

How to service tape recorders

C. A. Tuthill

HAYDEN

how to service TAPE RECORDERS

by C. A. TUTHILL



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PREFACE

In recent years, magnetic tape recorders have grown into highly developed, versatile instruments which are used on a very wide scale. A great variety of models are available at the present time, from the small portable machines to professional broadcast-station equipment and multichannel special-purpose recorders. Tape recorders have not only found acceptance in business, scientific laboratories, the professions, military services, and recording studios, but have also become increasingly popular with experimenters and audiophiles, who have come to use tape machines as an integral part of high-fidelity sound recording and reproducing equipment. Because of this widespread use, radio and television servicemen are frequently being asked to repair and maintain these complex electromechanical devices, on which little information is generally available.

This book was written with the requirements of these widely divergent users in mind. It presents, in a balanced manner, an introduction to the basic principles of magnetic recording as well as practical service information on many popular tape machines. The theoretical discussion in the first three chapters has been kept free of involved mathematics, in an attempt to present a simple but adequate account of magnetic recording principles and applications, making free use of graphical analysis and simplified illustrations. Tape recording mechanisms are discussed in Chapter 4, while the electronic requirements of tape recorders and their accessories are described in Chapter 5. In both chapters a number of widely differing commercial recorders are analyzed in detail. The practical mechanical and electronic information, presented in Chapters 4 and 5, is supplemented in Chapter 6 by detailed maintenance and repair data on a number of popular tape-recording machines. Chapter 6 also gives a logical step-by-step procedure for systematic troubleshooting and repair of tape recorders, by a detailed analysis of representative models, covering frequently occurring troubles and preventive maintenance requirements.

While thus being a convenient reference manual for servicemen, the book will also prove useful to the layman interested in the principles, operation, and maintenance of magnetic tape-recording machines. Experimenters and high-fidelity enthusiasts will find many suggestions on improving their own tape equipment and expanding its capabilities. They will also find the most important technical characteristics and prices of a wide cross-section of commercially available recorders and

tapes in the Appendix of the book. The material in this Appendix has been reproduced from an issue of *Audio Record* magazine by the permission of Audio Devices, Inc., New York City.

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Chapter 1

INTRODUCTION

The magnetic tape recorder has contributed a new and superior method of recording to the field of communications, a method far more flexible and economical than any heretofore known. The impact and importance of tape recorders is demonstrated by their acceptance by all major television and radio broadcast stations, the major recording and motion picture studios, Military Services, and hundreds of manufacturers both here and abroad.

This development did not come about by accident; it is founded on the many outstanding advantages which tape recording offers over other recording methods. That tape sound-quality excels, that expensive processing is not required, that playback is immediately available, and that tapes may be erased and used over and over again at no additional cost, are all factors which have helped to establish tape as the champion in the sound recording field.

The economy of tape recorders, both in construction and use, is perhaps their most outstanding characteristic. Despite their high quality of reproduction, tape machines require far less power than other types of recorders. Furthermore, tape recorders are readily portable, since their construction requires a minimum of weight. Thus, on-the-spot scenes can be recorded for later reproduction, a facility which is constantly used by all radio broadcasting companies. Besides remote pickup recordings, many of the major radio shows are taped prior to broadcasting. By editing and correcting the show during production, a finer show results without regrettable and costly mistakes on the air. Editing of programs is rapid and easy, requiring but a pair of scissors and tape for splicing. Amateurs, too, make wide use of this flexibility. Beyond this convenience, the greatest economy is derived from the erasure feature, which permits a single tape to be erased and reused hundreds of times. Considering all these factors, the rapid growth of commercial, military, and amateur markets for tape recorders is readily understandable. Thus, with the introduction of tape recording, a truly new business with a growing future and an excellent career incentive has arrived almost overnight.

Origins and Development

The idea of magnetic recording is not new. In 1898 the first magnetic recording machine, the *Telegraphone*, was patented by Valdemar Poulsen, the "Edison of Denmark". However, Poulsen's initial efforts were not followed immediately by much further progress; the sound quality then obtained was poor, and the process little understood.

In December 1907, Mr. Poulsen and his colleague, Peder Oluf Pedersen, were granted a patent in the United States; this patent described a direct-current "bias control" which represented some improvement. (The meaning of *bias control* is explained in Chapter 3.) Working in the U.S. Naval Research Laboratory, W. L. Carlson and G. W. Carpenter were granted a patent in August 1927; they described an *alternating-current bias control* which resulted in a greatly improved quality of recording. Up to that time, however, only wire and steel tapes had been used as a recording medium.

One of the first devices to introduce paper and plastic tapes coated with powdered magnetic substances was the German *Magnetophon*, demonstrated in 1935. Although the quality of reproduction from early plastic tapes was inferior to that then obtained from steel tapes, the obvious potential economic gains created sufficient interest to promote a rapid development of this new medium.

The major evolution of modern paper and plastic base tapes was first seen at a demonstration in 1937, by Mr. C. N. Hickman of the Bell Telephone Laboratories. At this demonstration, *vic alloy* was introduced as a new coating for nonmagnetic tapes, and Hickman's magnetic tape recorder offered an excellent quality of reproduction.

Both foreign and domestic capital quickly became interested in this convenient, economical method of recording, and a potentially enormous amateur market for home recording paralleled commercial possibilities. Soon the Armour Research Foundation in Chicago developed a means to bond a magnetic sound track upon motion-picture film; when the Eastman Kodak Company signed a license agreement with the Foundation, another high-potential market was opened.

Applications

Today there are literally thousands of commercial and military uses for magnetic tape recorders, many of these uses being far more exacting in frequency response than is the human ear. The Military Services use tape recordings for training programs, for recording the results of complex computing machines, telemetering, and a host of applications. In industrial research applications, test data may be recorded having an ultrasonic frequency spectrum (beyond 20,000 cycles per second) or a direct-current response. The recording of pressure, temperature, and other slowly varying quantities necessitates these d-c responsive tapes.

On the other hand, the recording of an extremely wide frequency band, far beyond that required by sound, has also been mastered. The

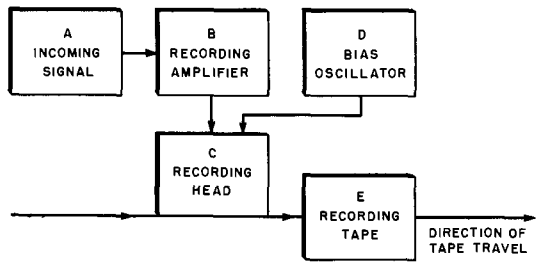


Fig. 1-1 Block diagram of magnetic-recording process.

Radio Corporation of America has announced coast-to-coast television demonstrations of magnetic picture transmission. Color television programs will also eventually be recorded on magnetic tapes, saving tremendous sums over kinescope recordings. These amazing feats are made possible only because ultrasonic frequencies may be recorded and reproduced by the magnetic tape process. Discussions of these techniques, however, exceed the scope of this book, which has been purposely limited to the field of sound recording.

Besides the unusual applications, tape recorders find increasing acceptance in many everyday sound-recording applications. Tape recorders have become an indispensable part of educational programs, and are in daily use in universities and schools throughout the world. The American University in Washington, D. C. has used repetitive and selective reproduction of tape recordings in foreign language studies for several years. Such "electronic language laboratories" are also in great favor in Georgetown University's Institute of Languages and Linguistics, at Louisiana State University, Cornell University, and many others.

The Tape Recording Process

The underlying physical process which makes magnetic tape recording possible is essentially very simple. The sounds to be recorded are converted into corresponding variations of an electric current. In turn, this varying electrical current induces variations of a magnetic field in a coating of tiny magnetic particles, which are bonded to a narrow strip of tape. The magnetic field variations force the magnetic particles to move to new positions on the tape, in accordance with the strength of the field at each point on the tape. Once moved, these particles remain stationary, and a magnetic record is the result.

Based on this magnetic action, a practical tape recorder performs three essential functions: *recording*, *reproduction*, and *erasure*. The method of accomplishing these three basic functions will now be briefly explained.

Recording. (Refer to the block diagram, Fig. 1-1.) A low-level incoming audio signal (block A), corresponding to the sound variations to be recorded, is introduced to the recording amplifier (block B). The signal is electronically amplified in the recording amplifier and then fed to the recording head (block C).

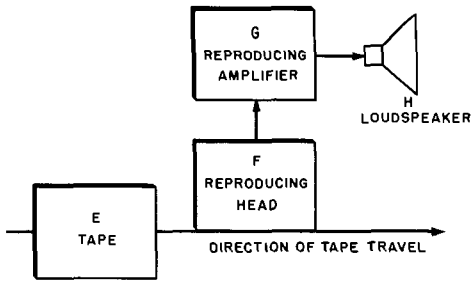


Fig. 1-2 Block diagram of magnetic-reproducing process.

As stated earlier, a *bias control* proved to be the crucial factor responsible for high quality of the recorded signal. This bias control is derived from a bias oscillator (block *D*) and is combined with the amplified audio signal at the recording head (block *C*).

The recording tape (block *E*) is in contact with and drawn across the recording head (block *C*). The combined functions of units *A*, *B*, *C*, *D*, and *E* make possible magnetic tape recording. These basic units are explained in detail in Chapter 3.

From the foregoing it becomes evident that some mechanical device must be employed to draw the tape across and keep it in contact with the recording head. These complex devices are known as *tape transport* or *tape drive* mechanisms. Thorough acquaintance with the functioning of these mechanisms is essential to the operator of tape machines (examples are discussed and illustrated in Chapters 4 and 5).

Reproduction. As in other forms of recording, making a record is only the first step; reproduction calls for a second magnetic process. The magnetic record preserved on the surface of the tape must in some way be scanned magnetically, and then amplified for audible reproduction.

Refer now to the block diagram of Fig. 1-2. During reproduction the tape (*E*) is in contact with and travels past a reproducing head (*F*). The speed and direction of travel must be the same as used during the recording process. The fixed magnetic pattern upon the tape then induces voltage variations in the windings of the reproducing head, these voltages varying in accordance with the recorded pattern of coated

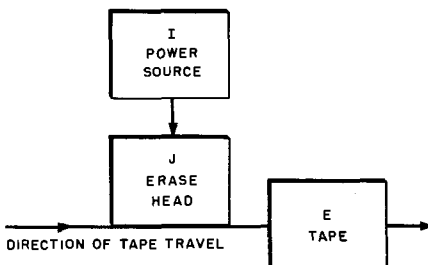


Fig. 1-3 Block diagram of magnetic-erase process.

particles on the tape. The resulting signals are amplified by the reproducing amplifier (G) and are made audible through a loudspeaker (H). Thus reproduction is essentially a reversal of the recording process. Note one important feature: a magnetic recording may be played back immediately after it is recorded; no further processing of the record is required.

Erasure. Any magnetic recording may be erased from the tape and the same tape reused hundreds of times. However, erasure calls for a third magnetic process: a magnetic field of considerable magnitude is applied to the tape to erase the record. (Fig. 1-3 illustrates magnetic erasure in block diagram form.)

A power source (I) energizes an erase head (J). A magnetic field of great intensity is produced by this erase head while the tape (E) is in contact and drawn past it. The erasure field then overpowers the recorded pattern of the aligned magnetic particles coated on the tape, and all particles are reoriented by the field, coming to rest in random positions. This action results in complete erasure, leaving the tape ready for a new recording.

The important fact to note is that all three of these processes, *recording*, *reproduction*, and *erasure*, depend entirely upon magnetic action. Because of this, the next chapter is devoted to a review of basic magnetism with an emphasis on characteristics applicable to tape recording.

The block diagrams (Figs. 1-1 through 1-3) include the basic components necessary for tape recorders. However, additional refinements are required in practical units. During the recording process, low-level incoming signals must be amplified, equalized (that is, frequency-compensated) and controlled against the possibility of overload or inadequate signal level (this is true of all recording methods). Equalization is again necessary during reproduction. An overall picture of a magnetic recording system including these additional refinements appears in Fig. 5-1. In Chapter 5 the circuits required for this system are analyzed and illustrated.

Chapter 2

BASIC MAGNETIC PRINCIPLES

For the purposes of this book, a discussion of basic magnetic principles need only concern the atoms, comprising material, and their *magnetic moments*. We will also consider the individual *domains* within the structure of all magnetic materials, including recording tape.

Atoms, Electrons, and Domains

All atoms contain minute negatively charged particles called *electrons*. Within each atom these electrons move in orbits around the heavier nucleus, and at the same time each electron (and each nucleus) spins about an axis of its own. Such a moving or spinning electron constitutes an electric current, and an electric current produces a *magnetic field*.

In the crystals of highly magnetic substances, each atom has more electrons spinning in one direction than in the other. Throughout a minute sub-crystalline region called a *domain*, containing about 10^{15} atoms, these uncompensated spins are all in the same direction. Within such a *domain* the spinning electrons produce an intense magnetic field. Thus, each individual domain may be considered a tiny magnet having a north and a south pole. When such a tiny magnet is placed within a magnetic field it tends to align its north-south pole axis with the direction of the field. The turning force, or torque, with which this alignment takes place is called the *magnetic moment*, and is proportional to the pole strength and the distance between the poles.

Thus the domains within a crystal of a magnetic substance, such as iron, are all individually magnetized, but these tiny domain magnets point in all conceivable random directions. With such unoriented domains, the individual magnetic (turning) moments cancel each other out, and no external magnetism is exhibited (see Fig. 2-1A). When an outside magnetizing force is applied these individual magnetic domains align themselves more and more in the direction of the applied field, and their individual magnetic moments begin to add up. When the substance becomes completely magnetized (or *saturated*) all the

domains are aligned with the direction of the field, and all the magnetic moments add up to a powerful magnetic force (Fig. 2-1B).

Magnetization and Magnetic Properties

The relative ease with which the alignment of the domains takes place determines a material's magnetic properties. For example, in iron this alignment is easily effected, hence iron is highly magnetic; on the other hand, steel requires a more intense field to produce a given degree of magnetization, because its domains become aligned with greater difficulty. When the magnetizing force is withdrawn, however, the domains of steel *remain* aligned, while those of soft iron return largely to their former random positions. Therefore, although hard to magnetize, once magnetized, steel retains its magnetism and is called a *permanent magnet*; soft iron can be magnetized easily, but only temporarily while being exposed to an outside magnetizing force. Even in soft iron, however, some *residual magnetism* remains after the magnetizing force is withdrawn.

All the *ferromagnetic* materials, such as iron, are easily magnetized. Non-ferromagnetic materials, such as chromium, either cannot be magnetized at all or magnetized only to a slight degree. Briefly, the reasons for these differences have to do with the crystalline and atomic structure of materials; the type of crystal structure, the atomic behavior, and the spin orientations of the electrons are among the important factors. Even ferromagnetic substances show a great decline in their magnetic characteristics when alloyed with other elements. For example, an alloy comprised of 0.3% carbon, 10% manganese, 6.5% nickel, and the balance iron, proves to be non-magnetic at room temperature (the magnetic properties of many materials are highly dependent on temperature).

Magnetic Characteristics

One way of finding out the magnetic characteristics of a material is to magnetize it. When a known magnetizing force (symbol H) is applied to a material, the resulting induced magnetization or *flux density* (symbol B) can be measured and recorded. As different values of the magnetizing force (H) are applied to the material, the resulting

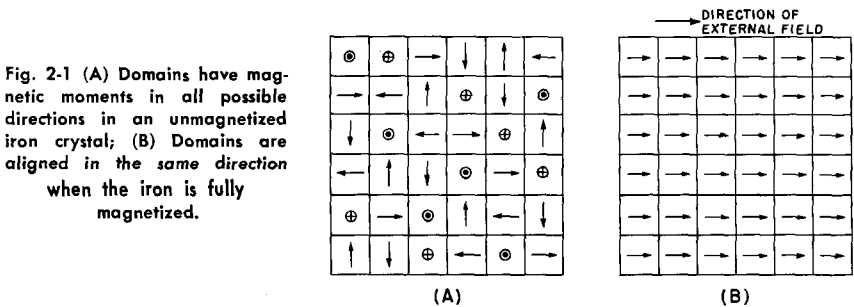


Fig. 2-1 (A) Domains have magnetic moments in all possible directions in an unmagnetized iron crystal; (B) Domains are aligned in the same direction when the iron is fully magnetized.

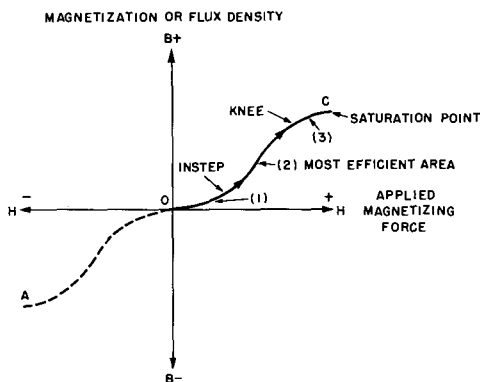


Fig. 2-2 Magnetization curve for iron.

flux densities (B) can be plotted, resulting in a characteristic magnetization curve which is of great importance to design engineers. Such a magnetization curve for iron is shown in Fig. 2-2. The explanation for the peculiar shape of the curve may be summarized as follows:

1. When a small but gradually increasing magnetizing force (H) is applied to unmagnetized iron, the domains affected by the force increase slightly in size, at the expense of adjacent unaffected domains. This results in a small amount of magnetization of the iron, which increases uniformly with increasing values of H . The portion of the solid curve (Fig. 2-2) where this occurs is marked (1).

2. As the applied magnetizing force is increased a sudden and more forceful change in the orientation of domains occurs. During this action the magnetic flux density (B) per unit of force applied, increases at a greater rate than discussed in the paragraph above. This portion of the ascending curve is marked (2) in the figure. Being the most efficient operating portion of the curve, it is used for most magnetic devices, including tape recorders.

3. As the magnetizing force is increased still further, the slow orientation of the remaining unaligned domains takes place, in the portion of the curve marked (3). Only a minute increase in flux density now results as shown by the "knee" in the curve, and the material is said to be magnetically *saturated*. Full saturation is actually reached at point c on the curve, after which further increase in the magnetizing force will have practically no effect on the flux density. From this it is apparent that full intensity of magnetization is a function of the volume of domain reaction.

4. If instead of the positive magnetizing force (H) had been applied to the unmagnetized sample of iron, a curve in Fig. 2-2, would have resulted. The magnetization curve for increasing negative values of the magnetizing force ($-H$) is shown dotted and is marked oa in Fig. 2-2.

5. The average slope or steepness of the magnetization curve (that is the ratio $\frac{B}{H}$) is a measure of the ease of magnetization of the material, and is called *permeability* (symbol μ).

Hysteresis

When the iron whose magnetization curve is shown in Fig. 2-2 is for some reason demagnetized, the magnetization curve is not retraced; but a second curve *cdef* (Fig. 2-3) is established with higher values of flux density for corresponding values of the magnetizing force. (The broken magnetizing curve *oabc* in Fig. 2-3 corresponds to curve *oc* in Fig. 2-2.) As the value of the magnetizing force (H) is decreased, it is found that the flux density (B) does not decrease as rapidly, as shown by the left-hand curve (*cde*) of Fig. 2-3. This characteristic lag of the flux density behind the magnetizing force is called *hysteresis*. When the magnetizing force decreases to zero, the flux density still has a positive value (*od*); that is, the iron remains to some extent permanently magnetized. The value of the flux density where the descending curve cuts the axis (at point *d*) is called the residual or *remanent flux density* (B_r) of the material. It is the value obtained when H equal zero again.

If the magnetizing force H is now increased again in the *negative* direction, the flux density B becomes zero for a certain value (*oe*) of the magnetizing force, called the *coercive force* (H_c). The characteristics of remanence and coercive force are of great importance in determining the performance of magnetic recorders.

Hysteresis Loops. When the negative magnetizing force is further increased to a negative maximum (*of*), numerically equal to the positive maximum, then reduced to zero and again raised to the original positive maximum, the graph traces through points *e*, *f*, *g*, *h*, and joins up with the original curve at point *c*. The closed curve, formed for one complete

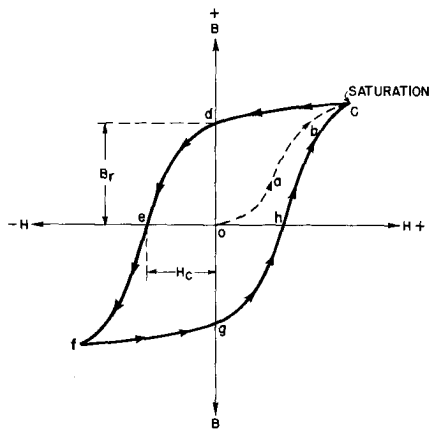


Fig. 2-3 Hysteresis loop for a complete cycle of the magnetizing force.

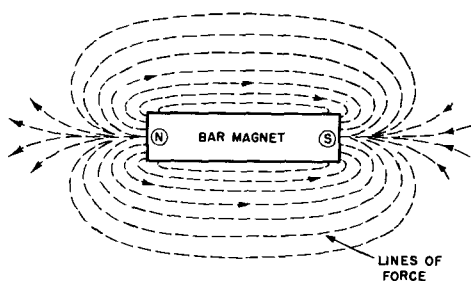


Fig. 2-4 Magnetic lines of force surrounding a bar magnet.

cycle of the magnetizing force (with an alternation in each direction), is called a *hysteresis loop*. The area inclosed within the loop (*cdefghc*) represents a measure of the energy lost as heat (the friction overcome in aligning the domains in one complete cycle of magnetization. It is important to remember that the values of B on the descending (left-hand) curve are greater than those on the ascending (right-hand) side of the curve *fc*.

Hysteresis loops cannot be expressed in analytical form, hence graphical representations, such as Fig. 2-3, must be used for calculations. The values of remanence and the coercive force are not a definite property of a particular magnetic material; the shape of the curve and the values of B_r and H_c depend on the magnitude of the positive and negative maxima of the magnetizing force and on whether the substance was originally unmagnetized. For different conditions a whole family of hysteresis loops may be produced, all more or less similar to Fig. 2-3. In the illustration only one magnetic cycle has been analyzed; in practice, however, the current in an a-c electromagnet alternates very rapidly, and the magnitude of the current, and hence the magnetizing force H , may vary over a considerable range of values. If the magnetizing force reaches different maxima during the hysteresis cycle (because of current variations), minor hysteresis loops are traced out within the main loop. Such minor loops occur when an a-c bias is applied to a tape during recording, as explained in Chapter 3. Hysteresis plays an important part in tape recorders; as the currents within the magnetizing coil of the recording head vary in amplitude, hysteresis losses in the form of heat are produced, and affect the magnetic field about the poles of the recording head.

Magnetic Fields

Interactions between magnets can be explained if we assume that there are centers of force at the poles of such magnets. Consider, for example, a permanent magnet consisting of a simple straight bar. It has a *north pole* of a certain strength at one end of the bar (the north-seeking end), and a *south pole* of equal strength at the other end of the bar. As is apparent from the field of force surrounding this bar magnet (Fig. 2-4), the north and south poles act as centers of force; for practi-

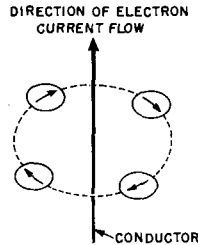
cal purposes the rest of the magnet can be ignored. The law of force found between a north and a south pole, either of the same magnet or of two different magnets, is comparable to the inverse square laws which hold for gravitation and electrostatic charges. Briefly it may be stated as:

The force between two magnetic poles is proportional to the product of their pole strengths and inversely proportional to the square of the distance between them. The force results in attraction if the poles are unlike (north and south), and results in repulsion if the poles are alike. This may be expressed mathematically, for two magnets placed in a vacuum or in air, as:

$$F = \frac{m \times m^1}{d^2}$$

where F is the force between the poles in dynes; m and m^1 are the pole strengths of the two magnets, respectively; and d is the distance between them in centimeters. This law must be modified by a multiplying con-

Fig. 2-5 Circular magnetic field around a conductor, through which electrons flow in the direction indicated.



stant, to take into account the characteristics of the medium, if the two magnets are not in a vacuum or in air.

The pole strengths (m and m^1) in the above equation are measured in *unit magnetic poles*. This unit is defined as having a strength or force of one dyne upon an equal pole when placed 1 centimeter away from it in a vacuum or in air.

When a magnet of pole strength m is placed in a magnetic field of strength H it experiences a force $m \times H$ in the direction of the field (that is, tangent to the lines of force). This important relation can be expressed quantitatively as:

$$F = m \times H$$

where F is the force in dynes, m the strength of the magnet in unit poles, and H is the field strength measured in *gauss*.

Demagnetization

When a bar of iron is magnetized longitudinally by placing it in a magnetic field, it develops a north pole at one end and a south pole at the other end (Fig. 2-4). If a unit north pole is placed externally near the center of this bar magnet, the attraction of the south pole of the bar magnet and the equal repulsion of its north pole will urge the

unit north pole toward the south pole of the magnet, or in a direction opposite to that in which it is magnetized. If this external unit north pole were introduced *within* the bar magnet, it would still experience a force urging it in the direction of the south pole of the bar magnet. Although it would be unable to move, this opposing force of the unit north pole would produce a magnetic field within the bar opposite in direction to the original field of magnetization of the bar. Such an opposing field, which tends to weaken the original magnetization, is called *demagnetization*. The stronger the opposing field, and the shorter the bar in comparison to its cross section, the greater this demagnetizing effect would be. This demagnetizing effect is of considerable importance in magnetic tape recording, as will be explained in Chapter 3.

Permanent Magnets

Permanent magnets of horseshoe or ring shape are sometimes used for the erasure of magnetic recordings. The materials used for permanent magnets have one common characteristic: the magnetic moments of their domains cannot be easily disturbed, nor easily reoriented. Therefore, the initial magnetization of these materials requires the application of high magnetizing field strengths, but once magnetized these materials keep their magnetic strength. This characteristic of permanent magnets to hold their magnetization, once acquired, is called *retentivity*.

The stability and retentivity of *Alnico* magnets (consisting chiefly of aluminum, nickel and cobalt) is noteworthy. Demagnetization from any but the most powerful stray fields will scarcely affect Alnico. The performance of permanent magnets also depends to a great extent on the structure and magnetic characteristics of their air gaps, which will be discussed later on in the chapter.

Magnetic Effect of Electric Currents

When a current flows through a wire or other conductor a *magnetic field* is set up, thus any conductor carrying current radiates a magnetic field of its own. If a magnetic compass is carried around a vertical wire, as shown in Fig. 2-5, it will be found that the magnetic field is circular about the wire at any point along its length. As shown here, when the electron current flows upward, the north-seeking pole of the compass needle will always point in the clockwise direction of the electron flow while the compass is moved around the wire (in this book, electron flow is assumed, rather than conventional current flow). Should the direction of the electron flow be reversed, the compass behavior will also reverse. The strength of the magnetic field around the wire diminishes as the distance from the wire increases. When the electron flow through the wire is constant, the magnitude of the magnetic field also remains constant.

The intensity of the field at any point near the wire may be expressed in oersteds, and is:

$$H = \frac{I}{5 \times r}$$

where H is the field intensity in oersteds; I is the current flow in amperes; and r is the distance from the axis of the wire in centimeters.

Solenoids. If the wire is formed into a loop and the electron flow in constant in one direction (Fig. 2-6A), the lines of magnetic force will all point in one direction with respect to the axis of the loop. When several loops form a coil (Fig. 2-6B), the lines of force passing through the center of the coil will all be aligned in the same direction, thereby creating a field of greater intensity than that surrounding a single loop. A north pole will appear at the end of the coil where the electrons enter and a south pole will appear at the opposite end. A still greater magnetic field intensity would be obtained were an iron core to be inserted into the coil. When the strength of the current flowing in the coil increases or decreases, the intensity of the magnetic fields varies accordingly. Within such a coil (called a *solenoid*) the intensity of the magnetic field is given by the equation:

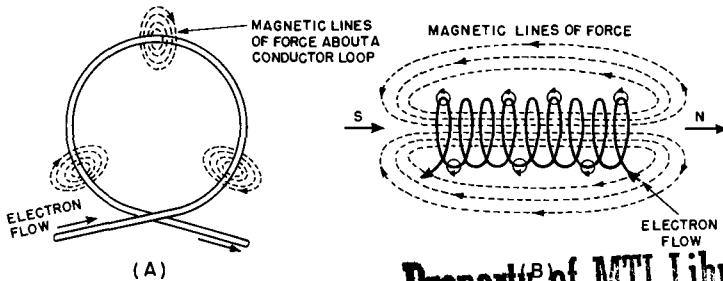
$$H = 1.257 \times I n$$

where H is the field intensity along the axis of the solenoid in oersteds; I is the current in amperes; and n is the number of turns per centimeter of length of the solenoid.

Strictly speaking, this relation gives the magnetic field intensity at the center of a solenoid. At each of the ends of a long solenoid so much of the magnetic flux has leaked out around the sides that the field intensity is only one-half of that given above.

Electromagnetism

When an iron core is inserted partially or wholly into the center of a solenoid, as shown in Figs. 2-7 (A) and 2-7 (B), the number of lines of force within the coil is greatly increased, because the iron core offers much less resistance to the flow of magnetic lines of force than does air. Flux lines will traverse the iron core in preference to air, even though the core may be partially outside the coil. As an example, Fig. 2-7 (A)



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Fig. 2-6 (A) Magnetic lines of force about a conductor loop; (B) Field around a coiled current-carrying conductor.

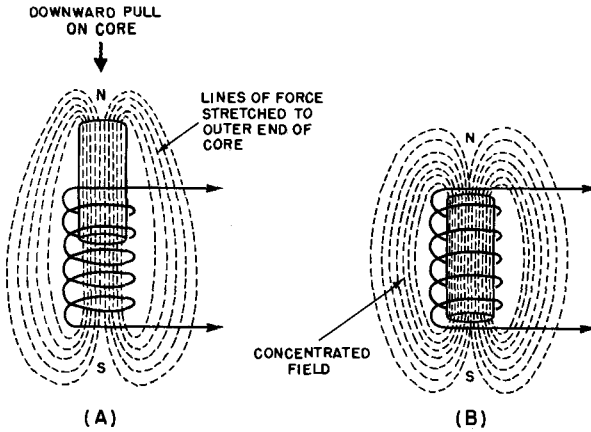


Fig. 2-7 Solenoid with an iron core, partly inserted in (A), and wholly inserted in (B).

shows the lines of force stretched out like rubber bands. Such “stretching” causes a pull upon the iron core, tending to drag it into the coil; when the field is sufficiently great the core will be entirely drawn into the solenoid. Such units are called *electromagnets* and are often employed to actuate direct-current solenoid-plunger switches and circuit breakers in tape recorders. The electromagnets are energized when a current is switched on and create a magnetic field within the solenoid.

In accordance with the equation for solenoids, it will be found that as the current in the coil of an electromagnet is doubled its magnetic intensity is doubled. If the number of turns in the coil is doubled, the magnetic intensity is once more doubled. From this we conclude that the flux density or magnetic intensity of an electromagnet is proportional to the product of the current, in amperes, and the number of turns of the coil.

Permeability. Electromagnets may be operated by direct current or by alternating current of any frequency, such as audio or higher frequencies. In fact, the flux emanating from the poles of a tape recording head is controlled directly by the audio-frequency signal voltages applied to the winding of the head. A magnetic material having high permeability is desirable for an electromagnet, so that the applied magnetizing force and the volume of the material may be held within practical limits. Relatively pure iron, or iron having a low silicon content, is generally used in laminated form for the core structure of electromagnets. Where extremely high permeability is desirable, nickle-iron alloys, such as *Permalloy*, *Hiperrik*, or a nickel-iron-copper alloy called *Mumetal*, are often used.

In some communication components, and particularly in recording heads, extreme stability of permeability is required throughout the working range. A nickle-iron-cobalt alloy known as *Perminvar* (mean-

ing: permeability invariable) and a nickle-iron alloy called *Copernik* possess this property at relatively low flux densities. Unfortunately their permeability is low, but they have the unique properties of negligible residual magnetism and of negligible coercive force throughout their useful range of permeability.

Comparison of Magnetic and Electric Circuits

Magnetic and electric circuits have marked differences. Electrical conductors are normally separated from each other by insulation having a conductivity in the order of that of conductors. Magnetic flux scarcely recognizes an insulator. Air, the most common flux insulator, has a permeability in the order of 1/10,000 that of ferromagnetic materials. Bismuth, the most diamagnetic substance known, has a permeability nearly equal to that of air. The resistance of a material to magnetic flux (this resistance is called *magnetic reluctance*) depends primarily upon the material and dimensions of the *magnetic circuit* in which it is placed. *Reluctance* is directly proportional to the length of the magnetic circuit (measured in the direction of flux) and inversely proportional to its cross-sectional area. Reluctance limits the quantity of magnetic flux in the magnetic circuit, being somewhat similar to the resistance of electrical circuits. However, while the resistance of an electrical circuit does not (ordinarily) depend on the current flowing through this circuit, the reluctance of a magnetic circuit *does* depend to some extent on the flux density already established in the circuit.

Ohm's Law in Magnetic Circuits. The rules for applying Ohm's law to series and parallel *magnetic* circuits are the same as for applying Ohm's law to series and parallel electrical circuits. As has previously been explained, the value of the fraction B/H (that is, the ratio of the flux density to the magnetizing force) is called the *permeability*. The inverse of that ratio (H/B) is called the *reluctivity* of the material, and corresponds to the form of Ohm's law. Thus we have:

$$\text{Reluctivity} = \frac{1}{\text{Permeability}} = \frac{H}{B}$$

As mentioned, the *reluctance* depends on the length of the magnetic circuit and its cross section:

$$\text{Reluctance} = \frac{\text{Reluctivity} \times \text{Length}}{\text{Area of cross section}}$$

The magnetizing force H (often called *magnetomotive force*) may be visualized as being similar to electric voltage, while the flux density B resembles the electric current.

Care must be exercised, however, against over-confident use of analogies between magnetic and electric circuits. The resistance of a certain copper wire may be 10.4 ohms per milfoot regardless of how many amperes are flowing through it. The reluctance of standard silicon steel, however, may be 0.0025 per cubic centimeter when only four flux lines are threading each square centimeter of the steel, while this same steel

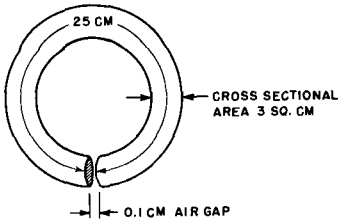


Fig. 2-8 Ring magnet with air gap.

may have a reluctance of only 0.00014 when its magnetic flux is increased to 7,000 lines per square centimeter. For this reason, standard values are not used for the permeability of these materials when magnetized to various degrees.

Air Gaps

When an air gap is introduced in series with a magnetic circuit, a great increase in the reluctance of that circuit results. This situation prevails, for example, in a magnetic recording head. Consider the example illustrated in Fig. 2-8; here an iron core has a cross-sectional area of 3 sq. cm; the length of the path within the core is 25cm; and the length of the air gap is 0.1cm. Assume the permeability of the iron ring to be 500. What is the total reluctance of the path?

$$\begin{aligned} \text{Reluctivity} &= \frac{1}{\text{Permeability}} \\ &= \frac{1}{500} \\ &= 0.002 \end{aligned}$$

$$\begin{aligned} \text{Reluctance (of iron)} &= \frac{\text{Reluctivity} \times \text{Length}}{\text{Area of Cross section}} \\ &= \frac{0.002 \times 25}{3} \\ &= 0.0167 \end{aligned}$$

$$\begin{aligned} \text{Reluctance (of air gap)} &= \frac{1 \times 0.1}{3} \\ &= 0.0333 \end{aligned}$$

Hence the total reluctance of the magnetic circuit equals 0.0167 plus 0.0333 or 0.05. (The determination of the actual flux distribution in the air gap, and of the fringing and leakage losses caused by the air gap, is an analytical problem beyond the concerns of this book.)

Magnetic Shields

It is sometimes necessary to prevent the flow of magnetic lines of force through certain components in a system. A magnetic shield, such

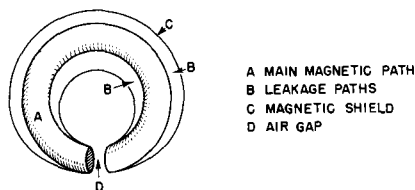
as that shown in Fig. 2-9 may then be introduced. In this case, a ring-type magnet is surrounded by an iron cover, which serves as a magnetic shield. The leakage flux lines surrounding the magnet follow the path of least reluctance, which is provided by the iron shield, and do not penetrate through the outside of the shield.

Magnetic shielding is generally applied to the recording and playback heads of a tape recording system. These heads must be adequately shielded against magnetic interaction between heads, as well as from the influence of external fields. When permanent-magnet type erase heads are used, magnetic shielding becomes imperative.

Soft-Iron Poles

A horseshoe or a ring-type magnet consisting wholly of one kind of material may not provide the specific flux pattern in and around its air gap which is best suited to a certain function. In such cases, correction and shaping of the flux pattern is sometimes achieved through the introduction of tapered soft-iron pole pieces (Fig. 2-10). The tapered poles offer a greater concentration of flux density across the air gap.

Fig. 2-9 Magnetic shield around ring-type magnet, showing leakage path.



A MAIN MAGNETIC PATH
B LEAKAGE PATHS
C MAGNETIC SHIELD
D AIR GAP

Electromagnetic Induction

Faraday discovered that a current is *induced* in an electric conductor which is placed into a varying magnetic field; that is, a field in which the number of magnetic flux lines change with time. This effect can be produced in a variety of ways, some of which are:

1. An alternating current constantly reversing its magnetic field (the resultant variations induce a current in a conductor placed within that field).

2. Moving a magnet relative to a conductor, or vice versa (so that a current is induced in that conductor).

3. Closing or opening a d-c current (if the source of the magnetic field is a direct current, a voltage will be induced in a conductor, placed within that field, at the instant when the direct-current circuit is closed or opened).

The effect of inducing an electromotive force (emf) into a conductor through the action of a magnetic field is called *electromagnetic induction*. There are but three conditions required to generate an induced voltage. These are: (1) a magnetic field, (2) the presence of a conductor within that field, and (3) motion between the conductor and the

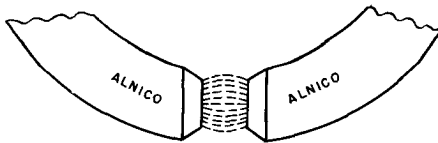


Fig. 2-10 Permanent Alnico magnet with tapered soft-iron poles.

field. When this induced voltage gives rise to a current through a closed circuit, it may be said that a current has been induced, although actually only a voltage can be induced.

The overall concept of electromagnetic induction is clarified in Lenz's law which states in effect: Whenever a current is established in a circuit by an induced emf through motion in a magnetic field, its direction is such that the magnetic field set up by the resulting current tends to oppose the motion which produced it.

The direction of an induced voltage is given by Faraday's law, which states: The emf induced in a circuit equals the negative of the rate of increase of flux through that circuit.

Conductor Moving in a Magnetic Field

The four parts of Fig. 2-11 illustrates these laws; (A), (B), (C), and (D) progressively analyze the result of moving a conductor in a magnetic field. Part (A) shows a conductor at rest in a fixed magnetic

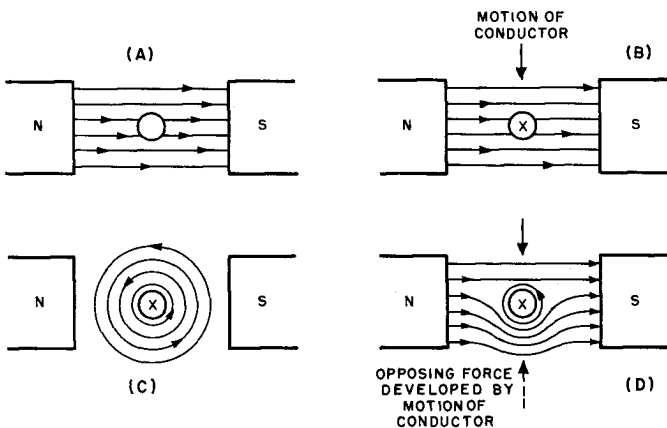


Fig. 2-11 Conductor moving in a magnetic field (A, B, C, and D). In (A) the conductor is at rest in the magnetic field; in (B) the conductor is pushed downward, inducing an electron flow which is directed into the page; (C) the field produced by the current-carrying conductor; (D) the composite magnetic field of the magnet and the conductor. A counter force is developed tending to push the conductor against the original motion.

field, established between the north and the south pole of a magnet. In this case no current flows through the stationary conductor. In (B) an external mechanical force is applied to push the conductor downward. This motion causes an electron flow in the conductor which is directed into the page, as indicated by the X across the conductor.

Part (C) shows the direction of the field around the conductor resulting from the electron flow through it (any conductor carrying a current has a field of its own, as previously explained). The induced field is counter clockwise around the conductor (for clarity, the magnetic field between the poles of the magnet is not shown).

In part (D) the resultant action is shown. The lines of flux between the magnetic poles and those of the field about the conductor become additive in such a manner that a stronger field is produced below the conductor than above it. Above the conductor the magnetic flux lines are weakened as they clash with the opposing-direction flux lines produced by the conductor. Because of this, the conductor opposes the original motion and tends to be pushed upward.

Induction. The same phenomenon occurs when current flows through one of two conductors placed parallel to each other. In the case of direct current no induction will take place, except at the instant when the current is either turned on or off. However, when an alternating current flows through one conductor, its lines of force will expand from it as the current rises in magnitude during one half-cycle. This, in turn, initiates an induced current in the second conductor, which flows in a direction opposite that of the current in the first conductor. For the second half-cycle, the conditions for each conductor will become reversed.

Similarly, a coil of wire subjected either to flux lines from a magnet, or coupled to a field of flux produced by another coil, will have a voltage induced in its winding.

Chapter 3

MAGNETIC RECORDING

All magnetic recording systems embrace three magnetic processes: recording, reproduction, and erasure. Each process will be discussed separately, with a natural emphasis being placed upon recording. Erasure is also of prime importance, however, being possible only with the magnetic method of recording. Any strip, section, or entire reel of magnetically recorded tape, wire, or film, may be erased *on the spot* by demagnetization.

The tape may then be reused immediately as virgin or neutral tape for further recordings. Since this cycle may be repeated almost indefinitely, erasure alone is a powerful economic factor in favor of magnetic recording.

Thus, in this chapter the three magnetic processes are discussed and various early methods are also taken into account, because techniques now considered obsolete may prove highly useful in the future. At the present time there are three established methods of magnetic recording; these are: perpendicular, tranverse, and longitudinal.

Perpendicular Recording

Perpendicular tape recording was first attempted years ago; in this method tape, is used which has previously been magnetized to saturation. The saturation flux is applied at right angles to the motion of the metallic tape surface, as shown in Fig. 3-1. One side of such a tape then has a north polarity and the other side a south polarity, such tape is a permanent magnet in strip form. When subjected to audio-frequency modulation, this saturated tape has its magnetic pattern disturbed and finally aligned laterally across its surface. Such a polarized tape, passed between two diametrically opposed perpendicular pole pieces, (P^1 and P^2 in Fig. 3-1) and subjected to a modulating flux, is capable of recording only positive half-cycles; changes in sign of the modulating signal are suppressed, because of the polarization of the tape, resulting in a highly distorted record. However, wider frequency response for a slow tape speed is still claimed by exponents of this method, which is rarely used at the present time.

Transverse Recording

Figure 3-2 shows an arrangement for transverse recording, in which the poles are placed at opposite edges of a saturated tape rather than perpendicular to its surface. This method also utilizes magnetically saturated tapes. In this case, however, the recording flux is spread across the width of the tape. One major difference between transverse and perpendicular recording is the greater distance between recording head poles in the transverse recording. As a consequence transverse recording requires a greater magnitude of the modulating signal.

Longitudinal Recording

In longitudinal recording magnetization is parallel to the motion of the tape. This method, used almost universally today, seems to be the only practicable one for *wire* recording, where there is bound to be a certain amount of twisting of the circular wire as it passes the pole pieces. Present-day longitudinal magnetization is produced in the recording tape by passing it over the pole pieces of a ringhead magnet having a gap perpendicular to the motion of the tape. However, there are two older methods of longitudinal magnetic recording which are also presented here, for reference. One is accomplished with a single pole piece (Fig. 3-3A) while the second utilizes two poles staggered laterally in relation to the tape (Fig. 3-3B). (Tape travel is from the left to the right in all examples shown.)

1. *Single Pole-Piece Longitudinal Recording.* Assume that the tape has been previously magnetized (saturated) and that the pole piece P_1 in Fig. 3-3 (A) emits a steady flux in the direction indicated by the arrows. Although at point 2 flux emitted from the pole will be perpendicular to the tape, at points 1 and 3, and throughout most of the area of travel past the pole, flux will be parallel to the motion of the tape. From the direction of the arrows in Fig. 3-3 (A) note that the elements of the tape approaching the pole piece are first subjected to flux 1, which approximated the same direction as the residual magnetization of

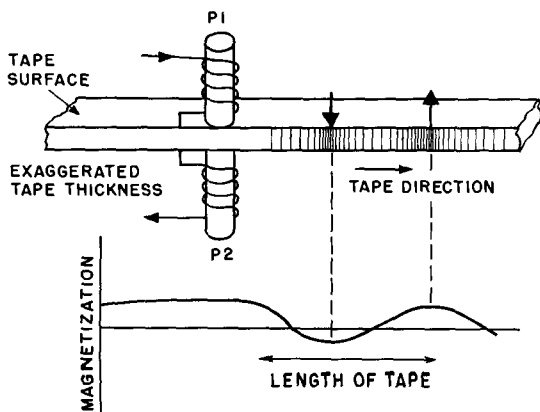


Fig. 3-1 Arrangement of pole pieces for perpendicular magnetization, and magnetization pattern resulting from audio modulation of a saturated steel tape. Courtesy: Bell Labs, Inc.

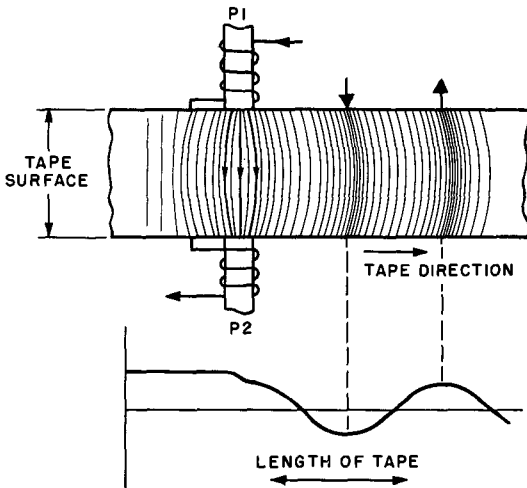


Fig. 3-2 Transverse magnetization of steel tape. Courtesy: Bell Labs, Inc.

the tape. This being true, no appreciable change in tape magnetization takes place. Directly opposite the pole the tape receives flux 2, perpendicular to its travel. When the same tape elements reach point 3 they encounter a flux in direct opposition to the residual magnetization within the tape and also in opposition to flux 1. This results in partial erasure of flux 1. If we had only flux 3, a modulating signal superimposed upon the steady flux of the pole piece could be induced in the tape with little distortion. However, because of the presence of flux 1 and 2, interactions occur, giving rise to distortion. Such interactions are still present to some degree in modern magnetic recorders.

2. *Staggered Double-Pole Longitudinal Recording.* In contrast to the case discussed above, flux will not spread so freely if the tape is subjected to two staggered poles, as shown in Fig. 3-3 (B). Assume that residual magnetism within the tape is in a direction opposite to the motion of the tape. In this case flux 1 from pole P1, has little effect upon residual tape magnetism. With two poles present, the tape elements must also pass pole P2. Thus we see that flux 4 is perpendicular to the saturated tape, while flux 5 is in a direction opposing that of the residual tape magnetism. It is evident that any impression upon the tape from flux 3 of pole P1 becomes distorted by the opposition of flux 4 and flux 5 of pole P2. Although this distortion is greater than for single-pole recording, the method has the advantage of an improved frequency response. With the staggered-pole method, longitudinal magnetization occurs at the longer wavelengths (low frequencies), while the magnetization becomes more nearly perpendicular for the higher frequencies, because the demagnetization effect at shorter wavelengths tends to steer lines of flux into the shortest possible paths. (This is discussed more fully later in this chapter.)

3. *Ring-Magnet Double-Pole Longitudinal Recording.* Modern tape recording employs a ring-shaped magnet provided with a small air gap between the two ends of the rings, which are its magnetic poles (Fig. 3-4). Fringing flux, emitted from the air gap, causes a magnetic change within the tape. This change creates a longitudinal magnetic record, as explained in succeeding paragraphs.

It may help us to understand the modern processes of longitudinal recording if we think of the magnetic-tape coating as composed of myriads of individual magnetic particles, each a tiny magnet. These particles rest in random distribution, as shown earlier in Fig. 2-1 (A). When the tape moves past the recorder-head air gap, the tape particles are subjected to the magnetizing force along the direction of tape travel and are turned or otherwise moved until they come to rest principally in the direction of that force. Such a line of particles (tiny magnets) will emit flux lines of their own from the edges of the tape, creating a magnetic field similar to that shown in Fig. 3-5. The magnitude and polarity of this field is a function of the magnitude and polarity of the signals introduced by the windings of the recorder head. It is desirable that the material used for the core of the recorder head have very high initial permeability, very low hysteresis losses, and very low eddy current losses.

According to Camras, several fundamental theoretical relations hold for longitudinal recording:

1. A complex wave (Fig. 3-5A) is represented by a corresponding flux distribution (Fig. 3-5B).

2. External flux emitted from the tape and perpendicular to the tape at any point P (Fig. 3-5B) is equal and opposite to its internal counterpart.

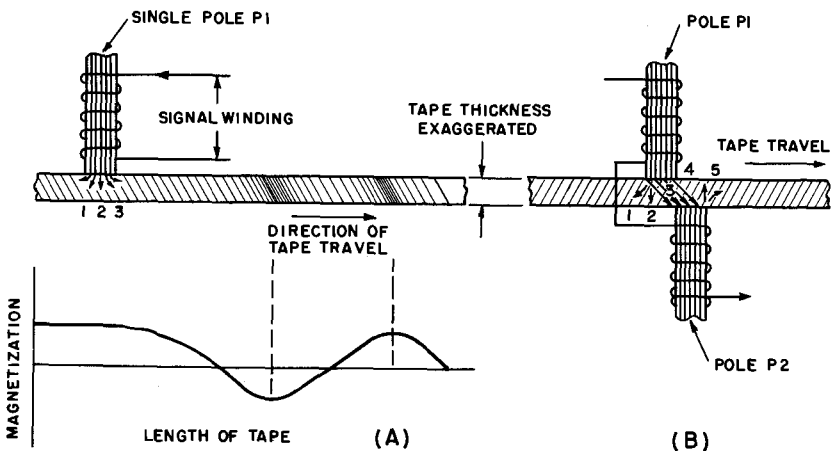


Fig. 3-3 (A) Single-pole longitudinal magnetization; (B) staggered-pole magnetization. This arrangement produces longitudinal magnetization at low frequencies, and perpendicular magnetization at high frequencies. Courtesy: Bell Labs, Inc.

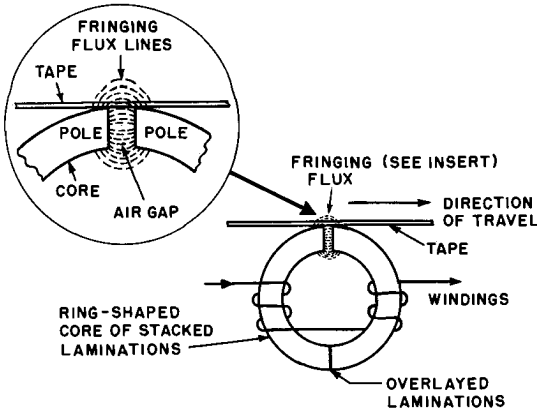


Fig. 3-4 Ring-magnet recording head. Longitudinal recording is produced by the fringing flux from the air gap of the recording head. Insert shows the field distribution around the gap.

3. The pole strength of any point on the tape surface is proportional to the rate of change of flux (either internal or external) through a perpendicular plane inserted at that point.

4. The amount of magnetic energy that can be stored at each frequency determines the voltage output to be expected from a given playback head.

Mechanical Relationships

Before further consideration of theory, it is well to visualize the mechanical relationships of tape transport which take place during an actual magnetic-tape recording. In modern practice the tape to be re-

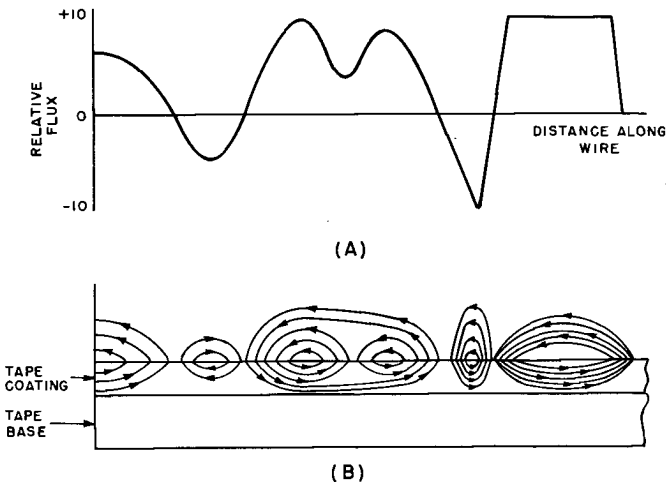


Fig. 3-5 Flux distribution along a tape. (A) Shows appearance of complex wave to be recorded. (B) The resulting magnetic pattern adjacent to the recorded tape. Courtesy: Armour Research Foundation

corded is drawn from a supply reel (Fig. 3-6) threaded past an idler pulley, and then passed over three different magnetic heads. In order of tape transit, these heads are an erase head (dc or ac), a recording head, and a reproducing head. The erase head removes any magnetization remaining on the tape prior to its arrival at the recording head. The tape is pulled at constant speed across the magnetic heads by the capstan and pressure roller, this latter preventing tape slippage at the capstan. The tape then travels past a second idler which keeps the tape under constant tension. Many machines utilize only two heads, one for erasure and the other for both recording and playback. Further constructional details appear in Chapter 4.

Magnetic Recording Characteristics

The importance of hysteresis loops has been discussed in Chapter 2. Such a loop, with reference to magnetic recording, is shown in Fig. 3-7, in which a typical B versus H relationship is represented by curve

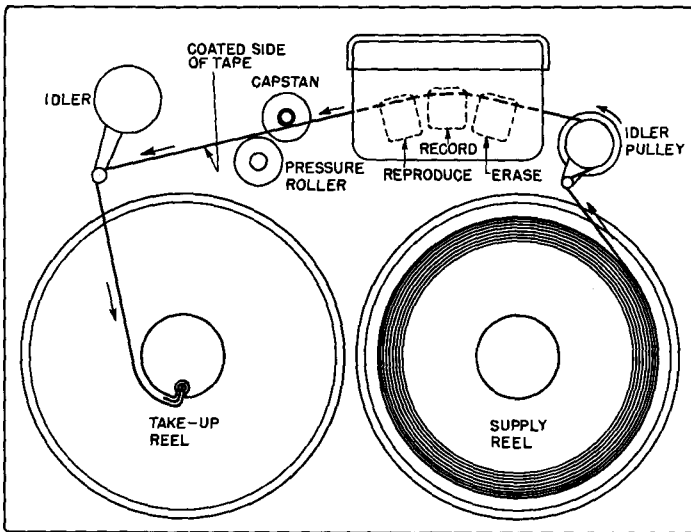


Fig. 3-6 Mechanical components of a typical tape recorder. Courtesy: RCA Victor

mbn. The residual induction (B_r) of a magnetic material is determined by the point (b) at which the upper curve mbn crosses the vertical axis, that is, where H is zero. The negative value of H necessary to reduce B to zero is called the coercive force (H_c). The above factors determine the performance characteristics of magnetic recording tapes. The flux density (B) depends upon both the magnetizing force (H) and the magnetization of the tape material itself. It is clear that once the tape becomes magnetized it contributes itself to the total flux

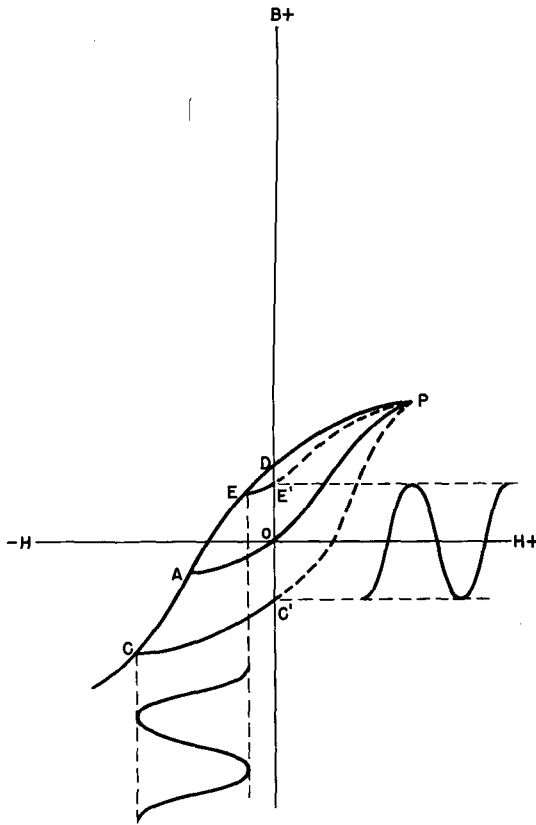


Fig. 3-9 D-c bias control for saturated steel tape, showing cycles of magnetization through which tape elements pass during process of recording.

Poulsen, consisted of a *d-c bias*. A d-c bias field of approximately 125 oersteds was applied to the recorder head winding, and an audio signal was superimposed upon this steady field. Fair linearity of magnetic recording resulted when the controlled bias *steered* the signal modulation to a straight-line sector of the hysteresis curve, such as point *A* of Fig. 3-9. Since only one-half of the characteristic magnetization curve was used in this method, only low levels of modulation in the narrow straight-line sector of the curve were obtained. The noise level was high because of the steady state of magnetization resulting from the d-c bias. A previously saturated steel tape was used, saturation (point *P* in Fig. 3-9) sometimes being attained through inclusion of polarizing poles.

High-Frequency Bias

At the present time, a high-frequency a-c bias is employed to aid transfer of audio signals from the recording gap to an unmagnetized or neutral tape. The frequency of this *bias carrier* is far above audibility, usually upward from 30 kc. The simple schematic of Fig. 3-10 shows one method of applying the audio input signal and the inaudible signal from the ultrasonic bias oscillator simultaneously to the recording head (several other methods appear in Chapter 5). The term *bias* has been applied to the high-frequency carrier as a hand-down from vacuum-tube bias control. When the bias magnitude is properly controlled, a straight-line recording characteristic results, as shown in Fig. 3-11. In

1. The recording characteristic is especially linear in the vicinity of the origin; that is, for small values of H .

2. The range over which linearity can be obtained is greater than for any other method of bias control.

3. The frequency of the high-frequency component is not especially critical. In fact, audible frequencies in the order of 1 kc or less will straighten the recording characteristic (but cannot be used, of course, since they would be heard).

In practice, the frequency of the ultrasonic bias carrier is several times greater than the highest frequency to be recorded; it varies from about 30 kc to 150 kc.

Theories. There is still some divergence in the theories advanced for explaining results obtained with high-frequency bias control. One reason is the complex magnetic influence a tape experiences as it traverses the recording-gap area. Another reason is the change of normal induction values due to demagnetization forces. The overall complexity is aggravated by the self-demagnetization factor occurring within the tape coating. Nevertheless, it has been accepted by all that the use of ultrasonic bias causes improved linearity, lower distortion, and reduction of noise produced by the tape.

Demagnetizing Force. As with other methods of magnetic recording, one of the most important factors effective during the process of recording with a high-frequency bias control is the resultant demagnetizing force and its effects on a recorded tape. The upper limit for maximum tape flux density after the tape passes the recording gap is determined by the value of remanent magnetization (B_r) for the tape. This upper limit is realized only at long signal wavelengths (low frequencies). As the signal wavelength is decreased (the frequency increases), surface poles along the tape exert a greater demagnetizing influence and the final flux density is reduced. In other words, the higher the signal frequency the greater the reduction of recorded signal amplitude, due to demagnetization effects, after the tape leaves the recording gap. Naturally, this effect is especially prominent at the ultrasonic bias frequency. Once the tape passes the recording gap, considerable demagnetization occurs at the bias frequency.

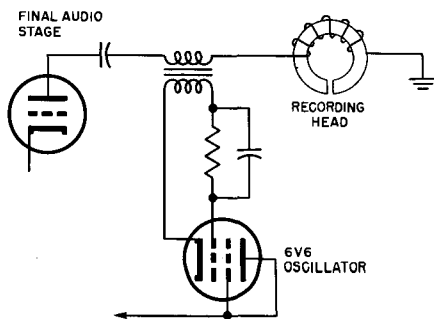


Fig. 3-10 Typical method of applying audio and high-frequency bias signal to recording head. Courtesy: Brush Development Co.

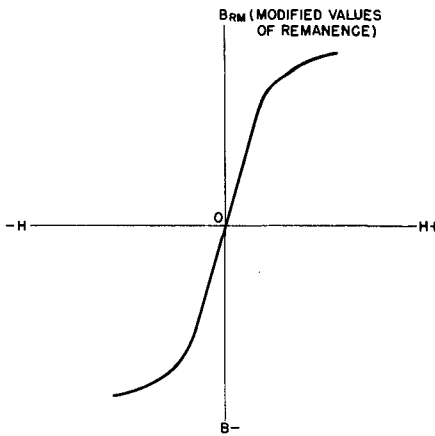


Fig. 3-11 Straight-line recording characteristic resulting when high-frequency bias is used.
Courtesy: Armour Research Foundation

Optimum Bias. Tests have proved that there is a critical value of optimum bias for any specific type of recording tape. It has been further demonstrated that a slight change of bias value is necessary when different types of magnetic heads are used. Essentially the optimum value of bias is that value which eliminates the bend of the characteristic curve at the intersection between B and H (see Fig. 3-8). The straightened curve of Fig. 3-11 is obtained when the proper bias is applied. Too great a bias results in two effects:

1. The slope near the origin of the curve becomes greater than shown in Fig. 3-11, resulting in a larger output.
2. Partial erasure, due to increased bias, reduces the total effective length of the curve.

As a direct result of these two effects, excessive bias produces an increase of distortion and reduces the permissible level. In some cases, the bias value which produces the greatest output level is double the *optimum* value required for the least distortion. Even at optimum bias values a slight amount of erasure occurs, but the effect is only of consequence to the higher audio frequencies, which begin to "roll off" above 4,000 cps. From the above facts, the importance of accurate bias adjustment for specific requirements becomes evident.

Summation. Thus far we have established that:

1. Controlled application of high-frequency bias minimizes distortion during magnetic transfer of signals from recorder to tape.
2. Demagnetization within the tape introduces non-linear frequency response and losses in final signal amplitude.
3. Inherent tape characteristics also contribute to non-linearity.

Obviously, the non-linear frequency response must be compensated for. This is achieved through electronic "equalization" during recording (*pre-emphasis*) and additional compensation during reproduction (*post-emphasis*); commercial methods of accomplishing this are given in Chapter 5.

Demagnetization

Because of the effect of *self demagnetization* and tape motion away from the polarizing field, the tape elements experience a decrease in field strength and hence in remanent induction (along the upper curve, point *C* to point *D* in Fig. 3-9). Note that point *D* is reached when the applied field (H) is zero. Assume initially that no signal is impressed ($H = 0$). In counteraction, the d-c bias current produces a flux at the recording head poles which is opposite in sign to the saturating flux previously induced in the tape by the polarizing or saturating poles. This biasing action brings the magnetic operating point of the tape down to point *A* when no signal current is present. Tape travel away from the recording head reduces the magnetic tape induction to zero. This tape motion is represented in the hysteresis loop by portion *A* to *O*, thus completing one magnetic cycle (*O* to *P* to *D* to *A* to *O*).

The presence of an applied signal, during the time when the tape contacts the recording head poles, reduces tape magnetism only to point *D* (Fig. 3-9), instead of down to point *A* when the flux produced by the incoming signal opposes the fixed bias flux. In contrast, when incoming signal flux and bias flux are additive, tape magnetization is reduced to point *C*. For these two cases the elements retain a value of magnetic induction corresponding to E' and C' , respectively. These two points represent the amplitudes of the alternating signal recorded. This method, then, makes it possible to record over a far greater portion of the characteristic magnetization curve than is possible with no tape saturation.

Magnetic Recording Tapes

From the days of Poulsen's early discoveries until about 15 years ago, magnetic wire or steel tapes served as the magnetic recording medium. (Cold-rolled carbon, chrome, and tungsten steels were among the first materials tried.) The magnetic and processing limitations of steel tapes, and their slow speed of travel, were responsible for the poor results obtained. Even today the performance of magnetic recording equipment is determined to a great degree by the characteristics of the recording tape. Metal tapes still serve specific functions where editing and splicing are not necessary. Some commercial and many military machines, using continuous loops, employ stainless steel tapes because of their durability, among commercial examples are vending machines, advertising devices and announcing-repeater systems. The stronger steel tapes are generally used in military devices and in high-speed calculating machines, such as computers and analyzers; in these, breakage is practically eliminated. Coin-operated instruments, business office equipment and sales campaign devices also frequently employ steel tapes. When the critical requirement is large output rather than wide-band frequency response, the greater thickness of the active magnetic material inherent in metal tapes is a factor favoring their use.

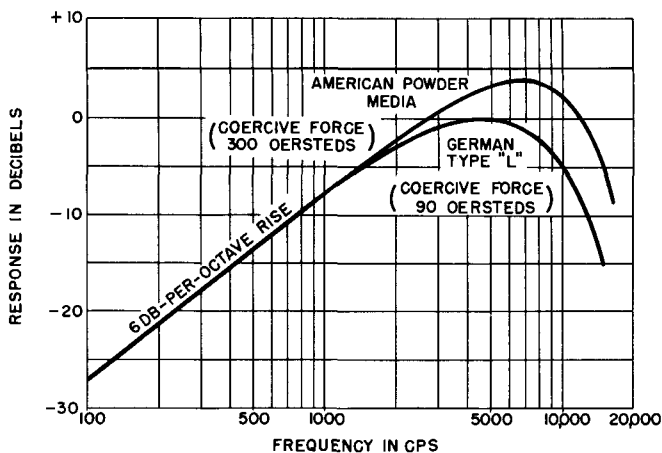


Fig. 3-12 Comparison between early type of German plastic and a later sample of American plastic tape.

Present-day plastic and paper-based tapes offer a wide choice ranging from the highly-coercive black oxide to the older low-coercive red oxide, used in World War II by the Germans. Compositions have been fairly well standardized so that equipment manufacturers can provide for the correct adjustments of bias currents for various tapes. However, most low-priced machines today are limited to one fixed bias value.

With few exceptions, modern machines use reels of tape wound with the oxide coating on the inside. (For a few machines, tape producers still must supply reels wound with the oxide coating outward.)

Tape Comparisons. Two early German tapes used red iron-oxide (Fe_2O_3) as the active magnetic material (coating). These tapes were $\frac{1}{4}$ -inch in width and 1.6 mils in thickness. One (type L) was an impregnated material consisting of equal weights of polyvinyl-chloride and Fe_2O_3 . The second (type LG) had a polyvinyl-chloride base 1.2 mils thick. The base was coated to about 0.7 mil with 90% Fe_2O_3 plus 1% vinyl chloride in a tetrahydro-furane solution. The intrinsic coercive force of the first tape (type L) was about 90 oersteds (see Fig. 3-12) while that of type LG was about 80 oersteds. Type L had a residual induction of 100 gaussers as against 550 gaussers for type LG. The particle size for either tape was less than 1 micron, or 0.039 mil. The *signal-to-noise ratios* of the L and LG tapes were about equal, in commercial use a value of 65 db was attained.

Coated tapes still employ magnetic coating particles of 1 micron or less in size; these particles being mixed with an element which binds them to their plastic or paper bases. Coercivity ranges from 100 to 500 oersteds, depending upon requirements (it is difficult to effect complete erasure of tapes whose coercivity is greater than 500). Remanence values

vary between 300 and 700 gauss. Tape width is still $\frac{1}{4}$ inch, except for tapes which have multiple sound tracks.

Modern production of coated tapes has reached such stability that an output level deviation of not more than 1 db can be expected between two reels, manufactured on a production-line basis of 9,000 miles of plastic tape every 60 days. A high order of homogeneity is maintained throughout a reel of virgin tape.

Modern domestic tape bases have a certain *limpness* to provide for easy alignment around the magnetic heads. This assures uniform recording and playback levels, particularly at the higher audio frequencies. Furthermore, a minute amount of lubrication is applied to tapes to augment their smoothness and limpness. Through this treatment a ripple-free transit over the magnetic heads is assured.

Tape Characteristics. Recording tape characteristics depend upon the composition, homogeneity, and thickness of the coating upon the tape. This coating possesses two magnetic qualities, *remanence* and *coercive force*, both of which have been explained previously.

Remanence controls the signal output of a tape at the lower audio frequencies, whereas coercive force provides a measure of attainable tape signal output in the upper audio range. There is no clearly defined frequency limit at which tape output can be considered controlled solely by either factor. In Fig. 3-12 we see frequency response curves for a domestic tape, having a coercive force of about 300 oersteds, and for the German "L" tape, with a coercive force of about 90 oersteds. From these curves it is evident that a higher coercive force produces a better high-frequency response. But it is also true that the high-coer-

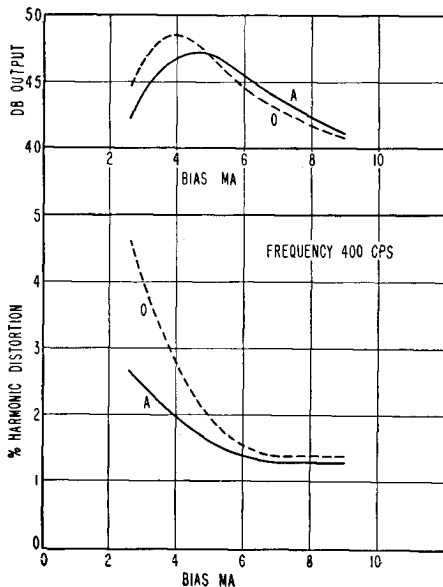


Fig. 3-13 Bias relationships: upper curves show relation between bias current and output, with fixed input; lower curves show relation between bias current and distortion, with fixed input. Courtesy: Audio Devices, Inc.

cive tapes produce a poorer low-frequency response. Therefore a compromise must be made between tapes with high remanence and those of highest coercive force.

Characteristics of paper- or plastic-based tapes depend almost entirely upon the oxide coating used and its uniformity of application. Modern oxides of various characteristics are available. The popular medium-coercive red oxides require only slight changes of bias when switching from one commercial brand to another.

The upper curves of Fig. 3-13 show (for two different modern tapes, *A* and *O*) the relationship between bias current and output for a fixed signal input of 400 cps. The two lower curves, in the same graph, show a reduction of distortion for an increase of bias for either tape. From this it is seen that output gains are derived for an increase of bias up to a certain operating point, beyond which the distortion levels off, while the output drops rapidly. We further see that a greater distortion content accompanies the greater output of tape *O*. Such differences are often chargeable to the use of different oxides in tapes.

Tape Life. Plastic tapes, such as the cellulose-acetate base, should not be exposed to continued temperatures above 80°F, nor should they be subjected to extended periods of high humidity. Excessive heat will cause brittleness, while dampness may cause adjacent layers to stick together. Tapes having historical value, which are to be stored for some years, should be kept in a humidifier with the temperature ranging between 65° and 70°F, and the humidity averaging between 50% and 70%; even for temporary storage, important tapes should be kept in a cool location.

Magnetic tapes have both a magnetic and physical life term. Of the former little is known, but it is reasonable to assume that there will be a slow loss of magnetism over extended periods, as occurs with any permanent magnet. It is also possible that there may be greater depreciation for peak-amplitude levels than for lower levels, thereby introducing distortion. Cases have occurred where tapes, recorded at high levels and stored for some years (while being tightly reeled) showed effects of *magnetic printing* or *cross talk*. There is some cross talk evident between layers of any tape reeled and recorded at excessive levels (safety limitations against such magnetic printing are given later).

The physical life of the common paper-based tapes compares to that of ordinary book paper. The care suggested above for storage of plastic-based tapes is the minimum precaution to be observed.

Reproduction

For reproduction from a tape, the magnetic process of recording is reversed. The irregular and temporarily fixed orientation of coated particles upon a recorded tape establishes myriads of tiny magnetic fields along its surface. When a recorded tape travels past a reproducer head these tiny fields induce a voltage in the coils of the head. This

voltage varies with the magnitude and polarity of the recorded signals and, when properly amplified, drives a loudspeaker to reproduce signals in correspondence with those originally recorded, thus the tape record is scanned magnetically.

Two major effects cause the response during playback to be far from *flat*. First, as will be explained, the reproducing-head output increases with frequency. Second, factors of self-demagnetization cause a rapid decline of frequency response above 5,000 cps. The voltage output from a reproducer is proportional to the *rate of change of the flux*, rather than to the amplitude of the flux. For a given distance along the tape, the rate of change of flux for a high frequency is greater than that for a low frequency; consequently, the voltage output of the reproducing head is proportional to frequency. This accounts for the 6-db-per-octave rise of the curve in Fig. 3-12.

The reproducing head is a generator having a stationary coil subjected to a changing magnetic field. Flux lines emanating from a recorded tape enter the reproducing-gap area and pass through the windings of the reproducing head, thereby inducing a voltage within the windings of the head.

Spurious Echoes. When a tape is recorded at excessive levels, spurious *magnetic printing* occurs from one layer to another after the recorded tape is wound on a reel. This condition may be avoided by confining the recording levels, by means of a limiter or other device, to peaks containing no more than 2% distortion at optimum bias. The higher the recorded level, the greater will be the spurious printing effects. These effects are sometimes called *echoes*, because they are heard as echoes when played back. High temperatures aggravate this crosstalk between layers of stored or reeled tape. Samples heated to 250°F have produced as many as four distinct echoes; such echoes become serious with thinly based coated-paper tapes, but are not of great concern in the more heavily based plastic tapes, which have a greater separation of layers on the spool.

Frequency Response

The frequency response reproduced from a magnetic tape depends mainly upon the effective width of the reproducing gap, the speed of tape travel, and the magnetic characteristic of the entire system, including the tape itself.

Recording-gap width is of little consequence, but the recording-gap field current is important. Field intensity within the recording gap is almost directly proportional to the current in the recording-head coil. Current in the recording-head coil will be constant for most frequencies of the input signal, if a resistance is inserted in series with the coil which is large compared to the reactance of the coil. This series resistor should be considerably larger in value than the impedance of the recording head. The internal resistance of the driver amplifier is

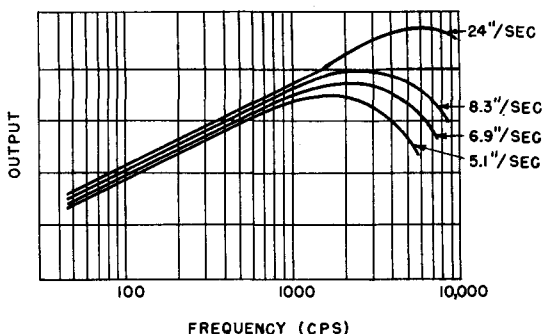


Fig. 3-14 Frequency response of oxide-coated paper tape at several recording speeds. Courtesy: Minn. Mining and Mfg. Co.

often used to serve this purpose; under this condition a constant input voltage should produce a constant intensity of the gap field for all frequencies. When a tried and proven optimum ratio between signal amplitude and bias amplitude is once set for a given tape, and the conditions stated above hold, the recorded signal should have low distortion and a high signal-to-noise ratio.

Reproducer output voltage is proportional to frequency and will rise at the rate of 6db per octave (Fig. 3-12) at the lower frequencies. It falls off at high frequencies because of demagnetization effects and the fixed width of the reproducing gap. Corrective equalization during reproduction will produce the overall response desired, and also result in a better signal-to-tape noise content (equalization is discussed later in this chapter).

Speed vs Frequency

Lower frequencies in the audio spectrum are practically independent of the speed at which the tape travels.

The low-frequency response, or the voltage output at any frequency for a given speed, however, is directly proportional to the remanent flux density (B_r) of the tape. The wavelengths at low frequencies are very long compared to air-gap length, hence the effect of demagnetization is negligible.

In the higher-frequency end of the spectrum the effect of self-demagnetization is very pronounced and increases rapidly as tape speed is reduced, as shown in Fig. 3-14. The high-frequency response is raised one octave when the tape speed is doubled. The high-frequency voltage is also proportional to the coercive force (H_c) of the tape.

Not long ago the better designed machines boasted of a frequency range of 1,000 cps per-inch second of tape speed. Advanced controls and more uniform dispersion of magnetic material in the present tapes have at least doubled that factor. The present relationship approximates 2,000 cps per-inch second of tape speed; this figure holds presently for professional-type recordings. For special purposes the factor is easily expanded, but only at the expense of signal-to-noise content. Tele-

metering facilities, using wider than normal tape or film, have already pushed the upper-frequency limit to 100 kc. This is certainly proof of the constant promise from development laboratories. It guarantees the future of tape recording, which today is commercially available with an upper-frequency reproduction limit of 15 kc for high-quality sound systems.

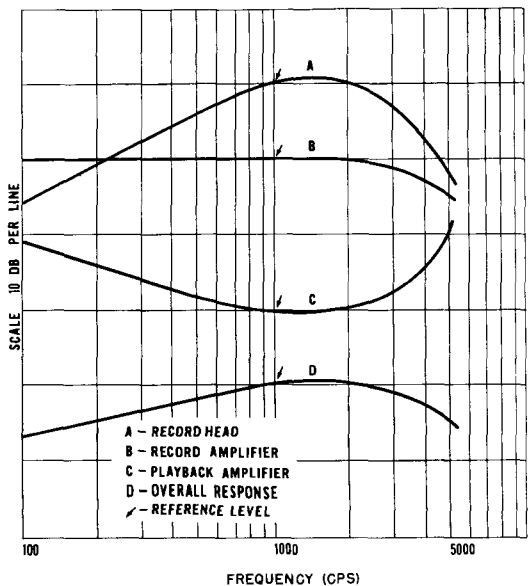
Noise

Mechanical or magnetic sources of noise may mar otherwise clean recordings. Carelessness of mechanical construction may contribute to noise content. For example, either transverse or longitudinal vibrations of the tape during transport past the recording head will create some degree of background noise. Therefore, uniformity of pulling torque and tape transport is imperative for best results, and is an item which too often is ignored.

A lack of uniform smoothness of the recording tape can also cause output noise. If the magnetic coating is placed on a rough surface the overall output will be unnecessarily noisy.

Magnetic noise has a tendency to follow signal amplitude; this type of noise increases with the amplitude of the signal. It is caused by a disturbance of the magnetic particles as the tape becomes magnetized (that is, modulated). When the high-frequency bias control is properly adjusted, however, the content of this type of noise is sufficiently low to be masked by the signal, and therefore is not too objectionable. Theory suggests that magnetic noise originates on the sur-

Fig. 3-15 Typical response curves with and without compensation. Courtesy: Brush Development Co.



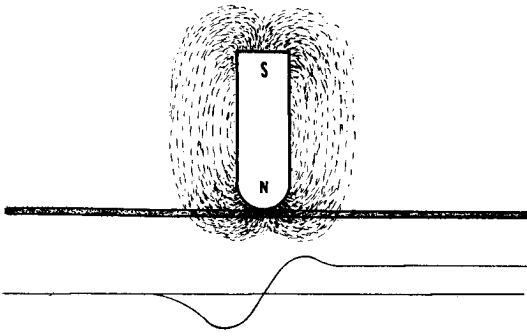


Fig. 3-16 D-c erasure utilizing a single-pole permanent magnet. Courtesy: Brush Development Co.

face of the tape, when the random elementary magnets which are smaller than the gap length become disturbed in their dormant orientation. This theory is borne out by the fact that in a saturated (d-c) tape the noise distribution has essentially the same frequency spread as it does in the demagnetized, a-c biased tape. The only difference is that there is a greater residual background noise in the saturated tape, which apparently is a function of the degree of saturation. Here again the high-frequency (a-c) biasing method of recording permits not only a better quality reproduction but also achieves noise reduction in the final recording.

Recording heads must be shielded against stray magnetic and electrostatic fields from nearby equipment to prevent foreign noises from being introduced into the record. Thermal noise and hum must also be held to a minimum through proper amplifier design.

Equalization

In magnetic as well as in disc recording, distortions occurring during recording are compensated for by *pre-emphasis* and *post-emphasis* equalization. Equalization must counteract the 6-db-per-octave rise previously discussed. The signal-to-noise ratio is also improved through equalization. The higher end of the spectrum may be augmented by means of a corrective network or left to droop, as in the curves of Fig. 3-12 and 3-14, depending on specific requirements.

Pre-emphasis equalization during a recording must be adjusted for the particular tape used; it should be variable, since it depends upon the modulation characteristic of the particular tape utilized. Adjustable equalization for both ends of the audio spectrum is advisable; however, equalizing facilities must be used with care. An excess boost of low register frequencies in the neighborhood of 40 cycles, for example, will introduce machine rumble. Since practical recording speeds for average purposes result in a loss of high frequencies, it is best to exaggerate the highs during recording. Pre-emphasis equalization can be adjusted so that all frequencies are likely to reach optimum levels before overload

occurs. Post emphasis of *highs* (during playback) will increase the noise component in mid-frequency-range.

Compensating networks are usually inserted after the first amplifier stage. The initially low signal-input voltages should not be further reduced by the insertion of unnecessary losses prior to amplification. The same general principle applies to corrective networks used for post-emphasis compensation. Post-emphasis networks can be adjusted to complement pre-emphasis for overall flat reproduction.

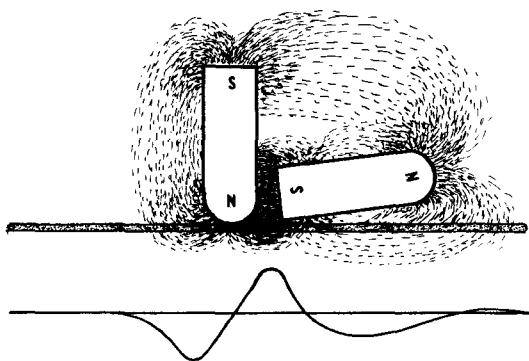
Typical compensation curves are shown in Fig. 3-15, curve *A* shows the frequency response to be expected if flat amplifiers are used for both recording and reproducing with a certain commercial machine (the Soundmirror, Model BK-411, described in later pages). Curve *B* shows the characteristic of the amplifier actually used for recording. Curve *C* shows the response of the playback amplifier, while curve *D* shows the overall frequency response resulting from superimposing curve *C* upon curves *A* and *B*. Actual equalization networks and their component values are detailed in Chapter 5.

Erasure (DC and AC)

It is merely necessary to apply a unidirectional magnetic field of sufficient magnitude to attain saturation in order to erase a magnetic recording from a tape. A single, strong permanent magnet applied to the tape as it moves past the pole piece, as shown in Fig. 3-16, will wipe out any previous recording. This method is not now used, however, since magnetic saturation of the tape produces a high content of ambient noise.

A better method of d-c erasure is shown in Fig. 3-17. Here two permanent magnets of opposite sign contact the tape during transit. Strong fields, first in one direction and then in the opposite, are applied to the tape. The resulting field alternation reduces the residual magnetism left over by the saturating field of the first pole. However, even when carefully adjusted, this method produces a somewhat higher content of residual tape noise than results from the use of high-frequency erasure.

Fig. 3-17 Erasure by two permanent magnets of opposite sign. The resultant alternation field reduces residual magnetism left by the single-pole type of erasure. Courtesy: Brush Development Co.



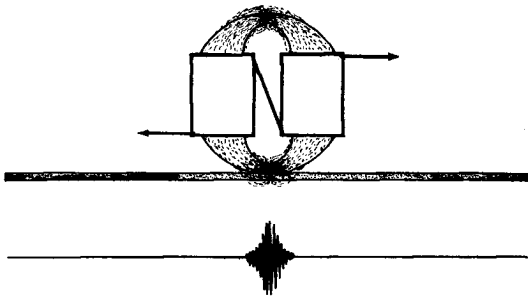


Fig. 3-18 Improved modern method of high-frequency erasure; the tape is demagnetized to a neutral condition. Courtesy: Brush Development Co.

High-Frequency Erasure. For the high-frequency method of erasure a signal of considerable magnitude from an ultrasonic power oscillator is applied to the windings of a laminated erasure head, which is similar in construction to a ring-type recording head. This is the most popular erasing technique. Several requirements must be met, however, for proper operation. First, the erasure signal must be of greater magnitude than any signal it is required to erase; secondly, the erasure gap must be much wider (about 20 mils) than the recording-head gap. The erasure-head gap literally spews its rapidly alternating flux into the tape, which is drawn across and in direct contact with it. Figure 3-18 illustrates the action which results in negligible remanence.

As the recorded tape nears the high-frequency field of the erasure gap, each magnetic particle on the tape surface becomes magnetized first in one direction and then in the other, due to the rapidly reversing field. As the particles cross the center of the gap they are saturated, the previous recording being completely erased. After the particles pass the gap center they are still subjected to alternating and fringing fluxes, which become rapidly weaker as the tape moves on. The result is that all residual magnetism is removed and the tape is left in a virgin or neutral state. A tape so erased has a very low noise component when used again. The erasure frequency is not critical. Often the same oscillator is used for both bias and erase, a weaker signal being applied for the bias function.

Chapter 4

TAPE RECORDING MECHANISMS

We now turn from the how's and why's of magnetic tape-recording to practical methods of accomplishment. Commercial recorders are primarily *machines*. This is true whether they be disc recorders, film recorders, graph paper recorders, or tape recorders. All these machines rely heavily upon their mechanisms for satisfactory results.

The tape recorder has its own stringent mechanical requirements. It is imperative that the motion of the tape past the recording head be linear and maintained at a constant velocity throughout the entire recording. The ostensibly simple process of unwinding a roll of tape, drawing it across magnetic heads, and then winding it onto another roll is, in fact, not at all simple. Present achievements realized in tape machines are a tribute to design engineers.

BASIC MECHANICAL COMPONENTS AND REQUIREMENTS

Before turning to the variety of mechanisms analyzed in this chapter, one should first understand the physical construction and function of each basic mechanical component. These components, along with their functional description, are listed for reference in Table 4-1; Fig. 4-1 illustrates the basic tape transport mechanism.

General Mechanical Features and Problems

The study of Table 4-1 and the accompanying illustration Fig. 4-1 should give the reader some familiarity with the basic mechanism which transports the magnetic tape from the supply reel past the magnetic heads to the take-up reel. While apparently simple, the rigid requirements pertaining to the basic mechanical components lead to many difficulties which are not easily overcome. Some of these mechanical requirements and problems, as well as the methods used by designers for overcoming them, will be described in the following general discussion.

TABLE 4-1
Basic Mechanical Components of a Magnetic Tape
Recorder Mechanism

Component	Description	Function
Supply reel (Fig. 4-1)	16-mm motion-picture reel or equivalent, vertically or laterally mounted on shaft, having friction or other slippage and braking facility for control of unwinding speed. The reel is keyed and locked to the shaft.	Supplies traveling tape under constant tension to magnetic heads and take-up reel during recording. Receives and stores recorded tape when mechanically reversed during <i>rewind</i> or <i>playback</i> .
Supply disc (Fig. 4-17)	Metal disc having three pins mating with supply-reel hub. Has constant mechanical or electrical braking facility.	Same as above.
Magnetic Heads (a) Record (Fig. 3-4)	Laminated, ring-shaped, balanced-winding magnet, precision-ground to tight gap width. Has polished poles for uniform contact across entire tape width.	Generates sharply defined flux field of a magnitude proportional to current in energizing windings. Resultant field rearranges magnetic tape particles, leaving a recorded magnetic pattern.
(b) Reproduce	Construction similar to recording head. Some machines use one head for both functions, by switching head windings from output to input of amplifier.	Intercepts magnetic-flux pattern, thus inducing corresponding voltage variations in reproducer windings. Resultant signals drive reproduce amplifier.
(c) Erase (ac) (Fig. 3-18)	Construction similar to recording head, but gap width is much wider and provided with heavier windings for higher current. Generally is energized by an ultrasonic frequency, and must be well shielded against stray influences.	Generates widely diffused fringing flux of magnitude far greater than largest recording peaks in order to demagnetize and so neutralize the recorded tape.
(d) Erase (dc) (Fig. 3-17)	Permanent magnet with sufficient field strength to saturate the tape. Has mechanical means for removal of influence during recording or playback. Alternately staggered poles somewhat simulate a-c erasure.	Single bar magnet saturates and thus neutralizes tape, but with undesirable noise content. Alternately staggered poles of gradually receding strength demagnetize the tape and simulate zero retentivity.

Capstan (Fig. 4-1)	Concentric rotational element, power driven by an electric motor, with sufficient torque to draw the tape across the magnetic heads at a constant rate of travel and supply it to a take-up reel. Circumference is usually rubberized to assure firm contact with tape.	Maintains correct tension on the tape, while drawing it at a highly constant speed past magnetic heads.
Pressure Pulley (Capstan) (Fig. 4-1)	Capstan pressure pulleys (sometimes called idlers) are adjusted to press the tape evenly against the capstan surface. Controlled pressure pads are sometimes used instead of pulleys.	Maintains firm and constant contact during travel of tape past capstan.
Take-up Reel (Fig. 4-1)	Identical to and interchangeable with supply reel. Directly or indirectly driven by electric motor, often the same motor which drives the capstan. Has friction or other braking and slippage facility for control of take-up during recording and of unwinding during <i>rewind</i> .	Receives and stores recorded tape.

Detailed mechanical features, as incorporated in a variety of commercial machines, will be pointed out in the examples which follow later in this chapter.

Supply and Take-up Reels

Since standard 16-millimeter motion-picture film reels (as shown later in Fig. 4-8) are convenient for tape handling, they are used by many manufacturers. Reeled-tape loads of various lengths are marketed, as listed in Table A-11 of the *Appendix*. These reels are mounted vertically or laterally upon shafts designed to align the tape correctly with the magnetic heads. Some professional machines of the console type use lateral 14-inch platters for supply and take-up, on which already reeled rolls of tape are placed. Rolls of virgin tape, wound upon 4-inch standard hubs, are widely available. These hubs are provided with notches which mate with three corresponding pins equally spaced around the center of a lateral platter. The reel of tape is secured to the platter by means of a heavily weighted knob, which is placed upon the central shaft around which the platter revolves (a typical arrangement for a professional recorder is illustrated later, in Fig. 4-16.)

Unwinding the Tape. As the supply reel is unwound, its *drag* (or load) upon the mechanism is continually depleted, while that of the take-up reel grows constantly heavier (Fig. 4-1).

Consider the take-up reel alone. If this reel were revolved at a constant speed during recording, the speed of tape motion past the recording

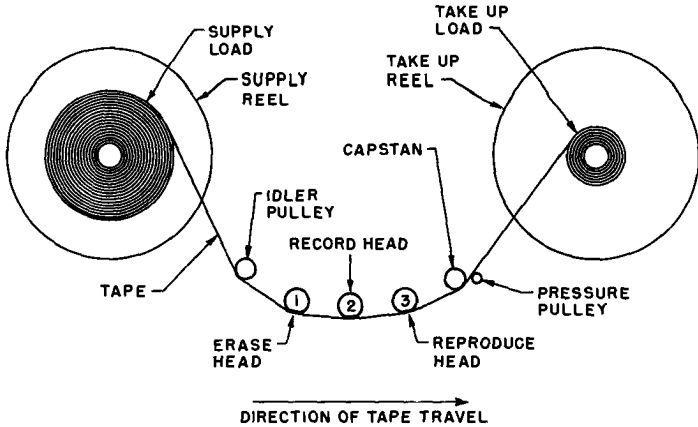


Fig. 4-1 Basic tape-transport mechanism.

head would initially be governed by the small diameter of the hub of the take-up reel. As the takeup process continued, however, the diameter of the reeled tape would rapidly increase, increasing the speed of tape travel past the recording head. Therefore, the direct result of running the take-up reel at constant speed would be a continuous change in tonal pitch and eventual breakage of the tape itself.

Now consider the supply reel under the above conditions. If the supply and take-up reels were both to revolve at the same speed, tape slack would accumulate from the supply reel much faster than it could be wound on the take-up reel, because of the difference in tape load diameters (Fig. 4-1). Thus, if the tape is to be transported past the recording head at a constant velocity, it is necessary that a mechanical or electrical control be introduced which will continually vary the speeds of both tape reels, increasing one while decreasing the other. Some machines employ slipping clutch assemblies, others utilize electrical torque of *drag* effects to achieve this. In addition, to assure stable and constant speed of tape travel past the magnetic heads, a capstan is required; this usually is installed between the take-up reel and the magnetic heads.

Capstan

The capstan is a power-driven pulley or disc secured to a drive shaft. Its circumference has an ample rubberized edge which engages and pulls the tape forward past the magnetic heads and onto the take-up reel (Fig. 4-1). A pressure pulley or a pressure pad is used to keep the tape pressed against the capstan at the proper tension. This pressure minimizes the possibility of tape slippage around the capstan.

There must be no slack of tape tension, either between the capstan and supply reel or between the capstan and take-up reel. As mentioned earlier, a compensated control of slippage of both tape reels is incor-

porated in design, to maintain proper tape tension at all times (slippage devices are discussed later in relation to specific examples).

Tape threading schemes differ widely from the basic tape transport shown in Fig. 4-1, some widely different methods are illustrated in this chapter. Leverages are often provided, which hold the tape free from contact with magnetic heads during periods of *high-speed rewind* or during *fast forward* tape transport. In this way excessive tape wear is avoided.

Magnetic Heads

Some tape machines use only two magnetic heads; these cost less to manufacture and are generally satisfactory for home or office use. All tape recorders, however, must have at least a recording head and an erasing head. When only these two are supplied, the recording head doubles as a reproducing or playback head; use of a third head provides separation of the functions of *recording*, and *reproduction*. Optimum performance requires three heads, since the requirements for recording and reproduction differ to some extent; a dual-purpose head is a compromise with high quality. Furthermore, a separate reproducer head provides for monitoring during the process of recording, a *must* for professional work.

Construction. Record and reproduce magnetic tape heads are available for replacement use in a variety of commercial machines. These accommodate various tape track widths between 0.014 and 0.12 of an inch. Erase heads, designed for a wide dispersion of flux, provide a spread of 0.150 of an inch. Erase gap widths run between 0.006 and 0.008 of an inch, while recording gaps are generally about 0.005 of an inch or less. Many commercial recorders use tape which has a number of parallel tracks on the same reel; these machines use multiple recording heads to obtain multi-track (multi-channel) recordings. Multiple heads stacked together for simultaneous multi-channel recordings, have a center-to-center spacing of approximately 0.125 of an inch separation between channels. Mu-metal shields are used between heads. With such a staggered head assembly up to 14 channels may be recorded on a tape width of 0.7 of an inch.

Typical individual or stacked heads, currently being released by The Brush Development Company, are cast in synthetic resin. They are moisture-proof non-microphonic, and operable through a wide range of temperatures. The core structure consist of thin molybdenum permalloy laminations, carefully annealed and cemented together to permit the use of high bias and erase frequencies. The gap faces are precision-ground for constant dimension. Dual balanced windings surround these core structures, providing magnetic symmetry and minimizing extraneous pickup. Pole pieces are ground to a high polish at the tape contact surfaces to allow good adhesion of the tape around the poles, resulting in uniform response.

Dual Tracks

Some tape machines are designed specifically for dual-track operation. Approximately one-half of the standard-width tape is used for one record, while a second recording is effected along the second half of the same tape surface, generally in the opposite direction of travel to that used for the parallel track. This makes possible a full hour of reproduction without the need for tape rewind, when a tape speed of 7.5 inches per-second is used (while one track is played the other is re-wound).

A narrow non-magnetic center strip separates the two parallel records, and special dual-magnetic heads are aligned accordingly. Recording may be simultaneous on both tracks in the same direction, and therefore synchronous, or may be in sequence, one track after the other. Since magnetization of highly coercive tape is confined to the narrow magnetic tracks, separated by a non-magnetic strip, cross-talk is of no consequence, except at the longer wavelength signals. When recording levels are properly maintained, this factor is held to a minimum.

Unlike the more popular single track, across the full width of a tape, dual-track tape recordings cannot be freely edited because any attempt at cutting and splicing may destroy the second track.

Controls

Instant starting, stopping, fast forward, and fast reverse controls are required in all types of tape machines to save time during editing and cueing of program material. Facilities for rapid shuttling from *Rapid Rewind* to *Fast Forward*, and vice versa, are standard features in modern units. Mechanical, solenoid-operated, or electrical torque brakes permit quick, smooth stops at any speed of tape transport without causing excessive tape tension. Remotely controlled operation is also available for most models.

Power Requirements

The power required for tape mechanisms and their associated electronic units is much less than that needed for other recording methods. This means that less weight is needed in portable units. The total power required for operation, under full load, ranges upward from 60 watts for the smaller machines. The Pentron machine, for example, includes a superheterodyne radio and tape recorder within one carrying case. The combination draws a total load of 100 watts. The Magnecorder (PT6) draws 70 watts for operation of its mechanism and built-in oscillator. Sixty more watts of power meet amplifier requirements. Higher-priced units sometimes use three motors: a dual-speed synchronous motor for capstan drive, a second motor for take-up-reel drive and braking, and a third motor for supply-reel rewind and braking.

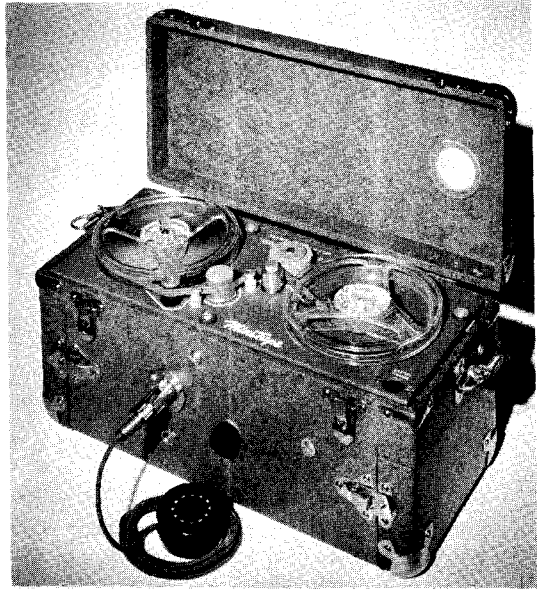


Fig. 4-2 Portable battery-operated Minitape recorder. Courtesy: Stancil-Hoffman Corp.

Installation

Equipment employed for recording systems in schools, colleges, and commercial recording studios varies to a great degree. Expansion possibilities, the number of channels required, and the space available for tape recording equipment. For that reason certain manufacturers have designed separately mounted units for installation in either a rack, console, or cabinet. Design has followed the building block approach to permit the owner to expand gradually while still using the original equipment purchased.

The smaller mechanisms and lighter amplifiers used in tape recorders, as compared with disc recorders, permit the installation of more recording channels in a given space. The studio layout must allow for placement of mechanisms at a convenient height to facilitate rapid loading, threading, and rewind. There must be ample ventilation, sometimes forced air-cooling through the racks, and adequate access (front and rear) for servicing.

Operating Instructions

There is great variation in controls, physical construction, and applicable operating procedure between different machines. For this reason no chapter has been wholly devoted to operation. The reader is advised to study and comply with the instructions set forth by the manufacturer of the unit he owns. However, in this chapter and in Chapter 5 will be found many instructions pertaining to the operation of particular units.

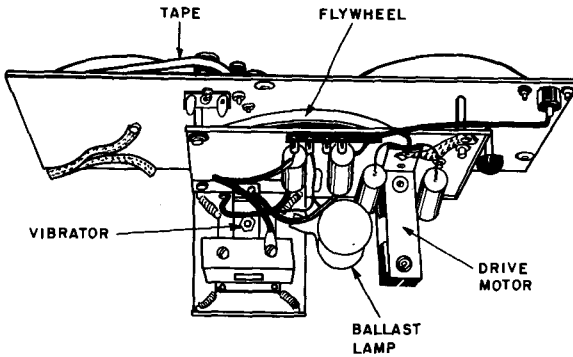


Fig. 4-3 Bottom view of Minitape main panel, showing motor-drive system. Courtesy: Stancil-Hoffman Corp.

TYPICAL TAPE RECORDING MECHANISMS

In subsequent paragraphs tape recording mechanisms are described which range in size from small battery-operated portables to multiple-channel machines capable of making fifteen simultaneous magnetic tape records. Electronic equipment, specifically designed for these units, is covered in Chapter 5. Frequent reference to Table 4-I, at the beginning of this chapter, should assist the reader in understanding the mechanisms described in the following illustrative examples of commercial designs.

Example 1. Minitape Portable Model 5, Stancil-Hoffman, (Figs. 4-2 and 4-3)

This small, battery-operated mechanism weighs only 13 pounds, mechanical components having been reduced to a minimum. Dimensions of this unit are 14 x 6½ x 6½ inches; two recording speeds are available (7.5 or 15.0 inches-per-second); dual speed is accomplished through the manual installation of an accessory capstan.

Figure 4-3 shows a bottom view of the simple drive mechanisms below the main panel. A judgement of the size of the components is gained by comparison with the standard ¼-inch tape visible above the main panel.

A single On-Off switch is the only control required, since a pre-set, fixed volume control assures optimum recording level and prevents overload. The On-Off switch energizes the drive motor and heaters of the amplifier tubes.

The battery-driven, portable unit is powered by two 67.5-volt miniature B-batteries (Ever Ready #467, or equivalent), two #2 flashlight cells for the filaments, and one 6-volt leakproof, rechargeable storage battery for the motor drive. The batteries will render several hours of operation without recharge, while standby batteries will extend this operating period. A battery charger and miniature playback amplifier are available as accessories. The amplifier may also be used as a pre-amplifier for extremely low-level pickup.

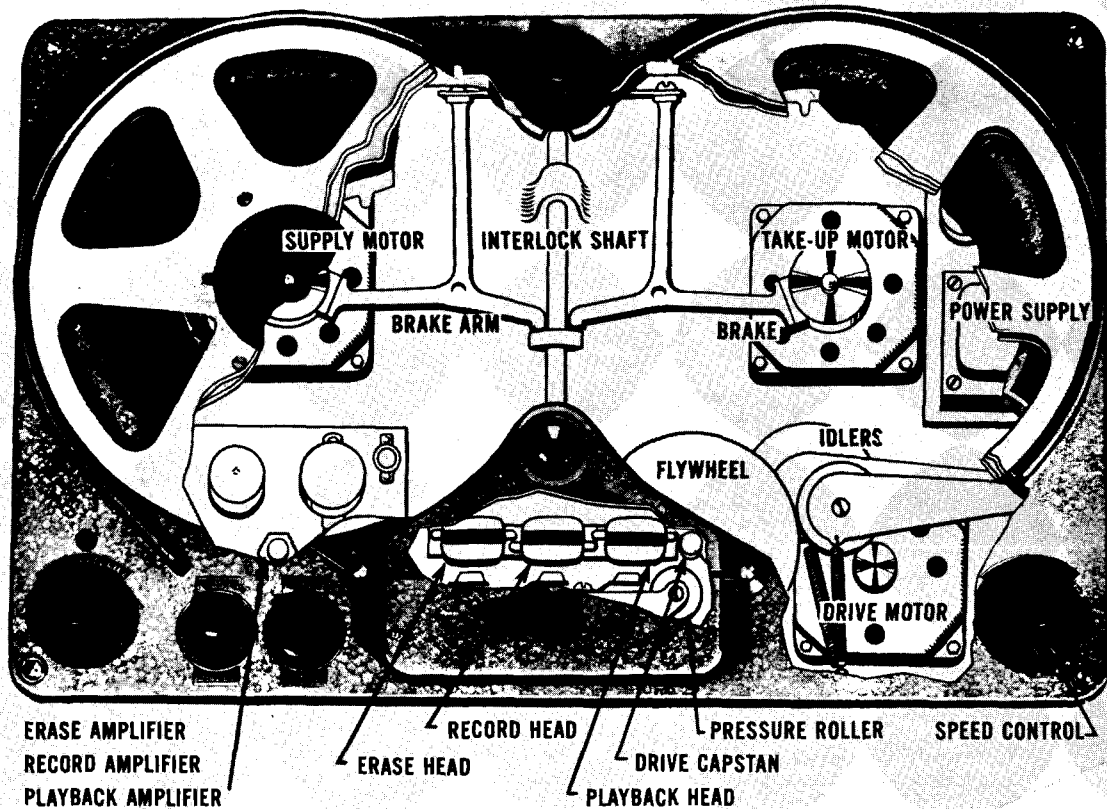


Fig. 4-4 Cut-away sketch of Concertone mechanism. Courtesy: Berlant Associates

Example 2. Concertone Model 1401, Berlant Associates, (Fig. 4-4)

This tape transport mechanism, manufactured by Berlant Associates of Los Angeles, California, is ordinarily marketed in commercial console and portable models, but is also available as a chassis for adaptation to custom installations. Electronic circuits recommended for the mechanism are described in Chapter 5. As shown in the cut-a-way sketch (Fig. 4-4), the transport mechanism is powered by three dynamically balanced and shock-mounted motors functioning as drive, take-up and supply motors. The unit is designed to operate from an a-c, 110/120 volt, 60 cycle source.

Engage Mechanism. The tape-drive control knob, located centrally in the main panel beneath the recording level indicator, actuates the Engage Mechanism (sub-assembly) which performs the following functions:

1. Releases brakes on take-up and supply motors.
2. Delivers a-c power to the drive motor.
3. Engages pressure pads to the erase, record, and playback heads, and maintains even contact between the recording tape and the magnetic heads during recording.
4. Engages the pressure roller which presses the tape against the rotating capstan.
5. Activates interlock mechanism, thus preventing operation of rewind knob during recording or playback.

Speed Controls. The idler-wheel arms, mounted above the drive plate, engage one of two rubber idler wheels when the Speed Control knob is positioned for a tape transport of 7.5 or 15 inches-per-second (ips). To provide dual transport speed, a cast fly-wheel offers a choice of two driving diameters. The main drive capstan is mounted on top of the flywheel shaft.

A ball bearing, mounted against a compression spring in a detent in the main panel, presses into a hole drilled into the cam which engages and disengages the 7.5-ips idler wheel. This insures positive positioning of the Speed Control knob in the Off position. A similar device indexes the Rewind-Fast Forward control knob, at the top center of the main panel.

Lockout Button. Next to the Record-Playback control knob there is a red Lockout button which must be depressed before the control can be moved into the Record position. This button prevents accidental erasure of the tape. A strap spring holds the button lockpin against a step on the underside of the Record-Playback knob. The knob thus acts as a stop for the downward motion of the strap spring and lockout pin.

Braking Mechanism. As shown in the cut-a-way view (Fig. 4-4), a mechanical interlock braking mechanism is centrally located under the top panel. This assembly performs the following functions:

1. Locks out Rewind-Fast Forward mechanism when the machine is used for recording or playback.

2. Locks out the engage mechanism when the machine is in the Rewind or Fast-Forward operation.
3. Releases brakes on the take-up and supply motors prior to operation, and reapplies brakes at the end of operation.

The interlock braking mechanism is operative during recording, playback or rewind; it may be activated by operation of the engage mechanism, or by using either the Rewind or Fast-Forward functions. Adjustment of the braking mechanism is described in Chapter 6.

Example 3. Presto Model SR-950 (Fig. 4-5)

Basic Mechanism. The entire tape-transport and drive mechanism of this machine is mounted upon a hinged top-plate, affording quick access to components (Fig. 4-5). The top-plate is normally placed upon a steel cabinet 40 inches high, providing ease of operation and a housing for electronic equipment. The tape-transport system is handled by three motors, used as individual drives for each of the two tape reels and the drive capstan. The capstan is driven by a synchronous-hysteresis motor, operating at either 900 rpm or 1,800 rpm. Choice of speed is controlled by a toggle switch at the front of the top plate. A speed accuracy of 0.20% at a tape transport of 7.5 ips, or of 0.15% at a transport of 15 ips, is claimed.

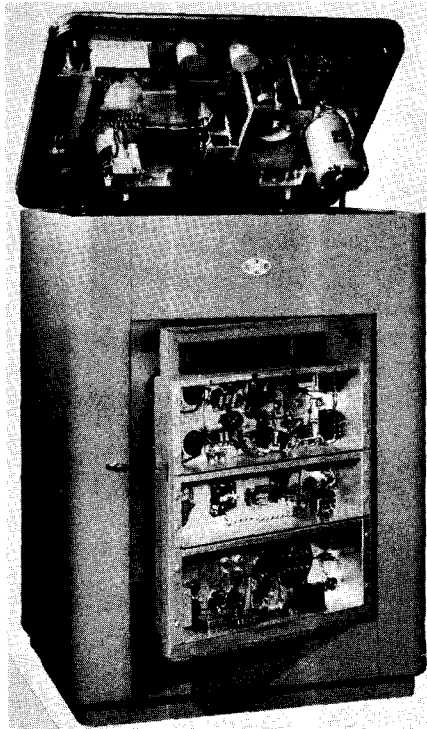


Fig. 4-5 Entire mechanism of Presto Model SR-950, shown mounted to a hinged top plate.
Courtesy: Presto Recording Corp.

Motor Drag. Torque-type induction motors drive the take-up and supply reels in a unique fashion. These motors are so connected that while either is serving as the take-up reel (for Forward or Reverse) the second, or supply-reel motor, introduces a drag by attempting to run in a reverse direction at a reduced voltage. By this arrangement the take-up motor gradually slows down while the supply-reel motor speeds up; a stabilized rate of tape travel at constant tension is thus achieved.

The standard film reel is not required on this machine, since 14-inch platters and 3.5-inch retainer hubs accommodate tape rolls carrying up to 5,200 feet of tape. This amount of footage represents one hour of recording or playing time at a tape speed of 15 ips, or two hours at a speed of 7.5 ips. When a reel is completely unwound, or if the tape breaks, the sudden relaxation of normal tape tension causes a safety switch to cut off power and apply mechanical brakes. These brakes, which are only used for stopping the mechanism, are actuated by solenoids supplied with direct current from selenium rectifiers.

Controls. The two large knobs at the front of the hinged top-plate are gain controls for the recording and playback amplifiers. Three of five control buttons at the left of the plate operate the motors for either Record, Playback, or Rewind; a fourth is for Fast Forward motion, and the fifth is a manual Stop button. Four other buttons on the right side of the plate control electronic circuits, described in Chapter 5. During Rewind or Fast Forward transport, the tape is threaded clear of the recording and playback heads and travels at fifteen times the rate of the 15-ips transport speed. A power of 400 watts at 115 volts, 60 cycles, ac is required to operate the complete machine, including mechanical and electronic equipment.

Example 4. Ampex Model 300 (Figs. 4-6 and 4-7)

Drive Mechanism. The physical layout of the tape-drive mechanism of the Ampex Model 300 professional recorder appears in Fig. 4-6. Start, Stop and Record functions are relay-operated, hence may be remotely controlled. Normal Play, Fast-Forward or Rewind operation are chosen by means of a selector switch. A rapid back and forth shuttling of tape transport for cueing or editing is possible, without stopping, between modes of operation. A choice of tape transport speed of either 7.5 or 15 ips is available, with a single control selecting the desired speed and cutting in the proper equalization for the speed chosen. A schematic of the control circuits is shown in Fig. 4-7, reference to both Figs. 4-6 and 4-7 will prove helpful in understanding the discussion which follows. As shown in Fig. 4-7, the drive system employs three motors: two induction motors (*B601* and *B701*), with solenoid-operated brake bands (*A-328*, Fig. 4-6) are used for take-up and rewind, a third synchronous motor, (*B490*), drives the capstan.

Torque of the take-up and rewind motors is adjusted, by means of resistors, for a mechanical tension of five to six ounces pull on the operative reel hub. Whenever the machine is moved from one location to

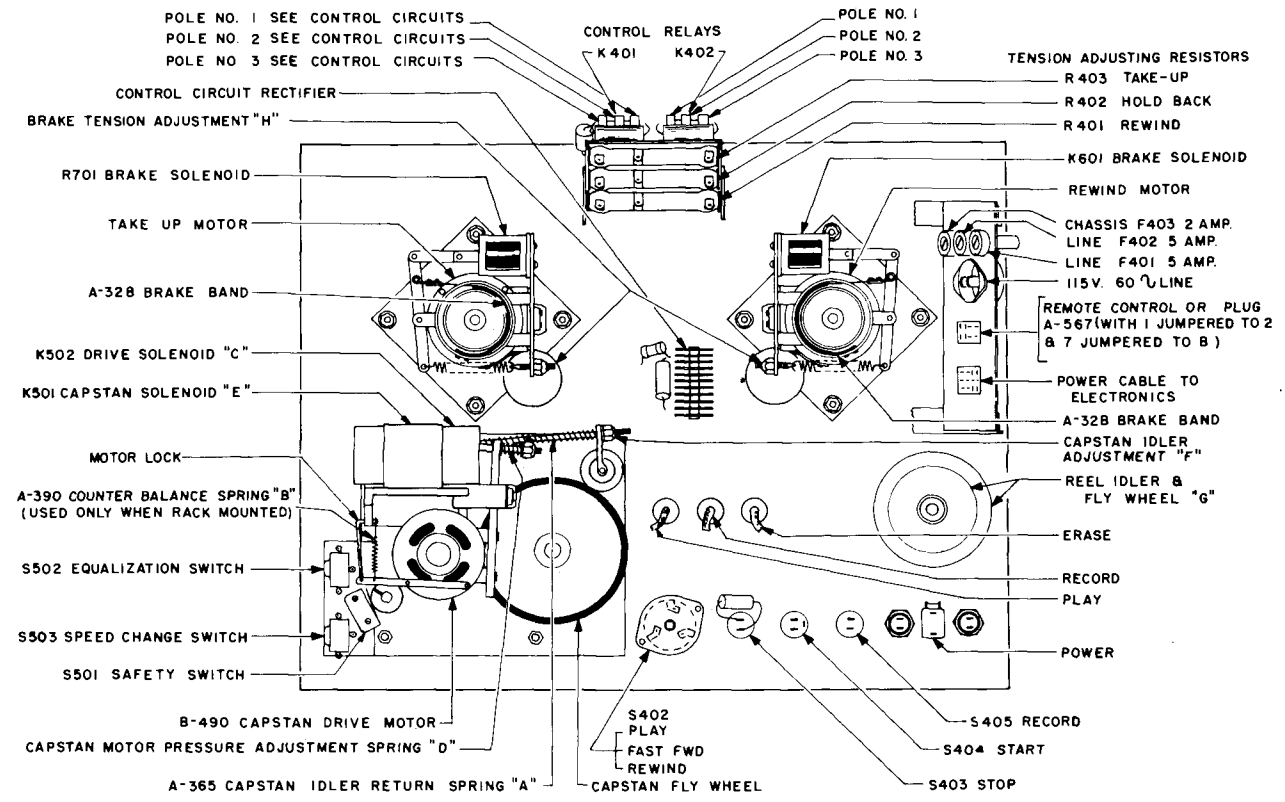


Fig. 4-6 Ampex top-plate assembly, bottom view. Courtesy: Ampex Electric Corp.

another the operator should lock the capstan motor out of contact with the capstan tire; otherwise the capstan will be damaged.

Capstan. The synchronous motor (B490) that drives the capstan is spring-hinge mounted; it engages the flywheel tire of the capstan when drive solenoid *C* becomes energized. The capstan idler mechanism is operated by solenoid *E* and is returned by spring *A*, which is adjustable at point *F*. Slight speed changes can be effected by a change in capstan drive-motor pressure. Correct speed adjustment shows no rotation when viewed with a stroboscope. Lubrication of the capstan and the adjustment of the brakes is discussed in Chapter 6.

Controls. The amplifiers and control circuits are energized by a power switch, which also starts the capstan drive when the machine has been threaded with tape. A take-up tension arm operates a switch which prevents operation of the drive motor until the machine has been threaded. This tension-arm switch opens when the tape runs out, thereby stopping the machine.

When the Stop button is depressed the machine comes to rest and the recording amplifier is turned off. In order to record it is necessary to push first the Start and then the Record button; although starting is instantaneous, it is always good practice to allow a few minutes of warm-up time when the machine has not been in use. For the normal mode of operation the tape comes up to speed in 1/10th of a second. When operating at 15 ips the tape travels less than two inches after the Stop button has been depressed.

Head Housing. The erase, record, and playback plug-in type magnetic heads are contained within a die-cast assembly centrally located on the top panel of the machine. Double mu-metal shielding is used. A gate across the housing face holds the playback- and record-head shield covers and the tape-lifting fingers. These fingers lift the tape clear of all three heads when the gate is opened during Fast-Forward or Fast-Rewind operation; such tape clearance reduces head wear and avoids accumulation of particles from the tape which might impair performance.

Example 5. RCA Model RT-11A (Figs. 4-8, 4-9, and 4-10)

Basic Mechanism. The tape-transport mechanism of the RCA-RT-11A magnetic recorder is powered by three motors, and uses either 10½-inch NAB or 7-inch RMA reels. Both reels must be of the same size for satisfactory operation of the brakes. On the front on the rack-mounted panel (Fig. 4-8) are the reel mounts, tape guides, capstan, head assembly and a row of operating control pushbuttons. The three motors are located on the rear of the mechanism (Fig. 4-9). The capstan drive motor runs at either 900 or 1,800 rpm. The other two single-phase motors drive the supply and take-up reels, respectively. A schematic of the control circuits is given in Fig. 4-10. A terminal block (#J2), shown in the schematic provides for remote control operation.

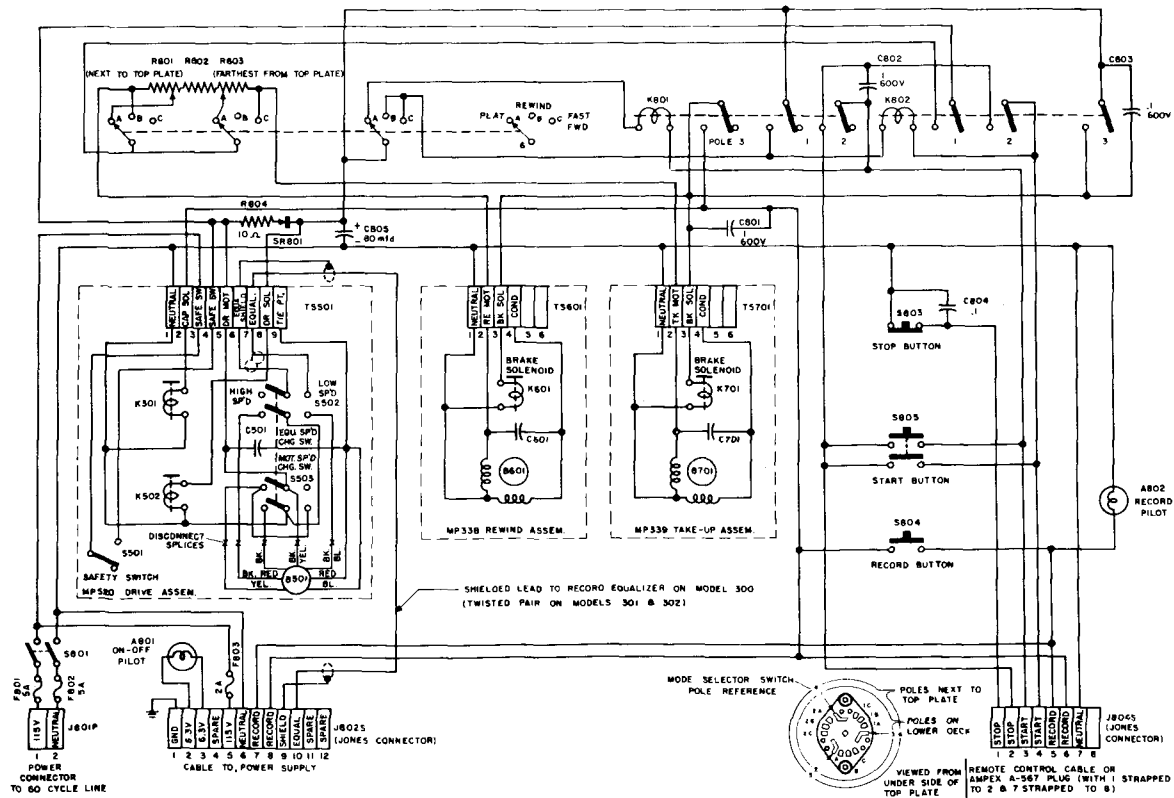


Fig. 4-7 Ampex control circuit schematic. Courtesy: Ampex Electric Corp.

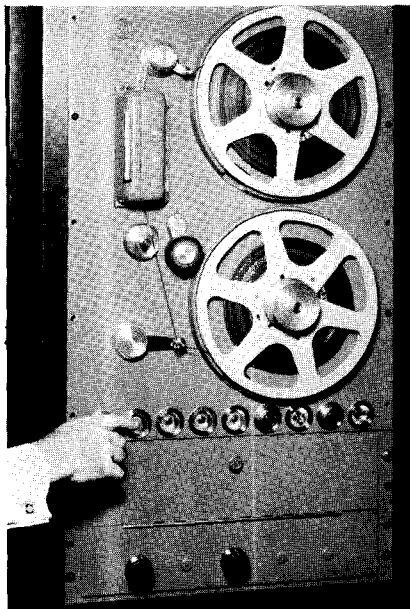


Fig. 4-8 RCA Model RT-11A, rack-mounted mechanism. Courtesy: RCA Victor

Operation. Facilities are provided for normal forward recording speeds of 15 or 7.5 inches per second and also for Fast-Forward and Fast-Reverse operation. When the Start pushbutton is depressed the Start relay is energized. This in turn energizes the pressure-roller solenoid and the brake solenoids, thereby releasing brakes on both reel motors. These motors then become energized at reduced power for normal forward speeds of tape transport. If high-speed forward operation is desired the Fast-Forward pushbutton is depressed. This action energizes both brake solenoids, thus releasing the brakes; it also energizes the tape-lifter solenoids, which raise the tape clear of all heads; it also operates the take-up reel motor at full power.

A high-reverse tape speed is attained by depressing the Fast-Reverse button. Remote relay control again releases the brakes, clears the tape from all three heads, and shifts the supply-reel motor to full power. Editing and cueing is expedited by the provision for jockeying the tape rapidly from Fast-Forward to Fast-Reverse, or vice versa.

Magnetic Heads. Three magnetic heads, in one case, are mounted on the tape drive mechanism. The erase head has a doubled gap to increase fringing flux and is covered with a copper shield. The recording head has a single gap, shielded by a hinged mu-metal case. The playback head also uses a single gap, but its hinged case includes two mu-metal shielding layers, separated by another layer of copper.

Further details pertaining to this mechanism are given in the maintenance section (Chapter 6), associated electrical equipment is discussed in Chapter 5.

Example 6. Presto Model CM-1 (Fig. 4-11)

This long-playing tape recorder for communications monitoring, which provides eight hours coverage has been brought out by the Presto-Recording Corporation. The novel feature of this machine is its unusually slow tape speed of *one inch per second*. This unit has been designed specifically for applications calling for continuous voice or code monitoring, such as air traffic control, police radio, fire departments, military communications, railroads and steamship lines. It has a uniform frequency response between 300 and 3,000 cps and a signal-to-noise ratio of about 40 db.

Tape Transport. The slow tape transport is achieved through modification of an earlier Presto tape-transport mechanism. Four continuous hours of recording can be obtained with one 1,200-foot RMA reel. Since the device is equipped for dual tracks, a total of eight hours of recording time is available. A break in continuity at the end of the first four hours of operation is avoided by the use of two mechanisms. An automatic

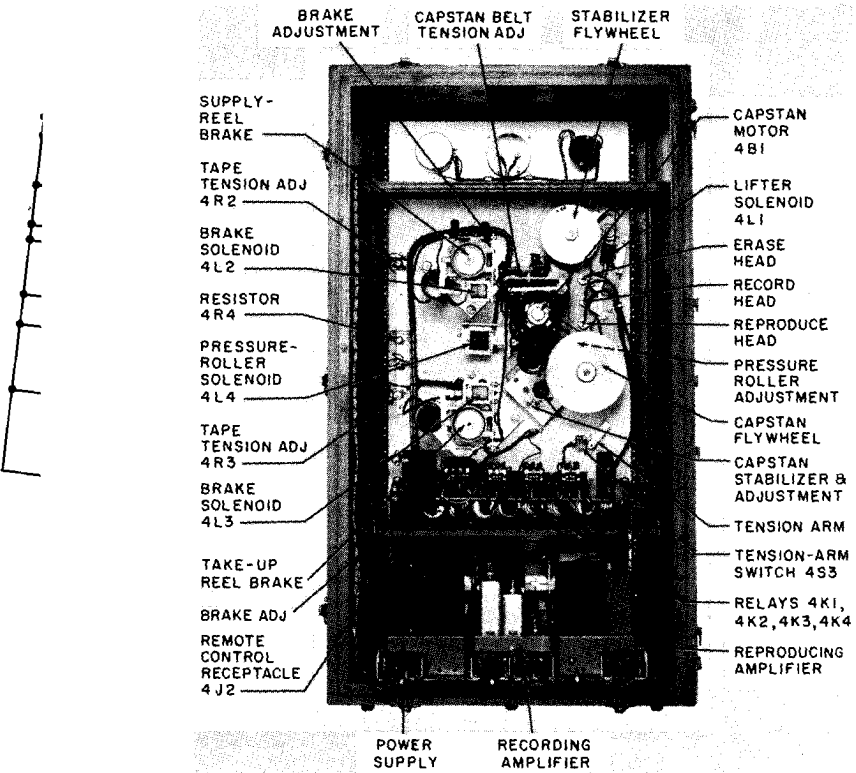


Fig. 4-9 Rear view of RCA model RT-11A rack-mounted mechanism. Courtesy: RCA Victor

Fig.

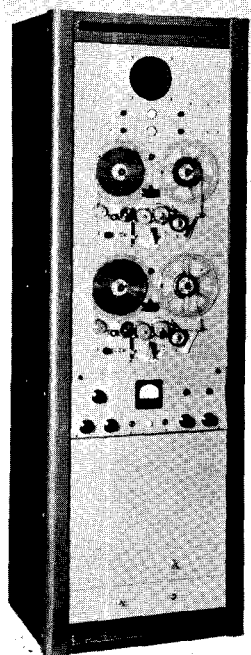


Fig. 4-11 Presto Model CM-1, long-playing tape recorder designed for eight hours of communications recording and playback. Courtesy: Presto Recording Corp.

Example 8. Stancil-Hoffman Model S5 Synchronous System (Figs. 4-13, 4-14 and 4-15)

This synchronous magnetic-recording system (Fig. 4-13) is designed especially for professional motion picture and television studios. It employs standard 16-mm or 17.5-mm motion picture film stock bonded to a highly coercive and narrow track of magnetic material. The dimensions of Fig. 4-14 show how the recording track is applied to regular film stock without disturbing the normal film area required for the synchronized picture. In some cases the track is applied to the back of the film. It is coated to a thickness of $5/10,000$ of an inch and has a width of 0.045 of an inch.

Synchronous electro-mechanical interlock is maintained for all units connected to such a system. Forward or reverse film-transport speeds of 36 or 72 feet-per-minute, normally used for motion picture work, are provided. At the slower speed, one hour of recording time is obtained with a 2,000-foot reel of film. The entire film load may be rewound in approximately two minutes.

Transport Mechanism. Each individual recorder, reproducer, projector or other unit connected into this system is individually driven by its own 110-volt, 60-cycle, single-phase hysteresis motor. These local motors are in turn driven by two 110-volt interlock generators, as shown in Fig. 4-15. The generators are coupled together by a chain with a 1:1 ratio,

both being locked to an 1,800-rpm synchronous motor. The generator for magnetic recording and playback revolves at 900 rpm, while the generator for the optical system turns at 1,800 rpm.

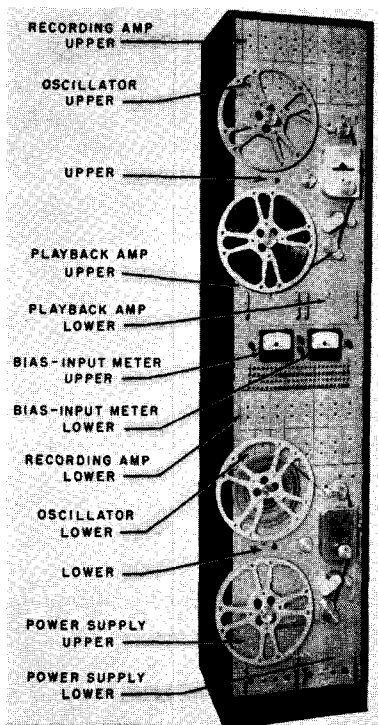
Mounting facilities are also included for 200-volt, 3-phase motors, or for d-c interlock motors which serve on locations where no power lines exist. For the latter, a d-c vibrator-battery combination power supply is sold as auxiliary equipment.

The use of electrical instead of mechanical gear drive lightens the mechanical load, reduces cost, and permits field of remote control operation with a minimum of power consumption. The magnetic-head assembly for the system is of the plug-in type, rigidly anchored yet readily replaceable. Electronic units are identical with the Stancil-Hoffman Model R-4 tape recorder, described in Chapter 5.

Example 9. Fairchild Model 126 (Figs. 4-16, 4-17, and 4-18)

Radically different in design from the mechanisms previously described are the synchronous machines produced by Fairchild Recording Equipment Corporation. Model 126 appears in Fig. 4-16. Because of its accepted uses in the television and motion picture fields, this model is worthy of study. There are three basic departures from the conventional:

Fig. 4-12 Stancil-Hoffman Model CRM15D, multi-channel communication recorder. Courtesy: Stancil-Hoffman Corp.



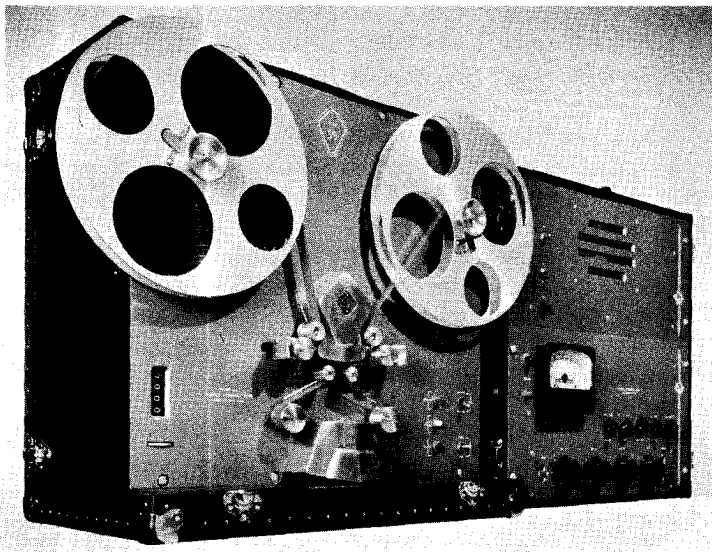


Fig. 4-13 Stancil-Hoffman Model S5, synchronous magnetic film recorder. Courtesy: Stancil-Hoffman Corp.

1. The fundamental drive mechanism aims for speed stability through a combination of a conventional rubber-puck drive, gear drive, and a follow-up servo-motor puck drive. Details are given in later paragraphs.

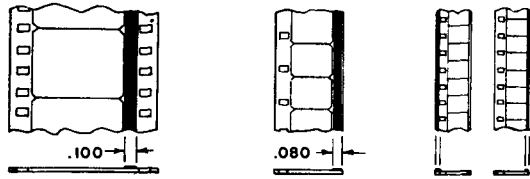
2. The capstan is placed between the supply reel and the erase head instead of in its usual position between the heads and the take-up reel. Constant speed of tape travel is maintained by an oversize drive motor in combination with a massive eight-pound flywheel, and a triple idler arrangement.

3. Three arrangements of threading are provided, as shown in Fig. 4-17. The solid line shows threading for recording and playback, the intermittently broken line shows threading for Rewind and Fast-Forward, the dashed line shows optional threading for Fast-Forward or for reverse shuttle across the magnetic heads.

Drive Mechanism. For motion picture work synchronism is imperative. Gear drives naturally maintain synchronism, but also introduce tooth ripple. This may be eliminated by use of a soft coupling, although this in turn could introduce objectionable lag which, when subjected to load changes, would give rise to wows. However, the *Synchroll* mechanism (Fig. 4-18) claims to hold tape creepage and slippage to less than 0.1%. This permits program timing to within four seconds for a sixty minute program. A synchronous motor drives the tape capstan through two couplings, consisting of a positive toothed belt in parallel with a rubber friction drive. Soft coupling to the tape capstan assists in filtering out any motional disturbance arising from the toothed belt. Synchronism is obtained while keeping the well-damped characteristic of a friction drive.

Fig. 4-14 Rapid progress in magnetic sound-on-film has aroused much interest. These drawings show the magnetic sound track on 35-, 16-, and 8-mm film.

Courtesy: Armour Research Foundation.



Stiff rubber pucks against the unusually heavy flywheel eliminate excessive flexible couplings.

Stabilizing System. The entire drive system is stabilized by means of a follow-up (servo) motor. This servo motor receives a stabilizing control signal from electronic circuits responsive to any errors in synchronism. Relative speed and torque of the servo motor are proportional to the phase relationship between the power-line source and the control signal. The follow-up motor (Fig. 4-18) is coupled to the main flywheel through a hard-rubber puck. As a consequence the motor provides a varying load upon the main drive motor, sometimes assisting, sometimes retarding it. This mechanically closed servo-loop thus attains positive synchronism.

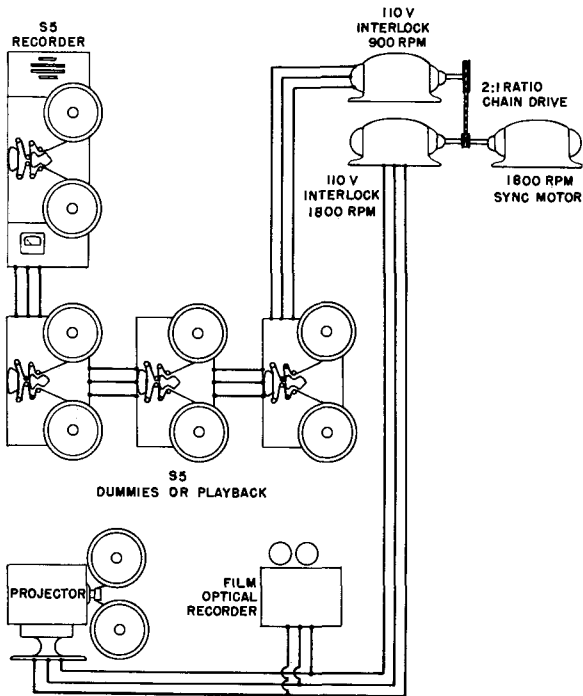


Fig. 4-15 One Stancil-Hoffman S5 16-mm tape recorder and three 16-mm dummies interlocked with a 16-mm projector and 16-mm film recorder. Courtesy: Stancil-Hoffman Corp.



Fig. 4-16 Fairchild Synchroll Model 126, one type of synchronous machine used extensively for motion-picture and television film installation. Courtesy: Fairchild Recording Equipment Corp.

Tape Transport. A normal tape speed of 15 ips is provided, but the machine can easily be converted to speeds of 7.5 or 30 ips.

Operation may be with or without tape reels, through adjustment of the height of the head plate. Reels up to 5,000 feet are accommodated, these run for one hour at 15 ips.

Tape transport is stabilized by a 180-degree wrap-around of the 1¼-inch capstan (see Fig. 4-17). With a regulated tape-transport speed tolerance of 0.1%, playback is accurate to better than one-half second for a fifteen minute period.

Dynamic reel braking is employed. A constant-torque type of motor drives each tape-reel shaft. When the stop button is depressed, reel braking is accomplished by passing direct current through the reel motor windings. There are no friction brakes or clutches.

Example 10. Presto Tape Drive TL-10 (Figs. 4-19 and 4-20)

The Presto TL-10 Tape Drive is a very useful and money-saving playback mechanism. It has no motor, but derives its power from any 16-inch transcription turntable, to which it is easily attached (see Fig. 4-19). The tape-reproducer consists of a triangular-shaped, cast chassis, mounted upon two small posts which fasten to the rear of a turntable top-panel. A capstan of considerable diameter rests directly upon and is driven by the center-pin of the turntable. The large capstan is rubber-rimmed and attains a tape wrap-around of 180°. Two capstans are available which offer tape speeds of either 7.5 or 15 ips for a turntable speed of 78 rpm. Construction details are shown in Fig. 4-20.

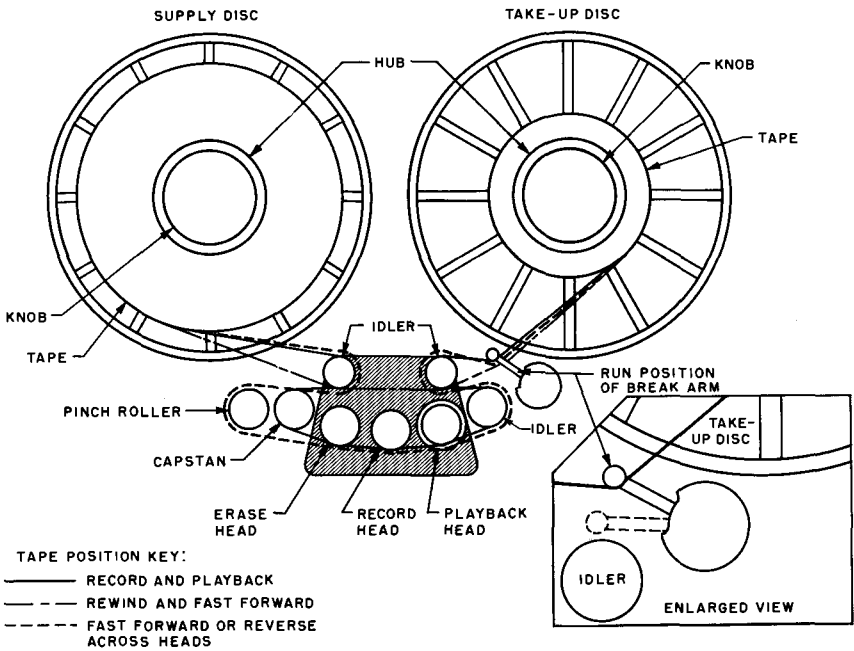
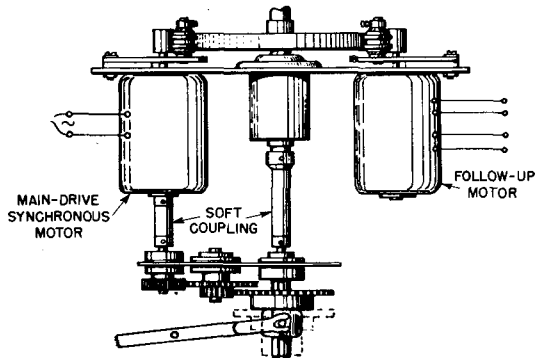


Fig. 4-17 Fairchild's three ways of threading. Courtesy: Fairchild Recording Equipment Corp.

Located on the underside of the chassis, a belt drive and slip-clutch rotate the take-up reel. An equalizer network, matching a 500-ohm speech input, is also mounted beneath the chassis. Reproducer head, guide pulleys, tape reels, and equalizer control knobs are mounted on the upper side of the unit, which may be readily tilted upward and back out of the way when not in use. Special adapter-plate mounts are provided which match the unit to any commercial turntable.

Fig. 4-18 Fairchild Synchroll mechanism basic drive unit, utilizing a mechanical servo loop. A combination of gearing and rubber-puck drive is augmented by a follow-up motor which is coupled back to the main fly-wheel through a hard rubber puck. The mechanism is used for synchronous motion-picture work. Courtesy: Fairchild Recording Equipment Corp.



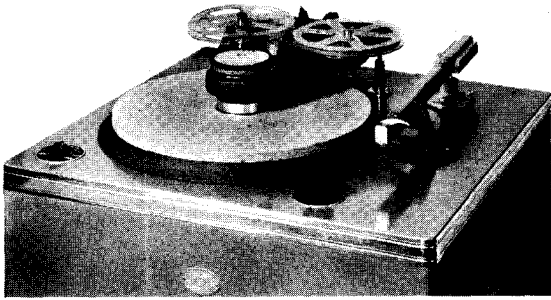


Fig. 4-19 Presto TL-10 playback mechanism, in position for use as driven by any standard 16-inch turntable. Courtesy Presto Recording Corp.

Example 11. Telemetering Mechanism, Ampex Model 500 (Figs. 4-21, 4-22, and 4-23)

Even the best tape recorders previously available have not been adequate to meet the exacting demands of telemetering. The new mechanism described here was designed by the Ampex Electric Company expressly to record AM/FM telemetering data without introduction of appreciable error. The model 500 has met US Navy and JAN specifications.

Stiction. One of the greater obstacles previously encountered was the sliding-friction type of flutter, called *stiction*, caused by variations in friction at the head and tape contact points. This stiction results in a high flutter frequency which may fall between 2,000 and 3,500 cps. An im-

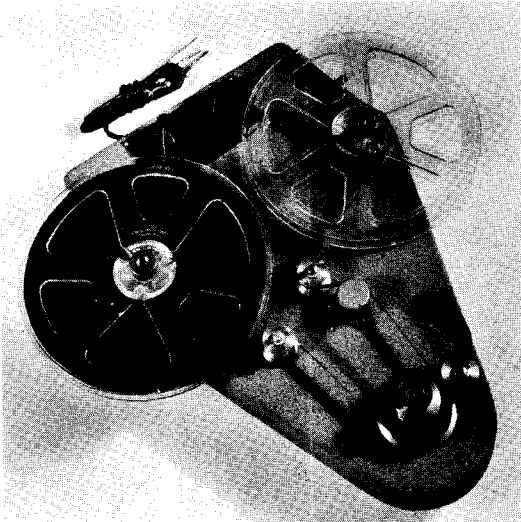
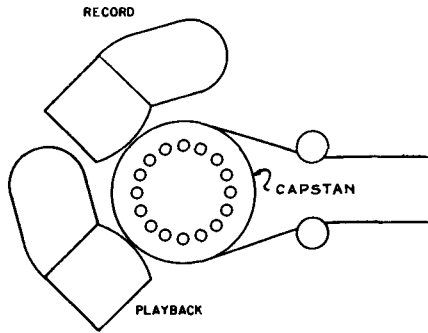


Fig. 4-20 Large capstan and threading details of Presto TL-10 playback mechanisms. Courtesy: Presto Recording Corp.

Fig. 4-21 Improved form of closed-loop tape transport, used in Ampex telemetering mechanism Model 500. (Note the circle of holes in top of capstan used in the tape-hold vacuum system.)
 Courtesy: Ampex Electric Corp.



proved form of the closed-loop type of tape transport is employed in Model 500 to overcome flutter due to stiction, (See Fig. 4-21). It can be seen that the length of unsupported tape has been reduced to a minimum. Furthermore, the record and playback heads contact the tape while it is still pressed against the capstan.

Vacuum System. A radically new vacuum feature is employed in this mechanism. Instead of being held against the capstan by tension, the tape is held in secure contact by means of a vacuum system. Figure 4-22 shows how the tape is secured between the four multiple heads and the correspondingly grooved capstan. There are four annular grooves around the capstan which are precisely in alignment with the points at which the four record heads contact the tape. The width of this tape is $\frac{1}{2}$ -inch (in the mechanisms previously discussed the width was $\frac{1}{4}$ -inch).

There are numerous lateral capstan holes connecting the annular capstan grooves with the hollow capstan interior. This air path is continued outward through the circle of holes around the top of the capstan

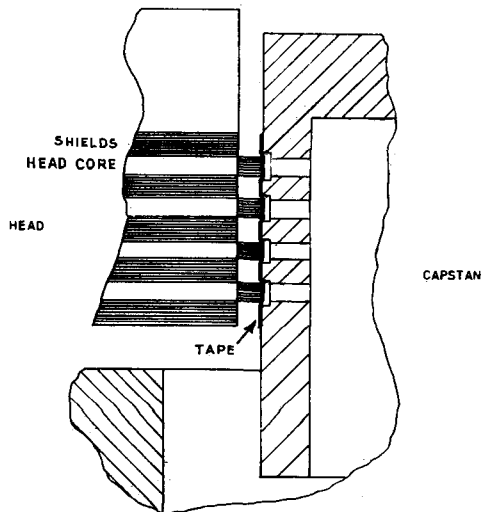


Fig. 4-22 Cross section of Ampex Model 500 vacuum-controlled capstan which accommodates four individually shielded recording heads. Courtesy: Ampex Electric Corp.

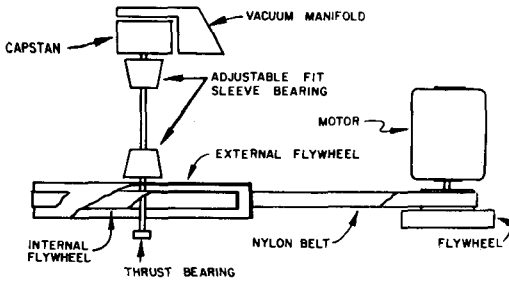


Fig. 4-23 Schematic diagram of drive mechanism for Ampex Model 500. Courtesy: Ampex Electric Corp.

(see Fig. 4-21). The capstan interior and annular grooves are evacuated by a valve system in the vacuum manifold, which is rigidly held to the rapidly revolving circle of holes (Fig. 4-23).

The simple vacuum is created when air is exhausted from the capstan (sealed by the tape), sucked into the vacuum manifold by a system pump, and finally exhausted through ports along the base of the machine cabinet. When the machine is stopped or reversed the pump is reversed, thus holding the tape away from the capstan for a minimum of wear. The same pump cools the electronic components within the cabinet.

Drive Mechanism. The tape capstan and its shaft are supported in a pair of adjustable sleeve bearings (Fig. 4-23). These provide close control according to requirements. A large flywheel is mounted at the lower end of the capstan shaft; inside this flywheel is a second stabilizing flywheel. Separation between the two flywheels is maintained by a 1/16 inch film of oil. With the two flywheels thus coupled together the resulting inertia is multiplied. Although coupled to the synchronous motor by a belt, a very low "Q" flywheel system results, which provides almost critical damping. A speed change switch allows speeds of 30 or 60 ips.

A tuning-fork driven power amplifier supplies an accurate source of 60-cycle power for the capstan drive motor. The tuning-fork oscillator supplies a 60-cycle signal to a control track generator and also provides a standard reference frequency during playback. Speed correction is sufficiently precise so that the carrier frequency reproduced from the tape will not deviate by more than 0.01% from the original frequency. One machine is capable of recording the output of four telemetering receivers simultaneously, since there is better than 40-db shielding between each of the four recording heads.

Chapter 5

TAPE RECORDING CIRCUITRY

Since the basic electronic requirements of magnetic tape-recording systems include amplification, equalization, and reproduction, they are similar to those of other types of sound recording. A recording amplifier is required to boost the low-level input signals to voltages adequate for driving the magnetic recording head. In contrast to the high output power needed for disc recording, tape systems require a relatively small amount of power (a few milliwatts) to drive the recording head; this represents a considerable saving in weight and cost. Because of the low power needed, care must be taken not to overload the amplifier and recording head, or distortion will result. Level adjustments for specific machines are described in later paragraphs.

Block Diagram

The block diagram of Fig. 5-1 shows, in simple form, the basic electronic and electromechanical components required for a modern magnetic-recording system. The theory behind most of these components has already been explained in previous chapters. Electronic requirements peculiar to magnetic recording are emphasized in this chapter. The oscillator required for generating the high-frequency bias signal (the theory of which was explained in Chapter 3) will be discussed. Very often this signal is derived from a dual-purpose vacuum tube within the recording amplifier. Frequently the h-f bias signal is further amplified to generate the strong high-frequency erase field needed for demagnetizing a previously recorded tape.

Performance Standards

Recording machines of varying capabilities were described in Chapter 4. The performance of these machines may be limited either by their mechanical or electronic characteristics, or by a combination of both. Given the best possible mechanism, a certain machine may still be incapable of top performance because of inadequate electronic equipment. In this chapter the reasons for this, and methods for overcoming certain electronic limitations, will be discussed.

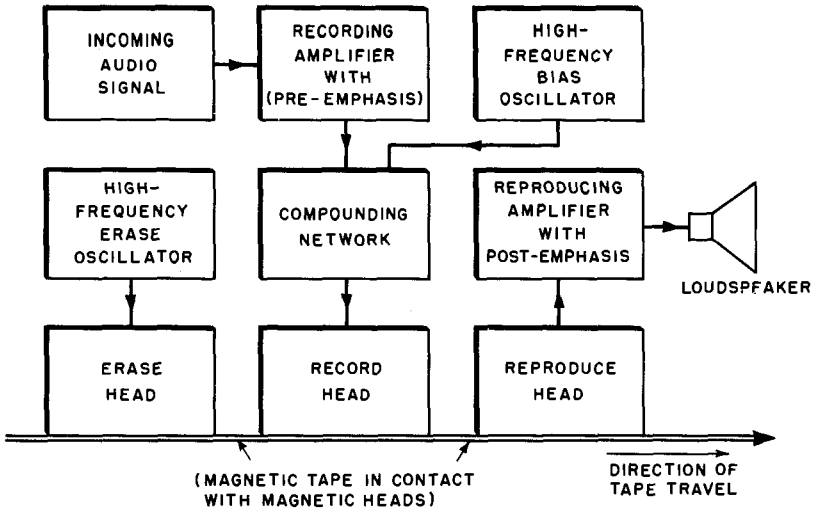


Fig. 5-1 Basic electronic and electromechanical components of a magnetic-recording system.

Electronically, the prime consideration is the frequency-response requirement of an installation. The wider the required frequency response of a system, the greater is its cost. Since there is generally no need for an extremely wide tonal range for amateur, home, or office recording, an upper range of 5,000 cps or less should be adequate for these applications. To meet broadcast standards, however, professional recording machines must be capable of recording all frequencies between 50 and 15,000 cycles. The National Association of Radio and Television Broadcasters (*NARTB*) has established primary and secondary standards, as defined graphically in Fig. 5-2. The primary standard response limits are for professional studio installations, while the secondary standards are acceptable for portable equipment. Harmonic distortion for professional equipment should be less than 2% at peak level, and the signal-to-noise ratio should be at least 50 decibels at peak output.

Chapter 3 explained that bias control directly affects the amount of output distortion. Often the lower-priced machines merely provide a fixed bias. Where two tape speeds are provided in these units, the bias is set at the optimum value for the slower (more critical) of the two speeds. Professional machines usually have an adjustable bias control which can be changed for dissimilar tapes or tape speeds. The manufacturer's data lists the proper values for bias adjustment.

Physical Construction

Desirable physical features of electronic units in tape recorders are listed and discussed in the following paragraphs.

1. *Sectionalized Construction.* Isolation of pre-amplifiers, oscillators, and power stages by sectional construction permits rapid replacement of these units and causes fewer interruptions in service while the defective component is being repaired. Rapid service is further assisted by plug-in construction of electronic units. Plug-in facilities also provide flexibility of input and output requirements. For example, a variety of plug-in input and output impedance values may afford radio-line pickoff or repeater work, as well as direct-pickup recording.

Front and/or rear hinges provide ready access for tube replacements or servicing. All, or a portion, of the unit may be opened for inspection.

2. *Weight.* Weight reduction is important in portable units. For this reason the amplifiers of light-weight machines almost always employ resistance-coupled stages, which also minimizes the cost.

Professional portable systems are often divided between two carrying cases; one containing the mechanism while the second houses the electronic equipment. This arrangement distributes carrying weight and reduces transmission of hum or machine rumble from the drive system to the amplifiers.

3. *Shielding.* The requirements for shielding tape recorders are considerable. Not only must magnetic heads be shielded from each other, but the strong fields of erase heads must be confined. When permanent-magnet erase heads are used, they must be automatically withdrawn from the vicinity of the tape during recording to avoid accidental erasure. Furthermore, the amplifiers of machines using three motors must be extremely well shielded against pickup of low-frequency hum. For example, to avoid such undesirable motor hum pickup, the Ampex

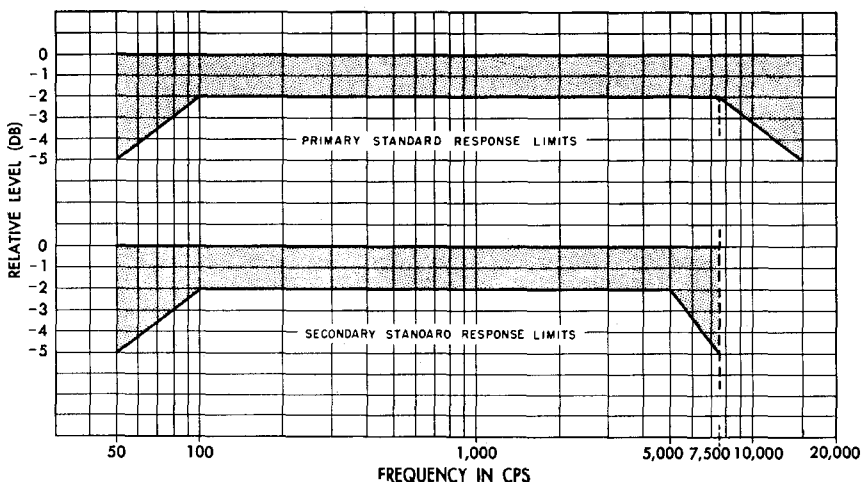


Fig. 5-2 NARTB primary and secondary response limits for magnetic-tape systems.
Courtesy: Audio Devices, Inc.

recorder mounts the triple-head assembly above a shielding plate which covers the entire top of the machine and its three motors. Other manufacturers are equally careful; some use mu-metal heads grouped under a common cover and above a shielding top-plate to guard against dust and external magnetic fields.

4. *Vibration-Proof Mounting.* Amplifiers and tape mechanisms located within the same cabinet must be mounted on a shock-proof base, such as that provided by rubber grommets, to avoid direct transmission of machine rumble or other disturbances to vacuum tubes.

5. *Ventilation.* Although the motors utilized in some tape recorders have a cooling fan directly attached, this may be insufficient to provide free circulation of air about the machine. Since electronic units employing vacuum tubes generate considerable heat, adequate ventilating provisions are a must. This fact becomes especially important when the chassis is mounted in drawers or a cabinet, as is the case in many custom-built installations. Built-in vents and a forced draft are often necessary to provide adequate ventilation.

6. *Controls.* Piano-key type switches, which operate solenoids to control forward and reverse operation, have recently appeared in small home models. Remotely controlled solenoid operation for professional models is discussed in Chapters 4 and 6.

Recording Amplifiers

The quality of a tape record can be no better than the limitations imposed upon it by the recording and playback amplifier. Therefore these amplifiers must be constructed of high-grade components. Amplifiers originally designed for other types of recording may be used for tapes, provided corrective networks are added which compensate for the inherent characteristics of magnetic recording.

Equalization is required because of the nonlinear response-versus-frequency characteristic of a magnetic recording. Corrective networks must be provided. Such networks are explained and illustrated in the equalization discussion which follows.

When an amplifier formerly used for other purposes is modified for tape recording its gain may be far too great for the small power required. A pick-off from an intermediate stage can be matched through a network or a transformer to the proper impedance for the magnetic head (refer to the output stages of schematics in this chapter for circuitry). Stages following the pick-off may be switched in to drive the loudspeaker during reproduction.

A small current of approximately 0.8 ma is adequate to drive the average magnetic head in a low or medium-priced machine. One method of converting an initial voltage output through a conversion stage supplying proper current to the head appears later in Fig. 5-20. The Brush BK-411 circuit is shown, in this case the 6SJ7 (V_2) is the converter stage.

Equalization. The variety of factors which affect the overall frequency response of a magnetic tape-recording system are discussed in Chapter 3. Manufacturers compensate for frequency response irregularities in various ways. Obviously, the mid-frequency characteristic 6 db-per-octave rise calls for correction (see Fig. 3-12). The same is true for the pronounced droop at the higher frequencies. Equalization must also be provided for the varying modulation characteristics of different commercially available tapes; specific data is available from the manufacturers.

Response correction accomplished during recording is called *pre-emphasis*, while that provided during playback is called *post-emphasis*. In order to attain a high signal-to-noise ratio, pre-emphasis is usually applied after the first stage of amplification. (Noise inserted into the first stage is subject to the full available amplification.) Compensation may be applied to both upper and lower frequencies with respect to the mid-frequency range. In some cases all low-frequency equalization is confined to a post-emphasis boost during reproduction. As previously mentioned, the high-frequency response is directly proportional to the tape speed utilized. When several speeds are provided, different degrees of high-frequency equalization must be available for correction.

Some manufacturers (RCA, for example) choose to raise the 60-cycle region of the recording characteristic during pre-emphasis. This permits a 6-db reduction of post-equalization during reproduction. In this way a gain in signal-to-noise ratio is achieved, since 60-cycle hum receives 6-db less amplification during playback. Such compensation may be inserted either before or after the recording amplifiers, depending upon its power handling capacity. Insertion loss for an equalizer of the constant-resistance type amounts to approximately 10 db.

A pre-emphasis boost of high frequencies greater than 15 db is not recommended, since high-frequency overload, and consequent distortion, is likely to occur.

Equalizers applied to recording circuits are essentially high- or low-pass filters, often adjustable to requirement or taste. *R-C* filters are often

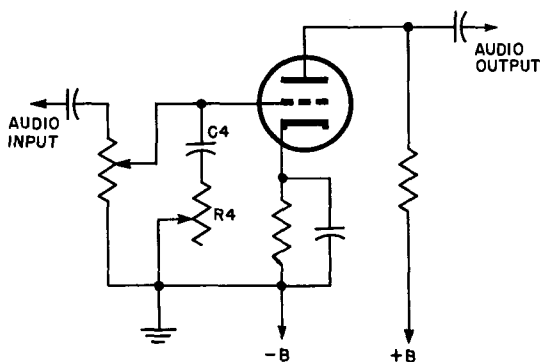


Fig. 5-3 Typical tone control for variable retardation of higher audio frequencies.

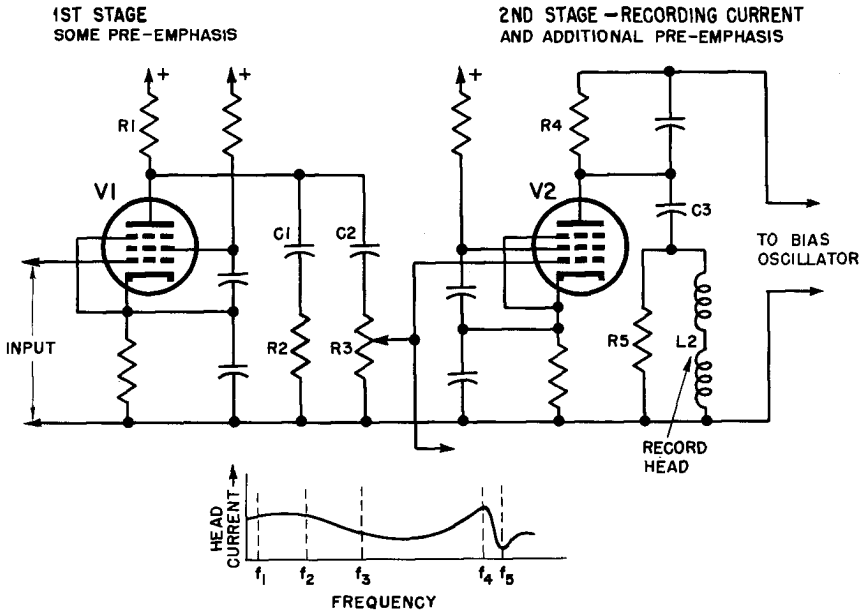


Fig. 5-4 Recording amplifier with two stages having pre-emphasis and producing record-head current according to the curve. Courtesy: Brush Development Co.

used, since the current flow is very low and the voltage drop of the resistor is not serious. The h-f oscillator coil, however, is sometimes switched in to become part of a compensating LC circuit during reproduction, when no oscillator is required.

Possibly one of the simplest circuits which can vary and retard high-frequency response appears in Fig. 5-3. Here $R4$ and $C4$ jointly effect a tone control. Maximum reduction of higher frequencies occurs when $R4$ is completely out of the circuit, whereupon $C4$ is directly between the grid of the tube and ground. The value of $R4$ should be large in comparison to the reactance value of $C4$; then the effect of $C4$ upon frequency response will be negligible when the full value of $R4$ is in the circuit.

One method, used by the Brush Development Company, distributes pre-emphasis between two stages of amplification. The circuitry and resultant response curve is shown in Fig. 5-4. The network in the first stage ($V1$), comprised of $R1$, $R2$, $R3$, $C1$, and $C2$, produces the low-frequency emphasis below $f3$ on the curve.

In the second stage ($V2$) capacitor $C3$ is in parallel with the signal source ($V2$) and the recording-head windings ($L2$). This network tunes the head to a value which produces the high-frequency emphasis at $f4$ on the curve (Fig. 5-4). One requirement of design is to avoid

pre-emphasis of recording current beyond the highest frequency to be recorded. Otherwise intermodulation distortion with the bias frequency may occur. The magnitude of $R4$ (Fig. 5-4) must exceed the reactance of the recording head at the top frequency to be recorded; if not, the recording system will become a constant-voltage rather than a constant-current system. The average recording head has a more uniform characteristic when a constant-current system is used.

For reproduction the same amplifier is used, but circuit values are changed. The playback head is connected across the input to tube $V1$ and the record head is removed from the $V2$ stage. Under this condition the network $R1$, $R2$, and $C1$ provides the additional gain required for post-emphasis of the lower frequencies below $F3$ on the curve (Fig. 5-4).

Another simple method of recording pre-emphasis is illustrated in the upper part of Fig. 5-5. This method employs plug-in equalizers, for the Magnecord PT6-J unit. One is supplied for each speed of tape transport requiring different component values. This type of R - C circuit and choke equalizer is inserted between the recording-amplifier output and the recorder head. Frequency correction for head behavior during the recording process is thus accomplished. Actual connections to the amplifier appear in Fig. 5-16.

During reproduction an R - C feedback network may be switched into the plate circuit of the first stage of the same amplifier. The basic feedback circuit appears in Fig. 5-6. Such a network allows high gain for low frequencies, but retards gain for high frequencies. The dual-purpose amplifier connections are shown in Fig. 5-16.

Still another method of equalization is employed in the circuit recommended for a product of the General Industries Company, a combination tape and disc recorder. The principle of compensation used here is inverse feedback with frequency discrimination. The feedback is primarily for reduction of harmonic distortion within the amplifier. It includes equalization of both high and low frequencies; this action occurs during playback only.

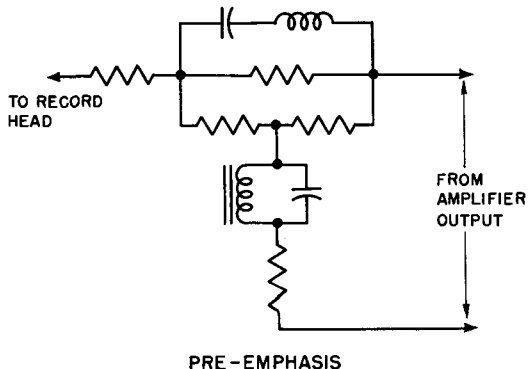


Fig. 5-5 Pre-emphasis equalizer for Magnecord PT6-J. Courtesy: Magnecord, Inc.

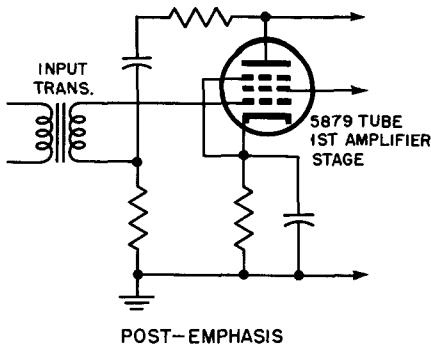


Fig. 5-6 Post-emphasis equalizer, Magnecord PT6-J. Courtesy: Magnecord, Inc.

Discriminating networks in the feedback loop prevent the feedback of any frequencies above or below the middle register. This attenuates the gain for the middle register to the second stage of the playback amplifier by the amount of feedback voltage. With this discriminatory condition the full gain of the amplifier is applied to the higher and lower frequencies during playback of either tape or disc. A number of actual equalizer circuits used in modern machines are shown in the schematic diagrams associated with the examples which follow later in the chapter.

High-Frequency Oscillators

A stable high-frequency bias oscillator is often built into the amplifier. A sine-wave frequency, somewhere between 30 and 100 kc, is generally used. Frequently two output levels are provided: a low-level output for biasing the recording characteristic to the proper operating point on the magnetization curve (as explained in Chapter 3), and a high-level output, amplified from the same oscillator, applied to the erasing head. Erase oscillators often must provide up to 300 volts output to obliterate any previous recording on the tape; hence careful shielding is required to prevent leakage into other circuits.

In one Magnecord unit the bias oscillator supplies the record and erase heads connected in series. A power output of four watts is employed. Much of this power is consumed by the erase head, which has a winding of 20 turns, at a current of between 1.1 and 1.3 amperes. The record head, connected in series, has a winding of only six turns. In contrast to most machines, this bias oscillator is built into the mechanical section; a second unit houses the amplifiers.

For the thorough erasing required in motion picture work, two erase heads, in cascade, are often used for each track. In one RCA unit, for example, each erase head dissipates 1.6 watts, totalling 3.2 watts per track of erase current power. The result is a 70-db erasure below 100% modulation. During the final recording of a motion picture, it is common practice to have three magnetic sound tracks on a single

35-mm strip of film. For erasure of these, a master oscillator of approximately 68 kc is used. A separate winding on the oscillator coil supplies the number of erasure amplifiers required. This same master oscillator supplies three independent push-pull amplifiers, which in turn furnish bias current to the three recording heads.

The frequency of the bias oscillator should be approximately five times greater than the highest audio tone to be recorded. Otherwise audible beats may occur between the oscillator and the signal recorded. Professional units often use 100 kc.

An *L-C* oscillator circuit is generally used to generate the bias and/or erase signal. Such a circuit is illustrated in Fig. 5-7. The plate output from the oscillator tank circuit is capacitance coupled to a push-pull amplifier (two 6SN7's). In this case (a BK-401 Soundmirror) the plate-to-plate potential of the push-pull amplifier averages between 80 and 100 v. A 30-kc current of approximately 20 ma is supplied to the erase-head coil. As shown in the overall schematic in Fig. 5-20, the record head is supplied prior to this amplification and through a coupling capacitor to the 6SJ7 converter stage. The bias signal and the audio signal are combined (not modulated) in this converter stage which drives the recording head.

To accommodate differences in recording tapes, at least two values of bias current should be made available. This may be accomplished by the simple method of switching two series resistors to a parallel connection. Average values of bias current run from 2.0 to 4.5 ma.

When high-frequency erasure is employed it often uses the same oscillator used to provide bias current. Amplification is applied to the oscillator output as previously indicated. Otherwise basic circuitry is the same.

Playback Amplifier

In the smaller tape machines the basic recording amplifier is also used for playback, with an extra power stage switched in during playback. The power output which drives the built-in speaker may be five watts or better. When the transfer from recording to playback is made, pre-emphasis equalization is replaced by post-emphasis circuits. Differences are explained under "Equalization". Some examples are explained and illustrated later in this chapter.

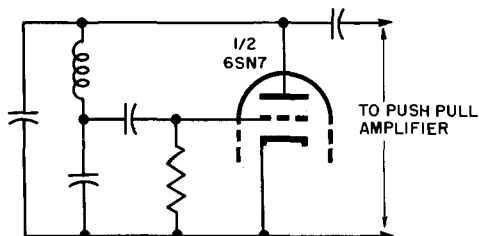


Fig. 5-7 Typical bias-oscillator
Courtesy: Brush Development
Co.

Larger professional machines, designed for more exacting requirements, employ separate amplifiers for reproduction; different values of equalization are provided for either of two speeds of tape transport. Remotely controlled relays are often used for switching, and are operated by a master switch which changes all facilities from Record to Play. Typical of this is the RCA reproducing amplifier described later (and shown in Fig. 5-10).

Another example is the Ampex 300 model. The playback amplifier will deliver plus 25 dbm at 1% total harmonic distortion into a 150- or 600-ohm line. Ample reserve power is allowed over normal operating levels.

Very often professional equipment is played before discriminating listeners. To avoid the weird sounds from a tape rewind at high speeds, a muting switch is attached to the lever or button causing the rewind. This muting switch short-circuits the playback head during the time the tape runs in the reverse direction.

Playback amplifiers are often used as a monitoring facility during the recording process; therefore, they are supplied with an individual level control independent of the record function. The high-frequency oscillator is usually automatically switched off during the playback period. If manual controls are not properly switched, such as from Record to Playback, before the tape is rewound, the record may be erased during rewind.

Input and Output Equipment

A tape recorder is merely part of a complete sound-recording and reproducing system, which must also include input sources and reproducing (output) equipment. This book is principally concerned with recordings made from a microphone, a radio, or line input signals to be reproduced through a loudspeaker.

Microphones of various types are often supplied with the recorder. Wide-range, expensive microphones are only necessary for professional equipment. Less expensive types are more than adequate to cover the frequency range of home recorders and, in addition, usually provide about 3 db more output than the more expensive units.

Built-in loudspeakers are also selected according to the frequency range of the particular machine. Often, however, an external baffle-mounted speaker greatly improves reproduction. It is also practical to couple the output of a home tape machine to the input of a radio amplifier to drive your present radio loudspeaker.

Professional machines are often used to drive a large public-address system. For this application it is necessary to match correctly the impedances between the tape machine and the PA system. The final stages of the tape amplifier are sometimes omitted to facilitate matching and to provide control of the overall gain of the system to avoid possible overload.

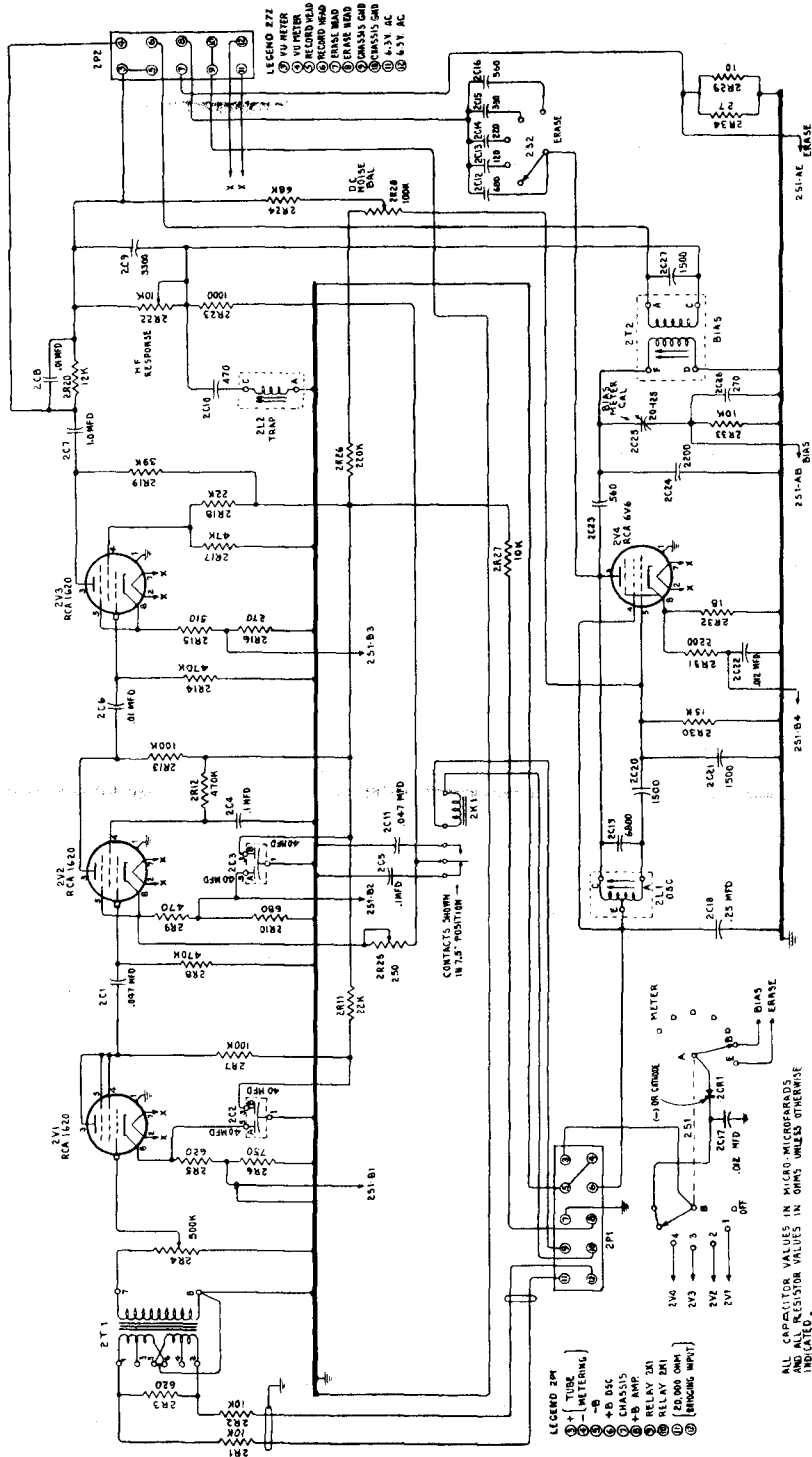


Fig. 5-8 Schematic of RCA Model RT-11A recording amplifier. Courtesy: RCA Victor

ALL CAPACITOR VALUES IN MICRO-MICROGRAMS AND ALL RESISTOR VALUES IN OHMS UNLESS OTHERWISE INDICATED.

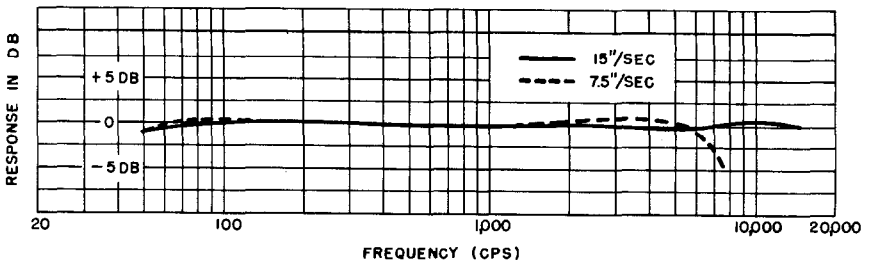


Fig. 5-9 Frequency-response curve of RCA RT-11A recorder with compensation. Courtesy: RCA Victor.

Because of their high fidelity, magnetic recorders are frequently used in custom-built installations, between the sound source and a power amplifier. A high-gain input is used for microphone connection and a low-gain input accommodates the output from a home radio. From the recorder output jack a shielded cable connects to the balance of the sound system.

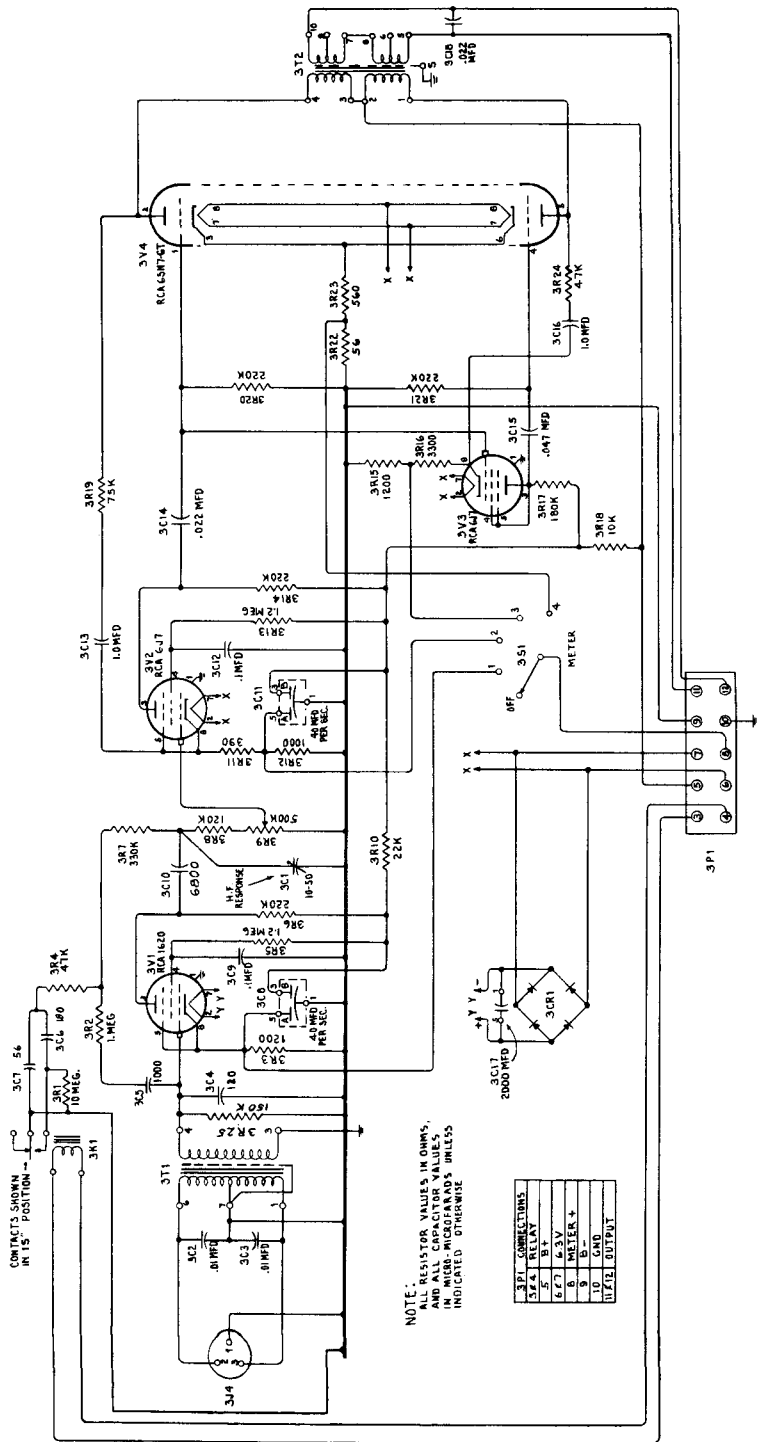
TYPICAL EXAMPLES

In the pages which follow, the electronic features of a number of modern tape recorders are analyzed to bring out both typical characteristics and significant differences. The examples chosen are typical of the wide range of electronic elaboration available, from the simple low-cost portable machine to multi-channel professional recorders. Some are the same machines as described in Chapter 4. The following discussion of electronic components supplements the description of the mechanical features for these models.

Example 1. RCA Model RT-11A (Figs. 5-8, 5-9, and 5-10)

Recording Amplifier. The recording amplifier chassis used in RT-11A and RT-12A professional tape recorders consists of a three-stage amplifier and a high-frequency oscillator. The latter serves both the bias and erase functions. A schematic of the combined amplifier-oscillator appears in Fig. 5-8. As is apparent, feedback is introduced through resistors 2R22, 2R23 and 2R25 to produce a constant current through the record head and also to provide adequate current for pre-emphasis. The schematic shows the recording amplifier normally connected for a 20,000-ohm bridging input across terminals 11 and 12 of input terminal block 2P1. Under this condition, and with full gain, the input signal required for maximum recording level is -10 dbm (or -20 volume units). Maximum recording level for this unit is defined as that level at which a 400-cycle input signal produces 3% total harmonic distortion, as read at the output of the reproducing amplifier. Levels are measured

TAPE RECORDING CIRCUITRY



NOTE:
ALL RESISTOR VALUES IN OHMS,
AND CAPACITOR VALUES IN MICRO-
MICROFARADS UNLESS INDICATED OTHERWISE

3P1 CONNECTIONS
5P4 RELAY
6 27 63V
6 W/METER +
8 B -
10 GND
METER OUTPUT

Fig. 5-10 Schematic of RCA RT-11A reproducing amplifier. Courtesy: RCA Victor

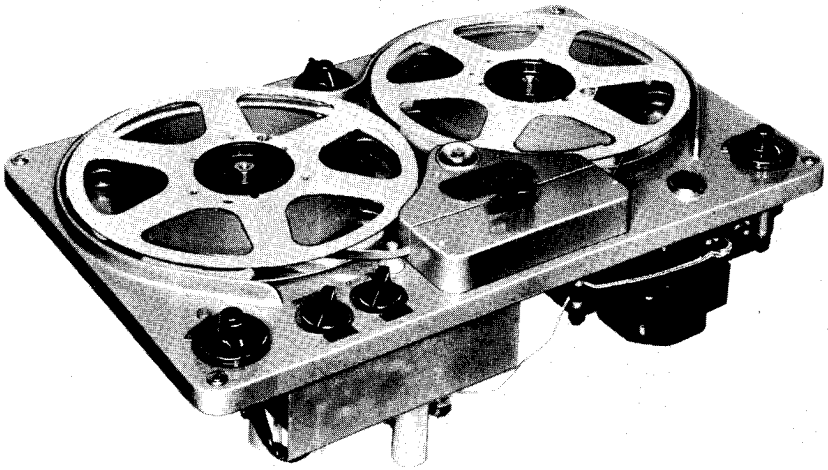


Fig. 5-11 Concertone tape-recorder chassis. Courtesy: Berlant Associates

through connection of a standard VU meter to terminals 3 and 4 of terminal block (2P2).

A conversion from a bridging input to a matching 600-ohm input is readily achieved by shorting the bridging resistors (2R1 and 2R2) and eliminating resistor 2R3. Under this condition a signal of -45 dbm (-55 vu) will again produce maximum recording level. The amplifier may also be easily changed to a 150-ohm input. The overall compensated frequency response of the RT-11A recorder is portrayed in Fig. 5-9.

Reproducing Amplifier. The reproducing amplifier (Fig. 5-10) is assembled on a separate chassis and includes two voltage amplifier stages, a phase inverter stage and a push-pull output stage. The solenoid-operated relay (3K1 at the upper left of the diagram) is employed automatically to select proper equalization values for either of the two speeds (7.5 or 15 ips). Shunted around the gain control (3R9) is a high-frequency response control (3C1) consisting of a variable capacitor which is normally set for 15,000 cps response at the 15-inch speed. Post-emphasis compensation is included in the feedback circuits. In addition, filtering has been provided for the removal of the 100-kc bias frequency. The bridge-type selenium rectifier (3CR1) when energized by the separate power supply provides d-c power to the 12.5- and 6.3-volt heaters. A five-position switch is provided for metering of tubes. The power capability of the amplifier exceeds the tape signal output and hence does not contribute to system distortion.

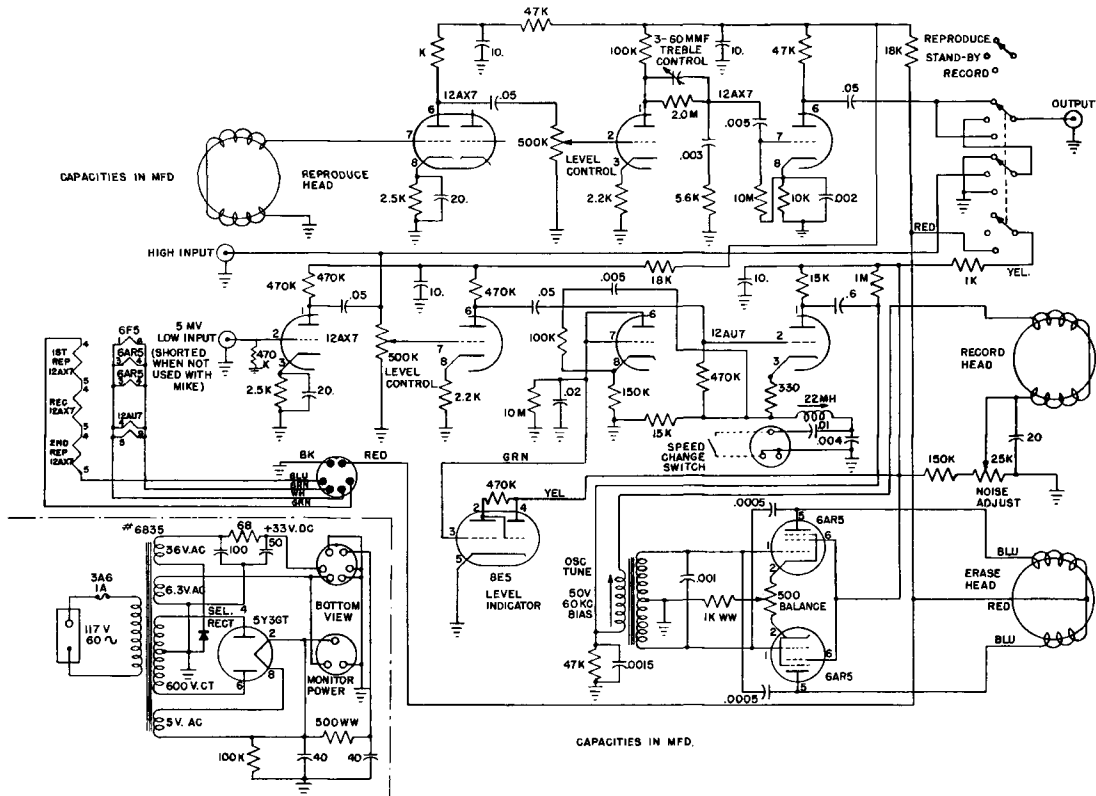


Fig. 5-12 Concertone schematic diagram. Courtesy: Berlant Associates

Example 2. Concertone Model 1401, Berlant Associates, (Figs. 5-11 and 5-12)

The Concertone tape recorder Model 1401 employs an electronic unit (RP-40IC) consisting of a recording amplifier, playback amplifier, a bias and erase oscillator, and a separate power supply (PS40I). The two main chassis are interconnected by a six conductor cable (circuit details are discussed later). The unit is illustrated in Fig. 5-11.

Switching System. A switching system (Fig. 5-12) has been included for adaptation of the Concertone recorder to a custom-built installation. The three switch positions of the system function as follows:

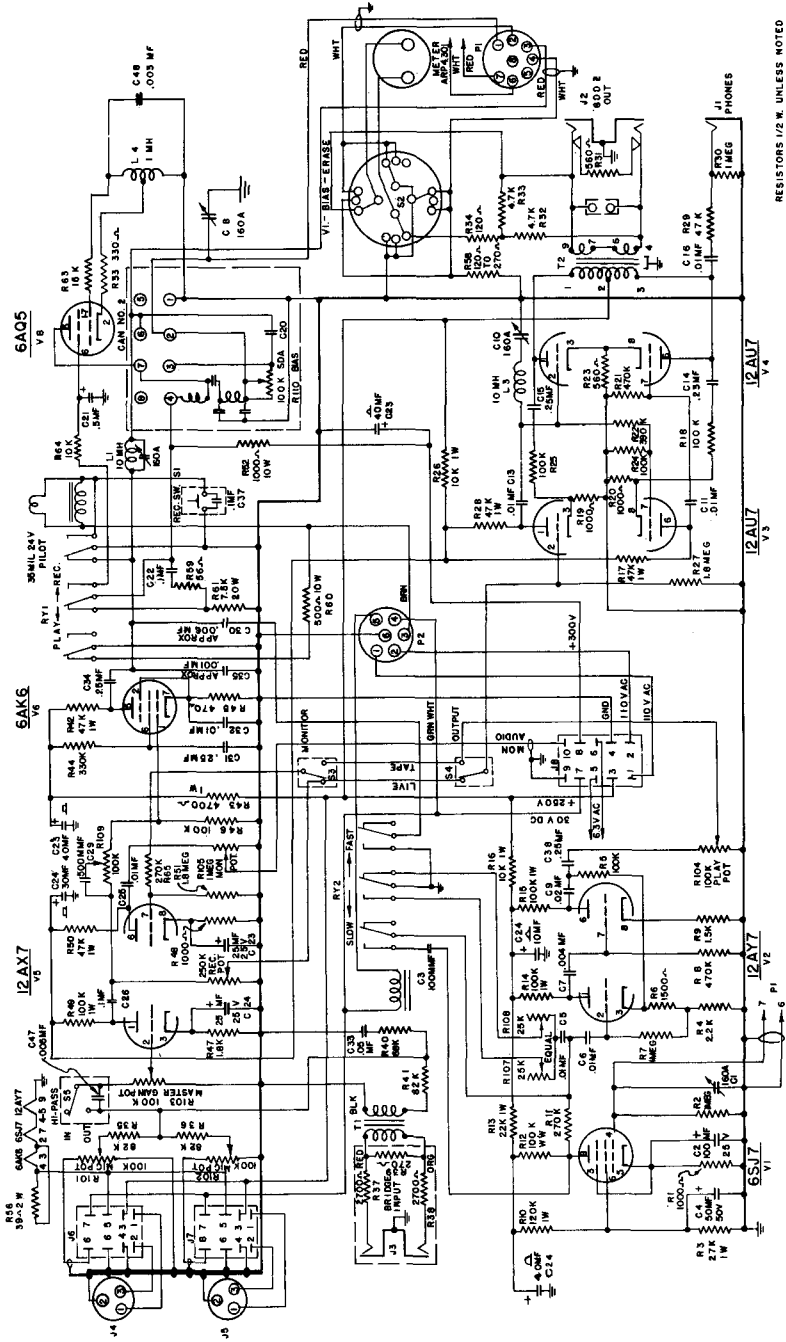
1. *Record Position.* Applies screen voltage to the oscillator tubes, which generate a 60-kc bias signal for the recording head. It also applies plate voltage to the final record amplifier tube (12AU7, second section). In the Record position the playback-amplifier output (12AX7) is connected to the output jack.

2. *Standby Position.* The oscillator and final recording amplifier tubes are disabled in this position. The high input jack is connected straight through to the output jack permitting the use of an external power amplifier for normal listening. With the tape recorder turned off this amounts to a shorted link in the audio system. With the recorder On, the microphone channel (low input) is energized, feeding amplified-microphone output to an external power amplifier for monitoring purposes. For this use the manufacturer offers a separate monitor amplifier.

3. *Reproduce Position.* The oscillator and final-recording amplifier tubes are disabled. The playback-amplifier output is connected to the output jack, as under condition (1) above.

Recording Amplifier. The recording amplifier (Fig. 5-12) employs two dual triodes (12AX7 and 12AU7). The first two stages are of standard unequalized design and use the two sections of the 12AX7 hi-mu dual triode in cascade to drive the final stage. The low-level input jack is shorted out when not used for microphone pickup. When a microphone is connected, the first 12AX7 section provides pre-amplification. The high-level input jack is connected to the grid of the second stage (12AX7) through a 500,000-ohm level control. Accessory input and output transformers of the plug-in type are available for matching of 500/600-ohm unbalanced lines. The gain-per-stage for the first two stages is approximately fifty, and the frequency response is essentially flat.

Level Indication. Stages three and four of the amplifier employ a dual-triode medium-mu tube (12AU7), which serves two functions. The first section of the 12AU7 tube is connected as a diode rectifier for the record-level indication circuit. Part of the output from the record-current amplifier (final stage) is supplied to the diode section of the 12AU7, and the negative diode output is applied to the grid of the 6E5 (magic-eye) level indicator tube, which thus gains its shadow in accordance with the recording signal. Because of the relatively large



RESISTORS 1/2 W. UNLESS NOTED

Fig. 5-13 Stancil-Hoffman Model R-4 record and playback amplifier, schematic diagram. Courtesy: Stancil-Hoffman Corp.

tube constant of the R - C combination in the plate return of the diode detector (10 megohms shunted by $0.02\text{ m}\mu$), a floating action results which avoids eye strain of the operator riding gain. Full eye closure is obtained when a five-millivolt signal is injected into the low-level input jack. The high-level input jack requires a signal of approximately 0.25 volts for full-eye closure.

Record Head Drive. The second section of the 12AU7 tube is designed to provide adequate current for driving the recording head, and includes the necessary frequency pre-emphasis. The cathode-return resistor of this final stage is shunted by an L - C resonant circuit, comprised of a $22\ \mu\text{h}$ inductance and two capacitors, $0.004\ \mu\text{f}$ and $0.01\ \mu\text{f}$, respectively. At the lower frequencies a degenerative feedback voltage is developed across the 15,000-ohm cathode-return resistor, which reduces the stage gain by over 20 db and minimizes distortion. As the frequency increases, the bypassing action of the shunt L - C circuit increases. This action reduces the amount of negative feedback, therefore increasing the stage gain. When the resonance frequency is reached, the feedback becomes negligible and the stage gain rises to a maximum (a 20-db boost).

The resonant frequency of the L - C circuit is changed in accordance with the position of the speed-control switch. For a tape speed of 15 ips the L - C circuit is tuned to 15 kc. When the machine is operated at a tape speed of 7.5 ips, the $0.01\ \mu\text{f}$ capacitor is connected in parallel with the L - C circuit, thus reducing its resonance frequency to approximately 8 kc. The resultant frequency characteristic closely follows that recommended by the NARTB.

Bias and Erase Oscillator. This is one of the most critical units of a tape recording system. The amount of hiss heard during playback is largely determined by the accuracy of adjustment of the bias oscillator. High-frequency oscillators used for this function must be capable of excellent waveform output. In this case, two 6AR5 tubes are connected (as shown in Fig. 5-12) to form a balanced circuit. The erase-head winding carries the plate currents of both tubes, thus forming part of the oscillating circuit. The balancing control in the cathode circuits of the 6AR5 tubes corrects for differences in emission of unmatched tubes, and must be adjusted for minimum noise, as described in Chapter 6.

The oscillator-coil primary is wound with a bifilar grid winding having essentially unity coupling between the grids; the iron-core placement is adjustable for tuning purposes. The secondary winding is in series with the record-head winding and supplies the record head with 60-kc bias. Since erasing power drops rapidly as frequency increases, the bias frequency should not greatly exceed 60 kc.

Playback Amplifier. The playback amplifier is electrically separated from the recording amplifier. Signal pickup from the reproducing head is applied directly to the grid of one section of a 12AX7 double triode. The second section of this tube is not used. This high-gain stage feeds another 12AX7 double triode, connected as a cascade amplifier. Level

P.4A MODIFICATIONS —FOR USE WITH

AP PLAY, AR RECORD AMPLIFIERS

1. INSERT 250 OHMS 10 WATT AT POINT (A)
2. OMIT ITEMS ENCLOSED IN (B)
3. INSERT 50 OHMS 10 WATT AT POINT (C)

P.4B MODIFICATIONS —FOR USE WITH

AP PLAY AMPLIFIER, PLAYBACK ONLY

1. INSERT 1000 OHMS 10 WATT AT POINT (A)
2. OMIT ITEMS ENCLOSED IN (B)
3. INSERT 50 OHMS 10 WATT AT POINT (C)
4. CONNECT GREY WIRE FROM PIN NO B TO +24 V AT POINT (D) INSTEAD OF +300V

R 430 (ARB & APIO)

1. INSERT 200Ω 10W AT (A)
2. CHANGE R2 TO 500Ω

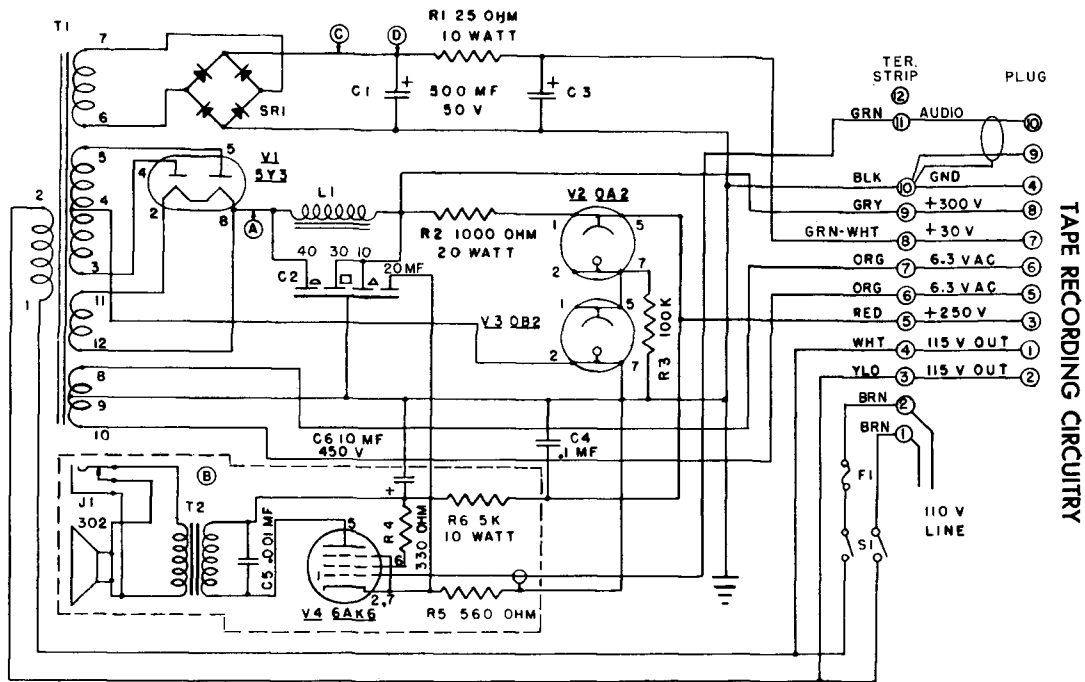


Fig. 5-14 Stancil-Hoffman power supply and monitor amplifier for R-4 recorder. Courtesy: Stancil-Hoffman Corp.

TAPE RECORDING CIRCUITRY

control of playback is achieved through a 500,000-ohm variable resistor inserted between the first and second stages of the amplifier.

Both low- and high-frequency equalization are provided. The recording deficiency at low frequencies, characteristic of magnetic tape, is corrected through post-emphasis reproduction. In this case, a non-adjustable low-frequency bass boost of about 30 db is accomplished through an $R-C$ network consisting of a 2-megohm resistor, a 0.003 μf capacitor and a 5,600-ohm resistor shunted across the plate circuit of the first section of the second 12AX7. High-frequency correction is obtained by a 2-megohm plate series resistor which is shunted by a small variable trimmer capacitor to allow for fine adjustment of treble response. (The treble response is affected by many variable factors.)

The output stage (second section of the 12AX7) utilizes considerable cathode degeneration for a minimum of distortion. The 0.002 μf cathode bypass capacitor reduces sensitivity of the output stage to capacitive loading caused by the use of shielded cable between this amplifier and an external power amplifier. Voltage at the output jack is between one and two volts rms. The heaters of the amplifier are energized by filtered dc to eliminate hum.

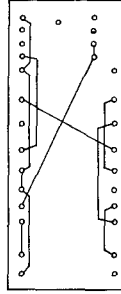
Equalization. Unequalized output from a tape reproducer is proportional to frequency up to the point of optimum output. This point is approximately 3 kc for a tape speed of 15 ips. An unequalized output would be inversely proportional to frequency above the optimum point. The corrective system of equalization used in this instrument provides most of the required treble boost within the circuits of the recording amplifier. Necessary bass boost is derived from the circuits of the playback amplifier. Response is not only flattened out, but the drooping playback curve attenuates thermal noise within the amplifier and the hiss inherent in the tape output.

The bass boost (around 30 db) included in the Concertone playback-amplifier circuits will not appreciably vary in value with time or with wearing of heads, and therefore is not made adjustable. The treble boost included in the recording amplifier is set at the factory and should not be altered unless the peaking coil or its associated capacitors are replaced. The treble response, however, is an element subject to change for various reasons including head wear. Therefore, a rather wide-range treble adjustment has been included in the playback amplifier circuits as detailed under "Playback Amplifier."

Example 3. Stancil-Hoffman, Model R4 (Figs. 5-13, 5-14, and 5-15)

Short cuts are not taken in this professional unit. The Model R4 tape recorder can be rack-mounted or supplied in a portable carrying case. In addition to the combination recording-playback amplifier (Fig. 5-13) and built-in power supply (Fig. 5-14), a plug-in pre-amplifier (Fig. 5-15 is furnished separately). A frequency response of ± 1 db from 50 to 15,000 cps at a tape speed of 15 ips, or ± 1 db from 50 to 7,500 cps

1	INPUT CONNECTIONS
2	JUMPER CONNECT TO 200 BRN TO BLU RED AND ORG
3	50 BLU TO RED AND ORG BRN TO ORG YEL IS C.T.



NOTE
 1. CAP C4 DEPENDS ON TRANSFORMER
 2. S-1 SHORTED OUT ON MODEL AL 3

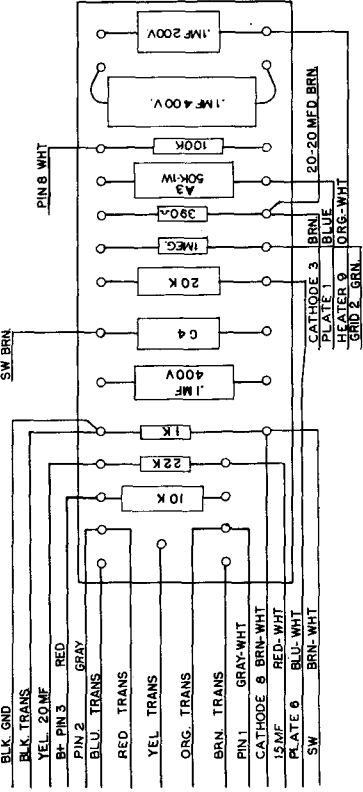
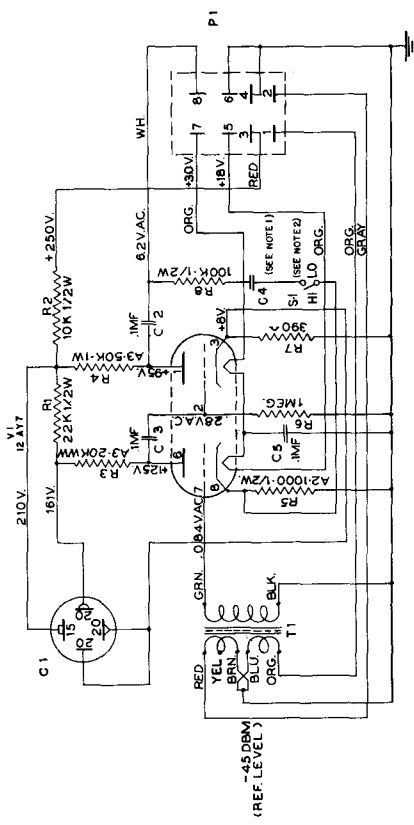


Fig. 5-15 Stencil-Hoffman preamplifier (AL3B), schematic diagram. Courtesy: Stencil-Hoffman Corp.

tice, The PT6-J amplifier (Fig. 5-16) was designed for recording, playback, and public address amplification; it is used in conjunction with the PT6-A tape mechanism. Any one of the three functions is available by means of a selector switch, located on the front of the amplifier.

Basic Amplifier. The low-level input stage (Fig. 5-16) includes a well-shielded transformer designed to receive the output of either a low-impedance microphone or of the head of the PT6-A tape mechanism. The transformer supplies the grid of the first tube (5879), which is used as a pentode-connected resistance amplifier. A 500,000-ohm gain control is connected between the first two stages and also to a bridging input jack, used for high-level, high-impedance inputs. The second stage, a 12SJ7 pentode is followed by a self-balancing phase inverter (6SN7), which in turn drives the 6V6 pushpull output stage.

The output transformer has two separate secondaries. One provides a balanced 600-ohm output, while the other is tapped for an output of either 4 or 16 ohms. The low-impedance secondary is included in an inverse feedback loop, providing excellent frequency response and 3-db regulation between full load and no load conditions. The maximum voltage gain between amplifier input and the 600-ohm output is 114 db. Maximum audio output is about 10 watts. The three amplifier functions will now be considered in detail.

1. *Recording.* When the function selector switch (*SI*) is positioned for Record, a signal applied to the microphone input is transmitted through the switch section (*SI-E*) to the input transformer. After passing through the tubes and the output transformer the signal is fed to the loudspeaker (if connected), the VU meter and through *SI-B* to the recording equalizer. One plug-in equalizer is provided for each tape speed. The desired frequency pre-emphasis for a 15-ips tape speed is shown in Fig. 5-17 (A). When combined with the post-emphasis characteristic during playback, shown in Fig. 5-17 (B), essentially flat response from 40 to 15,000 cps will result. Equalizer output is connected through *SI-D* to the record-head receptacle. At the same time *SI-B* (terminal 1) connects high voltage to the oscillator in the tape mechanism, thus energizing it for erasure and bias functions.

2. *Playback.* During playback the signal from a pickup head reaches the input transformer through switch sections *SI-D* and *SI-E*, and is impressed upon the grid of the 5879. An *R-C* feedback network is connected to the plate of this tube (5879), through *SI-E* (terminal 1), to compensate for the reproducing characteristic of the mechanism. The feedback circuit allows high gain for low frequencies, but limits the gain of the stage for high frequencies (as shown in Fig. 5-17B). This circuit also reduces overall noise and distortion generated within the input stage. The remaining amplification is identical with that of the Record function.

With *SI-B* in the Listen position, the output signal is fed through an isolating attenuator network to the 600-ohm output terminals; it can also be picked off from the 4- or 16-ohm output terminals. To

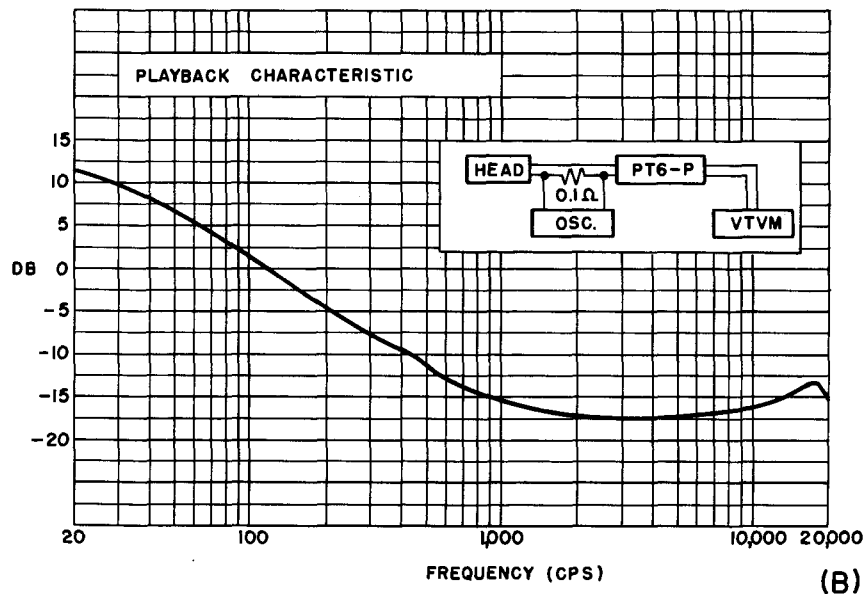
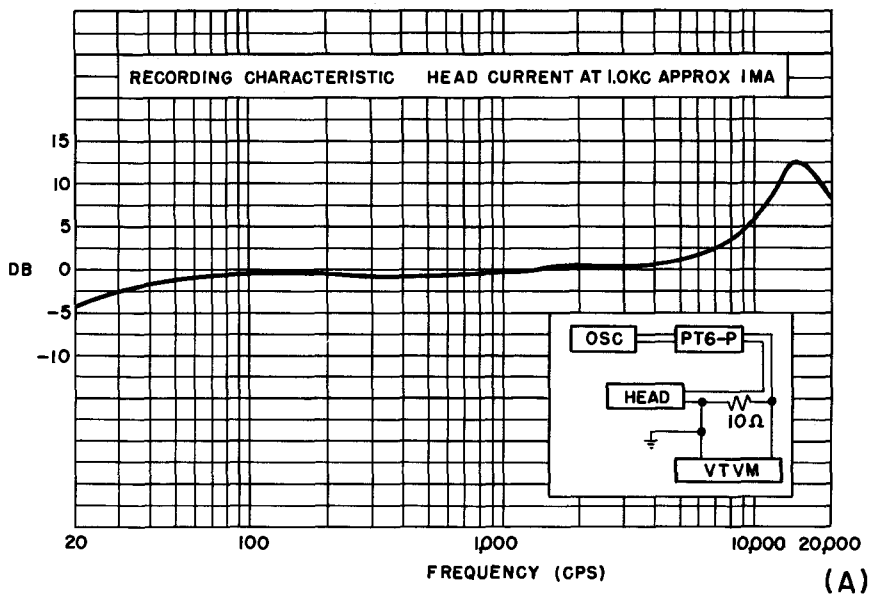


Fig. 5-17 Desired recording and playback amplifier characteristics for 15-ips tape speed. (A) Recording. (B) playback. Courtesy: *Magnecord, Inc.*

avoid overloading the telephone lines, full power is not delivered to the 600-ohm output, a maximum of 6 dbm being available.

3. *Public Address.* When the selector switch is in the Amplifier position, the unit becomes a conventional amplifier with a "flat" characteristic. Microphone input is amplified and fed to the 600-ohm output, as well as to the low-impedance outputs for external speaker coverage. Greater output is available if the internal speaker is disconnected through switch *S3*.

Power Supply. Built into the PT6 amplifier chassis, a local power supply furnishes the voltage requirements for the amplifier tubes and for the oscillator tube mounted in the PT6-A mechanism. The unit draws approximately 80 watts. Its well-shielded transformer minimizes hum level. A copper-oxide rectifier supplies 12SJ7 and 5879 heaters with filtered dc. A 25-ohm variable resistor permits adjustment of the heater voltage.

High voltage is taken from the 5Y3 rectifier, which is fed from the 700-volt secondary of the power transformer. High-voltage filtering is introduced at the rectifier output and at various strategic points, as shown in Fig. 5-16. Total power-supply output approximates 300 volts at 110 milliamperes.

Example 5. Ekotape Models 111 and 112, Webster Electric Co. (Fig. 5-18)

Ekotape Model 111 operates from a 117-volt, 60-cycle source, while Model 112 operates from a 115 or 230-volt, 50-cycle source. The amplifier in each model is the same (Fig. 5-18). Three electronic units, combined within one chassis, employ a total of five vacuum tubes which jointly or separately perform the functions of recording, playback, and bias/erase.

Input Circuits. A low-level input jack is provided for crystal-microphone operation; and the high-level input jack serves for radio or phonograph operation. The impedance of both inputs is 0.5 megohm. Through selector switch *S1A* either input is transmitted through the volume control (*R8*) to the grid of the first section of the dual-diode amplifier (12AX7). For normal recording level the minimum input signal should be 0.02 volt rms. A pre-amplifier input stage, used only for playback, employs a low-noise type 5879 tube. This stage is cut in through switch *S1A*. During playback, the volume control (*R8*) is switched to the plate output of the 5879 stage; hence serving for both record and playback.

Intermediate Circuits. The tone-control network (*R31* and *C9*) is inserted between the first two recording stages. This variable network provides bass and treble control during playback only; it does not affect the recording characteristic, since switch *S1B* is off during recording periods (it will be noted that capacitor *C10* is also eliminated from the corrective network during recording). When the selector switch is in the Record position, the erase-head circuits are automatically cut in to assure complete erasure before the tape reaches the recording head.

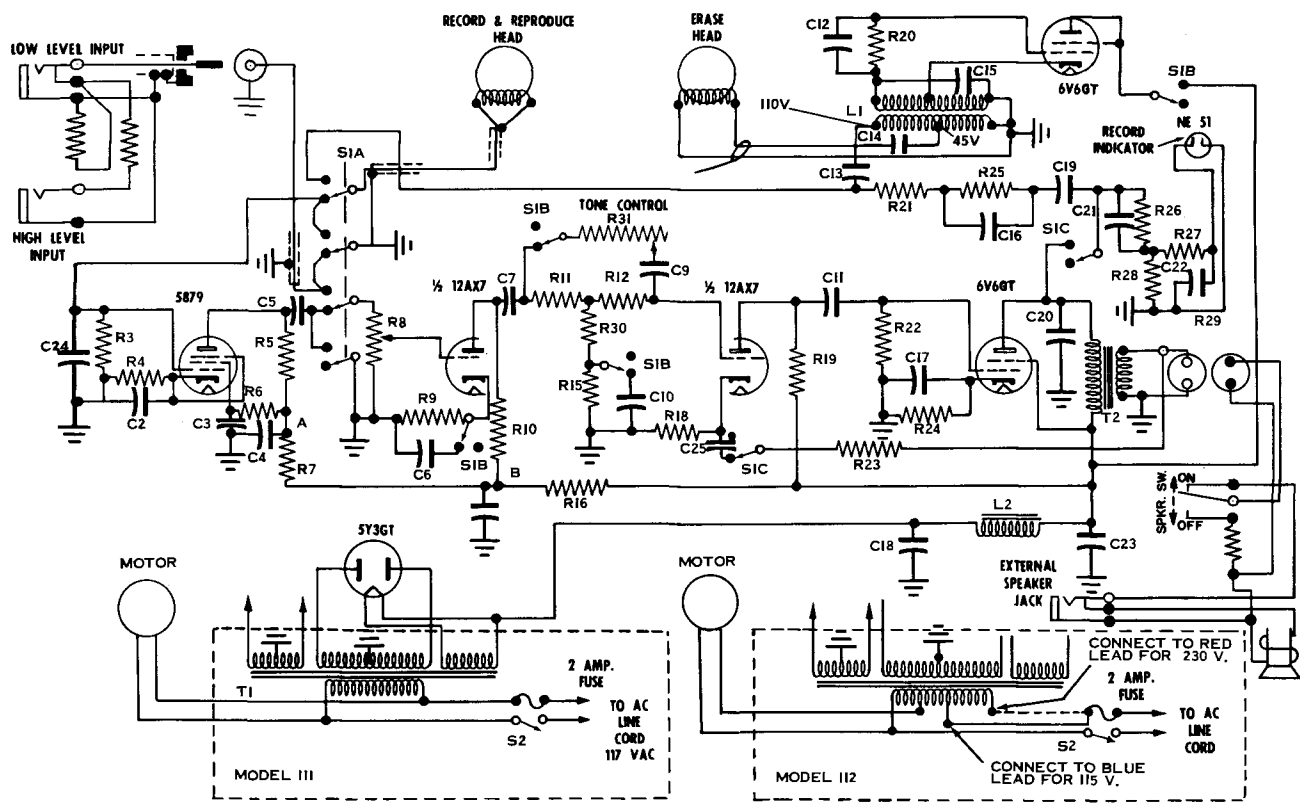


Fig. 5-18 Ekotape Models 111 and 222, schematic diagram. Courtesy: Webster Electric Co.

Output Circuit. The 6V6 output tube serves several purposes. Its plate output (2.5 watts) supplies the primary of the output transformer (*T2*) for loudspeaker drive; it feeds the amplified audio signal to the record head when switches *S1C* and *S1A* are in Record position; and finally it energizes the circuits of the record-level indicator (*NE-51*). An output speaker switch cuts out the local speaker during recording to prevent acoustic feedback to a local microphone.

Oscillator and Record Head. The high-frequency bias and erase current is generated by a 6V6GT tube and oscillator tank circuit (*L1* and *C15*). Taps from coil *L1* supply the proper voltages to the record and erase heads. The amplified audio and high-frequency bias signals are combined at the junction of capacitor *C13* and resistor *R21*, and are then supplied to the record head through *S1A*.

Example 6. Masco Tape Recorders (Fig. 5-19)

The portable Masco models, manufactured by Mark Simpson Manufacturing Co., are dual-track, dual-speed machines (3.75 and 7.5 ips) employing a plug-in type TR5H Shure record-erase head.

Amplifier. High- and low-level inputs are provided in the combined record-playback amplifier (Fig. 5-19). The low-level microphone input has an impedance of 1 megohm. Sensitivity is boosted to three millivolts by a pre-amplifier stage, using one half of a 6SL7GT dual triode. The second half of this 6SL7GT tube serves two purposes: during recording it receives the high-level input directly (high-level input impedance is 0.5 megohm with 0.4 volt sensitivity); during playback it serves as an intermediate amplifier, following a 12AX7 equalized pre-amplifier stage. A 0.5 megohm level control is inserted between the con-control switch and the grid of the 6SL7GT intermediate stage.

Functions of 6SN7. The 6SN7GT dual triode serves three functions:

1. During recording (position *A* of the Record-Playback switch) the plate circuit of one section of the 6SN7 triode is connected through two switch sections to drive the recording head. A fixed network in this stage provides adequate frequency compensation for recording.

2. The second section of the 6SN7 tube serves as a monitor amplifier during recording. The plate output of this triode is connected through the switch to the primary of the output transformer, which drives either the internal speaker, an external speaker, or an external amplifier of greater output. The external speaker jack also may be used for headphone monitoring.

3. For Playback (position *B* of the switch) the plate circuit of the second 6SN7 triode section is connected through a 0.01- μ f capacitor and a 100,000-ohm resistor to the output-transformer primary. The first section of the 6SN7 drives the final power-output stage (6V6GT) during playback.

Functions of 6V6GT. Two functions are performed by the 6V6GT tube.

1. For the Record condition (*A*) the tube serves as a 60-kc bias and erase oscillator. Plate output is carried through the switch to the primary of the oscillator coil. The grid return is through a 27-ohm resistor and a 100- μmf capacitor to the other end of the oscillator-coil primary winding. The oscillator-coil secondary output is applied to the combined record-erase head through a dividing capacitor arrangement which distributes proper voltage to each section of the head.

2. For the Playback condition (*B*), the 6V6 circuits are converted to a power-output stage delivering 5 watts of driving power to either the built-in or an external speaker. An external amplifier jack offers a 1.7-volt signal output of 500-ohms impedance. A line feed or any 500-600-ohm impedance input may be supplied from this output jack. It also serves well for headphone monitoring. Negative feedback is supplied from the 8-ohm secondary tap of the output transformer to the cathode of the first section of the 6SN7GT. The NE-51 neon tube acts as a level indicator during recording and as a pilot lamp during playback.

Functions of 12AX7. The dual-triode 12AX7 serves as a post-equalized pre-amplifier stage for playback only. It is not used during recording. Output from the record head, in the Playback position (*B*) of the selector switch, is run directly through the long shielded lead to the grid of the first section of the 12AX7 tube. Post-emphasis is derived from the combined networks linking the two triode sections of the 12AX7.

The plate of the second section of the 12AX7 tube drives the input grid of the intermediate amplifier stage (6SL7GT) when the selector switch is in playback position (*B*). Thus the basic recording amplifier uses the preamplified playback signal from the 12AX7 stage to furnish amplification for playback. Corrective equalization is automatically effected as the speed of tape transport is changed from 7.5 to 3.75 ips, or vice versa.

Example 7. Soundmirror BK-411 and BK-414, Brush Development Company (Figs. 5-20 and 5-21)

From an operational and functional viewpoint the BK-411 and BK-414 are the same. The former is a cabinet-enclosed table model while the latter is a portable unit. The electronic circuits of these two models are shown in the schematic of Fig. 5-20, while the functional relations are simplified by the block diagram of Fig. 5-21. Note that a permanent-magnet erase head is used with this machine instead of the usual high-frequency bias erase.

Input Circuits. The microphone input circuit is completed through contacts *A* and *B* (of selector switch *S-1*) from jack *J-1* to the grid of the input tube *V-1*. The input impedance of this circuit is approximately 1 megohm. This voltage-amplifier stage is normally switched to microphone, radio, or playback input sources.

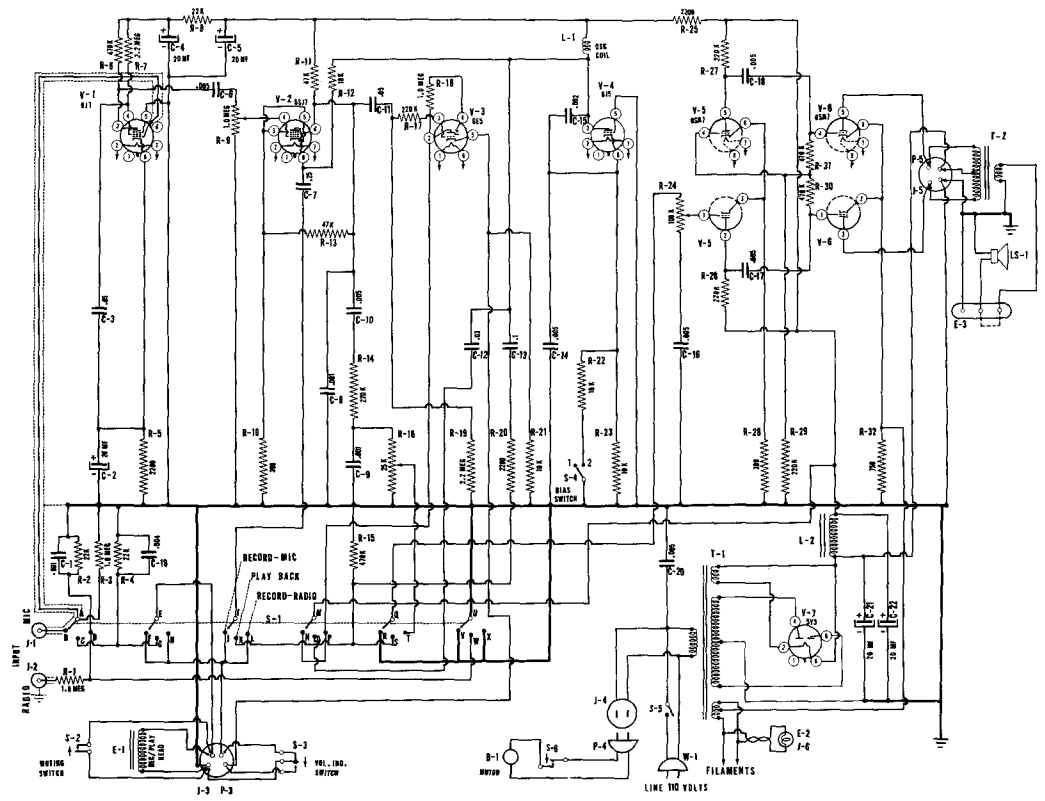


Fig. 5-20 Schematic diagram of Model BK-411 Soundmirror amplifier. Courtesy: Brush Development Co.

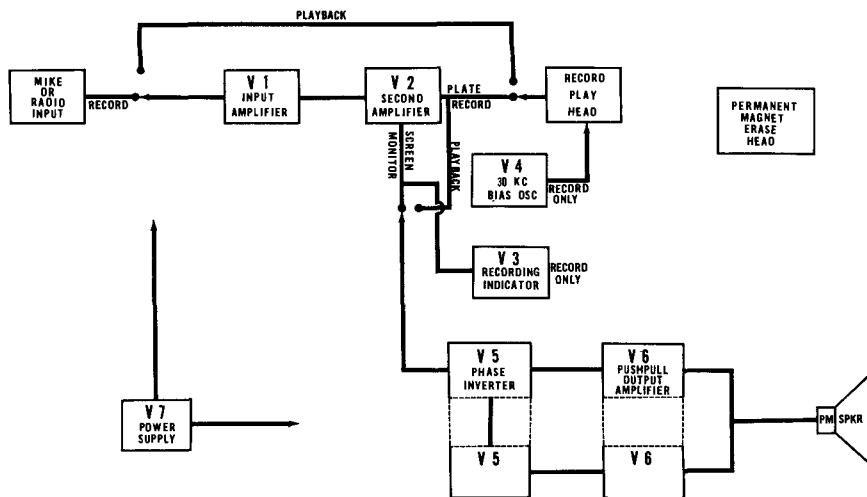


Fig. 5-21 Block diagram of Model BK-411 Soundmirror amplifier. Courtesy: Brush Development Co.

Radio input is completed through jack *J-2*, a 1-megohm resistor *R-1*, and through contacts *D* and *A* of selector switch *S-1*. A voltage-dropping resistor (*R-2*, connected in series with *R-1*) reduces the radio input voltage by a ratio of 46 to 1 before applying it to the grid of *V-1*. Even with this drop, no greater than a 10-volt signal can be applied to jack *J-2* without overloading the first stage.

Recording Amplifier. The first recording-amplifier stage (*V-1*) employs a 6J7 tube; it has a voltage gain of approximately 120. A b-supply filter network for this stage comprises capacitors *C-4* and *C-5*, and resistor *R-8*. This filter prevents the stage from motorboating and minimizes hum from the power supply. Screen and cathode are by-passed to ground conventionally. Essentially flat output is coupled through capacitor *C-6* and resistor *R-9*.

Stage two of the recording amplifier *V-2* produces a constant recording current for a given voltage input. The 6SJ7 tube (*V-2*) is applied as a converter. It converts the signal voltage from *V-1* into a current that flows through coupling capacitor *C-7* and through contacts *I* and *J* (for mike recording), or through contacts *I* and *L* (of the selector switch *S-1*, for radio recording) to the recording head (*E-1*). During the recording process, a 30-kc signal from the high-frequency bias oscillator (*V-4*) is fed to the plate of *V-2*, and is there combined with the incoming signal. Generation of the bias frequency is from a Colpitts circuit, which comprises inductance *L-1* and capacitor *C-15*. The recording bias signal almost triples the average audio signal, hence the signal to the "magic-eye" volume indicator (*V-3*) is taken from the screen of *V-2*.

The signal from the screen of $V-2$ is applied to the volume-indicator tube ($V-3$) through the coupling capacitor $C-11$ and the resistor $R-17$. The drop of $R-17$ prevents the grid current of $V-3$ from distorting the recording. When the selector switch ($S-1$) is in one of the Record positions, the volume indicator ($V-3$) remains inoperative until the Erase pin on the front panel is depressed to close the contacts of volume-indicator switch $S-3$. Depressing the switch connects the cathode of $V-3$ to ground, thus making it operative. In this way erasure of an old recording is assured before a new one is made. (When the Erase pin is depressed the erase head is brought into contact with the tape.)

Two values of recording bias current are provided by the 30-kc oscillator ($V-4$) to accommodate different types of recording tape. Switch $S-4$ in the cathode circuit of $V-4$ has two positions. In position 1 the switch is open and resistor $R-23$ in a bias current of 2 ma to the recording head. In position 2 the switch is closed and places resistor $R-22$ in parallel with $R-23$, thereby increasing the bias current to 4.5 ma. As stated earlier, high frequency erasure is not used in this model.

Monitor Amplifier. The monitor-amplifier section uses the same input as the recording amplifier, except that the signal is taken from the screen of $V-2$ and then coupled by means of the network comprising $C-10$, $R-14$ and volume control $R-16$ to the first grid of the 6SN7 twin-triode ($V-5$) phase-inverter stage. (A 6SL7 may be used in place of the 6SN7 if greater volume is required for either monitoring or playback.) Output from the phase inverter is coupled through capacitors $C-17$ and $C-18$ to another 6SN7 stage ($V-6$) which is connected for pushpull output. This output stage drives the loudspeaker ($LS-1$) through output transformer ($T-2$) in the usual manner. Monitoring volume is controlled by potentiometer $R-16$; tone is controlled by potentiometer $R-24$.

Playback Amplifier. The signal from the reproducer head ($E-1$) is introduced to the grid of $V-1$, where it is amplified and then coupled to the second stage ($V-2$) through capacitor $C-6$ and volume control $R-9$. The output signal from the plate of $V-2$ is coupled through capacitor $C-7$ and contacts I and K , and Q and S of selector switch $S-1$ to the first grid of the phase inverter stage ($V-5$). Potentiometer $R-24$ serves as the volume control. Signal flow from that point on to the loudspeaker is the same as described for the monitor amplifier.

During playback the 30-kc bias oscillator is not required, but its coil $L-1$ is put to another use. With switch $S-1$ in Playback position, coil $L-1$ is shunted by a $0.03\text{-}\mu\text{f}$ capacitor ($C-12$). $L-1$ and $C-12$, in conjunction with the combination of resistor $R-20$ and capacitor $C-13$, form a frequency-compensating network in the output circuit of the second stage ($V-2$). The $L-1$, $C-12$ tank circuit is resonant at 5,000 cycles. Thus the high-frequency response is boosted, while at middle frequencies (1,000 cps) the impedance of the combined network becomes quite low, and these frequencies are attenuated. For lower frequencies down to 100 cycles the impedance of capacitor $C-13$ becomes very high, hence the network has a negligible effect on the passage of these lower fre-

quencies through capacitor *C-7* to the next amplifying stage (*V-5*). Furthermore, during playback, capacitor *C-19* is connected across the reproduced head to tune it to the higher frequencies around 5,000 cycles.

Power Supply. The conventional power-supply circuit employs a 5Y3 full-wave rectifier tube (*V-7*). Choke *L-2* and capacitor *C-21* and *C-22* filter the rectified voltage. The filament center tap is returned to ground through the cathode resistor *R-32* of the *V-6* output stage. This serves to bias the filaments with a positive potential and tends to reduce hum content from the first stage (*V-1*) due to heater-cathode leakage. The receptacle (*J-4*) supplies power to the drive motor *B-1*.

Chapter 6

MAINTENANCE AND REPAIR

Maintenance and repair of tape recorders falls into the subdivisions of mechanical and electronic maintenance. Personnel required to service tape recorders must, therefore, be adept mechanically as well as electronically. As has been pointed out in previous chapters, most tape recorders are similar in their basic construction, and hence servicing problems are generally the same for all types of machines. For this reason the servicing of only a few dissimilar units is detailed later in this chapter, and most commercial recorders will correspond to one of the specific examples described.

No unit should be disassembled beyond the point necessary to determine and correct a fault; the preliminary tests, described later, will generally ascertain what that point is.

Preparation

The following preparatory procedure has been found to be of advantage:

Examine all mechanical sketches, exploded views, and circuit diagrams. Then arrange all tools required for convenient use. Prepare suitable pedestal or rack mounts (see Fig. 6-1) to receive a mechanism prior to its removal. Make sure that all power sources are disconnected before commencing with removal and servicing procedures, otherwise injurious voltages may be contacted in power supplies. Have plastic, non-magnetic containers or parts trays of generous size ready to receive screws, washers, nuts, and larger items during removal. As parts are removed they can be placed in positions similar to their assembled position. Such organization will pay off highly during reassembly of the unit after repair.

Handling of Parts

Always have several clean, lintless cloths and a supply of carbon tetrachloride on hand. Immediately clean any rubberized pulleys or felt

TABLE 6-1
Test Equipment Required for Servicing Tape Recorders

Equipment	Use
Analyzer (capable of f-m frequency spectrum)	For preliminary circuit tests, selective tests, and overall check after repair.
A high-pass filter-type distortion meter, such as the General Radio GR-732B, or equivalent.	To eliminate flutter and wow while checking distortion.
Flutter indicator, RCA MI-9763B, or equivalent.	Reads as follows: At 1 $\frac{7}{8}$ ips .8% avr. 1% peaks At 3 $\frac{3}{4}$ ips .6% avr. 8% peaks At 7.5 ips .5% avr. 7% peaks
Wow meter, Furst Model No. 115R, or equivalent	Reads peak values of periodic pitch variations.
Oscilloscope (general purpose type)	To check wave pattern, level, noise, and hum.
Signal generator (constant output 20-15,000 cps; good signal-to-noise ratio at 0.003 to 0.005 volt output)	Supplies audio signals for various tests.
Vacuum-tube voltmeter	For checking signal levels and voltages.
Pedestals and/or adjustable service racks (Fig. 6-1)	As mounts for mechanisms under test or repair.
Tachometer	Checks speed of rotating parts.
Tape splicer	For editing or repair of broken tapes.
Standard test tapes	Constant output tapes recorded at various frequencies, for overall system check and various comparative checks.
Lateral adjustment tapes	Adjustment of heads for maximum azimuth response.

Speed timing tapes (MMM No. 43)	To check speed of tape transport. At 7.5 ips, an 18.75-ft. length of tape should run 30 seconds ± 0.5 sec.
High powered magnifying glass	Examination of magnetic head gaps.
Low-loss shielded leads	Interconnection during tests.

pressure-pads which accidentally come in contact with oil or grease. Check with exploded views to account for all small items, such as washers and nuts. These items may become lodged in magnetic fields as well as crevices; if undetected, serious damage may result. When it is necessary to return a part to its exact original position, scribe a mark on it and its mating surface before removal. Handle all gears carefully to avoid damage to teeth or bearing surfaces.

Tools

Since tape recorders require both mechanical and electronic servicing, the general shop tools and equipment available to radio and record-player servicemen are generally used in servicing tape recorders also. A list of useful equipment is given in Table 6-I. In general, precision test equipment is required for servicing tape machines, particularly for the wide-range professional models.

Servicing Racks

Prior to the use of any tools for specific repair, a supporting pedestal or servicing rack should be arranged to mount the mechanisms properly during repair. One simple form of fixed pedestal is shown in Fig. 6-1 (A). Extra holes should be drilled around the perimeter of such a pedestal to permit moving the vertical holding dowels from one hole to another. This will accommodate different types of mechanisms.

Far more useful for servicing are adjustable racks (Fig. 6-1B), with variable tilt control and clamps to hold the mechanism. Cradles developed by servicemen for the repair of record changers may often be used for tape recorders. Slight modification of these cradles will accommodate servicing of other units. Generous wing nuts at the axle ends of these cradles should be provided to hold the mechanism at any desired tilt or permit a complete turnover for a specific repair.

Mechanical Tests

Overall check. Prior to any initial disassembly or repair, tests should be run to determine the necessary extent of repair. Various test tapes have been made available for this purpose, recorded under exacting conditions to NARTB standards. Before using such a standard test tape, put the machine through a 15-minute warm-up period. Then, for a

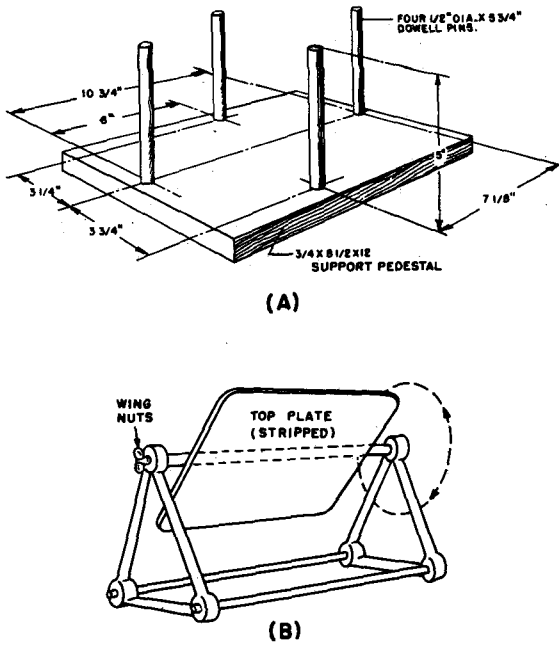


Fig. 6-1 (A) Fixed pedestal for servicing tape mechanisms. Courtesy: Bell Sound Systems Inc. (B) Adjustable service rack with stripped top-plate in place.

quick overall checkup of the magnetic system, play back a standard test tape and note the level indicator. Any sudden dips of the meter reading from normal response levels show trouble present, affecting a particular portion of the frequency spectrum. To determine the condition of the recording mechanisms, record frequencies identical to those in the standard test tape. Then play back the newly recorded tape and note any discrepancies between its output and that of the test tape.

Worn Magnetic Heads. Discrepancies in a frequency run may be caused by a worn magnetic head. The fastest way of eliminating such a fault is by substitution of a new head. Substitute a new head just as you would replace a spark plug in your car. Record and playback heads are not expensive, but they do wear rapidly due to the abrasive content of the iron-oxide coating or magnetic tapes. When substitution does not remedy the trouble, perform the lateral head adjustments described later in this chapter. A lateral-head adjustment tape (Table 6-I) is commercially available for this check.

Speed Checks. Timing tapes (Table 6-I) are available for speed checks of the tape-transport mechanism. The speed of the mechanism may be checked directly by a tachometer or with a stroboscope. Speed is read directly on the scale of a mechanical tachometer, when its prod

is applied to the shaft of the tape mechanism. Instructions for use of a stroboscope are supplied with commercial instruments.

Wow and Flutter. Wow and flutter are of the same nature and occur because of slight speed variations in the tape transport, which modulate the signal and distort reproduction. Periodic speed variations occurring at a rate of less than 10 cps are termed *wows*. *Flutter* is a speed variation occurring at a more rapid frequency, and is especially detrimental to sustained notes from the middle tones upward. Table 6-I lists equipment available for checking these faults.

Annoying wow or flutter is often caused by eccentric rotating parts, reel friction (bent reels or shafts), rough or thin spots in the tape, motor rumble, or floor vibration. Mark any suspected rotating part with a piece of chalk. If its rotation synchronizes with the speed variation of the flutter, replace the part or the spindle supporting it. When mechanical switching controls are left on while a machine is idle, dimples may form in rubber pucks and cause wows. Concentricity of capstans and flywheels can be checked by a calibrated scale, held across the diameter during rotation. A runout of 0.2 mils is sufficient to cause wow.

Preliminary Electronic Tests

Frequency Response. Differences in response between standard test tapes and the tape recorded by the machine under test may often be caused by a fault in the playback amplifier. Amplifiers may be checked quickly by gain and frequency runs familiar to all servicemen (see also *Overall Check*). Be sure to set the controls for proper equalization, both during recording and playback. Individual service manuals state the proper values of equalization and connections to signal generators, oscilloscopes, and vacuum-tube voltmeters.

Distortion. When waveform distortion is apparent, backtrack from the output stage. Check the waveform at each plate and grid to locate the specific stage in which distortion exists. Then check all resistors, capacitors, switches, and connections associated with that stage. Use a high-pass, filter-type meter (such as the GR-732B, Table 6-I) to measure distortion. *Null*-type or fundamental-cancellation type meters will show erroneously high distortion readings due to the presence of wow and flutter.

Makes notes of all irregularities, mechanical or electronic; this will prove very useful during repair. Refer to and check values listed in voltage and resistance charts before proceeding with disassembly. Remember that a leaky filter capacitor in the power supply may upset voltage values in several amplifier stages, while a leaky coupling capacitor will distort voltages in a succeeding stage. Use of the charts will aid in localizing defects.

Bias Currents. Determine whether normal bias current is present and properly adjustable by means of controls. Check the oscillator-tube

socket voltages against the voltage chart. Allow for the fact that some oscillators double as erase and bias oscillators. Refer to manufacturers' data and determine whether the record-head current is within allowable limits, when the proper signal level is supplied. Use a milliammeter for these checks.

Equalization. This subject has been thoroughly discussed in Chapter 5. Each manufacturer provides compensating networks of varying circuit design and effectiveness. No positive test procedures can be detailed, other than to advise the playback of a test tape and compare it with a recently recorded tape. Pre-emphasis and post-emphasis results are readily compared by this means. First check the playback circuit alone, since the fault may have no relation to the recording function. In general, check all compensating networks against valves shown in schematics. Often these networks are associated with feed-back circuits. Overall equalization should so complement the magnetic-recording characteristic as to result in "flat" response over the frequency spectrum (See Fig. 5-17).

Removal of Mechanism

Before removing the mechanism from its case or cabinet for servicing, *be sure that the power source has been disconnected.* Amplifiers and power supplies are often within the same enclosure, and dangerous voltages may be contacted. Rotating parts, especially vent fan blades, could also cause bodily harm.

It is essential that a cradle framework or other means of solid support (Fig. 6-1) be ready to receive a mechanism upon removal from its normal mount, in order to prevent possible damage to subassemblies, levers, spindles, and shafts. It is very poor practice to mount mechanisms on their sides on the work bench; considerable damage calling for replacement of parts may result from doing so.

Prior to any disassembly, remove both tape reels and any loose platters or other top-panel parts. Remove all external cables from their receptacles. Remove any access covers to terminal strips, then mark and disconnect all wires ordinarily connecting top-panel parts with parts within the cabinet or lower chassis. Servicing usually calls for removal of the top panel or plate, which often supports the entire mechanism. Generally, electronic components are individually mounted within the same enclosure. The example shown in Fig. 6-4 is typical of many mechanisms; the amplifier and loudspeaker remain in the cabinet after the mechanism and top plate are removed.

CAUTION: Be sure to rest the mechanism in an area where there are no local magnetic fields. Magnetic heads attached to the top plate should be definitely guarded from stray fields at all times.

Removal of Magnetic Heads

Single-duty magnetic heads may be keyed into position and secured by one holding screw. Some machines use only two heads, which may be

bracket-mounted and removed as one unit when the holding screws are released. Machines using three individual heads may house them within one die-cast assembly. Whenever practical, heads should be removed prior to removal of the mechanism. Naturally, magnetic heads should not be subjected to shock or other rough handling. Furthermore, head assemblies and mating surfaces should be marked before removal to insure accurate replacement. Removal of adjacent pressure-idlers, pads, and tape guides varies for different models. Typical procedures appear later in this chapter.

Removal of Electronic Components

CAUTION: Be sure that all electrical power is disconnected, dangerous voltages are present in power supplies. Allow tubes to cool to avoid burned fingers.

When preliminary tests indicate the need, removal of amplifiers, oscillators, or power supplies is easily accomplished by release of the appropriate holding screws and shock mounts. Make sure that the input, interconnecting, and output cables are first removed. Then place the electronic components on the test bench for individual checks. Be careful not to damage exposed parts of wiring.

Disassembly of Mechanisms

Motors. Manufacturers of the higher-priced machines may recommend temporary substitution for a component which has become worn, while the factory rebuilds it. The drive, take-up, and braking motors are easily removed after all electrical connectors have been physically cleared and properly marked. Mark the motor face plate and its mating surface to insure proper re-installation. Note the shape and positioning of belts prior to removal, and be sure that all lockwashers, nuts, and retaining screws supporting the motor are accounted for during removal, to avoid damage later.

Mechanical Linkages. Most mechanical linkages are capable of withstanding extensive use without replacement. The average machine requires little attention to its mechanism. When excessive wear becomes apparent in a part, replace it. Often locking pins, setscrews, or lock nuts must be removed to release actuating collars, cams, or levers from their pinions or shafts. All parts should be laid out in an orderly sequence. This not only expedites assembly, but is of real value when a second person is assigned to reassembly. It is sometimes best not to disturb setscrews locked for a specific adjustment. This may expedite proper adjustment later.

Use scribe marks to spot all fixed relationships. Keep all parts and partial disassemblies covered against dust and foreign particles. Remove solenoid plungers and clean them and their cores, being careful to keep the windings dry (see "Cleaning").

Pressure and Tension Assemblies. Remove pressure rollers and their shafts for cleaning. Clean cores as well as shafts. If a shaft or spindle is

riveted in place, clean with high-test gasoline, then lubricate with one or two drops of camera oil. Do not disturb the rivet unless the shaft is bent.

When pressure pads become worn in thickness, replacement of the pads is the only remedy. Some are held in place merely by adhesives, which may be released by solvents recommended by the manufacturer. The free use of solvents, however, is dangerous; follow service-manual instructions. Do not let the springs which support the pressure pads become even slightly bent, or tensions will be incorrect. Be careful that cleaning cloths do not catch in and bend these springs.

Tape tensions during forward and reverse tape transport differ for different models. Variable motor drags and braking facilities, slotted brackets with locking screws, and other similar adjustments are critical. Adhere to specific instructions and follow exploded views and sketches of subassemblies for proper removal procedure.

Clutch Assemblies. Simple dry or oil-clutch assemblies may be disassembled and cleaned by servicemen having adequate reference data and mechanical ability; the layman, however, should never attempt this chore. When cleaning and lubrication does not remove the trouble, it is advisable to return the clutches to the manufacturer for rebuilding or replacement.

Removal of Flywheels and Belts. Locking pins or nuts must first be removed, after which flywheels may be gently tapped and twisted from their shafts. Realize their weight and guard against any accidental fall and resultant damage to other components. Secure flywheels in a safe compartment until they are re-installed.

Belts vary in shape; note which side is in contact with pulleys, to avoid reversal later on. Some belts have teeth on the inner side and cannot be reversed. Generally an adjustment is provided for slack prior to removal; do not force or the belt will stretch.

Disassembly of Electronic Components

Disconnect all power sources before disassembly. No amplifier or power supply should be disassembled beyond the point required to correct a defect localized by preliminary tests. When an inaccessible component must be reached, attempt to remove the obstructing assembly as one unit to avoid unnecessary separation of parts. Partial removal will often suffice, with wiring still intact. In many cases no disassembly is required beyond removal of tubes or an occasional connector to clear a single component under test.

Carefully tag any unmarked connecting wires to avoid misconnection later. Small, narrow strips of adhesive or white scotch tape serve well for the purpose. Mark all transformers before removal, to assure remounting in the original position.

Cleaning

Cleaning is a *must*, particularly for those parts of the tape-transport mechanism which contact the tape. A small deposit of magnetic

oxide accumulates on the head faces and tape guides because of friction. This coating separates the tape from direct contact with the heads and impairs the high-frequency response. A separation of a few thousandths of an inch will completely obliterate the higher frequencies. Old tapes with many splices may even leave deposits of splicing compounds. Rubber-rimmed drive pucks or pulleys occasionally should be cleaned with alcohol.

Cleaning Methods. Mechanical subassemblies must be kept free from excessive oil or grease. All joints and linkages must be kept clean to prevent sluggishness or complete jamming. Immediately after removal of a part or subassembly, cover any openings or lubricated parts to prevent the entry of foreign matter. Keep all driving surfaces and belts free from oil or dirt. Dirt is the chief cause of many irregularities in performance. A low-pressure air stream may be used to blow dirt from an exposed mechanism, provided the stream is not directed at fragile components such as pressure pads and flexible lead wires. It is good practice *not* to use an air hose above the top plate or panel.

Electrical wiring must be kept free from oils or greases. Use alcohol or carbon tetrachloride to clean exposed insulation. Remove excessive resin from soldered joints. Clean them with a camel hair brush which has been dipped sparingly in alcohol. Clean the tube sockets and multi-pole input and output jacks in a similar manner.

Medical swabs (on a stick), pipe cleaners, camel brushes, or clean lintness cloths dipped in cleaning fluid may be used for cleaning magnetic heads or other parts of the recording mechanism. Use the cleansers listed below. Squeeze all excess liquid from the cleaning tool. Do not let the fluid drop into head gaps or other small parts of the tape-transport mechanism. Rub carefully until all traces of foreign deposit are removed. Draw the cleaning tool across the felt pressure pads in the direction of tape travel. When laminated heads are framed with bakelite or other borders, be sure that these are also well cleaned or they may still prevent the tape from positive contact with the head.

Almost any of the following cleaners will serve well for cleaning heads or other parts of the recording mechanism: pure high-test gasoline, alcohol, inflammable cleaning and lighter fluids, acetone, nail polish remover, or carbon tetrachloride. Do not use solvents other than those recommended by the manufacturer or listed above. Improper fluids may leave detrimental coatings upon parts, pit or otherwise damage components, or loosen adhesives used on small parts, such as pressure pads. In all cases be careful not to catch the cleaning tool in exposed small parts, such as tension springs of the strap type. Improper tensions result when these springs become even slightly bent.

Inspection Prior to Repair

Mechanical Inspection Prior to Repair. Inspect for the following conditions:

1. Dirt, which can cause many irregularities of performance.
2. Oxide deposits, scratches, grooves, and other wear of parts which contact the tape.
3. Irregular tape travel in either direction.
4. Excessive oil and oil leakage.
5. Vibration; check motor clearance in shock mounts.
6. Worn bearings in all rotating parts.
7. Bent shafts; lack of alignment and concentricity.
8. Sound heads loose within shields.
9. Loose pressure rollers and springs.
10. Loose leverages and actuating arms.
11. Loose screws, nuts, and locking pins.
12. Loose controls on top plate or panel.

Electronic Inspection Prior to Repair

Inspect for the following conditions:

1. Melted wax from transformers or capacitors.
2. Burnt, charred, or oil-soaked insulation.
3. Loose or sprung connectors and rosin joints.
4. Faulty or noisy switch contacts.
5. Cracked tube sockets or tube bases.
6. Defective tubes; check all tubes carefully in a tube tester.
7. Loose plug and jack contacts and fittings.
8. Loose mounting screws and nuts.

Mechanical Repair and Replacement

Motor. Subnormal pitch indicates subnormal speed. Motor bearings, or directly driven rotating parts, may need cleaning and fresh lubrication. Check the line voltage to the motor, it may be low. Also check concentricity of the motor shaft. Use an indicator to check the amount of run-out; where the motor shaft directly contacts the flywheel, the run-out should not exceed 0.0002 of an inch (2 mils). If excessive, replace the motor. If within tolerance, check for oil on the motor shaft, which would cause slippage.

Capstan and Rollers. Rotate the capstan and any associated pressure roller to check for binding. If parts do not revolve freely, clean the bearing and lubricate with one drop of light camera oil or equivalent. Replace any bent shafts. Concentric alignment is of great importance to all tape mechanism. This particularly applies to the capstan and any rotating parts which contact it. Whenever rubber driving discs or pucks are left in contact with other driving elements, dimples or *flats* are developed. The only correction for this condition is replacement.

Magnetic Heads. No attempt should be made to repair worn magnetic heads. Instead, replace them. Record and reproduce heads have a life expectancy approximating 1,000 hours. The bulkier erase heads, having less critical gaps, may serve for a longer period.

Pressure Pads. Machines using pressure pads instead of rollers must be checked periodically, when pads are worn they must be replaced. The pressures maintained by these pads are critical. As wear sets in these pressures vary, and tape spillage may result. Sometimes these pads are cemented to strap springs and may be removed by solvents, such as naphtha. When new pads are cemented in place, be sure to align them correctly so that the pad edges and sides are flush with the sides and ends of the springs to which they are attached. In some cases pressure pads must enter slots in magnetic heads, here again alignment is critical.

Tape Guidance. Tape guides often directly precede the contact of the tape with the magnetic heads. Run a test strip and observe the behavior of the tape. Any tendency to weave or deviate from true alignment is traceable to some idler or other rotating part which is not concentric. This may also be caused by worn or misaligned pads. Careful observation will localize the fault. Pressure should be adequate to wind the tape evenly on the take-up reel, but never great enough to pull it past the capstan. The speed of transport should be determined by the capstan alone.

Electronic Repair and Replacement

Amplifiers (record and playback). Correct for any defects listed under "inspection". Cleaning or soldering of contacts may correct the fault; if not, replace the component. Replace underrated or apparently overheated resistors and capacitors with substitutes of better construction and higher rating. Wire-wound power resistors are reliable. A few holes drilled in a chassis wall for ventilation will often forestall future failure. Replace badly worn switches or jacks. After checking, replace doubtful tubes. Look for weaknesses in the original design, since undersign may result in breakdown. Overdesign, achieved by your own corrective efforts, generally provides for long periods of uninterrupted service.

Oscillators. Oscillator capacitors and coils in continuous use depreciate in quality, since the high oscillating currents may generate considerable heat, particularly in an erase oscillator, test these items for breakdown under a heat run, and replace them when performance is doubtful. Check and replace noisy resistors and switches. When trap circuits are included, to prevent high-frequency leakage into other circuits, check their effectiveness with an oscilloscope. Check the oscillator tube thoroughly. Make sure that bias current control is effective and that it maintains steady current, once set.

Power Supply. To avoid breakdown, filter capacitors must have ratings adequate to withstand instantaneous a-c peak values, approximately 1.4 times the rms value. If this is not the case, replace them. Maximum rectifier-tube ratings are design maximums and should not be exceeded for a line voltage of 117 volts. Replace rectifier tubes, incapable of fulfilling the current requirements, with a larger type. Substitute a heavier choke for one which shows consistent over-heating.

Reassembly of Subassemblies

Mechanical. In general, the last subassembly removed from the main mechanism should be the first returned to its original position. Study the exploded views, sketches, and photos for clarification of the relationships between various subassemblies and parts. Install the major parts first. For example, when a pressure wheel or idler normally rides against the capstan, replace the capstan first, then install the secondary or pressure item. Do not attempt their mutual adjustment at this time. Proper adjustments cannot be made until the mechanism is completely assembled and subjected to an extended warm-up period for observation.

Make sure that all locking pins, lock nuts and washers are installed in exactly the sequence shown in exploded views. Clearances must be held to close tolerance. Therefore, replace any small washers which may be missing. Scrutinize the cabinet and chassis for lost parts, since small parts may cause costly damage later, when the machine is tilted or carried about.

Clutches and belts differ for each type of machine and, once disassembled, must be re-assembled in strict accordance with the manufacturer's instructions. Often service manuals do not even include such instruction, this being considered a factory job.

Electronic. Prior to re-assembly of electronic subassemblies, ascertain that all electrical contacting screws, nuts, and terminals are tightly secured. Scrape excess rosin from soldered joints and make sure that they are mechanically solid. Clean all contacts on terminal boards with a small brush dipped in alcohol. Mechanically operate all multipole switches prior to re-installation to determine whether contacts are properly aligned.

Check each subassembly against the wiring diagram or schematic, to avoid transposition of leads, such as input and output pairs. The color or tracer color of the wires will aid this check. Make sure there is ample clearance between terminals in amplifiers and power supplies. When in doubt, insert and secure some adequate insulating material.

When shafted keyways are not provided, set up all locking screws securely on control knobs or levers. A misplaced control could easily cause erasure of a treasured record. Check all disassembly scribe marks on parts to be sure they are reinstalled in their original position. A change of position, such as in a transformer, may cause excessive hum. Carefully check the alignment of all rubber grommets. Components are floated in rubber or plastic for a definite reason, carelessness during reassembly may cause vibration and microphonic feedback.

Tests and Adjustments

After reassembly of the mechanism, perform the following mechanical and electrical tests and adjustments:

1. Run the machine through a 15-minute warm-up period.

2. Repeat the preliminary mechanical and electrical tests listed earlier.

3. Inspect for proper tape travel. Watch for any weaving or creeping of the tape upon the capstan or other rotating parts; an adjustment of tape alignment at the point of irregularity should eliminate such a fault.

4. Check all forward and reverse controls by operating them under normal tape load.

Hum. Check the output hum content with the gain control wide open and all shields in place. A slight turn of the power transformer to the right or to the left may reduce the amount of hum; some units have hum bucking controls (refer to individual instructions for correction). All motors should be running during hum adjustments.

Head Adjustments. Thread the machine with an azimuth adjustment tape and connect a level indicator (preferably a VTVM) across the output terminals. Rotate the playback head slowly in each direction for maximum output. Two peaks may be encountered; lock the head in position for the greater of the two peaks (the false peak is caused by two waves being scanned at once). Air gaps in record and erase heads must be accurately aligned with respect to each other. To align the record head, apply an input signal from an audio oscillator. Use the highest frequency the particular machine will record before rapid roll-off. Adjust the record head for maximum output response and lock it in place. Follow the manufacturer's instruction for replacement of magnetic heads. When new types are substituted, bias values are changed.

In place of this mechanical head adjustment, the following electrical head adjustment may be performed:

1. Remove both connecting leads from the record head and transfer the lead from the playback head to the record head.

2. Connect an output meter across the output of the playback amplifier.

3. Playback a lateral-adjustment test tape, using the record head as a playback head.

4. Adjust the head for maximum response and lock it.

5. Reconnect all head leads to their original positions and remove the test tape, replacing it with an erasable one.

6. Record 12,000 cps or higher as supplied from an audio oscillator, for several minutes.

7. Play back the new 12,000 cps record and adjust the playback head for maximum response. Lock this head in place and the two heads will be in alignment.

Note: If 12,000 cps is impractical, record the highest frequency the machine can handle properly.

Erasing Hiss. When an erase-head balance control is provided, insert a calling card or matchbook cover between the record head and a tape in normal transit past this head. Adjust the erase head for minimum hiss and then remove the cardboard from the record head. Now reset

the hum balance controls at midpoint. Warm up all electronic equipment and start all motors. Then finally re-adjust the hum balance for minimum hum.

Tube Check. If a check of vacuum tubes is again necessary, realize the limitations of most tube testers. They can only indicate the difference between the actual characteristics of the tube under test and those which are standard for that type. When in doubt, check the tube under actual operating conditions. During this check insert a milliammeter in the plate circuit and apply a test voltmeter to the pertinent terminals. A tube manual will supply adequate reference data for this test. Check all grid and cathode bias values against available voltage charts or schematics.

Lubrication

The basic rule for tape-recorder lubrication is *do not* overlubricate. Since the requirements vary for different machines, the manufacturer's instructions should be followed. Some motors, for example, are furnished with grease-packed ball bearings and require no attention. Others, having plain bearings, may need attention every 100 hours of operation.

Always lubricate sparingly, especially the tape transport section of the mechanism, to avoid any possible contact between the tape and the lubricant. After lubrication, wipe any excess lubricant from the part, using a cleaning tool. (Never use an oil can.) Small, tight spots may be reached with a broom straw. Pipe cleaners are also useful, but don't let the metal stem come in contact with polished surfaces. Specific lubricants are listed for a few typical mechanisms later in this chapter.

Since highly polished plain bearings are under little strain they need practically no lubrication. A small amount of instrument oil, camera-shutter oil, or watch oil, applied occasionally, will prolong life. Two or three drops of light spindle oil, such as Kensington No. 9, may be applied to shafts and spindles during routine lubrication. Also wipe the surfaces of mechanical linkages occasionally with No. 18-H grease, or an equivalent.

Reinstallation

Rack-type units are individually installed and secured by mounting screws. After installation, interconnection between the units may be completed behind the rack panels.

Cabinet or console models usually require the installation of the loudspeaker and other electronic units within the cabinet. For these cases, position the assembled top plate and mechanism adjacent to the cabinet and make all connections required between the top plate and electronic equipment. To avoid damage, clear the interconnections and carefully lower the tape mechanism and top plate into position in the cabinet. Secure it with the retaining screws and washers provided.

Restore the tape platters or reels to their normally keyed positions. Use only recommended reels. Some machines are adjusted for the lighter plastic reels with large hubs (1¾ inches); smaller hubs and metal reels may prove unsatisfactory in these machines. Check all rotating parts for freedom of motion, before the initial warm-up. Install any external connectors, including the power plug.

Final Tests

A final overall check comprises all mechanical and electrical components in a combined performance test. For this purpose use a signal generator with a constant output between 20 and 15,000 cps and record the full-frequency spectrum of which the particular machine is capable. Allow an adequate warm-up period and ascertain that input levels and equalizer settings are correct.

Play back the finished record and record the relative response with an output meter. Compare the output-meter readings with the normal frequency-response characteristics of the machine. The readings may also be compared to the playback readings from a standard test tape. If discrepancies are noted, the record and playback circuits may then be individually checked by connection of appropriate test equipment.

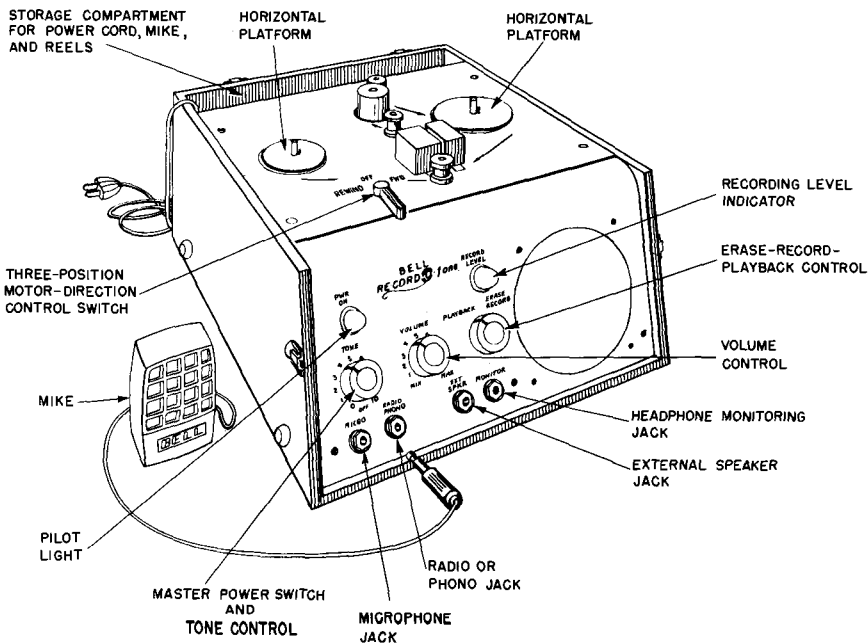


Fig. 6-2 Re-Cord-O-Fone, Model RT-65, controls. Courtesy: Bell Sound Systems, Inc.

Specific instructions for the servicing of several typical tape machines, commercially available at the present time, are detailed throughout the balance of this chapter. These machines range from home recorders through semi-professional types, to radio station recorders. Supplementary mechanical and electronic details of several of these machines appear in Chapters 4 and 5.

Example 1. Bell Re-Cord-O-Fone, Model RT-65 (Figs. 6-2, 6-3, 6-4, and 6-5)

This machine is arranged for dual-track operation at a forward speed of 7.5 ips. Each of the two tracks has a width of $\frac{3}{32}$ of an inch. Either five- or seven-inch tape reels may be used. These are placed upon and driven by the horizontal platforms (Fig. 6-2). The entire machine, including amplifier and built-in speaker, weighs only 33 pounds.

A rewind speed ratio of 6:1 provides complete rewind of a 5-inch reel in $2\frac{1}{2}$ minutes, while four minutes are required to rewind a 7-inch reel. The drive motor is shock-mounted in rubber to avoid transmission of vibration to other components. An internal cooling fan is included for ventilation. Since this fan is at the base of the mechanism, it must be protected by a pedestal or rack when the mechanism is removed from its case. The physical arrangement of external parts appears in Fig. 6-2.

CONTROLS

All controls, except those for tape motion, appear on the front panel (Fig. 6-2). The right center knob is the Erase-Record-Playback control. In the right-hand position the machine is ready for recording. In the left position the unit is ready for playback.

The center knob is the volume control, which is augmented by the recording level indicator. The left-hand knob is the master power switch and tone control. The pilot light provides a check upon the action of the power-control switch.

Four jacks are mounted along the bottom of the front panel. From left to right these jacks are: microphone, radio or phonograph, external speaker, and headphone monitoring.

Near the front of the mechanism's top plate, a three-position motor-direction control switch is provided. From left to right these positions are: Rewind, Off, and Forward. A compartment in the rear of the unit is for storage of the power cord, tape reels, and microphone.

DISASSEMBLY

Removal of the mechanical assembly from the complete unit is effected as follows:

1. Remove the four $\frac{10}{32}$ truss-head screws along the right and left edges of the top plate or panel.

2. Grasp the take-up reel platform with the left hand and lift that side of the top plate clear. Next grasp the right corner of the top plate with the right hand and grasp the left rear corner with the left hand. Pull the plate sufficiently to the right for the casting to clear the brackets on the left side of the cabinet, and lift upward. This action frees the plate, except for the magnetic head wires and the five-prong plug. Be careful to allow for short connectors.

3. Push the plate to the extreme rear of the cabinet and rest its rear edge on the vent grill. Rest the front of the plate on a wooden prop, or equivalent, while the four head leads are unsoldered. Detach the five-prong plug. The mechanical assembly is now free for removal.

4. Remove the plate and assembly carefully and rest it on a pre-arranged pedestal or rack (Figs. 6-1A and 6-1B). This action protects fan blades and other easily damaged components. If no mounting rack is available, remove the fan and rest the assembly on its motor shaft, after blocking it for safety.

If it becomes necessary to remove the top plate from the remainder of the mechanical assembly, carry out these three steps:

1. Remove pointer knob from control shaft.

2. Remove four Phillips oval-head 10/32 screws, recessed in the panel. The top plate will then lift clear of the mechanical assembly.

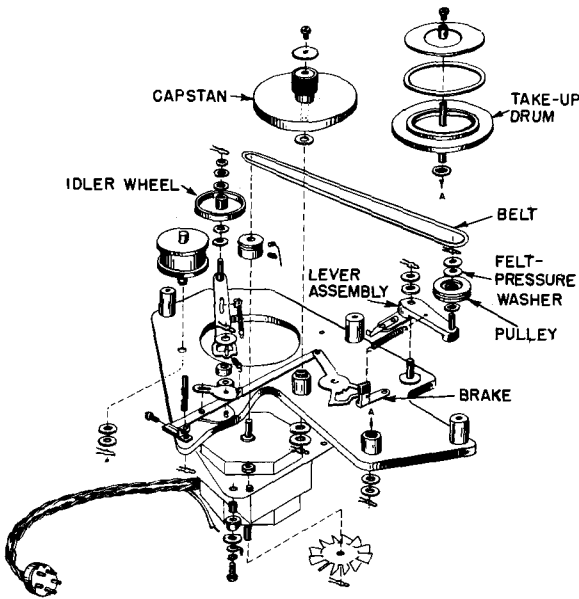


Fig. 6-3 Bell Model RT-65 tape recorder, exploded view of mechanical assembly. Courtesy: Bell Sound Systems, Inc.

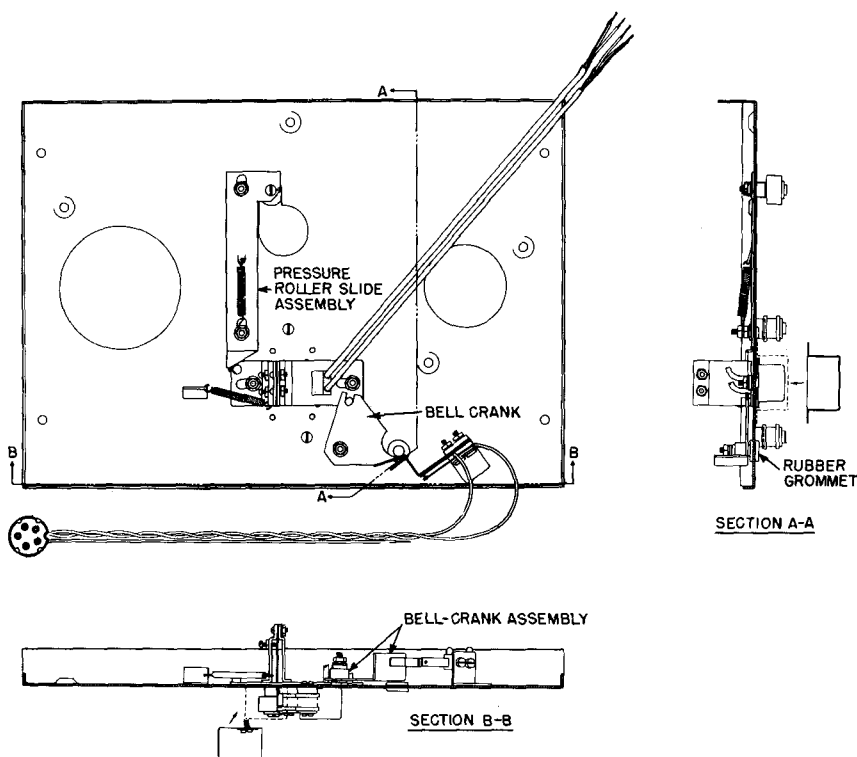


Fig. 6-4 Bell Model RT-65 mechanical assembly linkages. Courtesy: Bell Sound Systems, Inc.

3. Disconnect the two wires to the blade switch, to allow separation of top plate from mechanism.

Before proceeding with any service work, it is advisable to study the exploded view of the mechanical assemblies, which are tabulated in Fig. 6-3. Also study the leverages as detailed in Fig. 6-4. Rapid familiarization with the entire mechanism is thus facilitated.

LUBRICATION

No sliding or rotating part should stick in any position. Burred parts can be corrected with a fine mill file. If dirt causes sticking, it should be removed by either a lintless rag or a pipe cleaner sparingly dipped in carbon tetrachloride.

The bell-crank assembly (Fig. 6-4) and the pressure-roller slide assembly should be exercised manually to check for free action. Check the bell crank to see that it moves freely and does not strike the rubber grommet. The bell-crank assembly and all wiping surfaces of mechanical linkages should be thoroughly cleaned, and then lightly lubricated with

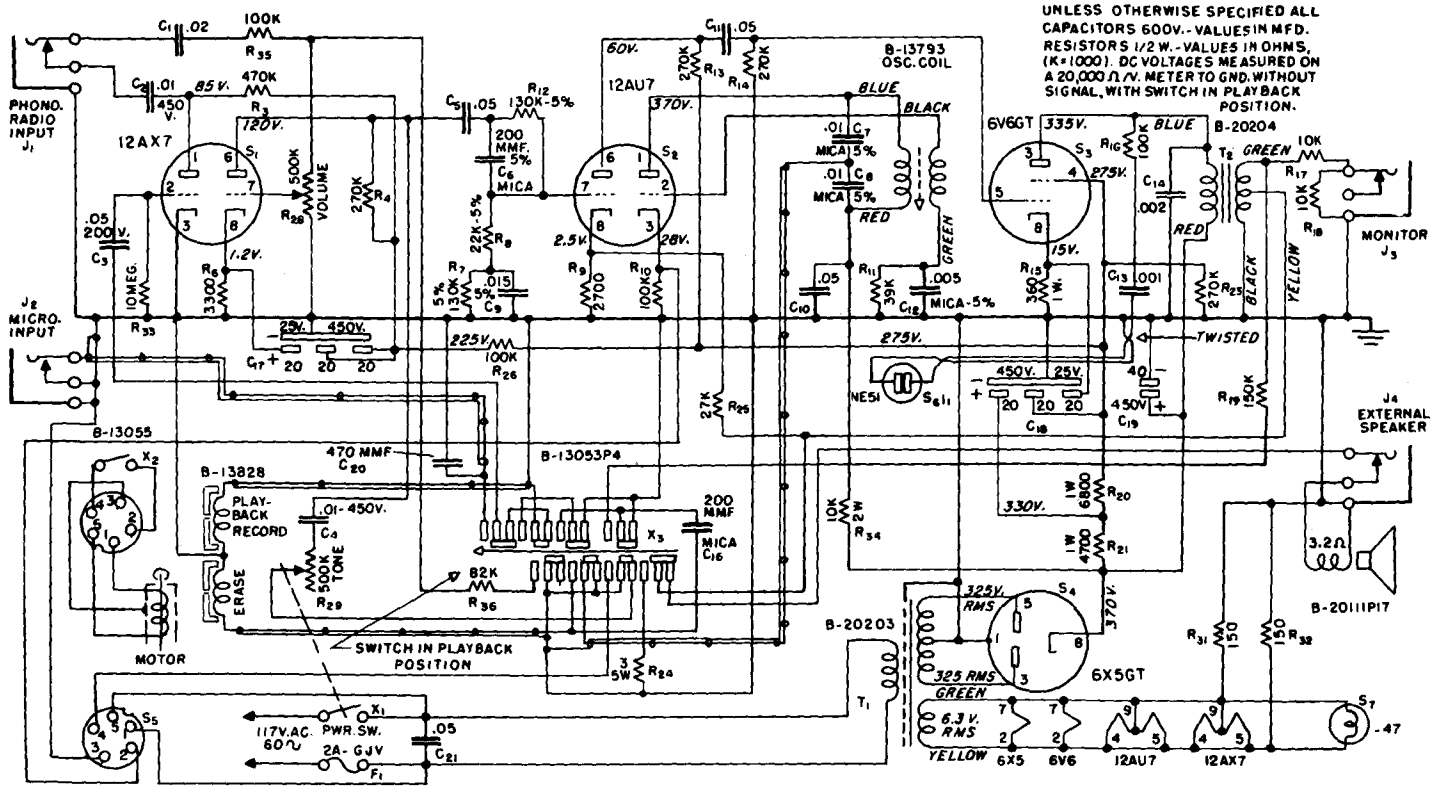


Fig. 6-5 Bell Model RT-65, schematic circuit diagram. Courtesy: Bell Sound Systems, Inc.

2. For improper pressure of felt pads: Start the recorder and turn the volume up to maximum. Using the index finger, push the pressure felt which is farthest from the front gently toward the head. If this action results in a rise of 1 or 2 db (2 or 3 volts), check the pressure of the felts with a gram or ounce scale gage (after stopping the machine). This check is accomplished as follows:

Turn the control lever to Forward: connect the gage to the top of the felt pad and to the spring; now pull the gage at right angles, just enough to lift the felt pad off the head, and then read the gage. If the indicated pressure is under 2 ounces, the spring can be bent forward by carefully applying pressure at their bottoms. If the spring set screws are loose, tighten them very carefully to increase the pressure. The latter adjustment is very critical; too much pressure will wear the head unnecessarily, may cause dirt to accumulate rapidly, or may slow down the tape or vary its speed, giving rise to wows.

3. For improper head alignment: to obtain optimum results the alignment of the recording head must correspond with the tape motion. Tape travel must be vertically and laterally parallel with head fixation. Deviations will introduce output losses. If the tape output is below normal, although the head is clean and the pressure pads have proper tension, check the retaining screws on each side of the head. If both screws are tight, mark the position of each screw in the bracket which it holds. Now loosen one retaining head screw slightly and gently twist the head alignment, while the 7,500-cycle head-alignment tape is being played back. If no change is noted in the reading of the output meter, retighten the first screw exactly upon its original mark, then slightly loosen the second retainer screw. Vary the position of the head slightly, either way from its original position, until maximum response is noted on the output meter. Secure retaining screws at this specific point.

MECHANICAL INSTABILITY

Wows. Check the idler wheel (Fig. 6-3) capstan, belt, take-up drum, and felt-pressure washer for *wow* or instability. These parts should not have flat spots or be oily or greasy, with the one exception of the felt washer. Make a mark with chalk or crayon on each of the above rotating parts, in order to make their motion visible during normal operation. Then record a constant tone of 400 or 1,000 cps and play it back while listening to and watching for a relation between any evident *wow* in the new record and the chalk marks on rotating parts. Replace those parts which show a synchronous relation between their respective mark and the *wow* frequency.

Flutter. The cause of *flutter*, which is a very rapid *wow*, is very difficult to locate. In early models the roller nearest to the front panel was made of bakelite; it is advantageous to replace it by one of aluminum. Pressure-pad pressure should be checked, as previously discussed.

Check the motor for undue vibration or a slightly bent shaft; also check the motor shock mounts, these should be free, vertically, but must be set firm against the rubber sideways. Check the spacing of the idler wheel and belt for abnormal vibration. Finally check the fan blades and, if necessary, bend one slightly for rotational balance.

Example 2. Soundmirror Models BK 443 (Portable) and BK 442 (Table Model), Brush Development Co. (Figs. 6-6 through 6-14)

Service data on these models of the Brush Development Company is given here in considerable detail, because a large part of the information also applies to other Soundmirror models and similar popular equipment of other manufacturers. It is often necessary to remove and replace major components before mechanical and electrical adjustments can be made. Servicing instructions follow in that order.

MECHANICAL DISASSEMBLY AND REASSEMBLY

For general disassembly of the complete machine and removal of the main units, proceed as follows:

Removal of Sub-Assembly from Case (Fig. 6-6)

1. Remove trim covers (Fig. 6-6), secured by three knurled thumb screws. Remove main trim cover after releasing its four binding head screws. Remove the three retainer screws across the rear of the mechanical chassis. Remove the two carrying-handle retainer screws.

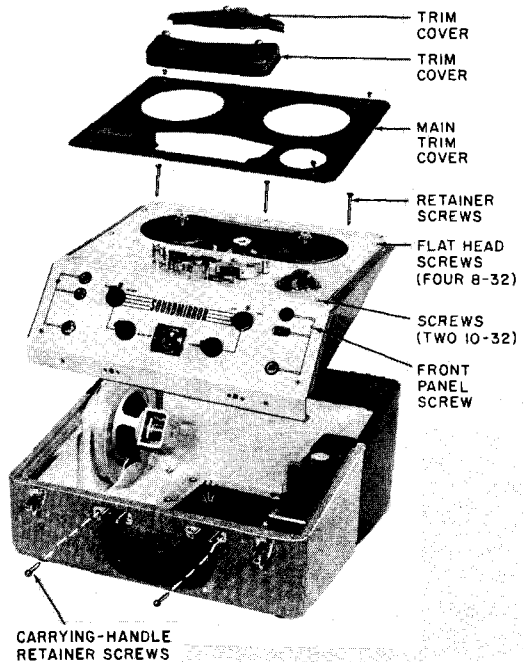


Fig. 6-6 Disassembly of Soundmirror BK-443. Courtesy: Brush Development Co.

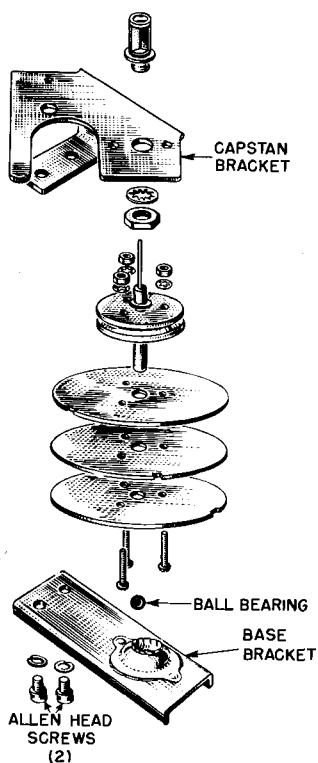


Fig. 6-7 Exploded view capstan assembly, Brush BK-443. Courtesy: Brush Development Co.

2. Lift the complete subassembly out of the case slightly, to permit disconnecting the power supply and speaker plugs. After disconnecting these, remove the main subassembly. This exposes the power supply and speaker, both attached to the walls of the case.

3. Disconnect the plugs for the erase head, record head, and motor.

4. Remove the four 8-32 flat head screws (Fig. 6-6) and the two 10-32 screws located on the front corners of the mechanism.

5. Remove the mechanism by sliding it away from the amplifier.

Removal of Amplifier. Remove the four screws (Fig. 6-6) on the front etched panel.

Reassembly. To reassemble the complete unit, reverse the above procedure. When attaching the mechanism, make sure that the projecting edge of the front etched panel clears between the erase-spring actuator and the main chassis of the mechanism.

REPLACING PARTS

Replacement of Record-Play Head. Take the following steps:

1. Remove the mechanical chassis as previously explained.

2. Remove the record-play head mounting screws. Unsolder the three wires from the erase switch (S-20 Fig. 6-11) and cut the lashing securing the head cable to the capstan bracket (Fig. 6-7).

3. Remove the capstan drive-assembly screws and carefully lower the assembly away from the panel enough to slip the record-play head through the hole provided.

4. Assemble the capstan drive assembly and the record-play head by placing the head and the mounting clamp between the flywheel and the bracket.

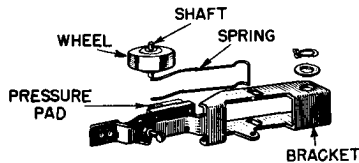
5. Hold the assembly in the left hand and position it onto the panel while tightening the flat head screw; this holds the drive assembly until the other mounting screws are placed in position, in the following sequence:

- a. Place the screw between the head and the capstan spindle.
- b. Replace the screw nearest the erase head.
- c. Replace the screw between the capstan spindle and the right-hand ribbon guide.

6. Adjust the head for hum cancellation (as described later in this chapter under "Adjustment of Record-Play Head").

7. Tighten all screws securely.

Fig. 6-8 Pressure wheel assembly, Brush BK-443. Courtesy: Brush Development Co.



Replacement of Erase Head. Proceed as follows:

1. Remove the mechanical chassis from the unit.
2. Remove the mounting assembly by removing the three screws which secure it to the chassis, cut the lashing which holds the head cable to the capstan bracket, and unsolder the connecting wires.
3. Remove the mounting plate.
4. For reassembly reverse the above procedure.

Replacement of Pressure Wheel Assembly. The pressure wheel assembly (Fig. 6-8) consists of a bracket, spring, shaft, wheel, and pressure pad. The latter is attached to the bracket. To replace the complete assembly:

1. Remove the small cover and Tru-Arc retainer ring.
2. Lift the assembly off the post, being careful not to damage the spring. Then slide the spring out from the end of the bracket. This will release the wheel and shaft.
3. Reassemble in reverse sequence.

Replacement of Pressure Pad. Friction between the pressure pad and the recording tape will wear the felt pad. Any quick drying cement may be used for replacement, but take care that no cement remains on that part of the felt pad which will contact the tape. After replacement, pressure should be adjusted (as outlined in a later section, "Adjustment of Tape Tension").

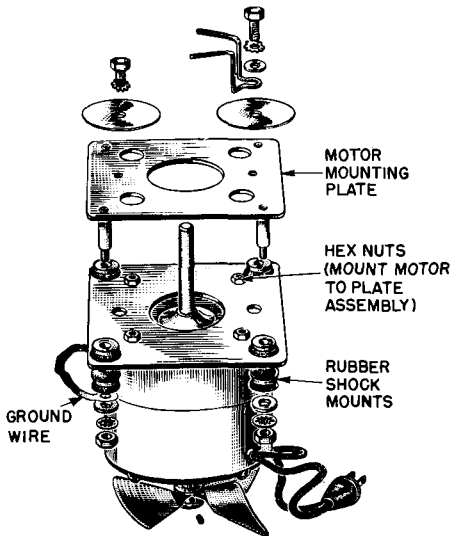


Fig. 6-9 Motor assembly, Brush BK-443. Courtesy: Brush Development Co.

Replacement of Tape Transport Springs. Push a screwdriver up through the slot of the cup assembly. Tap lightly and remove the control knob; the control knob spring will then be released. Remove the Tru-Arc retaining ring, washer, and the control shaft spring. When reassembling, make sure that the turned edge of the control-shaft spring falls into its square limit stop; the knob should have as little play as possible in its vertical elevated position.

Replacement of Belts. Belts should be replaced whenever they show noticeable wear. When replacing either belt, check the height of the motor pulley to be sure that the capstan drive belt is parallel to the panel. Under normal operation rubber dust from the clutch belt will accumulate; clean this dust thoroughly from the mechanism.

Replacement of Turntable Assembly.

1. Remove the Tru-Arc retaining ring, using No. 22 Tru-Arc pliers.
2. Lift the turntable assembly from the reel post (this assembly is divided into upper and lower cups).
3. During reassembly, make sure that the cups fit together with the insides facing each other and are indexed according to the notches and slots in their edges.

NOTE: If the reel guide pin is broken off, the reel post must be replaced. If the pin is more than slightly bent it will be badly weakened by any attempt at straightening, the post should be replaced.

4. Install the assembly on the reel post and replace the Tru-Arc retaining ring. Make sure that this fits into the groove on the reel post and that its sharper edge is upward.

Replacement of Clutch Assembly.

1. Remove the mechanical chassis from the unit.

2. Remove the turntable assembly and clutch belt.

3. Remove the two screws which mount the clutch-lifter bracket assembly. Slide the assembly out at one side, being careful not to distort the clutch-lifter spring attached to the bracket.

4. While holding the clutch raising lever in its extreme position, carefully remove the small Tru-Arc retaining ring and washer located at the lower end of the reel post, (this requires the use of No. 0018 Tru-Arc pliers).

5. Lift out the reel post assembly, being careful not to loose the clutch-lifter pin. This allows the clutch and pulley to be lifted from the clutch bearing assembly.

6. The felt clutch is cemented to the upper face of the pulley and ground flat after assembly. Under normal conditions it should not require replacement; should it become damaged, however, the pulley assembly may have to be replaced.

7. If necessary, remove the clutch-pulley bearing assembly by removing the hex nut on the panel of the chassis. Replace any damaged or worn-out parts.

8. Reassemble the clutch pulley, reel post and lifter pin, and install them upon the clutch bearing.

9. Install the washer and Tru-Arc retaining ring on the lower end of the reel post.

Replacement of Capstan Assembly (Fig. 6-7). Proceed as follows:

1. Remove the mechanical chassis from the unit.

2. Remove the capstan drive belt.

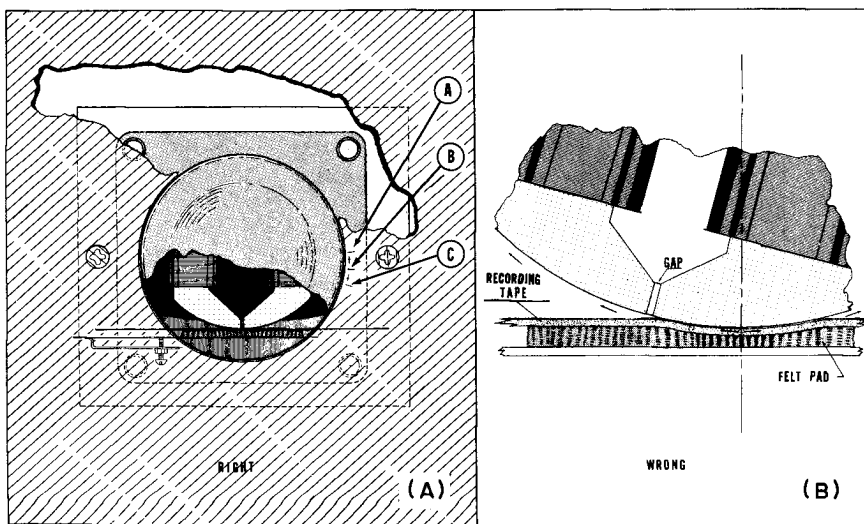


Fig. 6-10 Record-play head alignment, Brush BK-443. Courtesy: Brush Development Co.

3. Remove the two Allen head screws on the base (Fig. 6-7).

4. Carefully pull out the capstan assembly and base bracket. Take care that the ball bearing on the base of the capstan assembly is not lost.

5. Replace parts and/or assemblies in reverse order.

Replacement of Motor (Fig. 6-9). The drive motor is a 115-V, 60-cycle, four-pole shaded-pole induction motor and has a cooling fan attached to the lower end of its vertical shaft. When required, replace it as follows:

1. Remove the mechanical chassis from the unit and remove the rubber belts.

2. Remove the toggle switch bracket from the chassis and disconnect motor connectors from both the motor and plug.

3. Remove the two binding head screws which mount the motor to the chassis.

4. Loosen the 8-32 Allen head screw and remove the drive pulley from the motor shaft. Remove the four hex nuts which mount the motor to the plate assembly.

5. To replace the rubber shock mounts, remove the four hex nuts holding the mounts in place; next remove the motor mounting plate from the plate assembly; now remove the rubber mounts from the plate and install new ones, finally install the mounts on the plate assembly and replace the screws.

NOTE: All four rubber mounts should be replaced to assure proper balance of the motor. Make sure, also, to replace the ground wire to avoid electrical hum from the motor.

6. Install the new motor and reassemble upon the chassis (in reverse order from the above).

7. After installation of the rubber drive belt, adjust the height of the drive pulley so that the capstan belt is parallel to the panel.

8. Adjust the position of the motor on the chassis to a location which causes minimum vibration of the drive belt and which assures greater tension to the clutch belt than to the drive belt.

ADJUSTMENTS

The necessary adjustment of newly installed or misaligned parts will now be described.

Adjustment of Pressure Roller. Pressure of the rubber wheel against the tape and capstan spindle is set at the factory. It is not recommended that adjustment be attempted in the field, but that the defective part be replaced.

If the tape tends to crawl up or down on the capstan spindle, the spring may be not seating properly in the grooves of the wheel shaft. If this is not the case, the spring may have been bent so as to cause more pressure from one arm than from the other. Since this is a critical adjustment, it is recommended that the spring be replaced.

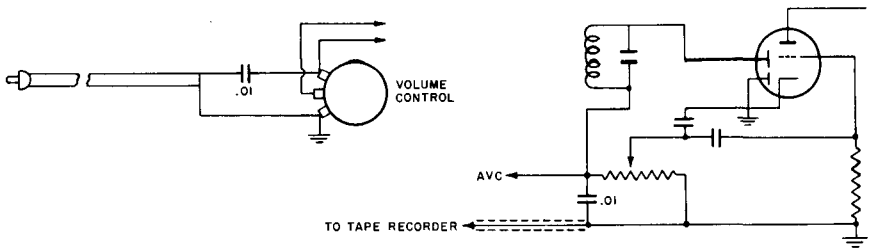


Fig. 6-12 Suggested detector-tube pickoff for Soundmirror BK-443. Courtesy: Brush Development Co.

Adjustment of Tape Tension and Guides. Once the trim covers are removed, pressure of the tape against the record head can be adjusted by turning the screw mounted on the pressure-wheel bracket assembly. Loosen the locking hex nut before attempting this adjustment. Proper tension is measured by attaching a scale to the end of a strip of tape which is drawn through the tape guides, record head, pressure pad, and behind the capstan assembly, at 7.5 ips. A scale reading of 1.5 to 2.5 ounces is normal.

Adjustment of the tape guides, beneath the trim covers, is made by slightly rotating the guides clockwise or counterclockwise around the guide posts so as to increase or decrease the friction of the tape through the guides, while operating in Fast Forward or Fast Reverse. The tape should wind tightly onto the reel in a short length of time. Guides should be positioned in a vertical plane with respect to the posts to facilitate ease of threading. Some units do not require tape guides, because proper friction or *drag* upon the turntables is obtained from small friction brakes attached to the clutch-cup face.

Adjustment of Record-Play Head. Improper head alignment will cause faulty operation of any tape recorder. The normal position for the record-play head is shown in Fig. 6-10 (A). The cut-a-way drawing of this figure shows how the pole pieces should contact the tape. It is important to make sure of this alignment and to avoid the abnormal position shown in Fig. 6-10 (B). The latter condition would prevent the gap from contacting the tape, with the possible result of no signal recorded, or at least a severe loss of highs. To guard against this condition take the following steps:

1. Place a mark on the panel at point *B* (Fig. 6-10A) to identify the position for minimum hum as determined from previous rotation of the head. This mark should be made in line with the end edge of the opening in the record head.
2. Place a recorded portion of the tape through the record-play head and the capstan drive spindle, and change the control to the Play position.
3. Loosen the head mounting screws enough to rotate the head toward position *A* or *C* while listening to the reproduced signal. When

the position is found which better reproduces the higher frequencies, place a second mark on the panel to identify that position. If this position does not coincide with the position for least hum, a compromise position must be selected. The head mounting screws may then be tightened in the selection position.

Adjustment of Erase Head. The erasing process should disarrange the minute particles of magnetic coating on the tape so that no signal is reproduced during playback. However, if the two magnets in the erase head do not approach the tape at the proper angle, a noise may be reproduced during playback. Corrective steps follow:

1. Thread the machine with a recorded portion of tape which can be erased during this adjustment. Remove the two small trim covers, turn the power switch to On and allow the tubes to warm up.

2. Set the amplifier controls for Playback operation and the top panel controls for Record operation. This step puts the erase head in contact with the tape, causing erasure before the tape enters the playback head.

3. Set the playback volume control to *maximum* and the tone control for greatest high-frequency response (the tone control affects the Playback function only).

4. Loosen the screws that hold the erase head to its mounting bracket and rotate the head slightly, first in one direction then the other, until a point of minimum noise is found. Do not rotate the head too far in either direction or erasure will be incomplete. Tighten the retainer screw to lock the head in the selected position.

5. Shift the control lever to the Stop position to allow the erase head to drop away from contact with the tape. Finally, replace the trim covers.

Adjustment for the multipole heads used in later models is the same as given above.

Adjustment of Clutches. Clutches are adjusted at the factory; under normal operating conditions they should not require readjustment. If, for some reason, it becomes necessary to replace any part of the clutch

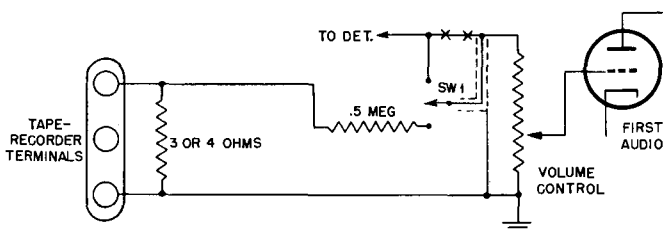


Fig. 6-13 Use of single-pole, double-throw switch for radio-tape recorder operation.
Courtesy: Brush Development Co.

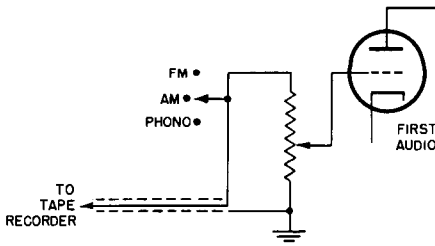


Fig. 6-14 Use of selector switch for FM, AM, or Phono signal application to Soundmirror tape recorder, BK-443. Courtesy: Brush Development Co.

assembly, readjustment becomes necessary and the following procedure should be followed:

Turn the power Off and place a loaded reel of tape on the supply turntable. Next rotate the control knob from the neutral position toward the Fast Forward position. As this is done, the supply turntable should rise visibly, but not over $1/32$ of an inch. If the turntable does not rise this amount, the locking nut on the clutch-adjusting screw should be loosened with a pliers or wrench; the Allen screw must then be turned in with a No. 8 Allen wrench until the specified amount of lift is obtained.

The adjustment should then be relocked. With the control in the Fast Forward position, the turntable should be manually lifted, by grasping the reel post. Make certain that the turntable still has vertical clearance when it is fully elevated and in this operative position.

Now move the loaded tape reel to the take-up turntable, rotate the control knob toward the Fast Rewind position and observe the take-up reel for lift. Adjustment should be made as previously outlined for the supply turntable. If, after this correction, the recorder does not function properly it is possible that either the clutch pads require cleaning, or the tape guides have become bent, thus causing too much drag on the tape.

Adjustment of Motor Switch Bracket. The motor switch bracket accomplishes two functions: it centers the control knob and clutch lever, and regulates the motion of the clutch lever. There should be a minimum amount of play between the switch and the bracket during conditions of Fast Forward, Fast Reverse and Off.

Rotate the control knob clockwise to the Fast Forward position, then slowly move it to the Off (center) position. If the bracket moves more than $1/64$ of an inch, it must be moved closer to the motor switch to reduce the amount of play. The same holds true for Fast Reverse, when the knob is rotated counterclockwise in the direction of the Fast Rewind position.

LUBRICATION

Do not over lubricate any component. The motor should be oiled with SAE No. 20 oil once every three months. All moving or sliding

parts should be cleaned of any accumulated dirt or rubber dust and a thin coat of light oil applied. Keep all driving surfaces and belts free from oil. The cam surface of the control arm and cam follower should be lightly greased periodically.

MOTOR VIBRATION

When motor noise is apparent, the clutch and capstan drive belts should be disengaged to ascertain whether the vibration originates from the motor itself. Check the fan for bent or loose blades. Many cases may be traced to misalignment of shock mounts. The motor must float freely and not touch any other part of the machine. Early models used heavy ground strap material which transmitted vibration to the chassis, and some of those models had no belt guides. Such belt guides should be installed in such a way to prevent the belt from rubbing against itself, thus causing rapid wear. The belt guide is simply installed by replacing the present motor-mounting screw with a half-inch #10 self-tapping screw, then slipping the new belt guide under the screw head, with a flat washer and a lock washer installed between it and the screw head.

ELECTRICAL MAINTENANCE

Repairs or adjustments to the electronic section of Model BK-443 (Soundmirror) are accomplished in a manner with which all radio servicemen are familiar. The amplifier schematic and values for components are given in Fig. 6-11. Voltage and resistance data appears in Table 6-II.

MEASUREMENT OF DYNAMIC RANGE

Soundmirrors are built to a dynamic-range specification of 35 db. which means that there should be a 35-db difference between the maximum sound output reproduced at rated distortion and the noise level. Before a machine is condemned as having too high noise or hum content, its dynamic range should be measured. A simple method of measurement is described in the following paragraph.

Connect a wide-range, a-c voltmeter across the voice coil of the loudspeaker. Record a constant tone at the maximum level possible below the accepted distortion factor. Let the machine continue to run normally, but turn off the volume control to prevent further recording, then let the tape be erased during a few more feet of travel. When the recording is played back, the voltage produced by the tone should be measured and compared to the voltage produced by the noise during the non-recorded footage. The ratio of these two voltages should be 35 db. Bear in mind the fact that the noise level of a new tape of good quality will always be less than that of a tape which has previously been erased and reused, regardless of the erasing process.

TABLE 6-II
VOLTAGE AND RESISTANCE CHART

These measurements are from indicated Pin to Ground. Voltages are plus unless otherwise indicated, and are at 117 Volts, 60 cycle. K indicates value of resistance times 1000. Remove line connection when measuring resistances.

TUBE	POSITION	MEASURE	PIN								NOTES
			1	2	3	4	5	6	7	8	
V-1	PLAY	VOLTAGE RESISTANCE	0 0	30* 22 K	100 500 K	35 2.2 meg.	0 0	— 22 K	30* 22 K	1.1 2200	*—6.3 volts a.c. between pins to marked—4.5 volts a.c. on 6J7 pins 2 to 7.
6J7***	RECORD	VOLTAGE RESISTANCE	0 0	30* 22 K	95 500 K	37 2.2 meg.	0 0	— 22 K	30* 22 K	1.1 2200	
V-2	PLAY	VOLTAGE RESISTANCE	0 0	30* 22 K	0 0	0 1 meg.	3.5 390	120 45 K	30* 22 K	110 150 K	**—70 volts of 40 kc.
6SJ7	RECORD	VOLTAGE RESISTANCE	0 0	30* 22 K	0 0	0 1 meg.	3 390	100 45 K	30* 22 K	120** 150 K	***—Grid Cap—130 ohms play—1 meg. record.
V-3	PLAY	VOLTAGE RESISTANCE	0 220 K	0 open	0 22 K	0 220 K	0 open	0 22 K	30* 22 K	30* 22 K	x—80 volts at 40 kc. xx—25 volts at 40 kc.
6SN7	RECORD	VOLTAGE RESISTANCE	—40x 220 K	300x 100 K	0 22 K	—39 220 K	300x 100 K	0 0	30* 22 K	30* 22 K	
V-4	PLAY	VOLTAGE RESISTANCE	0 470 K	160 150 K	6 2200	0 220 K	30 300 K	1.2 2200	30* 22 K	30* 22 K	
6SN7	RECORD	VOLTAGE RESISTANCE	0 470 K	155 150 K	6 2200	0 25 K	30 300 K	1.1 2200	30* 22 K	30* 22 K	
V-5	PLAY	VOLTAGE RESISTANCE	0 0	30* 22 K	310 100 K	325 100 K	0 470 K	0 open	30* 22 K	19 390	
6V6	RECORD	VOLTAGE RESISTANCE	0 0	30* 22 K	300 100 K	315 100 K	0 470 K	0 open	30* 22 K	17 390	
V-6	PLAY	VOLTAGE RESISTANCE	30* 22 K	0 open	0 2.2 meg.	0 open	0 0	30* 22 K	— —	— —	
6E5	RECORD	VOLTAGE RESISTANCE	30* 22 K	30 1 meg.	— $\frac{1}{4}$ 2.2 meg.	310 100 K	0 0	30 22 K	— —	— —	
V-7	PLAY	VOLTAGE RESISTANCE	— 22 K	350 100 K	— 22 K	325 a.c. 100 K	— open	325 a.c. 100 K	— open	350 100 K	
5Y3	RECORD	VOLTAGE RESISTANCE	— 22 K	330 100 K	— 22 K	310 a.c. 100 K	— open	310 a.c. 100 K	— open	330 100 K	

Signal measurements: Line 117 volts, 60 cycles. Record position 0.2 volts, 300 cycle signal radio input, V-3 removed. Measured with electronic a.c. voltmeter ($\frac{1}{2}$ meg. input).

Location	Signal Strength	Location	Signal Strength	Location	Signal Strength	Location	Signal Strength
Radio input . . .	0.2 Volts	V-2 Plate-Pin 8 . . .	1. Volt	V-4 Pin 5	9 Volts	V-5 Pin 3	130 Volts
V-1 Grid-Cap005 Volts	V-2 Screen-Pin 6 . . .	5. Volts	V-4 Pin 1	9 Volts	Voice Coil-output . . .	2.8 Volts
V-1 Plate-Pin 3 . . .	0.7 Volts	V-6 Pin 3	3. Volts	V-4 Pin 2	23 Volts		
V-2 Grid-Pin 4 . . .	0.7 Volts	V-4 Pin 4	0.8 Volts	V-5 Pin 5	23 Volts		

RADIO AND RECORDER CONNECTIONS

Recording from the radio is one of the most popular uses of home tape recorders. Often the mistake is made of placing the microphone in front of the radio loudspeaker. This introduces acoustic distortion as well as some room noise. Since there is an ample signal level available at the detector plate of most radios, it is rarely necessary to include the audio of the radio for pickoff. Pickoff at the detector provides a signal of low distortion to the amplifier of the tape recorder. Furthermore, the chances of overloading the amplifier are minimized.

Each manufacturer has his own reason for recommending a certain radio pickoff connection. The detector pickoff for the Soundmirror models is shown in Fig. 6-12. A single-pole, double-throw switch may be installed to swing the detector output from the radio to the tape recorder amplifier, as shown in Fig. 6-13. In the case of a console having a choice of FM, AM, or Phono outputs, connection is made as shown in Fig. 6-14. This allows all three facilities to be switched to the tape recorder amplifier.

Example 3. RCA Model RT-11A (Figs. 6-15 and 6-16)

The tape transport mechanism of the RCA RT-11A tape recorder is described in Chapter 4, where the main units were illustrated (Figs. 4-8 and 4-9) and the power control circuits shown (Fig. 4-10). Electronic features of the unit were described in Example 1 of Chapter 5, and the amplifier circuit schematics were given in Figs. 5-8 and 5-10. Specific servicing details follow in the succeeding paragraphs.

ADJUSTMENTS

Capstan Stabilizer Adjustment. Major components and units behind the face of the RT-11A tape-drive mechanisms were identified in Fig. 4-9. The capstan stabilizer and adjustment is centrally located. For correction, proceed as follows:

Loosen the three screws holding the stabilizer plate to the casting just enough to permit movement of the plate. Loosen the locknut on the knurled adjusting screw and turn in the direction that forces the rubber roller toward the flywheel. The minimum compression into the rubber that will cause the stabilizer to be driven by the flywheel is the optimum setting. Check this setting by grasping the capstan flywheel with one hand and oscillating it through an arc of 90° at a rate of about one oscillation per second. If there is no evidence of the rubber tire slipping on the flywheel when the direction of rotation is reversed, the setting is correct. Tighten the locknut and the three mounting screws, then repeat the test as a final check.

Capstan and Pressure Roller Adjustments. With the machine running on Reproduce, increase the pressure between the rubber roller and capstan, by turning the elastic stop-nut on the pressure-roller solenoid

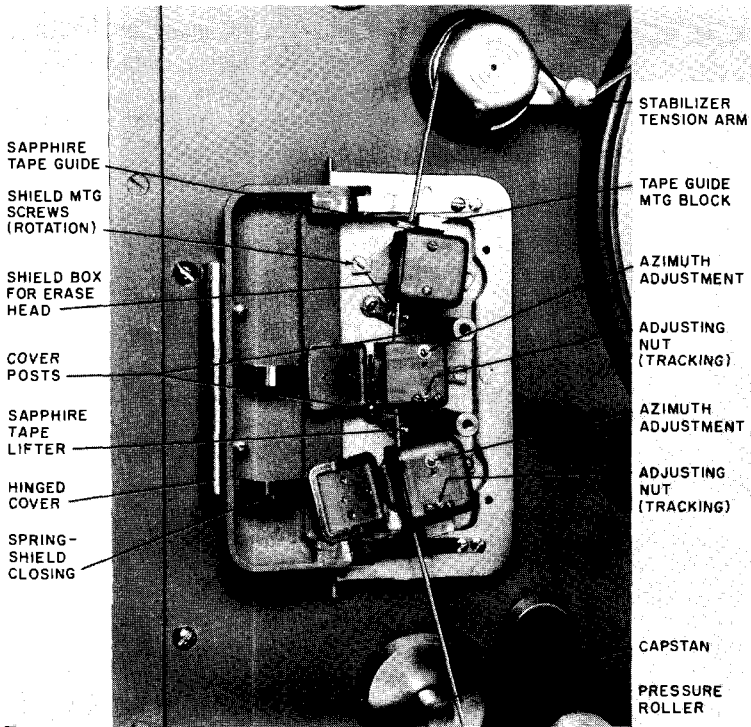


Fig. 6-15 Magnetic-head and tape-tension adjustment, RCA RT-11A. Courtesy: RCA Victor

linkage clockwise, until the capstan exerts a pull of three pounds on the tape when slippage occurs.

Supply Stabilizer and Tension Arm Adjustment. The supply tension arm on the stabilizer (Fig. 4-9) should be set at approximately 3 oz. when rotated to its position of maximum tension. The adjustment is made by loosening the set screw and rotating the collar underneath the stabilizer roller. Access is gained by removal of the flywheel and withdrawal of the roller and shaft sufficiently to expose the collar. When tightening the collar after the spring tension has been set, insert a 0.002 of an inch spacer between arm and collar to establish proper clearance. Tighten the setscrew just enough to hold the collar securely. Remove the 0.002 of an inch spacer and test the motion of the arm, which should be free at all points. Next insert the shaft and roller in the housing, making certain the roller is pushed as far back as it will go. Then replace the spacer (small diameter toward the ball bearing) and the flywheel. Make sure that all axial clearance between flywheel and housing is removed. Tighten the two setscrews in the flywheel securely and the stabilizer should spin freely.

Brake Adjustments. Close the brake solenoid by hand and check that the brake band clears the brake drum at all points. Correction is obtained by means of the brake adjustments shown in Fig. 4-9. Ordinarily the factory adjustment should be permanent. Both reels must be of the same size for satisfactory operation of the brakes.

Tape Tension Adjustment. Operate the machine on Reproduce and attach a cord to the hub of a standard NAB reel. Using a spring scale, measure the hold-back and take-up tensions of the supply reel and take-up reel respectively. Set the tension at $6\frac{1}{4}$ oz. for each reel. This is accomplished by adjusting resistor $4R2$ for the supply reel and resistors $4R3$ and $4R4$ for the take-up reel (see Fig. 4-9). The setting is approximately 95 ohms for all resistors when the NAB $10\frac{1}{2}$ -inch reel is used, and approximately 140 ohms when the RMA 7-inch reel is used. At its maximum clockwise rotation, the take-up tension arm operates a microswitch which stops the machine, when for any reason the tape tension is lost, such as in the case of tape breakage.

Belt Adjustments. Never run the machine with the notched driving belt taut. Set the belt-adjusting screw on the capstan motor-mounting plate so that the belt can be deflected about $\frac{1}{2}$ -inch from the straight line at a midpoint between the driving sprockets.

Adjust the cone-point screws axially to align the motor sprocket with the sprocket on the capstan assembly. Then tighten the cone points sufficiently to remove all play, tighten their locknuts securely.

With the machine running, slightly loosen the nut that holds the rear-cone point assembly to the casting. Then, using a $\frac{1}{2}$ -inch wrench, slightly rotate the assembly so as to align the motor shaft with the capstan shaft. The shafts are parallel when the running belt does not touch either flange on the motor pulley, or when a very slight adjustment causes the belt to shift from one flange to the opposite flange. Finally tighten the nut securely, being careful not to disturb the correct adjustment.

LUBRICATION

Never lubricate to excess. Oiling requirements depend upon the number of hours of continuous operation; too frequent oiling will create an excess seepage along the capstan. The tape, heads, stabilizer and belts must be kept free from oil and dirt at all times. The use of SAE 10 (light) and SAE 30 medium machine oil is recommended for lubrication of the RCA Type RT-11A mechanism.

REMOVAL AND REPLACEMENT OF MAGNETIC HEADS (SEE FIG. 6-15)

Erase and Record Heads. Proceed as follows:

1. Unsolder the cable leads (at the Jones receptacle) which run to the recording amplifier.
2. Loosen the two clamp screws at base of shield.
3. Pull out the shield assembly.

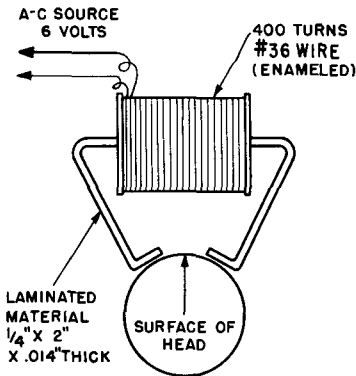


Fig. 6-16 Demagnetizer for magnetic heads. Courtesy: RCA Victor

4. Remove the head from the shield.
5. Unsolder the wiring at the two terminals on the head.
6. Solder the same wires to the terminals on the replacement head.
7. Reassemble the head and shielding, reversing the above procedure. Make sure of a good soldered joint when reconnecting the Jones plug.

Reproduce Head. Replace the Reproduce head as follows:

1. Pull out the plug from the reproducing amplifier.
2. Loosen the two clamp screws at the base of the shield.
3. Pull out the shielded head with its cable attached.
4. Remove the screws holding the head in the shield.
5. Pull the head out of its shield and unsolder the cable leads.
6. Solder the cable leads to the replacement head.
7. Reassemble the head, shield and mount by reversing the procedure given above.

TAPE TRACKING

All three magnetic heads must be centered and aligned with respect to the tape. For the following adjustments refer to Fig. 6-15:

1. Thread the tape-drive unit as shown in Figs. 4-8 and 6-15:
2. Operate the equipment in the Reproducing mode.
3. Adjust the tape guides on the reproduce and erase head-shield cases so that the inside edge of the tape, as it enters and leaves the heads, is exactly $\frac{3}{4}$ of an inch from the panel.
4. Loosen both tilting screws which straddle the center screw-and-nut assembly and adjust each head until the tape tracks directly over each of its gaps.
5. Turn the nut on the center screw until the tape coincides with the center of the lamination stack; in correct position several laminations show on both sides of the tape.
6. Adjust the tilting screws until the top of the lamination stack is parallel to the top of the shield case. This adjustment may be facil-

itated by laying a *non-magnetic* straight-edge across the mounting surface of the shield cases and observing the adjustment. Tighten the screws tightly, but be careful not to strip the threads.

7. Care must be taken to assure that the angular tape "wrap-around" (contact around the head) is the same over both sides of the gap. Slightly loosen the two clamp screws at the base of the shield and, while maintaining tension, rotate the head slowly until centered; then tighten these clamping screws.

AZIMUTH ADJUSTMENT

For proper azimuth adjustment of both reproduce and record heads adjust the single screw opposite the three tilting screws (Fig. 6-15). Proceed as follows:

1. Thread a standard azimuth tape, such as MMM 1-mil wavelength, on the tape drive unit. Operate on Reproduce. Adjust the single screw until the azimuth position of the reproduce head is adjusted for maximum output from the reproducing amplifier.
2. Remove the standard test tape and thread a new tape.
3. Record a 15-kc signal at a level 20 db below maximum recording level. Monitor this process and note the level recorded. While recording, adjust the azimuth of the record head for maximum output from the reproducing amplifier.

FREQUENCY RESPONSE

The various components comprising the RT-11A tape equipment are adjusted at the factory until their electrical overall response corresponds to that indicated in the curves of Fig. 5-9. When it becomes necessary to replace one or more of the magnetic heads or the amplifiers, the high-frequency response may differ from that indicated by the curves. In order to have a permanent check upon performance, to compare with the original adjustment, it is advisable to establish a standard-frequency reference tape shortly after the equipment is received. For this purpose, a tape of average remanence is recommended, for which the proper bias has been previously set. A constant input to the recording amplifier, 20 db below maximum recording level, should be applied when this reference tape is recorded.

The following sequence of frequencies is recommended:

1,000	400	10,000
50	1,000	12,000
70	2,000	15,000
100	4,000	1,000
200	7,000	

CORRECTION FOR WORN HEADS

After several hundred hours of operation the heads become somewhat worn, with a resultant change of inductance and frequency response. Correction can be effected through the use of the standard response tape recommended, but first three adjustments should be checked:

1. Center all three heads with respect to tape travel.
2. Rotate heads, if required, so that the angular wrap-around of the tape is the same on both sides of the gaps. Both of these mechanical adjustments are discussed previously in this chapter.
3. Adjust the azimuth of the reproduce and record heads for maximum output from the reproducing amplifier, as explained under "Azimuth Adjustment".

After the three steps have been completed, it is possible to use the standard-response tape for frequency-response correction. Adjustment is provided through the h-f capacitor (Fig. 6-15) on the reproducing amplifier. Frequency response variations should be noted on an output meter. For a speed of 15 ips the response should be flat, within ± 2 db, in accordance with the curves of Fig. 5-9.

As a final check, thread a new tape of average remanence value in the machine and record the frequencies listed previously under "Frequency Response". Observe the output meter and make any necessary final adjustments by means of the h-f resistor (2R22, Fig. 5-3) on the recording amplifier.

OSCILLATOR ADJUSTMENTS

When a new record or erase head, or a new recording amplifier is installed the oscillator circuit must be tuned for the correct bias and erase currents as explained below.

Erase Current. Adjust the erase current as follows (refer to Fig. 5-8 for location of parts):

1. Set the power switch on and depress the Start and Record push-buttons.
2. On the recording-amplifier chassis turn the meter selector switch 2S1 to the *E*-position.
3. Adjust the erase switch 2S2 and Osc-screw 2L1 for maximum reading on a d-c voltmeter of 20,000 ohms-per-volt sensitivity, connected to terminals 3 and 4 on 2P1. The Meter switch 2S1 should be in *E*-position. The reading should be at least 1 volt.
4. Run a recorded tape through the machine and erase it. Now depress the Start and Record pushbuttons. No trace of the former record should remain detectable. The erase operation should always be checked when new heads are installed.
5. Adjust trap 2I2 for minimum reading on a *VU* meter, connected to 2P2 terminals 3 and 4.

Bias Current. Whenever heads are replaced the bias current should be adjusted as follows (refer to Fig. 5-8 for location of parts):

1. Feed a 400-cps signal into the recording amplifier at a level approximately 10 db below maximum recording level.
2. Adjust the bias current by tuning transformer 2T2 until maximum output is obtained during reproduction from the recorded 400-cycle tape. (Transformer 2T2 is tuned by means of a screw on the top

of its can.) Make sure that for the final bias adjustment, transformer 2T2 is tuned below resonance. Turning the osc-screw clockwise causes an increase in output.

3. Calibrate the reading with the Meter switch in the *B*-position, so that it reads 1.0 volt. This calibration is made through Bias Meter Cal 2C25, and affords a bias check from time to time during operation.

NOISE ADJUSTMENT

A variable resistor (1R5, Fig. 5-8) across the 6.3-volt transformer winding in the power supply is used to balance out or minimize hum from the reproducing amplifier. This control should be adjusted with the tape removed from the recorder but with the Start pushbutton depressed. The head shields must be closed to obtain minimum noise.

When a recording head becomes even slightly magnetized, a sharp increase in the residual noise level will distort the recorded signal. The recording head may become magnetized by large unsymmetrical signals, such as those generated by switching clicks. A d-c Balance Noise Control (2R28, Fig. 5-8) has been provided in the recording amplifier for temporary correction until such time that it becomes necessary to demagnetize the head itself. When the control is balanced, minimum noise will be read on a meter or heard on the loudspeaker. An adjustment of this control more than halfway from center indicates the need for head demagnetization. The amount of direct current passed through the head by means of this balance control is insufficient to magnetize the head permanently. Instead, it sets up a small field which opposes any residual magnetic field acquired by the recording head.

DEMAGNETIZATION OF HEADS

Routine demagnetization should be established for heads which are subjected to daily use. Demagnetizers are now available from several manufacturers. Details of the construction of one simple type of demagnetizer are shown in Fig. 6-16.

Example 4. Ampex Models 300 and 303 (Figs 4-6 and 4-7)

Operational maintenance or servicing of the Ampex models requires little beyond periodic lubrication and cleaning. All surfaces of the capstan shaft, head faces and tape guides should be cleaned daily, applying carbon tetrachloride with a soft, lintless rag. (Be sure all parts are dry before threading tape.)

DRIVE SYSTEMS

Speed variations have been minimized through basic design rather than through requirements for excessive precision. Three motors are used in the drive system, the details of which are described under Example 4 in Chapter 4. In Fig. 4-6 the physical layout of the drive system was shown.

The rewind and take-up motors require no attention. Their torque is factory adjusted by means of resistors *R401* (Rewind), *R402* (Hold-back), and *R403* (Take-up). These controls are shown in Fig. 4-6. Each motor is adjusted for a tension of from 5 to 6 ounces of pull on the reel hub. Maximum hold-back tension, during Fast Forward and Rewind will allow the tape to accelerate rapidly when a fully loaded reel (2,400 ft.) is applied. These adjustments should prove satisfactory until the brake bands wear out. Start, Stop and Record functions are relay-operated, and hence may be remotely controlled.

Reels. The turntables supporting the tape reels are attached directly to the shafts of the Rewind and Take-up motors. A hold-down knob locks the reels in place. This knob is constructed in such a manner that it centers and locks either the standard NAB or RMA reel regardless of thickness.

Identically sized reels must always be used on both turntables in order to maintain even hold-back tension. The smaller RMA (7-inch) reels cause abnormal hold-back tension near the end of a reel due to the smaller hub diameter. As a result slippage at the capstan idler is likely to occur, although cleaning the capstan idler weekly with ethyl alcohol may help somewhat. If the small-type reels are to be used exclusively, an additional 150-ohm, 50-watt resistor should be inserted in series with each of the resistors *R401* and *R403* (Fig. 4-6).

Capstan Idler. The mechanism of the capstan idler is operated by a solenoid (*E* in Fig. 4-6) and is returned by a spring (*A*). Capstan idler pressure is adjusted at point *F* so that it will barely deform the tape if the tape transport is stopped by hand while the machine is running.

Capstan Flywheel. When the machine is turned On after the tape is properly threaded, drive solenoid *C* (Fig. 4-6) engages the capstan drive motor *B-490* with the capstan flywheel tire, causing it to rotate. Pressure between the drive motor and flywheel tire, adjustable at spring *D*, may be varied slightly until a normally synchronous (60-cycle) speed is obtained. This speed may be checked by applying a stroboscope over the capstan shaft. When the spokes of the stroboscope appear to stand still, the speed is correct.

Brakes. Solenoid-operated mechanical brakes are employed and provide quick, smooth stops regardless of the speed of tape transport. The brake bands may be adjusted by the tension-adjustment nuts at point *H* (Fig. 4-6). The machine can be shifted back and forth from one mode of operation to another with but one exception: in changing from Fast Forward Winding or Take-up to Normal Play the machine automatically stops to avoid tape breakage.

When brake bands become glazed after extended service a tightening action occurs. Graphite should be applied to the brake bands to minimize this action. A mixture of one level tablespoon of graphite to eight ounces of carbon-tetrachloride can be applied to the felts of the brake bands with an oil can. Following this, the motors should be

run for 10 minutes with the brakes On to wear in the graphite. The correct tension measured on the NAB reel hub should be 14 oz. for both the unwinding and energizing directions.

LUBRICATION

In some Ampex models, the synchronous capstan-drive motor is provided with sleeve bearings; in this case SAE No. 30 oil is required every three months. If the motor has a sealed ball-bearing no lubrication is required. The upper bearing on the capstan shaft is a precision bronze sleeve bearing requiring SAE No. 30 motor oil every six months. To oil this upper capstan-shaft bearing, loosen the set screw in the dust cap around the capstan shaft, just below the tape-contact point. Push the idler wheel away from the shaft so that the cap can be removed. Remove the felt washer covering the oil hole and apply oil through the larger of two holes beneath the washer. In general, one drop of oil should be applied to all bearing surfaces every six months. Great care must be taken to make sure that no oil is allowed to contact rubber surfaces, such as the capstan idler or the flywheel.

To reach the upper bearing in the Ampex Console Model, use a pump-type can with a flexible spout, or attach a piece of spaghetti to the end of the spout. For lubrication of the portable models it is necessary to unbolt the top plate and tip it up by raising the right-hand corner, while facing the front of the machine. Grasp the hold-down knob on the take-up motor spindle as a means for lifting the top plate. A few inches of clearance will expose the bearing for lubrication.

HEAD ALIGNMENT

The physical alignment of the record and playback heads is accomplished by placing a 1/2-inch spintite socket wrench on the left-hand elastic stop nut in each head. This permits forward or backward adjustment for proper azimuth angle. To make the azimuth adjustment, play back a standard 15,000-cps tape and adjust the playback head back and forth until the proper azimuth is indicated by maximum output. Next, the record head is aligned with the playback head by recording 15,000 cps on a blank tape and adjusting the record head for maximum playback output. The triple head assembly is a plug-in unit, and hence readily replaceable.

HEAD MAGNETIZATION

Magnetic heads often become magnetized through electrical faults or contact with magnetized objects. Magnetization will also occur when a sufficiently high signal saturates the recording amplifier or excessive pulses cause an unbalanced current in the head windings. The operator should not depress the Record button until the Start button has been depressed. In this way the transient caused by switching circuits is allowed to die out before the record head is connected. As the heads become magnetized the noise level of the finished record rises. Demagnetization methods have been discussed in the previous example.

APPENDIX

Tape Machine Performance Data

Two convenient reference tables are reproduced here from *Audio Record*, a magazine published by Audio Devices, Inc., New York City. These tables quickly acquaint the reader with comparative reference data on tapes and tape recorders. A complete cross-section of contemporary tape recording equipment with relevant performance data appears in Table A-I. Table A-II lists the recording time to be expected for various tape speeds and reel sizes. Recording times are given for single and dual track machines, operated at standard speeds of tape transport.

TABLE A-I
Cross Section of Present Market

Manufacturer	Model and Price	Frequency Response	Type of Machine
Ampex Electric Corporation	Portable Model 400	50-15,000 cycles (\pm 2 db) at 15 ips. 70-10,000 cycles (\pm 2 db) at 7½ ips.	Portable, dual-track recorder. Either half- or full-track.
	Console Model 300C	50-15,000 cycles (\pm 2 db) at 15 ips.	Professional-type single-track recorder. Custom-built instrumentation machines available with response to 100 kc.
	"Twin-Trax Mag-nemuse" Model 810B (7½ ips)	50-9,000 cycles (\pm 3 db) at 7½ ips.	Portable, dual-track recorder.
Amplifier Corporation of America	Model 810C (15 ips)	30-13,000 cycles (\pm 2 db) at 15 ips.	
	"Magnemaster Consolette" Model 815	50-15,000 cycles at 15 ips. 50-10,000 cycles, at 7½ ips.	Single- or dual-track recorder.

Table A-I Cont'd

Ampro Corporation	"Ampro-Tape" Model 731	100-7,000 cycles at $3\frac{3}{4}$ ips.	Portable, dual-track recorder.
Bell Sound Systems, Inc.	"Re-Cord-O-Fone" Model RT-65-B	70-8,000 cycles (\pm 3 db) at $7\frac{1}{2}$ ips.	Portable, dual-track recorder.
Berlant Associates	"Concertone" Model 1401	40-15,000 cycles (\pm 2 db) at 15 ips. 40-7,500 cycles (\pm 2 db) at $7\frac{1}{2}$ ips.	Professional-type, single- or dual-track recorder.
	"Soundmirror" Model BK-443P	To 7,000 cycles at $7\frac{1}{2}$ ips.	Portable, single-track unit.
The Brush Development Co.	Model BK-443PS	To 4,000 cycles at $3\frac{3}{4}$ ips.	
	"Soundmirror" Model BK-442	To 7,000 cycles, at $7\frac{1}{2}$ ips.	Table model, single-track unit.
Califone Corporation	"Dynacord" Portable Model C3-C3A	50-15,000 cycles (\pm 2 db) at 15 ips. 50-7,500 cycles (\pm 2 db) at $7\frac{1}{2}$ ips.	Portable, single-track, dual-speed recorder.
Crestwood Recorder Corp.	"Magictape" Model CP-201F	50-8,000 cycles, at $7\frac{1}{2}$ ips.	Portable, dual-track recorder.
Eicor Inc.	Portable Model 115	80-7,500 cycles at $7\frac{1}{2}$ ips.	Portable, dual-track recorder.
The General Industries Co.	Tape-Disc Recorder Assembly Model 250	(Depends on amplifier used.)	Combined disc and tape recorder assembly.
Fairchild Recording Equipment Corp.	Console Model Unit 125	50-15,000 cycles (\pm 1 db) at 15 ips.	Professional-type, single-track recorder.

Table A-I Cont'd

Fairchild Recording Equipment Corp.	Console Model "PIC-SYNC"	50-15,000 cycles (\pm 1 db) at 15 ips.	Same as model 125 with the addition of lip synchronous operation. Used with motion picture camera and film projector.
Magnetic Recording Industries	Model VM-56	To 9,000 cycles (2, 3.75, 7.5 or 15 ips).	Portable, single-track recorders.
Mark Simpson Mfg. Co. Inc.	"Masco" Model LD-37	80-8,400 cycles (\pm 3 db) at 7½ ips.	Portable, dual-track, dual-speed recorders.
Operadio Mfg. Co.	"Du-Kane" Portable	50-8,000 cycles at 7½ ips.	Portable, dual-track recorder.
Magnecord Inc.	Model PT6-J Amplifier	50-15,000 cycles (\pm 2 db) at 15 ips.	Portable, single-track recorder.
	Model PT6-A Recorder		
	Model PT63-A Recorder	50-15,000 cycles (\pm 2 db) at 15 ips.	Professional.
	Model PT63-J Amplifier		
	Model PT7-P Amplifier	50-15,000 cycles (\pm 2 db) at 15 ips.	Professional.
	Model PT7-A Recorder		
	Console Model PT7-CC	50-15,000 cycles (\pm 2 db) at 15 ips.	Complete console combination including PT7 recorder (as above) and PT7-C line-level amplifier
Macon Electronics	"Musictape" Portable	50-7,000 cycles, at 3¾ ips.	Portable combination tape and disc recorder.

Table A-I Cont'd

The Pentron Corp.	Portable Model 9T3-C	50-8,000 cycles, at 7½ ips.	Portable, dual- track, dual-speed unit.
Permoflux Corporation	Permoflux Scribe Dictating Unit	Voice only	Compact magnetic tape recorder de- signed for office dictation service.
	Permoflux Scribe Transcribing Unit		
	RC-7 Transport Mechanism	To 15,000 cycles, at 15 ips.	Professional.
Presto Recording Corporation	A-920 Amplifier		
	Model RC-10-14	To 15,000 cycles, at 15 ips.	Professional.
	Model RC-10-24		
	Console Model SR-950	50-15,000 cycles (\pm 1 db) at 15 ips.	Professional-type, single-channel recorder.
Rangertone Inc.	Portable Model R-5P (less pre-amp)	45-15,000 cycles (\pm 2 db) at 15 ips. 50-8,000 cycles (\pm 2 db) at 7½ ips.	Professional-type, single-track, dual- speed recorders.
	Console Model R-5C (less MP syn- chronizer)	45-15,000 cycles (\pm 2 db) at 15 ips.	Professional.
RCA Broadcast Equipment Section	Cabinet Rack Model RT-11A	50-15,000 cycles (\pm 2 db) at 15 ips.	Single-track, dual- speed professional- type recorder, available in cabinet rack or console mounting.
	Console Model RT-12A		
Revere Camera Co.	Model T-100 1 hour play	To 7,500 cycles (\pm 3 db) at 3¼ ips.	Portable, dual- track recorder.

Table A-I Cont'd

Sonar Radio Corporation	Model PTM transport mechanism	30-10,000 cycles (\pm 2 $\frac{3}{4}$ db) at 7 $\frac{1}{2}$ ips.	Portable, single-channel recorder.
	Model RPA-1 amplifier	100-5,500 cycles (\pm 2 db) at 7 $\frac{1}{2}$ or 15 ips.	Portable, single-track recorder.
The Stancil-Hoffman Corp.	"Minitape" Model M5A	100-4,000 cycles (\pm 2 db) at 3 $\frac{3}{4}$ ips.	Professional.
	Model R4	50-15,000 cycles (\pm 1 db) at 15 ips.	Synchronous magnetic film equipment for motion picture and TV sound recording.
	Model S5 Synchronous Magnetic Film Recorder and Reproducer	45-7,500 cycles (\pm 2 db) 16 mm. 45-15,000 cycles (\pm 2 db) 17 $\frac{1}{2}$ mm.	Provides up to 15 simultaneous recording channels on 0.7" wide tape.
	Model CRM-15 Multi-Channel Communications Recorder.	200-7,500 cycles (\pm 3 db) at 7 $\frac{1}{2}$ ips.	Portable, dual-track recorder.
Universal Electronics Sales Corp.	"Reelest" Model C-1-A	70-8,000 cycles (\pm 3 db) at 7 $\frac{1}{2}$ ips.	Portable, dual-track recorder.
Webster Chicago Corporation	Web-Cor Portable Model 210	70-7,500 cycles at 7 $\frac{1}{2}$ ips.	Portable, dual-track recorders.
	Model 111	60-7,000 cycles at 7 $\frac{1}{2}$ ips.	
Webster Electric Co.	"Ekotape" Portable Model 101-8	40-8,000 cycles, at 7 $\frac{1}{2}$ ips.	Portable, dual-track unit giving 2 hours recording on 5" reel. Includes phonograph turntable and pick-up for recording from disc to tape.
	Model 101-9		
Wilcox-Gay Corporation	"Recordio" Model 1B10	85-6,000 cycles at 1.875 ips.	

TABLE A-II

Recording Time

For Various Tape Speeds and Reel Sizes

Reel Size		3"	4"	5"	7"	10½"	14"
Length in Feet		150	300	600	1200	2400- 2500	4800- 5000
Recording Speed		Total Recording Time					
1⅞ ips.	Single Track	16 min.	32 min.	1 hr. 4 min.	2 hr. 8 min.	4 hr. 26 min.	8 hr. 52 min.
	Dual Track	32 min.	1 hr. 4 min.	2 hr. 8 min.	4 hr. 16 min.	8 hr. 52 min.	17 hr. 44 min.
3¾ ips.	Single Track	8 min.	16 min.	32 min.	1 hr. 6 min.	2 hr. 13 min.	4 hr. 26 min.
	Dual Track	16 min.	32 min.	1 hr. 4 min.	2 hr. 12 min.	4 hr. 26 min.	8 hr. 52 min.
7½ ips.	Single Track	4 min.	8 min.	16 min.	32 min.	1 hr. 6½ min.	2 hr. 13 min.
	Dual Track	8 min.	16 min.	32 min.	1 hr. 6 min.	2 hr. 13 min.	4 hr. 26 min.
15 ips.	Single Track	2 min.	4 min.	8 min.	16 min.	33 1/3 min.	1 hr. 6½ min.
	Dual Track	4 min.	8 min.	16 min.	32 min.	1 hr. 6½ min.	2 hr. 13 min.
30 ips.	Single Track	1 min.	2 min.	4 min.	8 min.	16½ min.	33 1/3 min.
	Dual Track	2 min.	4 min.	8 min.	16 min.	33 1/3 min.	1 hr. 6½ min.

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