The Magnetophon

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

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

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

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

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

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

The Tapes

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

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

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

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

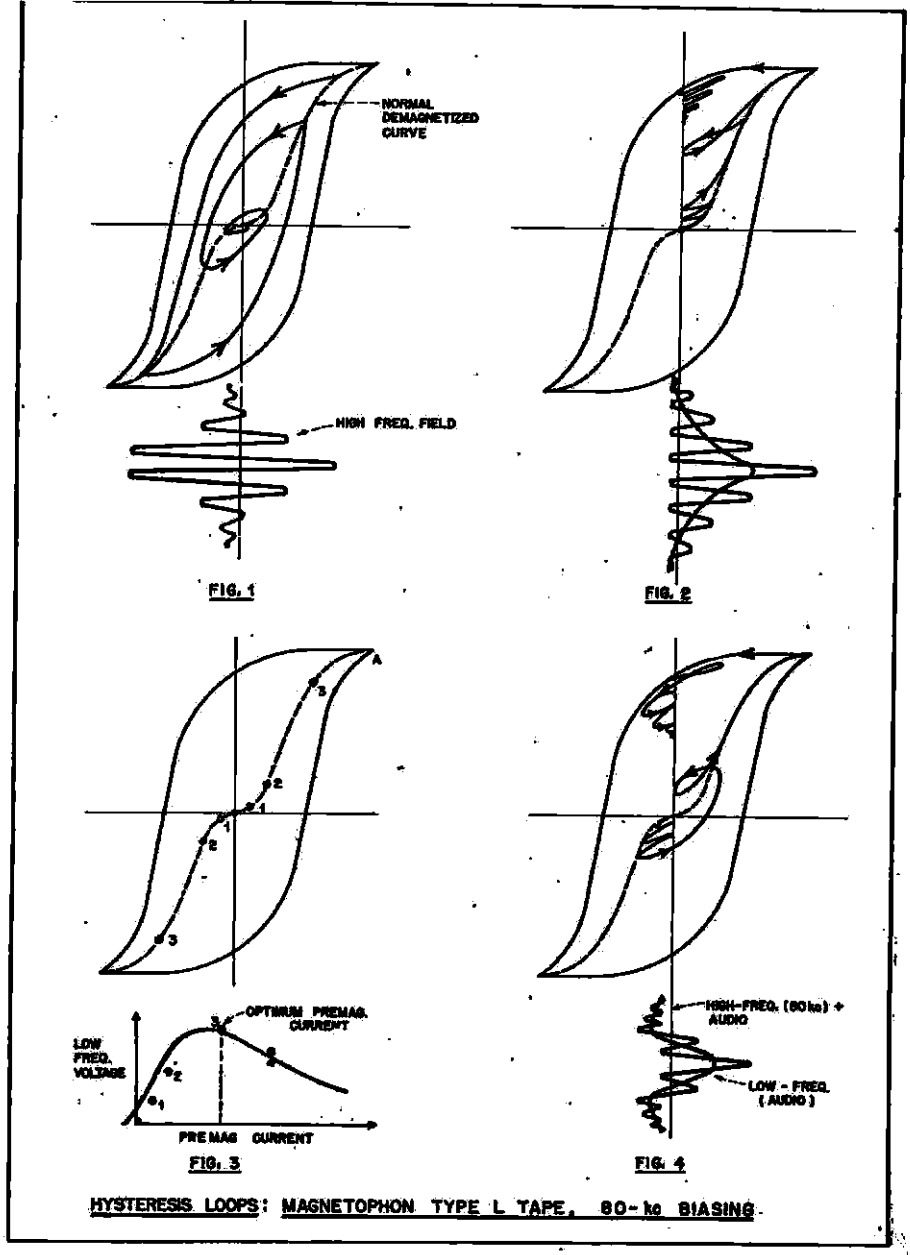
The erasing head has a gap of 0.5 mm, an inductance of 1.7 mh. The erasing current is about 40 kc at 160 ma. The recording head has a gap of 40 microns, and a gap of 0.3 mm in the rear. Inductance is 8 mh, and the recording current (bias current) about 80 kc at 10 ma. The reproduction head has a gap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

In practice, wearing of the tape-bearing

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[1] "The Blattnerphone."

[2] Dept. of Commerce report No. PB-1346.



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

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

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

High-Frequency Bias

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

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

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

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

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

Recording Field

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

magnetization is concerned, *Fig. 4*. In practice this is counteracted by pre-emphasis in the recording and reproducing amplifiers.

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

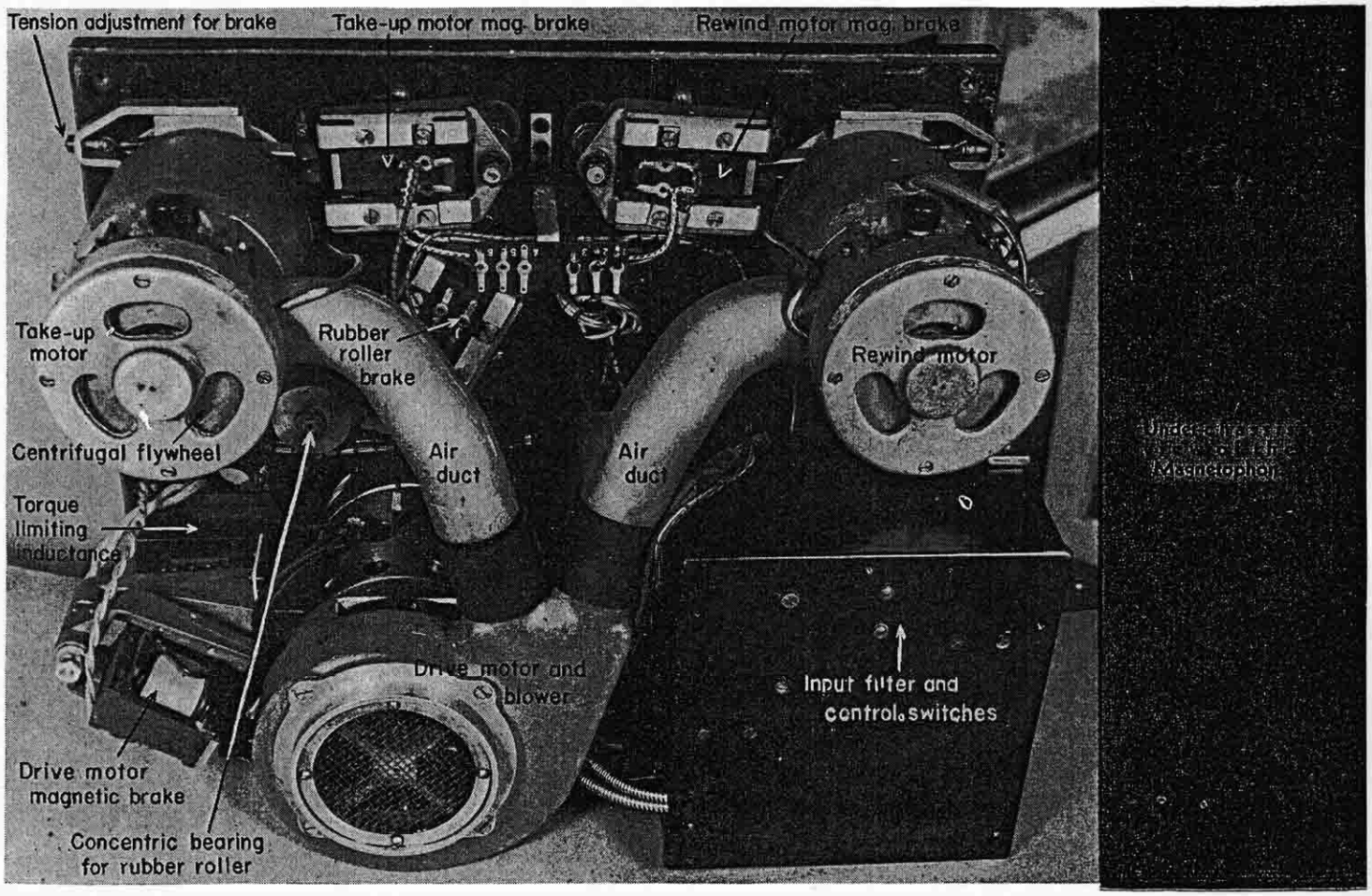
As previously stated, the tape runs past the three heads at 77 cm/sec. The first head—erasing—and the second—recording—are fed from an amplifier, shown in *Fig. 5*. This amplifier produces the 40-kc erasing current, the 80-kc biasing (premagnetizing) current, and has a single-stage amplifier, with high-frequency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

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

Reproduction Amplifier

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

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



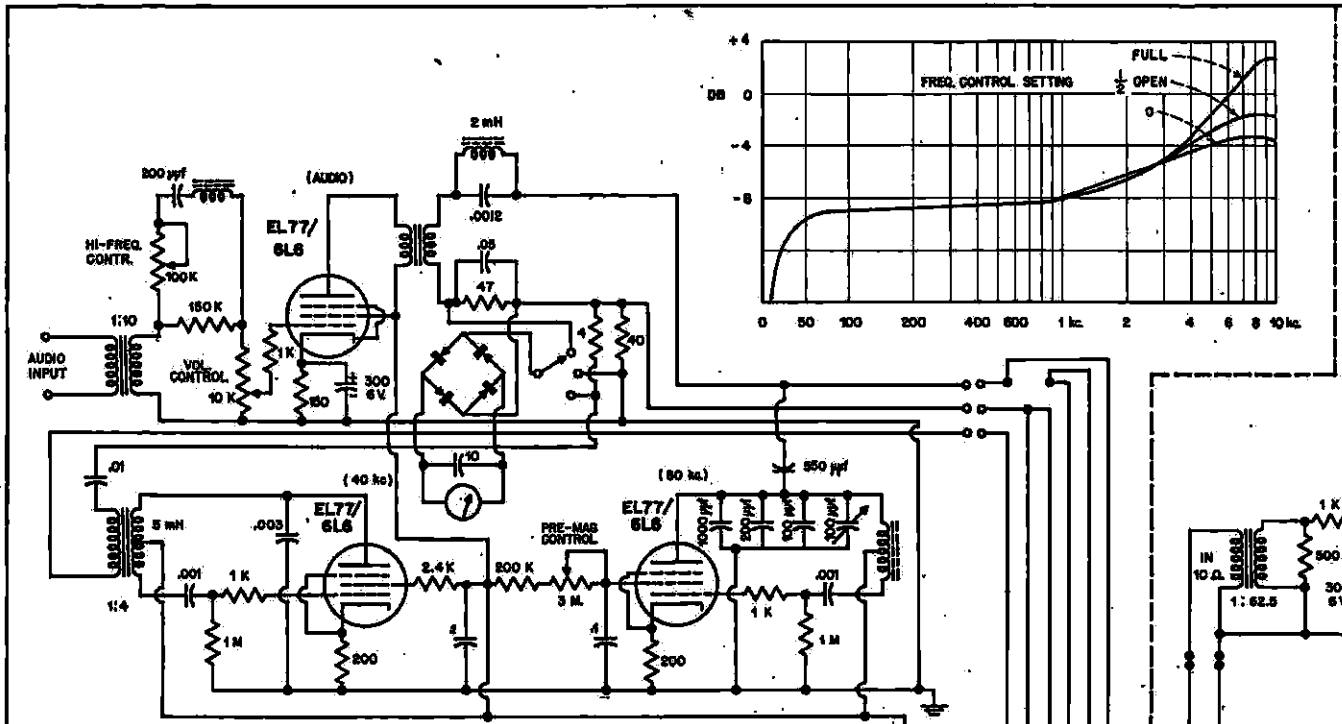


FIG. 5.– RECORD AMP (AUDIO, 40 KC. & 80 KC. OSC.)

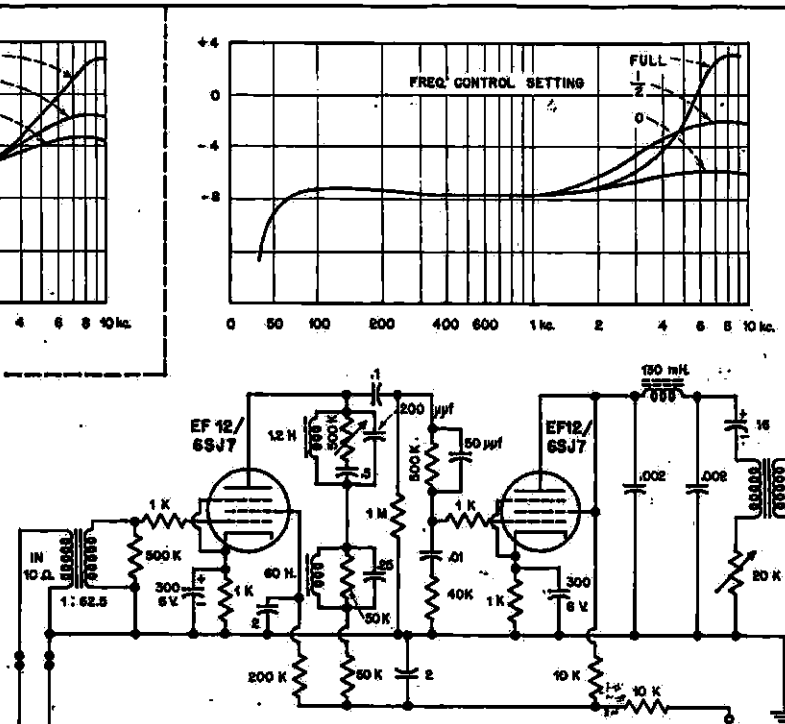


FIG. 6 – REPRODUCTION AMP.

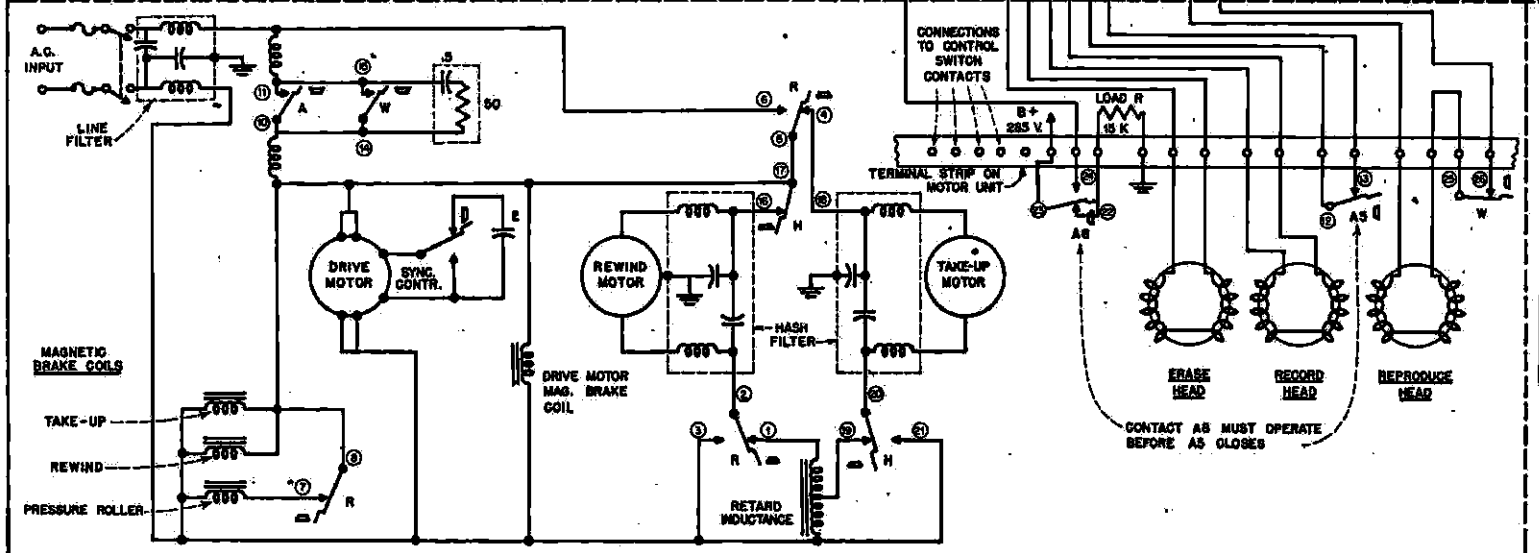
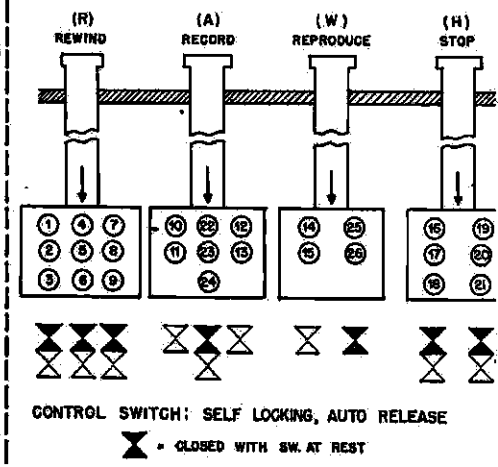
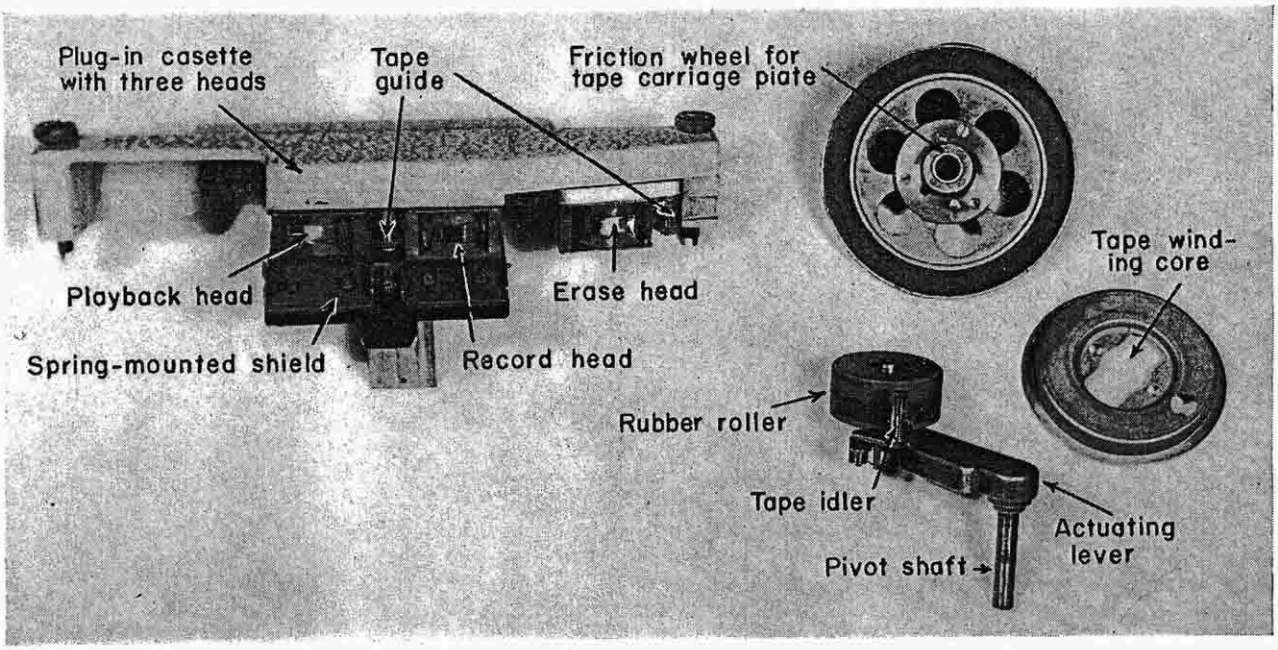


FIG. 7 – MOTOR CONNECTIONS



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A few of the components used in the Magnetophon.

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

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

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

The average tape, of 5/8ths mile in length, runs for about 20 minutes, and takes about 3 minutes to rewind. Since two machines are necessary for continuous playing, each machine is fitted with a synchronizing control so that the program on the machine about to be switched into the audio circuit can be matched with that of the one playing. This control is on the drive motor, and serves to short the series condenser with which this motor is fitted. In practise, the tapes are recorded with a "lapped"

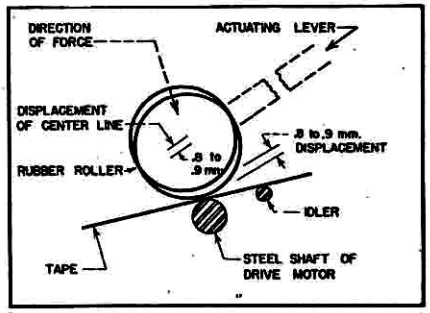


Fig. 8. Detail of tape drive mechanism.

recording, so that the end of one and beginning of the other are the same. The second machine is started ahead of time and then slowed down until the two are in sync, and at the proper moment the change-over takes place—without any indication to the ear whatsoever. The control switches—push-button locking type—have been labeled on the schematic, and their function can be easily followed.

Electrical Troubles

The following electrical troubles sometimes occur:

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

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

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

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

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

Various Models

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

[*Continued on page 35*]

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

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

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[*From page 11*]

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

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

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