to or less than about 4 mils.

As shown by the values of the preceding example, the higher audio frequencies produce the shorter groove wavelengths, and thus a limitation is imposed upon the maximum frequency range which can be reproduced under given recording conditions. Carrying the example a bit further, at 78 rpm and at 4 inches from the center of the disk, a 3000 cps audio note has a groove wavelength of about 10.8 mils, but at $33\frac{1}{3}$ rpm the wavelength is approximately 4.3 mils long. That is, at $33\frac{1}{3}$ rpm the groove wavelength approximates the diameter of the reproducing needle, and frequencies higher than 3000 cps will be reproduced very weakly, if at all.

Finally, at a recording radius of 2 inches, a 4000 cps audio note will have a wavelength of about 4 mils at 78 rpm, and a little over 1 mil at $33\frac{1}{3}$ rpm. Because of these short wavelength limitations, in high fidelity recording it is standard practice to limit the minimum recording diameter to 9 inches when a turntable speed of $33\frac{1}{3}$ rpm is used, and to 4 inches for 78 rpm.

Although a greater part of the center portion of a record blank may be utilized when 78 rpm is employed, this speed is not so practical near the outer edge of the disk. For, the higher the speed of the record, the greater the wear on the grooves when the record is played back. For instance, at a point near the outer edge of a 16 inch blank, the cutter-disk speed is 25 inches per second at $33\frac{1}{3}$ rpm, but at 78 rpm and the same distance from the center of the record, this speed is 62 inches per second.

It is due to these various factors that only the 6, 8, 10 and 12 inch blanks are used for 78 rpm recording, while for $33\frac{1}{3}$ rpm cutting, the 10, 12 and 16 inch sizes are employed. Though they vary with the number of grooves cut per inch, a few representative values of approximate playing times are given in the following tabulation:

Disk Size	RPM	Approximate Playing Time
6 inch	78	up to 1 minute
8 inch	78	1 to 2 minutes
10 inch	78	2½ to 3½ minutes
10 inch	33⅓	4 to 6 minutes
12 inch	78	4 to 5½ minutes
12 inch	33⅓	7 to 10 minutes
16 inch	33⅓	14 to 18 minutes

CUTTING ANGLE

In order that the recording be free of surface noise and squeaks, it is very important that the cutting angle be correct. This is the angle formed between the forward face of the cutting stylus and the surface of the record blank. The exact angle required for any particular case will depend upon the type of cutting head, type of stylus and the material of which the disk is made. Therefore, this angle must be found by trial methods and no one value can be stated as being applicable to all conditions. The cutting angle can be checked by placing the stylus upon an uncut record blank with the turntable stationary, and viewing the reflection of the stylus on the shiny surface of the blank. The general appearance of this arrangement is illustrated in Figure 6. To show the position of the stylus in relation to the disk, the direction in which the latter moves during cutting is indicated in the figure. As seen here, when the face of the stylus is in a straight line with its reflection on the surface of the disk, the cutting angle will be 90°. Since any change in this angle will be accompanied by an equal change in the reflection, it is easy to detect a relatively small deviation from 90°.

Many operators prefer to cut with the face of the stylus leaning slightly forward, while others insist that they obtain best results with the cutting face leaning slightly backward. The desired angle can be determined experimentally by cutting a number of grooves, without modulation, with the stylus at various angles from the vertical. The angle producing the least amount of hiss, noise, or squeak when the record is played back is the correct one to use and with good equipment, usually this will be found to be within 2 or 3 degrees, plus or minus, of ninety degrees.

Besides requiring a definite cutting angle, the face of the stylus is pitched slightly toward the inside of the record as an aid in throwing the chip toward the center of the turntable. This is to prevent the chip from falling in front of the cutter, where if it is collected by the stylus, it can cause considerable noise when the recording is reproduced.

RECORDING LEVEL

The level at which the audio signal is applied to the cutting head must be a compromise between acceptable surface noise and the amount of distortion which can be tolerated. Since, with a given type of record blank, cutting angle, etc., the amount of surface noise has a definite value, the signal-to-noise ratio can be improved by increasing the level of the audio signals. However, when this level is high, the excursions of the cutting stylus have greater amplitude, and it becomes difficult for the reproducing needle to follow the groove variations. This results in distortion of the reproduced sound.

In practice, it has been found that the presence of a small amount of distortion is often less objectionable than excessive surface noise, and for this reason, the amount of measured distortion is not necessarily a good indication of the correct recording level. The best operating level for a particular cut can be determined by making a series of test cuts at gradually increasing levels, and the last point at which the reproduction is acceptable from a quality standpoint indicates the maximum usable level.

GROOVE SPACING

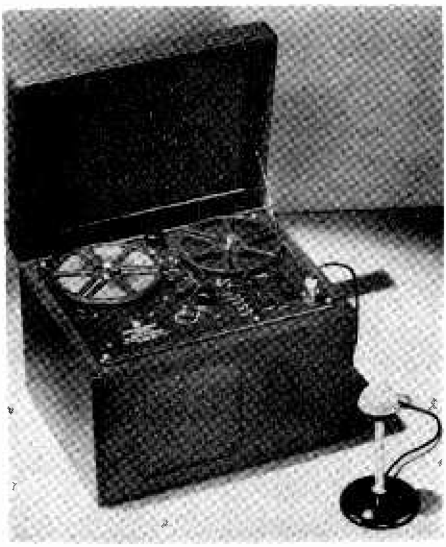
The number of grooves or lines per inch is determined largely by the signal level at which the recording is to be made and by the required width of the groove. The required width of the groove depends upon the radius of the tip of the playback needle and the groove depth necessary to insure faithful tracking by this needle.

Referring to Figure 7A, the groove width w, is determined by the depth d, at which the cutting stylus is operated. If the groove is too shallow, there is danger that the pickup needle will jump out and slide across the face of the record, or jump from groove to groove. Figure 7B shows that the width should be such that the tip of the pickup needle contacts the side walls of the groove about 0.5 mil below the surface of the record. This depth of contact prevents the needle from being affected by the light surface scratches which would add to the over-all record noise. To minimize wear, the tip radius of the cutting stylus should be slightly less than that of the pickup needle

Portable magnetic wire recorder and reproducing unit.
Courtesy Brush Development Company

so that the bottom of record groove is cleared and does not form the major support for the reproducer.

Since most pickup needles have a tip radius of from 2 to 2.5 mils, the groove must be 4.5 to 5.5 mils wide. A rough check of this width can be made by running a short test cut and then examining



Portable magnetic tape receiver and reproducing unit.
Courtesy Brush Development Company

the appearance of the chip which should be dark and about the thickness of the human hair. If the cut is too deep, the chip will be very black and thick, while if the cut is too shallow, it will be gray in color and very silky.

As an example of typical values employed in practice, assume a groove width of approximately 5 mils and that the amplitude of the average cutter excursion is 0.77 mils. To prevent the stylus breaking through the wall from one groove to the next, a suitable allowance for the high amplitude excursions of the cutter during loud signals gives a value of 2.43 mils. As the cutter swings to both sides of its unmodulated position, its peak-to-peak excursion is 4.86 mils. Also, a 1 mil safety factor is allowed as a further precaution against the break through due to overmodulation, therefore the total surface space needed for each groove is 5 + 4.86 + 1 or 10.86 mils. Since 1 inch equals 1000 mils, the recording level and groove width conditions assumed in this example will permit the cutting of 1000 ÷ 10.86 = 92 grooves per inch.

COMPENSATION CIRCUITS

The magnetic and crystal types of cutting heads differ in their actions in such a way that it is necessary to employ some type of compensating network between them and the output of the amplifier in order to make the crystal head operation correspond to that of the magnetic head, or vice versa.

With the crystal type cutter, the amplitude of the stylus movement is proportional to the audio voltages applied, but is independent of their frequency. That is, with a constant applied voltage, the stylus displacement (swing) will be the same for all frequencies in its operating range. This action is illustrated in the drawing of Figure 8A, and is called "constant amplitude" recording.

With a magnetic cutter, the amplitude of the stylus movement varies inversely with the frequency of the applied audio voltage, as shown in Figure 8B, because the velocity (speed) of the stylus is independent of the frequency. Therefore, the groove undulations are cut with greater magnitude at the low frequencies than at the higher frequencies. This type of cutting is termed "constant velocity" recording.

Present commercial practice employs a combination of these two types of recording wherein the constant amplitude method is used up to some chosen "turnover frequency", such as 500 or 800 cycles, and above this the constant velocity system is used. To cause this change in the frequency response of a particular cutter requires the insertion of compensation circuits.

The reasons for employing this combination of methods, is that when a magnetic cutter is used, the range in amplitude of stylus swing over the cutter frequency range is so great that it prevents efficient use of the record area. For instance, suppose it is desired to make a record with frequencies ranging from 50 to 5000 cycles per second, and the normal excursion of the cutting stylus is to be about 0.8 mil, as in the previous example. With the amplitude of cutter swing inversely proportional to the frequency, if the recording level is set for a normal excursion of 0.8 mil at 50 cps, then at 5000 cps the excursion will be 50/5000 or 1/100 of 0.8 = .008 mil. This is only eight millionths of an inch, which is less than the variations in the record material itself, and therefore, this frequency will not record.

If the level is set for a cutter excursion of 0.8 mil at 5000 cps, then a variation of 5000/50 or 100 times 0.8 = 80 mils would be the theoretical value required at 50 cps. Even if this amplitude of cutter displacement could take place, the recording would have to be made with less than 3 grooves per inch, an entirely impractical arrangement.

However, with the recording level adjusted for an 0.8 mil excursion at a turnover frequency of say 800 cps, the amplitude at 5000 cps will be 800/5000 of 0.8, or 0.128 mil. Actually, the cutter swing will be somewhat greater than this at the high frequencies, because it is present practice to operate the audio amplifier with a rising response at high frequencies to obtain a better signal-to-noise ratio in this region.

With this turnover frequency, all signals which are less than 800 cps would normally cause the cutter to swing too far and overcut into adjacent grooves. However, with a suitable filter circuit between the cutter and amplifier, the output of the latter can be reduced as the frequency decreases, so that all values below the turnover produce groove variations of the same amplitude, thus eliminating the danger of over-cutting.

Since the crystal type cutter is inherently a constant amplitude device, no special filter arrangements are necessary when it is desired to make a constant amplitude recording. But to make a recording of the commercial type having the combination of characteristics described above, the coupling circuits to the driving amplifier must be selected so that, above the turnover frequency, the amplitude of the cutter excursions will decrease the desired amount as the frequency rises.

MAGNETIC RECORDING

The first experiments with magnetic recording of sound were performed in 1898 by Valdemar Poulsen who used a pair of magnets to magnetize a steel wire as shown in Figure 9. The magnets were energized by audio or voice frequency currents, and as the wire moved along, succeeding short sections of it were magnetized to different intensities in accordance with the varying a-f signal. During playback, this wire was moved past induction coils arranged like the electromagnets, and the varying field around the magnetized wire induced a-f voltages in the coils. These voltages, were then applied to a headphone or similar device which reproduced the original sound.

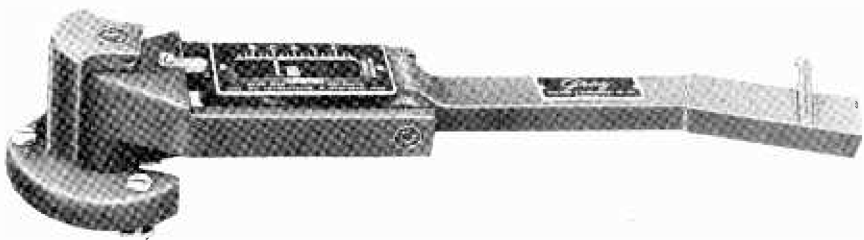
Poulsen's device was bulky and noisy, and his method of magnetizing required the wire to travel at such a great speed that it broke frequently, while the electromagnet pole-pieces wore so rapidly that frequent replacement was necessary. Since that time a great many improvements in the art of magnetic recording have taken place, and the fidelity that may be achieved with present commercially available equipment compares favorably with that which can be accomplished with the disk cutting equipment described in this lesson.

The magnetic method by no means eliminates the basic problems of sound recording which were mentioned in connection with disk cutting. In every recording process there exists an inherent minimum noise level which is due to differences in the minute structure of the recording medium (the disk, wire, or film). Also, all systems are limited as to maximum amplitude and to the highest frequency that it is practical to record. Further, the minor problems of wow and flutter, due to changes in speed, and of wear of the recording medium are ever present.

Compared to disk recording, (1) Magnetic recording offers possibilities of superior quality of reproduction with relatively simple equipment. (2) Magnetic recording can be erased easily and the medium re-used as often as is desired. (3) The magnetic recording process is relatively simple and is comparatively independent of temperature changes, high humidity, etc., so that the unskilled operator may quickly learn the technique. (4) Magnetic recordings of from one half hour to several hours in length may be made on a small spool of material (wire or tape), which requires only a comparatively small amount of storage space.

On the other hand, the disk records have the advantage of greater convenience when it is desired to record or to play individual selections of short duration. Also, new disk materials and methods of manufacture are being investigated, one result of which is the long playing (LP) almost noise free disk made of vinylite and having a playing time of 45 minutes at 33⅓ rpm.

Before taking up the details of the modern magnetic recording process, a brief review of a few of the fundamental ideas of magnetism may be of benefit.



Adjustable pickup arm for the reproduction of laterally cut recordings and transcriptions.
Courtesy Gray Research & Development Company

MAGNETIC DIPOLES

According to the German physicist, Wilhelm Weber, the various substances which can be magnetized are made up of minute molecular magnets, called dipoles. When the substance is not magnetized, these dipoles are assumed to have their axes pointing at random in all directions so that their fields neutralize each other. This condition is illustrated in Figure 10A, which represents the greatly enlarged molecules of a piece of iron or steel. When the bar is placed in a strong magnetic field, due to the attraction of unlike magnetic poles, the molecules are caused to line up as shown in Figure 10B. Here, all like poles are pointing the same way, their individual fields add to each other, and the bar as a whole becomes a magnet with free or induced poles at its ends.

Complicating this process of magnetizing an iron bar is a phenomenon known as the "demagnetizing effect". To understand this action, suppose that a bar to be magnetized is placed in the field of a large horseshoe permanent magnet, as shown in Figure 11. Due to the field of the permanent magnet, the bar will have the poles N′ and S′ induced in it. However, these poles give rise to a new field in the bar, as indicated by the dotted arrow. This new field opposes, and therefore tends to weaken the field due to the permanent magnet; and the actual total magnetizing force in the bar is not as great as it would be if this demagnetizing field were not present. The demagnetizing field is small in a long thin bar, but in a short thick bar it is very strong

The degree to which an iron bar becomes magnetized by a magnetic field, that is, how far the little dipoles in Figure 10 will turn, depends upon the strength of the applied field. If the latter is sufficiently strong, they will be lined up completely as in Figure 10B, and the bar is said to be saturated.

Hence, it appears that the dipoles do not move freely, and this idea is further substantiated by the fact that once they are lined up, they tend to remain more or less fixed in that condition. This property of a substance to retain its magnetism is called retentivity. Soft iron may be magnetized by means of a comparatively weak field, but when this field is removed, the dipoles begin turning around due to the demagnetizing field created by the induced poles. This demagnetizing field decreases in strength as the dipoles turn around, and the magnetism of the iron soon drops to zero. Thus, soft iron has poor retentivity.

On the other hand, a strong field is required to magnetize hard steel; but when the field is taken away, the dipoles do not turn readily under the demagnetizing action of their poles, and consequently the steel, having high retentivity, remains permanently magnetized.

The permanent magnet in Figure 11 is said to exert a magnetizing force on the region surrounding it and this force, also called the field strength or field intensity, is defined as: The force in dynes acting upon a unit north pole at a specified point in the field. (The dyne is a unit of force). Magnetizing force is denoted by the letter H, and is equal to the force F exerted on an ideal pole divided by its pole strength m, that is,

$$H = \frac{F}{m}$$

and its unit of measurement is the oersted (gilberts per centimeter). The magnetizing force H corresponds to volts per centimeter in an electrical circuit.

In Figure 11, the magnetic field of the permanent magnet is assumed to be made up of many lines of force called magnetic flux. The flux density, or number of magnetic lines of force per unit area at right angles to the lines, determines the magnitude of the voltage that will be induced in a conductor moving through a particular point in a magnetic field. In a magnetic circuit, the total flux may be thought of as the equivalent of the current in an electrical circuit.

The amount of opposition or resistance to magnetic flux, offerred by a particular substance, depends upon the property known as "reluctivity" as well as the dimensions of the object in question. Therefore, the amount of flux in a magnetic circuit is directly proportional to the magnetizing force and inversely proportional to the reluctivity. Letting σ denote reluctivity, and B the flux density, these relationships may be shown by:

$$B = \frac{H}{\sigma}$$

Since the reluctivity of most materials used in magnetic apparatus is less than that of air, and since the reluctivity of a vacuum (which is practically that of air) has been arbitrarily taken as unity, to simplify calculations usually the reciprocal of reluctivity, known as permeability, is used by engineers in designing electrical and magnetic equipment. Permeability may be defined as a measure of how much better a given material is than air as a path for magnetic lines of force. Its symbol is μ, and substituting μ for $1/\sigma$ in the above equation gives:

$$B = \mu H$$

HYSTERESIS

Suppose an unmagnetized bar of steel is placed in the field of force of an electromagnet and the flux density noted for various values of magnetizing force. When these values are plotted, they result in a curve like that of oc in Figure 12. This is called a B-H curve, and shows the change of flux density with increases of field strength which when raised to a value h, causes a flux density of value a. However, if H is now reduced to zero, the flux density will drop only to the value b.

If the magnetizing force had been increased to point c, and then reduced to zero, the flux density would have decreased to the value at point d. In each case there is still a definite amount of flux density remaining in and about the steel bar, even after the magnetizing field of the electromagnet is removed. This induced magnetism which remains is called residual flux density, and is due to the retentivity of the steel bar.

Transcription turntable for use in broadcast station studios.
Courtesy Gray Research & Development Company

To reduce B to zero, it is necessary to apply a magnetizing force in the opposite direction and of a value shown at point e in Figure 12. This value of H, called the "coercive force", must be maintained to hold B at zero. If this coercive force is removed, B will return to a value near point d.

If H is now increased further in the reverse direction, a point f will be reached as shown; and when the magnetizing force is again reduced to zero, there will remain a residual flux density equal to the value g in the figure. By reversing H once more and increasing it to its original maximum strength, the value of B is reduced from g to zero at h, and then it increases to c, following the route ghc, as shown.

Thereafter, as H is varied from maximum in one direction to a maximum in the other direction and back, the instantaneous values of B will be as shown by the loop or curve cdefghc, the dimensions of which are determined by the amplitude of H and the material of which the bar is made. This behavior has been ascribed to the lack of freedom of the molecular dipoles within the steel bar, and is called magnetic "hysteresis" from a Greek word meaning to lag behind.

MODERN MAGNETIC RECORDING METHODS

As mentioned in the explanation of Figure 12, a certain amount of residual magnetism remains in a piece of magnetic material after the removal of the magnetizing force. The same result is accomplished whether the magnetic field is reduced to zero or the material is removed from the influence of the magnetizing force. If a series of values of H are applied to a bar of iron or steel, the field being reduced to zero after each application, and the corresponding values of residual density noted, the results will be illustrated by the residual magnetism curve in Figure 13. Here, the residual flux density Br, is plotted against the original magnetizing force H. Thus, at any instant, the bar of steel or iron becomes magnetized by an amount depending directly upon the magnitude of the applied field.

When magnetized, a short piece of steel or iron bar normally has an induced pole at each end, and the lines of magnetic flux are as shown in Figure 14A. However, it also is possible to magnetize that same bar so that it has a pole in the middle as well as at each end, with the flux lines appearing as in Figure 14B. Furthermore, a long bar, rod, or length of wire may be magnetized so that it has a large number of unequally spaced poles of various strengths, as in Figure 14C.

This latter effect may be accomplished by moving a wire (or a metal coated tape) through a relatively short, changing magnetic field, in a manner like that explained for Figure 9. As the wire moves, each short section, corresponding in length to that of the exciting field, becomes magnetized in a direction and by an amount which depends upon the instantaneous density of the varying field.

To correct the difficulties attending Poulsen's method, a recording head which operates on the plan of Figure 15 has been developed. The electromagnet has a core with the shape shown and includes a small air gap about .001 of an inch in width. Due to the a-f current in the coil, an alternating flux is produced in the core, and the air gap forms part of the magnetic circuit. A hole in the core permits the wire, with a diameter of about .004 inch, to move through it from left to right as indicated.

Assuming that the flux density B is constant throughout the magnetic circuit, the magnetizing force at any point varies inversely as the permeability. That is, the formula given previously may be written:

$$H = \frac{B}{\mu}$$

and as the permeability of the pole pieces is about 1000 times that of air, the magnetizing force of the gap is therefore approximately 1000 times as strong as that in the interior of the core.

Thus, when a particular portion of the wire is inside the pole piece, the magnetizing force acting on it is practically zero, but when this portion of the wire passes into the air gap b, it is magnetized by the concentrated field existing there. As the wire continues moving, the magnetized section passes into the field free interior of the second pole piece c.

Because the air gap is extremely short, only a very small portion of the wire is affected at any instant. The advantage of this ar-arrangement over that of Figure 9 is that shorter wavelengths (higher frequencies) can be recorded, and at the same time the use of reduced wire speeds is made possible.

Usually this same arrangement is used for playback of the recording from a magnetized wire. The coil in Figure 15 is switched to the input of the audio amplifier, the output of which is then connected to a speaker. The magnetic field of the magnetized wire varies from point to point in accordance with the recorded sound and as each small section of wire passes through the gap, a flux of corresponding intensity and polarity is produced in the core. This changing flux cuts the turns of the coil and induces an emf which is amplified and applied to the speaker, thus reproducing the recorded sound.

RECORDING BIAS

If an a-f signal is applied to a magnetic recording head in the simple manner described above, a certain amount of distortion of the recorded waveform is produced. This is due to the action indicated by the curves of Figure 13, where the sine wave i represents the input signal to the recording head, and the curve o shows the shape of the magnetic flux produced on the wire. The distortion occurs because the residual magnetism curve is not linear over its entire length. To prevent this distortion, it is necessary to add some sort of bias arrangement which will provide operation on the linear portion of this curve.

One arrangement, called d-c bias, employs a permanent magnet, or an electromagnet carrying d-c, through which the wire passes before or at the same time that it moves through the recording head. This biasing magnet imparts to the wire a residual magnetism of a value such as is indicated by point d in Figure 16. Then as the input signal varies between points a and b, it causes the wire to be magnetized to various degrees lying between points c and e on the curve. Since this portion of the residual magnetism curve is more linear, the distortion of recorded waves is reduced.

A second biasing method employs a constant-amplitude high-frequency signal (30 kc to 60 kc), which after being mixed with the modulating audio signal, is applied to the coil of the recording head. Because the frequency of this bias signal is above the audible range, it has been given the name "supersonic bias". The audio signal causes the axis of the high-frequency signal to vary about the zero line in accordance with the a-f waveform and the resulting magnetism of the wire, due to this combination of a-f and supersonic bias, is illustrated in Figure 17.

Since the air gap of Figure 15 is long enough to contain several negative and positive peaks of the supersonic bias at any instant, the total flux in the gap will depend upon the sum of several fluxes due to the various high-frequency peaks. In Figure 17, the projection of the positive peaks on the residual flux curve at each instant of the audo signal produces curve m, and the projection of the negative peaks forms curve n. The addition of m and n gives curve o, which represents the total magnetism residing in the wire after leaving the gap.

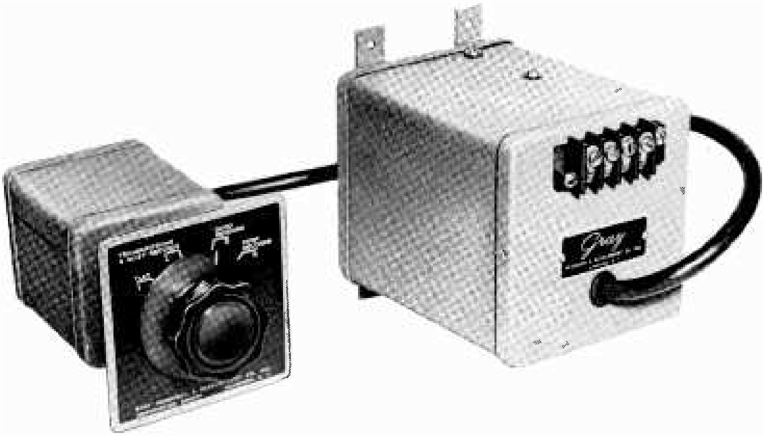
This method virtually eliminates that part of the Br—H curve which lies near the origin O, and the width of the eliminated section can be adjusted by changing the amplitude of the bias signal. An advantage of this method over that using d-c bias is that both linear sections of the Br—H curve are employed, thus permitting recording of a greater a-f signal amplitude.

ERASURE

It was mentioned above that the recording on a wire or tape can be erased and the wire reused for another recording. This is accomplished by the use of an erase magnet through which the wire passes before arriving at the recording head. With systems using d-c biasing, these two operations are performed by the same magnet. In this case, the erase magnet magnetizes the wire to saturation, this is, point c in Figure 12, and when the wire leaves this d-c field, the magnetism drops to point d. Thus, the modulation has been removed and the wire retains the required value of residual magnetism for proper operation at point d in Figure 16.

When the supersonic or a-c biasing method is employed, erasure is accomplished by means of demagnetization rather than by saturation. It has been mentioned that the flux density of a material in an a-c field follows a loop like cdefghc in Figure 12, the amplitude of which depends upon that of the exciting field. However, there must be some point on this loop where, if H were reduced to zero, the flux density would drop to zero also.

As this point is hard to find, it is easier to demagnetize the material by causing H to decrease gradually in the magnitude of its variations as it goes through successive cycles, until the loop collapses on the origin O. This is done easily by gradually withdrawing the material from an alternating magnetic field to which it has been subjected. Therefore it is common practice to energize the erase coil, which precedes the recording head, with the same supersonic signal that is mixed with the a-f signal to provide the a-c bias.



Broadcast studio Equalizer for improving the response characteristics of different recordings and transcriptions.
Courtesy Gray Research and Development Company

FREQUENCY RESPONSE

Analysis shows that the amplitude of the pickup output voltage varies directly with the flux density in the wire, the velocity of wire travel, the width of the air gap, and the recorded frequency. Thus, if a wire which contains two alternating fields, both of the same magnitude but one having twice the frequency of the other, is passed through a reproducing head, the higher frequency will induce an emf which is twice that induced by the lower frequency. Therefore, since the voltage output of a magnetic recorder decreases with frequency, there exists a limit to the low frequency response obtainable with a given unit.

To improve the low frequency response, the flux density of the wire can be increased if a material having high retentivity is employed as the recording medium. However, at high frequencies (short wavelengths) the adjacent magnetic poles are so close that they produce a strong self-demagnetizing effect which tends to reduce the higher frequency output voltage. This demagnetizing effect depends upon the coercive force of the material, such that those materials having a high coercive force experience the least demagnetization. Furthermore, the high coercive force materials have a low retentivity, and therefore, in practice, some low-frequency output amplitude must be sacrificed in order to extend the upper frequency range by the use of high coercive force wire.

The speed of the wire through the recording head has little effect on the low frequencies, but does have a considerable effect upon the high-frequency response. This is due to the fact that for a given frequency, the recorded wavelength varies directly with the wire speed. When the wavelength approaches the length of the air gap, a sharp drop-off in the response occurs. Thus, a high wire speed and a short air gap are requirements of a recorder having high frequency response.

Commercial magnetic recorders operate at speeds ranging from about 2 feet per second up to 6 feet per second with air gaps of from 0.0005 inch to 0.0015 inch in width. Hard drawn carbon steel wire with a coercive force of about 50 oersteds, gives a frequency response up to 3000 cps, while stainless steel wire with a coercive force of 175 oersteds will give recordings that are superior to the common shellac coated disk records used for commercial pressings.

MAGNETIC TAPE RECORDING

Basically, recording on wire or magnetic coated tape is the same. That is, the magnetic materials drawn past a recording head become and remain magnetized, and the amount of magnetism remaining in the materials at each instant is determined by amplitude of the audio signal applied to the recording head.

The tapes in use today are made with a base of flexible non-magnetic material, such as paper or plastic, that has a coating of magnetizable material, such as iron oxide, that has been prepared in powder form. The most important factors governing the quality of magnetic tapes are: (1) the magnetic characteristics of the coating, (2) uniformity of the coating thickness, (3) excellence of dispersion, (4) smoothness of surface of base material, and (5) smoothness of surface of the coating. Any roughness in the surface results in random audio rates of variation of the flux in the pickup head during playback and consequently is heard as background noise. Because of these factors, accurate control in the production of tapes is required, and in this respect, wire has the advantage in that it is comparatively simple to manufacture.

The width of recording tapes is determined on the basis of breaking strength, convenience in threading, and avoidance of tendencies to skew, the usual width being approximately ¼ inch. Due to its width, the tape presents a greater cross sectional area to the record-playback head than does the wire, and therefore, comparable amplitude of recording can be obtained with the tape being driven past the head at a lower speed. While providing about the same frequency range as the wire systems, most tape devices operate at speeds of 7½ or 8 inches per second as compared to the higher speeds for wire recording, as mentioned above.

A problem associated with the use of wire is that when this homogenious magnetic medium is coiled on itself for storage after a recording has been placed on it, part of the signal recorded on one turn will transfer itself to the adjacent turns, thus lowering the signal-to-noise ratio. In order to avoid or minimize this transfer problem, the wire should be of a material with a Br—H curve on which: (1) the lower bend occurs as far away from the origin as possible, (2) the linear portion is as steep as possible, and (3) the flux density required for saturation is as low as possible. This transfer does not occur with magnetic tapes because the adjacent turns are separated by the non-magnetic base material between them.

Wire has the advantages of high strength (infrequent breaks), and since less tape than wire can be wound on a reel of a given size, the wire requires less storage space for a given recording time. This last advantage is balanced out somewhat by the lower tape speeds employed, and the recent development of tapes on which two or more parallel adjacent channels can be impressed. One model of a tape recorder using this type of tape is so constructed that one channel is used in the forward direction and the other in the reverse direction. Additional factors favoring tape are that it offers greater convenience in handling, splicing, and editing.

MAGNETIC RECORDER CONNECTIONS

The block layout of a typical magnetic recorder, given in Figure 18, includes a combination record-playback head, and a supersonic oscillator which supplies a signal used both as an a-c bias and to energize the erase coil. A mixing network combines the output of this high frequency oscillator with the a-f modulation signal, and then applies them to the recording head. The audio amplifier, together with two frequency equalizing networks, supplies an audio signal of the desired amplitude and frequency characteristics to energize the recording head during recording, and to operate the speaker during playback.

Because the magnetic recording head is mostly inductive, its impedance increases with frequency, and it is necessary to use an amplifying circuit with a rising characteristic in the high-frequency region in order to prevent a decrease in recording head current with increase in frequency. Also, as has been mentioned, being normally lower in response than the middle frequencies, the low frequencies must be emphasized. This is the function of the equalizing networks. Pre-equalization (equalization during recording), to extend the higher frequency range, can be used only to a limited extent before overloading. Since this is insufficient to provide the required increase of the low frequencies, post-equalization (equalization during playback) is also employed. However, post-equalization is undesirable for the high frequencies because most noise lies in this region. Thereore, the best arrangement has been found to be a combination of the two, as shown in the diagram.

When the four-gang, two-position, record-listen switch is in the R (record) position, the microphone is connected to the input of the amplifier, the output of which then connects through the pre-equalizing network to the mixing network; and after being combined with the supersonic bias signal, drives the recording head. When the switch is in the L (listen) position, the signal picked up from the wire by the playback head, is coupled through the post-equalizing network to the amplifier, the output of which then drives the speaker.

IMPORTANT WORDS USED IN THIS LESSON

CUTTING HEAD—That part of a sound recorder that cuts the groove into the blank or disk.

FIELD INTENSITY—The force exerted at a given point in a magnetic field on a unit magnet pole. Usually represented by the letter H.

FLUX DENSITY—The number of magnetic lines of force per unit area at right angles to the lines. Usually represented by the letter B.

HILL-AND-DALE—A type of disk recording in which the groove is uniform in direction and width but varies in depth in accordance with the recorded sound impulses.

HYSTERESIS LOSS—The energy loss that occurs within a magnetic substance due to internal friction when the magnetization is varied rapidly. This loss usually is manifested as heat.

LAND—The space on a disk recording between two adjacent grooves.

LATERAL CUTTING—A type of disk recording in which the cutting stylus moves laterally (from side to side) in the plane of the disk, and the depth of the groove is practically constant.

MAGNETIC DIPOLES—A term often applied to the molecules of a magnetic material, which are believed to be tiny magnets possessing a north and south magnetic pole.

MAGNETIC HYSTERESIS—The internal friction occurring within a magnetic substance due to which the magnetization lags the exciting force when the material is placed in a varying magnetic field.

MAGNETIC TAPE—A narrow ribbon of paper or plastic material on one side of which a thin layer of finely granulated iron oxide or other readily magnetized material is deposited.

PHONOGRAPH PICKUP—An electric-mechanical device which converts the variations in the grooves of a phonograph record into corresponding electrical pulses.

PLAYBACK—Reproducing a recording immediately after it has been cut.

PRESSING—A phonograph record produced by stamping or pressing the record blank with a master.

RECORDING—The process of making a permanent physical register of a speech, musical selection, or other series of sounds.

RECORDING DISK—A smooth-surfaced disk or blank on which a sound recording is made.

ROCHELLE SALT—A salt composed of sodium potassium tartrate which in the crystalline form exhibits the property of piezo electricity to a marked degree. Used in crystal cutting heads, microphones and phonograph pickups.

SOUND RECORDER—A device for impressing a physical record of a series of sounds on a base or carrier, such as a disk, a steel wire, or a magnetic tape.

STYLUS—A specially shaped steel needle or crystal (sapphire or diamond) that actually cuts the groove into the recording disk or blank.

SUPERSONIC—A term applied to frequencies above the audible range.

TRANSCRIPTION—A high-fidelity recording usually inscribed on a 16 inch, 33⅓ rpm record.

TURNTABLE—An electric or spring motor-driven platform on which the recording or reproducing disk or record is placed.

WOW—The variations in pitch noticeable during the reproduction of a recording, and caused by slight recurrent changes in the speed of the turntable.

STUDENT NOTES

STUDENT NOTES

STUDENT NOTES

STUDENT NOTES

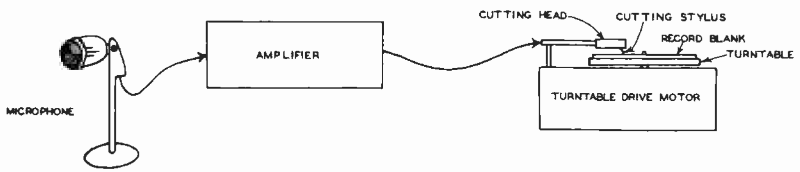


FIGURE 1

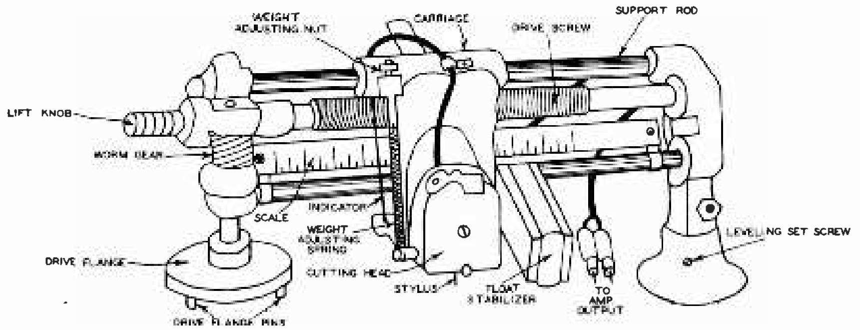


FIGURE 2

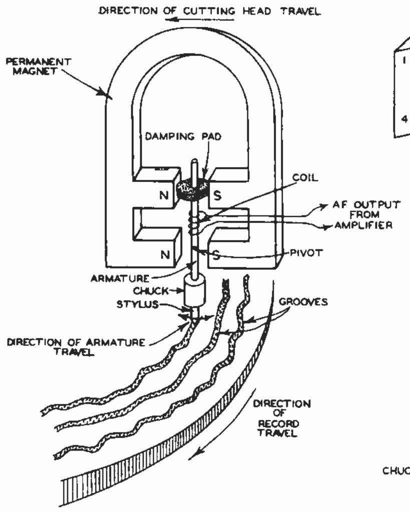


FIGURE 3

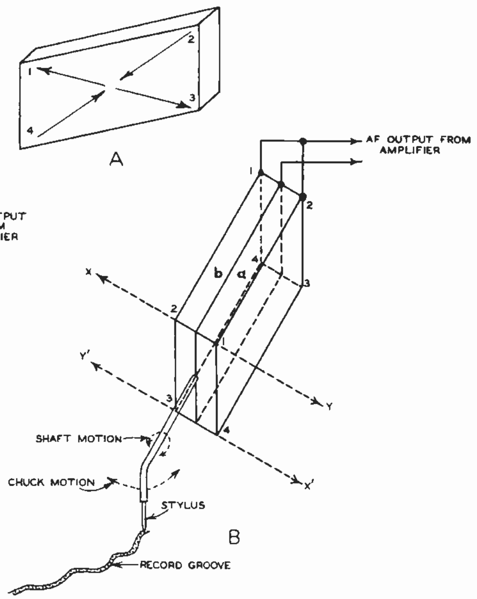
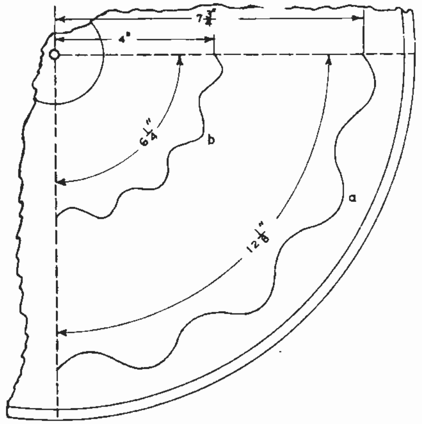


FIGURE 4

RRT-6



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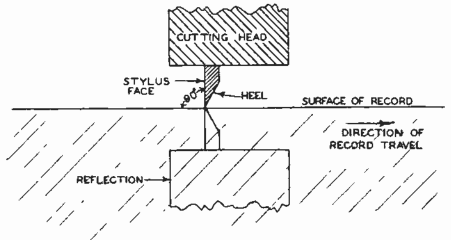

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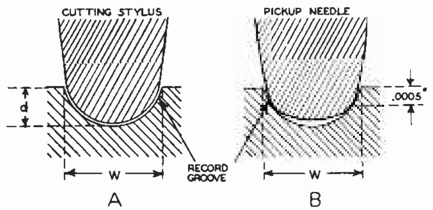

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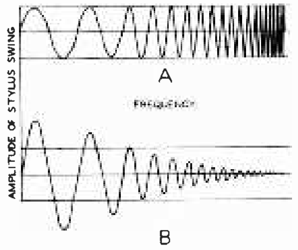

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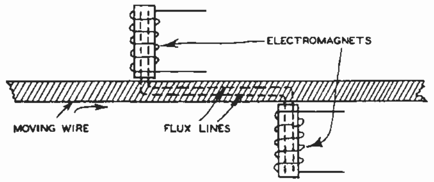

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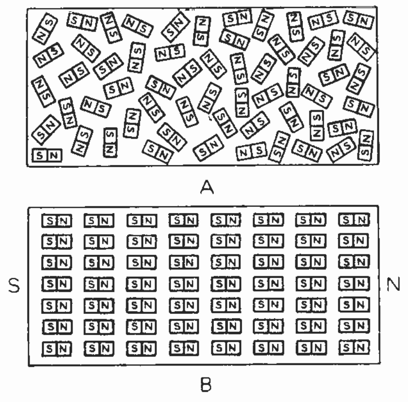

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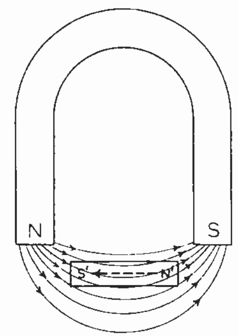
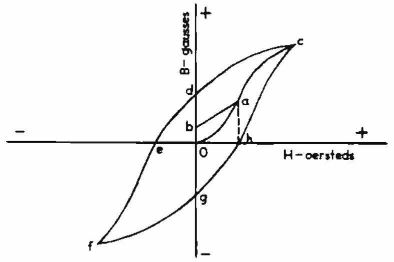


RRT-6

FIGURE 11



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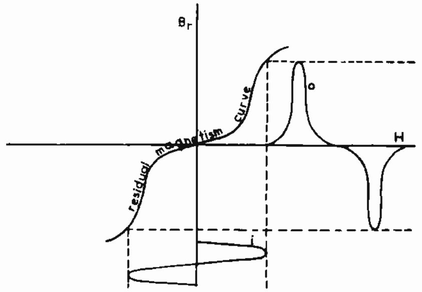

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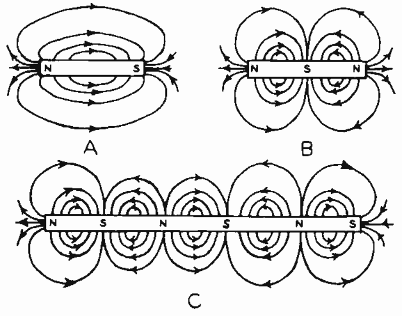
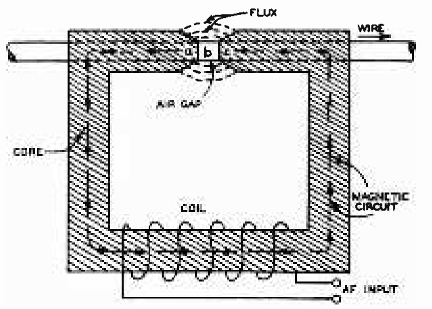


FIGURE 14



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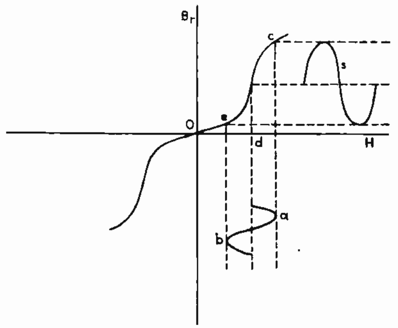

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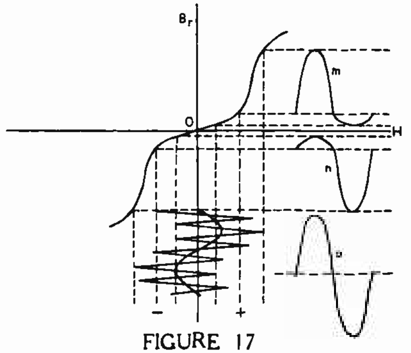

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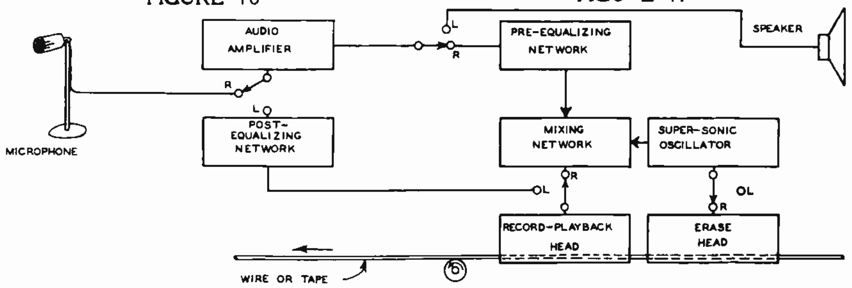


FIGURE 18

FROM OUR *President's* NOTEBOOK

GOOD LOSERS

Most men can win gracefully, but to lose with a smile is not such an easy thing. Yet in this world no man can expect to be always a winner, and he had better learn to lose as cheerfully as he can.

It must always be remembered that the man who is a good loser is not necessarily indifferent to the result of his efforts. He will never lie calmly down after defeat. On the contrary, he will make every loss a stepping stone to victory. He will go over the lost game most carefully and see where he failed; and he will learn by his defeats. He will look far ahead and plan for future victories even while the defeat is fresh in his mind.

Yours for success,

E. B. DeVry

PRESIDENT

STUDENT NOTES

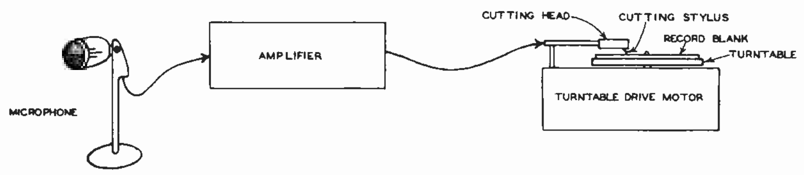


FIGURE 1

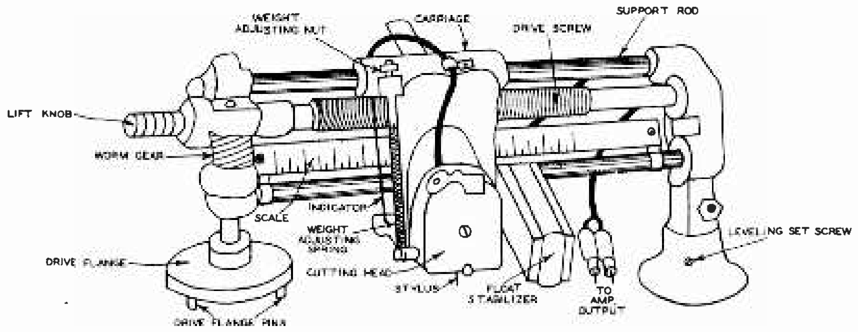


FIGURE 2

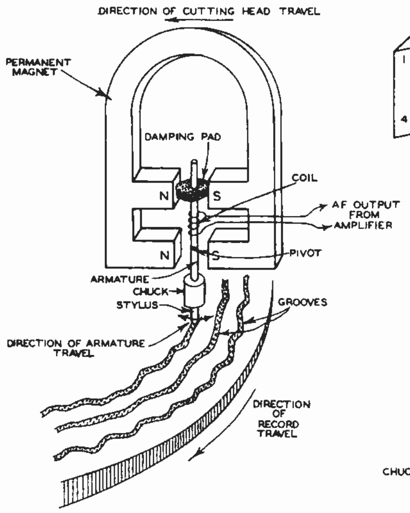


FIGURE 3

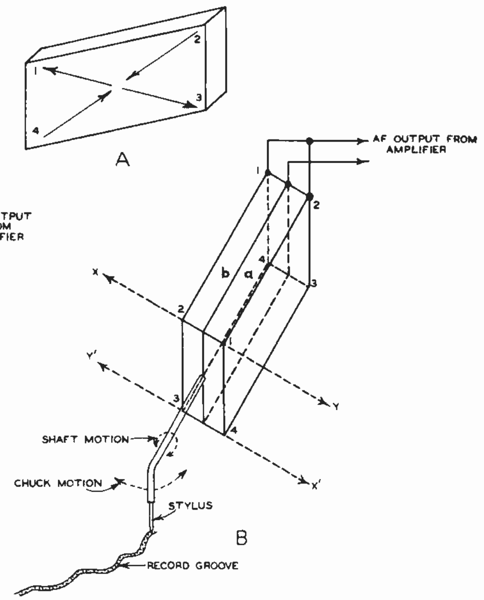
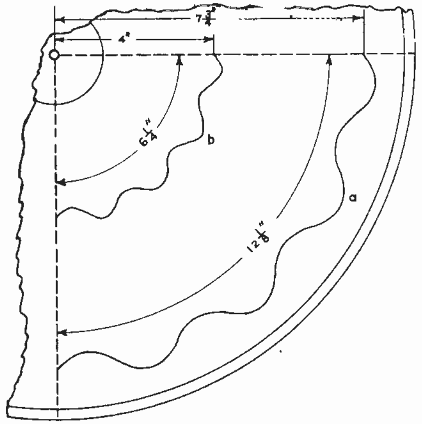


FIGURE 4

RRT–6



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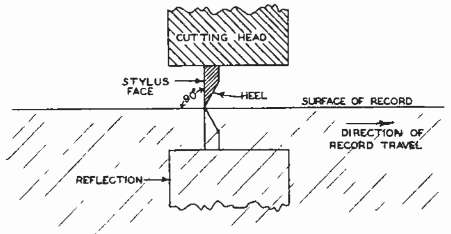

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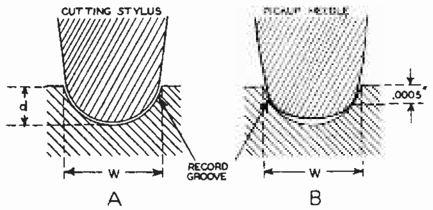

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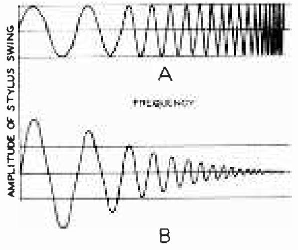

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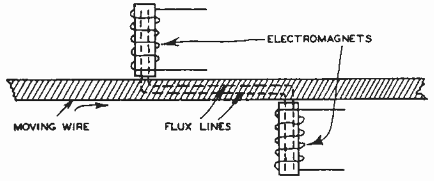

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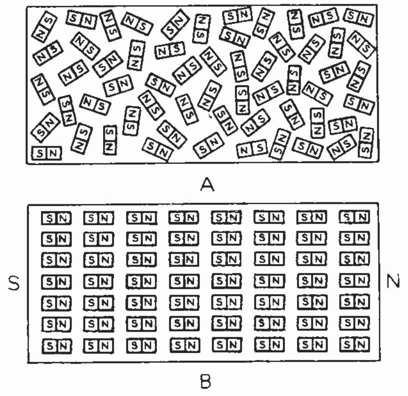

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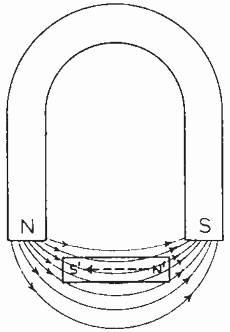
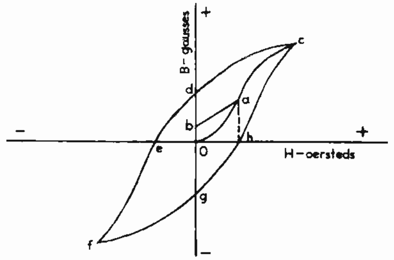


RRT–6

FIGURE 11



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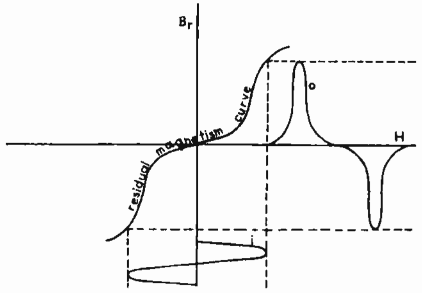
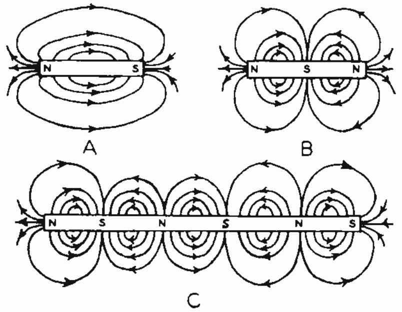


FIGURE 13



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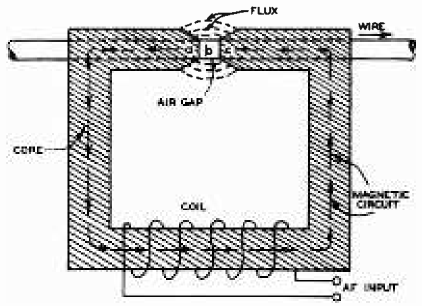

FIGURE 15

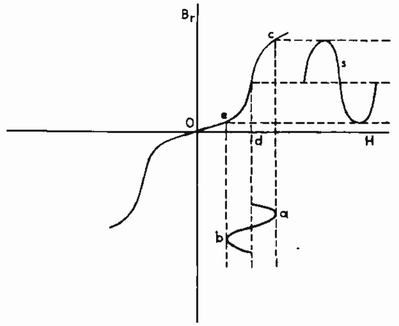

FIGURE 16

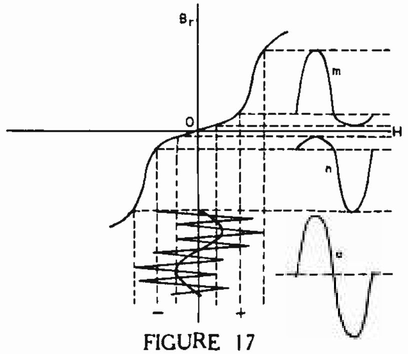

FIGURE 17

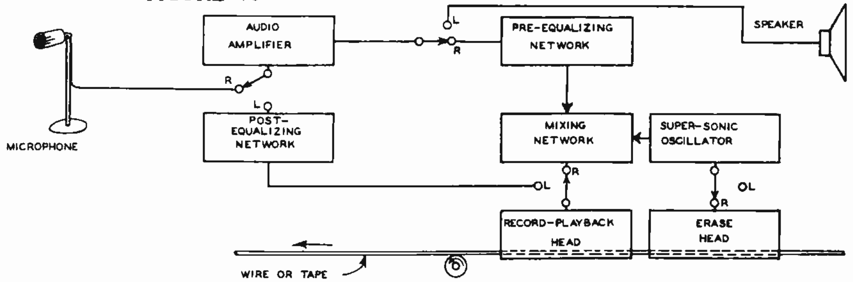

FIGURE 18