MAGNETIC TAPE RECORDING

By

CARL E. WINTER

Resumé of the development of magnetic tape recording and a description of a modern recorder of this type.

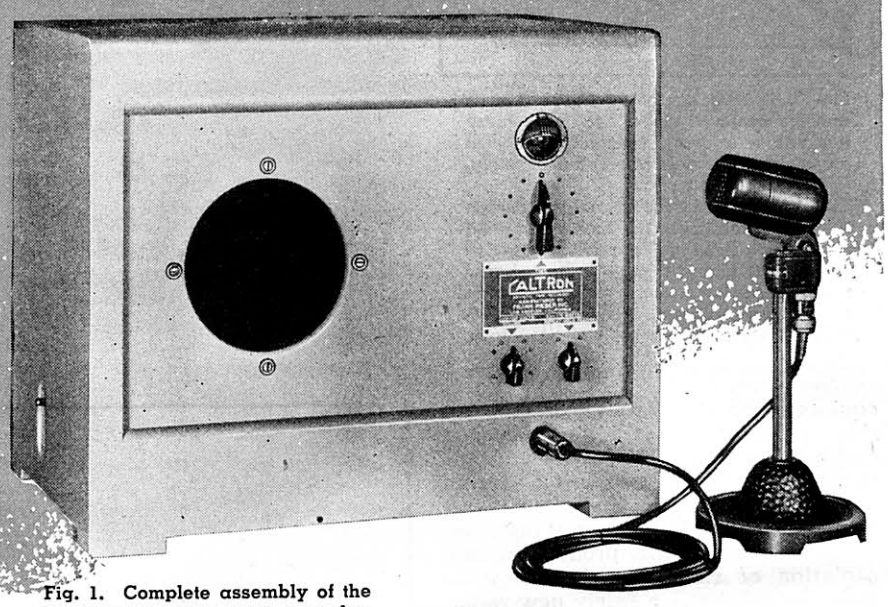


Fig. 1. Complete assembly of the Caltron magnetic tape recorder.

ALMOST a half century ago Victor Poulsen, well known in his day as a conscientious investigator of electronic phenomena, developed a method of magnetically recording speech upon steel wire. But it was not until scientific advances overcame some of the limiting factors encountered by Poulsen and his associates, that magnetic recording was able to take its proper place among the electronic equipment which is doing so much to speed the war's end.

The principle upon which Poulsen founded his "telegraphone" remains the basic principle used today in the several types of magnetic recorders. Essentially, his method was to draw a steel wire rapidly past a pair of pole-pieces surrounded by coils carrying the electrical components of audio speech impulses. Variations in these speech currents would impress a corresponding magnetic pattern upon the wire, and when the wire bearing this magnetic pattern was again drawn past the pole-pieces, a current, corresponding to the variations in the original speech current, would be reinduced in the coils surrounding the pole-pieces, and utilized for audio reproduction.

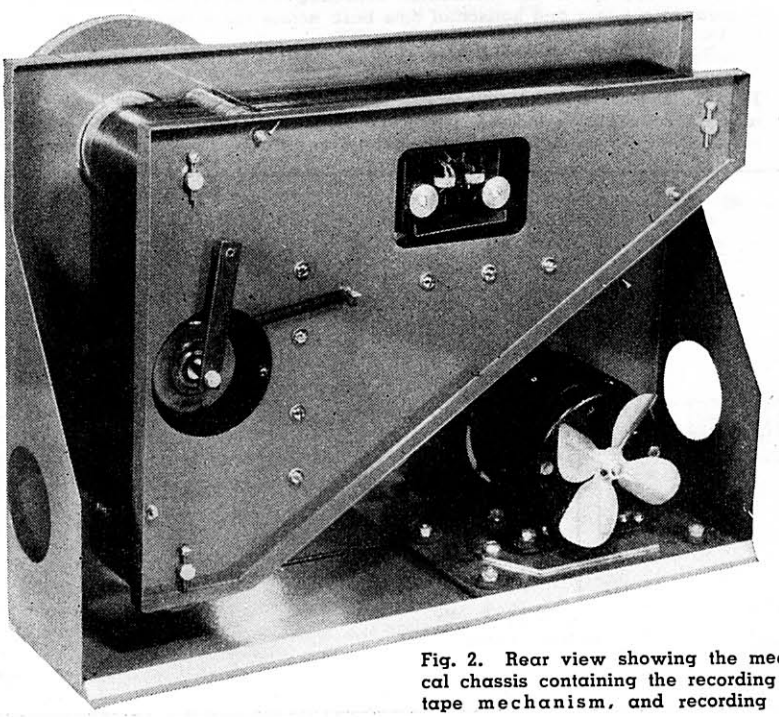


Fig. 2. Rear view showing the mechanical chassis containing the recording tape, tape mechanism, and recording head.

Recording Mediums

Steel wire was usually used as a recording medium in the earlier types of magnetic recorders. During its travel past the pole-pieces, the steel wire would tend to rotate about its axis, thus constantly altering the relationship of the wire's magnetic pattern to the recording and reproducing pole-piece faces. To minimize distortion occasioned by this effect, the recording and reproducing pole-pieces were placed rather far apart. This however, then made it necessary to draw the recording medium past the pole-pieces at a very high rate of speed in order to record and reproduce the higher audio frequencies which do not exert too definite current variations upon the coils surrounding the pole-pieces. Thus, excessive speed of the recording medium's movement became of primary importance.

In Poulsen's time this fact presented mechanical difficulties which were hard to overcome. The steel wire traveling past the pole-pieces at high speed soon wore the pole-piece faces away. Also, it was almost impossible to construct pole-pieces so that they

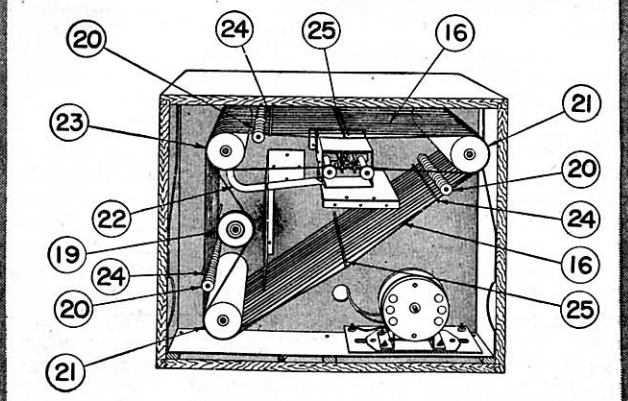


Fig. 3.

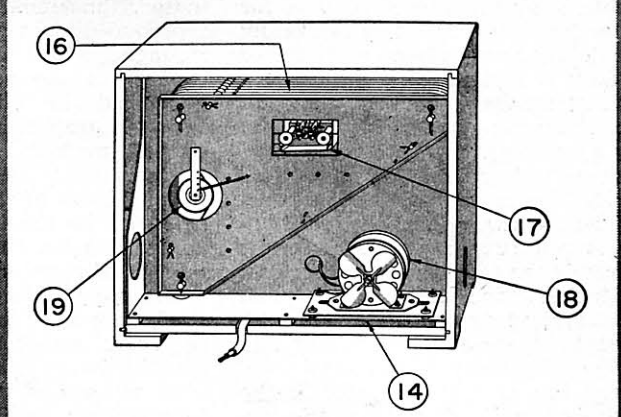


Fig. 4.

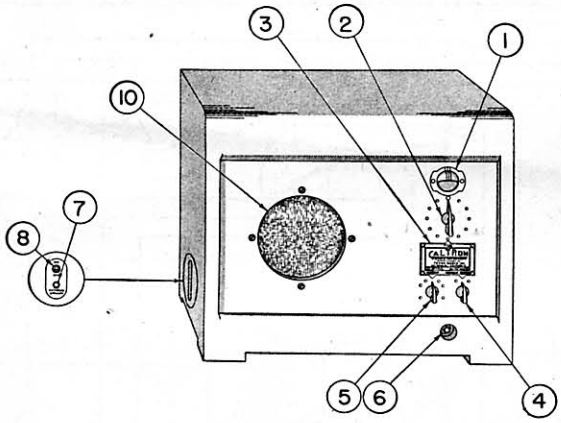


Fig. 5.

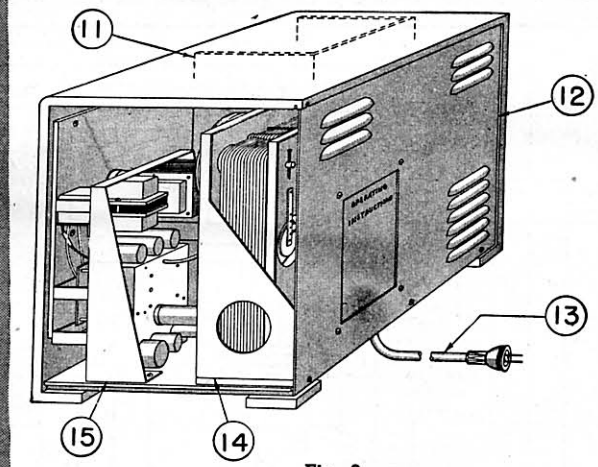


Fig. 6.

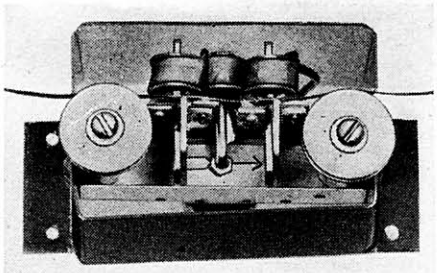
Various views of the Caltron magnetic tape recorder, showing position of all controls and component parts. Coded parts are, 1, "magic eye" indicator tube; 2, elapsed-time indicator; 3, nameplate; 4, selector switch; 5, power switch and volume control; 6, microphone jack; 7, remote-speaker phone-jack; 8, unit speaker "on-off" switch; 9, serial number plate; 10, loud-speaker; 11, speaker box; 12, back plate; 13, power input cable; 14, mechanical chassis; 15, amplifier; 16, recording tape; 17, recorder pole and housing; 18, tape drive motor assembly; 19, tape idler pulley; 20, tape spacer assembly; 21, idler drum assembly; 22, tape lubricating system; 23, tape drive drum assembly; 24, rod-guides; and 25, wire separators.

would ride securely against, and smoothly along, the wire. The tendency of the wire to rotate about its axis increased the difficulty of maintaining good contact and good contact was important for irregularities caused the magnetic reluctance of the wire's flux path to change so that the strength of the recorded signal varied and an excessive amount of noise was introduced.

In 1900 Poulsen secured a patent on the use of steel tape as a recording medium. The use of tape instead of wire eliminated many of the troublesome features of magnetic recording systems. Tape permitted the use of smaller guide pulleys than was advisable with steel wire, thus enabling over-all dimensions of recorder cases to be smaller without cramping, and without exceeding the bending fatigue limits of the recording medium itself.

Steel tape eliminated the snarling difficulties encountered with wire, and prevented the effects of the wire's tendency to rotate about its axis. Therefore, the most important advantage gained through the use of tape instead of wire as a recording medium, was that the magnetic patterns imposed upon the tape during the recording process would occupy the same position relative to the pole-pieces during reproduction. This one factor made excessive tape speed relatively unimportant and put magnetic recording well within the scope of sound mechanical design.

Fig. 7. Recording head showing magnetic steel tape passing through pole-piece contacts. The arrow between the pole-pieces shows direction of tape travel.



Advantages of Magnetic Recording

Magnetic tape recording differs from other methods in many respects. Since no processing of the recording medium is required, the record may be reproduced without delay. As the only effects upon the recording medium are

electronic, the tape may be used over and over again for new records. It is only necessary to subject the tape to a strong neutralizing magnetic field to obliterate a record and prepare for another recording, and this is usually conveniently accomplished when a new recording is replacing an old one.

When temporary recordings are desired, magnetic tape recording has many advantages over other methods. It is very convenient for use where short delays in reproduction are desired, as, basically, the entire equipment is self supporting. All that is required is the tape, the recording and reproducing tone head, and audio amplifier, and the mechanical units needed to operate drive motors and other rotating components.

There are no moving parts in the modulating unit of a magnetic recorder. (The modulating unit corresponds to the cutting stylus of a mechanical recording system.) The difficulties of obtaining high-frequency response due to the effect of inertia of the cutting stylus is therefore eliminated, thus making great fidelity of reproduced tones possible.

Magnetic tape recording systems are subject to the same difficulties encountered in eliminating "flutter" which is present in other types of recording methods, but mechanical vibrations due to motor drives and other moving parts of the recording system need not be considered as they have no effect upon this purely electronic method of registering recordings.

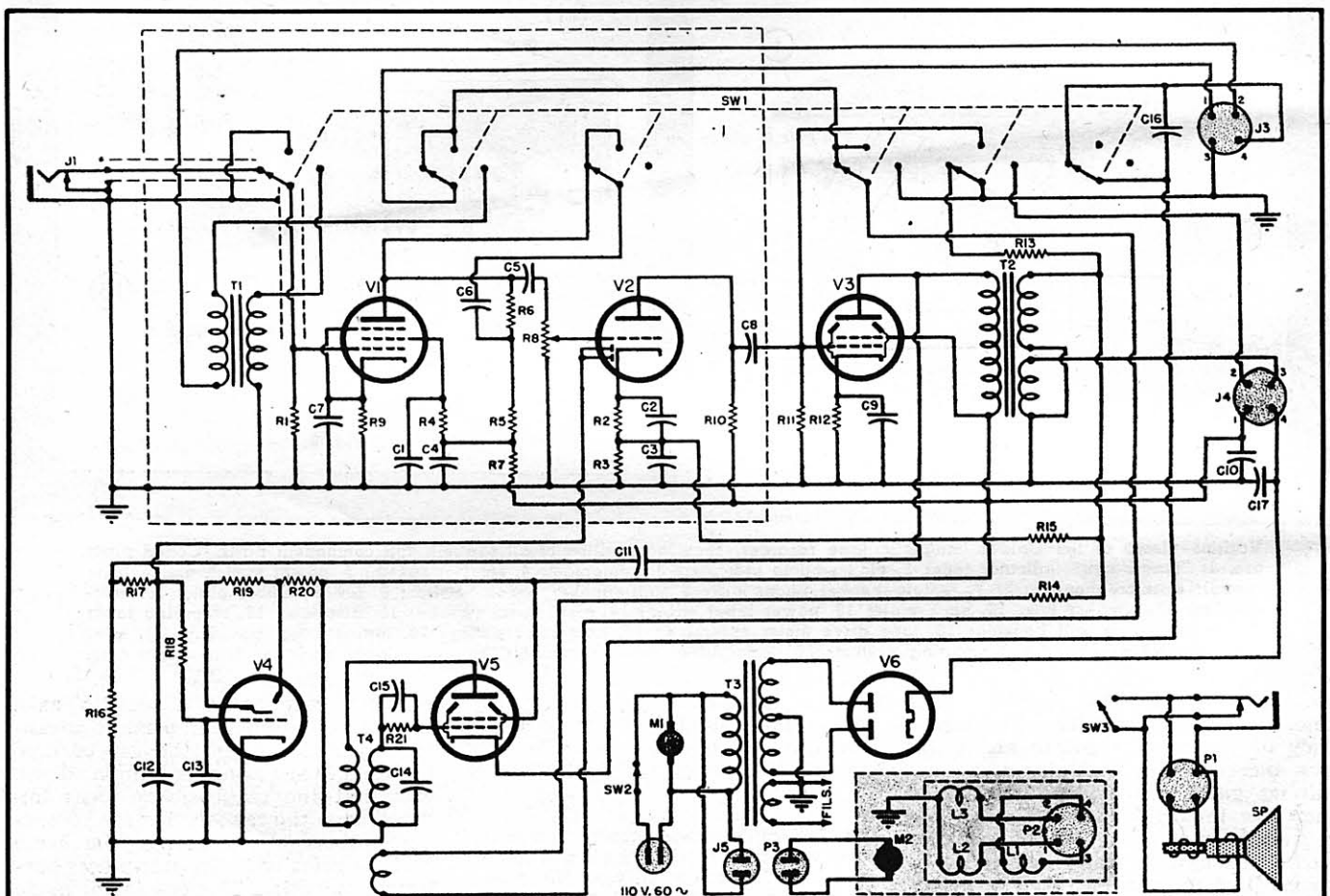
The special alloy, high permeability steel tape used in modern magnetic recorders cannot be easily scratched; may be handled and exposed to any kind of light, and subjected to large temperature variations without decreasing its efficiency or adversely affecting it in any way. When the tape is properly wound and securely fixed in its operating position, it is not liable to damage or breakage during transportation of portable equipment.

The greatest demand for magnetic tape recorders is for use as training devices. In schools and veterans' rehabilitation centers, they record, for immediate analysis, accents, and dialects. Aircraft crews are trained by magnetic recorders to distinguish orders and instructions through the simulated din of gunfire and screaming, and other blasting battle noises. In rehabilitation centers veterans exercise unresponsive vocal cords with this "voice mirror," and many a man in the Armed Forces owes his life to a conditioned reflex action to a specific sound, developed by constant training with these devices.

Throughout this country and at many foreign bases which our Armed

(*Continued on page* 138)

Fig. 8. Complete wiring diagram of the Caltron magnetic tape recorder. This unit is designed to record, reproduce, and erase sound impulses which are applied electronically to a magnetic steel tape.



C_1, C_3—.1-μfd., 400-v. cond.
C_2, C_7—25-μfd., 25-v. elec. cond.
C_4—25-μfd., 250-v. elec. cond.
C_5, C_{12}—.005-μfd. mica cond.
C_6, C_{11}—.01-μfd., 400-v. cond.
C_8, C_{13}—.05-μfd., 400-v. cond.
C_9, C_{10}, C_{17}—3-section elec. cond.
C_{14}—.001-μfd., mica cond.
C_{15}—51-μμfd. mica cond.
C_{16}—8-μfd., 350-v. elec. cond.
R_1, R_{11}—500,000-ohm, ½-w. res.
R_2—2500-ohm, ½-w. res.
R_3—100-ohm, ½-w. res.
R_4, R_{18}, R_{19}—1-meg., ½-w. res.
R_5—50,000-ohm, ½-w. res.
R_6—200,000-ohm, ½-w. res.
R_7—51,000-ohm, ½-w. res.
R_8—500,000-ohm pot.
R_9—1000-ohm, ½-w. res.
R_{10}, R_{16}—100,000-ohm, ½-w. res.
R_{12}, R_{13}—500-ohm, ½-w. res.
R_{14}—1500-ohm, ½-w. res.
R_{15}, R_{20}—3500-ohm, ½-w. res.
R_{17}—150,000-ohm, ½-w. res.
R_{21}—300,000-ohm, 1-w. res.
J_1—Shorting-type microphone jack
J_2—Shorting-type external speaker jack
J_3—4-prong socket (recording head)
J_4—4-prong socket (speaker)
J_5—110-v. receptacle (drive motor)
L_1—Erasure coil
L_2—Voice coil
L_3—Hum-bucking coil
Sp—Loud Speaker
M_1—Motor (timing clock)
M_2—Motor (tape drive)
P_1—Speaker plug
P_2—Tone head plug
P_3—110-v. plug (drive motor)
Sw_1—6.p.3.p. selector switch
Sw_2—S.p.s.t. switch on volume control
Sw_3—S.p.s.t. switch
T_1—Input trans.
T_2—Output trans.
T_3—Power trans.
T_4—Oscillator trans.
V_1—6SJ7 tube
V_2—6SQ7GT tube
V_3, V_5—6V6GT tubes
V_4—6E5 electric-eye tube
V_6—6X5GT rectifier tube

and the entire device simply acts as the front end of a superheterodyne, using the FM receiver as an i.f. amplifier. This unit is provided with its own tuning dial. When connected to a prewar FM receiver, the receiver must be tuned to 42 megacycles and the stations in the new band tuned in on the converter.

In the event that a shift is made in FM frequencies, prewar FM receivers will be able to operate during the shift by switching the converter in or out, depending on whether the desired station is operating at its old frequency or has shifted to its new location.

The present plans of the company do not include the manufacture of these units, the development work having been done merely as an indication that such a unit is possible and could be manufactured in quantity should the frequency shift make the existing 390,000 receivers obsolete.

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Magnetic Recording

(*Continued from page* 34)

Forces occupy, magnetic tape recorders are in constant use for these, and other purposes. In any circumstance where only temporary recordings are required, magnetic tape recording is the best method available from the standpoint of high fidelity, economy of operation, and sturdiness.

Modern Magnetic Recorders

Modern magnetic tape recorders have reached a high degree of perfection in both design and construction for specific applications. The representative recorder shown in Fig. 1, is a portable unit designed to record, reproduce, and erase sound impulses which are applied to its recording medium consisting of a special alloy, magnetic steel tape. This tape is carried in an endless series of intricate loops around idler drums and past the recording and reproducing pole-pieces.

A full minute's recording can be applied to the tape, held intact, or played back. A recording upon the tape will be automatically erased upon beginning a subsequent recording but will be indefinitely retained until the new recording is applied to the tape. No servicing or adjustments between recordings is necessary.

All voltages required to operate the equipment are obtained from a built-in power supply and the equipment is designed to operate from a 110-volt, 60-cycle, single-phase, alternating-current power source.

Operation of the recorder illustrated is exceedingly simple. Four controls are provided; a 6E5 "magic eye" indicator tube is used to indicate the proper recording level at which a signal should be applied to the equipment's microphone in order to make a satisfactory recording. A dual-purpose power switch and volume control is used by the operator to turn the equipment on and off and also to control both recording and playback volume levels, and a three-position selector switch provides for the selection of recording, playback, or stand-by operation.

An elapsed time indicator which serves to indicate the amount of unused recording space available on the recording medium, consists of a revolving pointer index driven by a motor synchronized to the recording tape so that the pointer travels around a circular scale of twelve divisions as the tape passes the recording and reproducing pole-pieces.

A closed-circuit microphone jack enables a high-impedance microphone to be connected to the equipment for recording purposes and a built-in electromagnetic loudspeaker, housed in a box lined with cellular acoustic insulation to minimize resonating effects, is provided to permit recordings to be played back. Provision is made through a closed-circuit phone jack for the connection of an external speaker or earphones. A switch connected across the speaker input lug permits the selection of either the built-in or external speaker.

Principles of Operation

Basic principles of operation of the recorder, shown in Fig. 1, are not very different from those used by Poulsen many years ago, but more specifically, the 6V6 oscillator tube of the recorder's amplifier circuit supplies a 25-kilocycle frequency which is applied through a pole-piece assembly containing two electromagnetic pole-pieces, to the recording medium, a steel tape carried in an endless loop past the pole-pieces. The purpose of this applied frequency is to return the tape to a neutral magnetic condition thus minimizing distortion and keeping the noise level at a low value.

During the recording process, electrical impulses from the equipment's microphone are amplified in the amplifier circuit and applied as an audio-frequency current to the coils surrounding the recording pole-piece. The variations of these audio-frequency electrical impulses cause corresponding variations in the magnetic field of the pole-piece. As the recording tape is subjected to the pole-piece's magnetic influence, these variations establish a magnetic pattern corresponding to the audio-frequency electric impulses in the recording tape. These impulses will be retained by the tape until erased.

A second pole-piece assembly which has a d.c. potential applied to its coil, applies a unidirectional magnetic field to the recording tape as it passes. This field intensity erases the variations of the magnetic pattern in the tape, returning it to the correct condition for subsequent recording. The tape is subjected to this erasing process just before the recording process' impulses are applied to it and this may be considered the normal method of operation during recording.

The erasing process is automatic, and because the tape, being endless, will continue in its revolution past the point at which recording began, it will be seen that if a recording exceeding the limit of the tape's capacity (one full minute) is applied, the beginning of that recording will be erased and replaced with that portion of the recording which exceeds one minute. By observing the position of the elapsed time indicator's pointer, the operator can maintain a constant check on the unused time available during a recording and so prevent overlapping recordings.

During the process of playing back a recording, the variations present in the tape's magnetic pattern induce an audio-frequency current in the reproducing pole-piece as the tape passes by it. This audio frequency is amplified in the amplifier circuit of the recorder and fed through the speaker voice coil for audible reproduction. The action of a hum-bucking coil which is connected in series opposition with the reproducing pole-piece's coil, prevents extraneous a.c. fields from producing a hum in the playback.

When a recording is to be retained but the equipment must be left in operation, the recording and reproducing pole-piece assemblies and the erasing pole-piece assembly can be disconnected from the circuit while the tape continues to travel. The elapsed time indicator will continue to indicate the tape's movement and by observing the pointer's position the correct moment to commence recording or to play back a recording, can be determined.

Reference to the schematic wiring diagram, Fig. 8, will clarify details of the changeover switching arrangements.

Basic Mechanical and Electrical Components

As is true in the case of most electronic equipment, classification of major electrical and mechanical components is quite difficult due to the fact that each must be considered in direct relationship to the other. In the main, however, the major mechanical features of the recorder shown in Fig. 1 are concentrated in the tape recorder chassis. This chassis contains the tape drive motor assembly; lubricating system, recording tape, tape guide assemblies, and the heart of the magnetic tape recorder; the recorder pole and housing. The recorder poles and housing are usually referred to, as in the case of mechanical recorders, as the recording head.

A shaded pole induction motor is connected in parallel with the primary of the amplifier power transformer and the 110-volt power source. This tape drive motor's shaft rotates at a constant speed of approximately 1690 r.p.m. and drives the flywheel of the tape drive drum at a proportionate speed of 268.5 r.p.m. This flywheel thus imparts a speed of 140 feet per minute to the endless, special alloy, high permeability magnetic steel tape

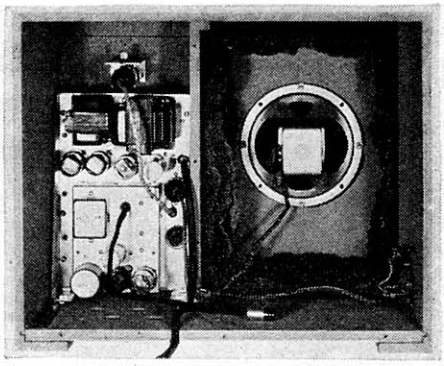


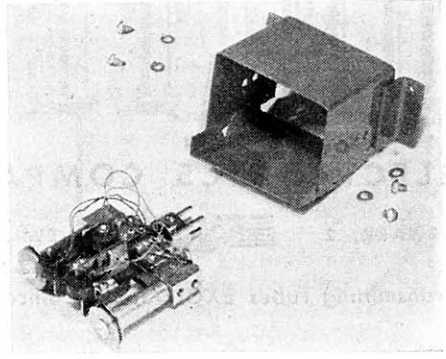
Fig. 9. Interior view of the recorder cabinet. The amplifier chassis is on the left, and the speaker unit and speaker box which is lined with acoustic insulation is on the right-hand side of the cabinet. The mechanical chassis, which houses the recording tape, tape mechanism, and recording head, is not shown.

upon when the recordings are impressed.

This tape, which possesses an extremely high bending fatigue limit, is .002 inch thick, 140.5 feet long, and .046 inch wide. It passes in an endless series of 38 loops around three idler drums, each of which is mounted on two "oiless" bronze bearings. The tape is guided in tracks during its rapid revolutions by three sets of tape spacer assemblies each consisting of 38 brass spacers and 39 phosphor bronze washers and a tape idler pulley is provided to maintain a constant tension on the tape to take up slight variations which would otherwise cause uneven recordings.

The recording tape is constantly lubricated by a system consisting of an oilpan and wick feed tube which oils the surface of the tape drive drum. Oil is applied to the recording tape as it passes around this drum and the oil accumulation is removed by the pole-pieces in the recording head assembly as the tape brushes past them. This surplus oil then drips into the oilpan and drains through the wick feed tube to be again reapplied to the drum and tape. This method of lub-

Fig. 10. Recording head removed from its housing. The guide washers which maintain the tape in its proper path through the pole-piece contacts can be seen clearly at the ends of the tubular spacer supports. The two coils in juxtaposition to these guide washers are the coils for the recording-reproducing pole-piece and the erasing pole-piece respectively.



rication serves to adequately lubricate the tape over long periods of time.

Recording Head

The recording head assembly contains the recording and reproducing pole-pieces and the erasing pole-piece. It is in this assembly that electric impulses received from the amplifier are converted into magnetic impulses and are impressed upon the tape during recording, and during playback, the tape's magnetic impulses are converted into electrical impulses. The erasing pole-piece erases the variations of the magnetic field in the tape, thus returning it to the correct condition for subsequent recording.

Each of these assemblies' pole-pieces consist of two sections. The upper section of the erasing pole-piece is constructed of 1/16-inch thick special high-permeability iron, and the lower section is of .005-inch thick brass. The upper and lower sections of the recording and reproducing pole-pieces are of laminar construction, .003 inch silicon steel against .050 brass. Each pole-piece bears a coil which, when current is applied to it, induces a magnetic field in its pole-piece.

A hum-bucking coil is connected in series with the recording head voice coils to counteract the effects of extraneous magnetic fields in the voice coils. This hum-bucking coil's magnetic field opposes that of the voice coils' and cancels out all undesired variations in the magnetic field intensity in and around the voice coils. In this manner the effects of outside interference are eliminated.

Amplifier Unit

The record's amplifier is a conventional resistance-coupled amplifier employing three stages of audio amplification. Its function is to supply power for recording operation and to raise the volume of a reproduced recording to convenient audio level.

The amplifier utilizes a 6SJ7 vacuum tube as the first stage of voltage amplification and a 6SQ7 as the second stage. As the 6SQ7 is a multiple purpose tube, its diode section rectifies the output voltage applied to the 6E5 tube which serves as the "magic eye" indicator tube. The power amplifier stage uses a 6V6 vacuum tube and another 6V6 tube serves as the oscillator supplying the frequency of 25 kilocycles which is applied to the magnetic coils of the recording head to maintain a field intensity in the recording tape sufficient to counteract distortion and reduce the noise level. A 6X5 tube is used as a rectifier in the amplifier's power supply.

The loudspeaker used in conjunction with this equipment has a field coil resistance of 2,500 ohms and its voice coil's impedance is 4 ohms. Either a high-impedance, matched-output, dynamic-type microphone or a high-impedance crystal microphone may be used.

While many refinements were added to the magnetic tape recorder discussed in this article, and many obstacles had to be overcome in the design and specification limitations of this equipment, the basic principles utilized are those developed by Poulsen during the early days of the twentieth century. It is a safe surmise that magnetic recording is even now a long way from its ultimate development and its applications are still mainly unexplored. But just as magnetic tape recording is still in the experimental stages of its evolution, just so is all recording still in its infancy, and who is to say that some day the spoken word, in the form of recordings, may not ultimately replace the written word for the transmission of ideas?

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For the Record
(*Continued from page* 8)

are all being prepared, fully aware of restrictions set forth by the Army and Navy Security Boards, and even though lacking in certain technical discussions future articles will present highly authentic facts and will reveal other information which will enable the reader to gain considerable knowledge of the subject matter.

As far as security permits, we will endeavor to show how radar will be used by the postwar amateur and experimeter for his host of intriguing experiments and practical uses.

Our London representative is also gathering material from British sources and the English version will also be included in later issues. Throughout the present war there has been a very close liaison between the American and British military in the development of radar devices. Our tremendous military success has been due in great measure to the finesse of radar and Radiolocator systems.

Our readers will recall that there was a sudden reduction in the number of ships sunk by Axis submarines. While we cannot reveal the effective range of radar equipment used to combat enemy submarines, we do know that the use of radar has been highly successful. In fact, in the original RADIO NEWS story, August 1941, Page 40, is a statement by the author, "In fact, speaking about its use at sea, *Radiolocators may be the answer to the submarine menace!!*" Just what has happened since that prediction was made is now history. The answer can be found on the bottom of the Atlantic and Pacific Oceans.

MANY of our readers have written asking us to resume the International Short-Wave column. If the letters continue to come in at their present rate, we will again present information of specific interest to short-wave listeners. It is our policy to give our readers what they most desire. Therefore, we invite all those who are interested to drop us a postcard...O.R.