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Ampex Electric Corporation

Precision Magnetic Tape Recorder for High-fidelity Professional Use

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Compact professional tape recorder developed to provide performance and reliability equal to that of the more costly full-frequency-range broadcast-type master model.

Precision magnetic tape recorder for high-fidelity professional use

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WITH the development of magnetic recording the necessity arose for devising equipment which would realize fully the capabilities of this basic system. Early in 1947 it was decided to develop a magnetic tape recorder with performance capabilities beyond any equipment in existence. Major development target was the attainment of recordings with reliability and continuity of performance satisfying the most rigid professional standards. By 1948 a recorder was developed and produced with these capabilities:

1. Full coverage of the audible spectrum (±1 db from 30 to 15,000 cps).
2. Low distortion. From input to output terminals the system shows 4 per cent intermodulation distortion at peak meter reading—with harmonic distortion not exceeding 5 per cent 10 db above peak meter reading.
3. Great dynamic range. The overall unweighted noise level of the system (measured flat from 30 to 15,000 cps) 60 db below full modulation, or 5 per cent harmonic distortion.

Significance of these statements is that reproduction of sound on such a system is, for all practical purposes, substantially perfect.

After many months of daily operation this original design (Model 200) proved itself an ideal instrument for recording network shows, masters, and other program material where no deterioration in original quality can be tolerated. The many advantages of magnetic recording—simplicity of operation, ability to edit, reuse of the medium—were here combined with a faithfulness of reproduction heretofore never achieved in practical day-to-day operations.

Following a steadily increasing demand for this broadcast-type recorder, it was decided to equal the high quality performance of Model 200 in a more compact professional-type instrument and at minimum cost, without sacrificing operational convenience and reliability. This has been attained by development of many new design principles and production techniques.

The new Model 300 recorder comprises two basic elements: (1) the "top-plate" assembly, which mounts the tape transport mechanism and head housing, and (2) the electronic assembly, consisting of the power supply, record and playback amplifiers and bias and erase oscillator. These assemblies have been designed to allow maximum flexibility with respect to housing or mounting requirements.

Primarily designed for standard relay rack mounting, these assemblies have become most popular when combined into a console model (see facing illustration). The meter control panel shown is optional; electronic assembly is accessible by removal of front panel. Another popular form is the portable version, with the mechanical and electronic assemblies in separate cases. Although weight is rather heavy (80 lb for each case) this was accepted rather than sacrifice performance.

Outset of this design project coincided with the initial work of the National Association of Broadcasters Subcommittee on Magnetic Recording Standards. Though such standards were then still somewhat nebulous, it was firmly decided that the new recorder would adhere strictly to the committee's proposals so that the final design would be as nearly as possible in complete agreement with the new standards when established. Accordingly, tape speed is 15 in. per sec with an auxiliary speed of 7.5 in. per sec. A single control knob permits convenient and rapid speed selection and simultaneously provides the necessary equalization changes. As an additional standard element, the double-flanged 10½-in. diam NAB reel was incorporated. This reel has a capacity of 33 min at 15 in. per sec and allows tape to be safely and conveniently stored and handled.

Tape transport mechanism consists of two standard NAB reels, one a supply reel, the other a take-up reel, each on a turntable carried on vertically extending shafts of the rewind and take-up drive assemblies; a capstan-drive assembly with its tape-locking idler; a

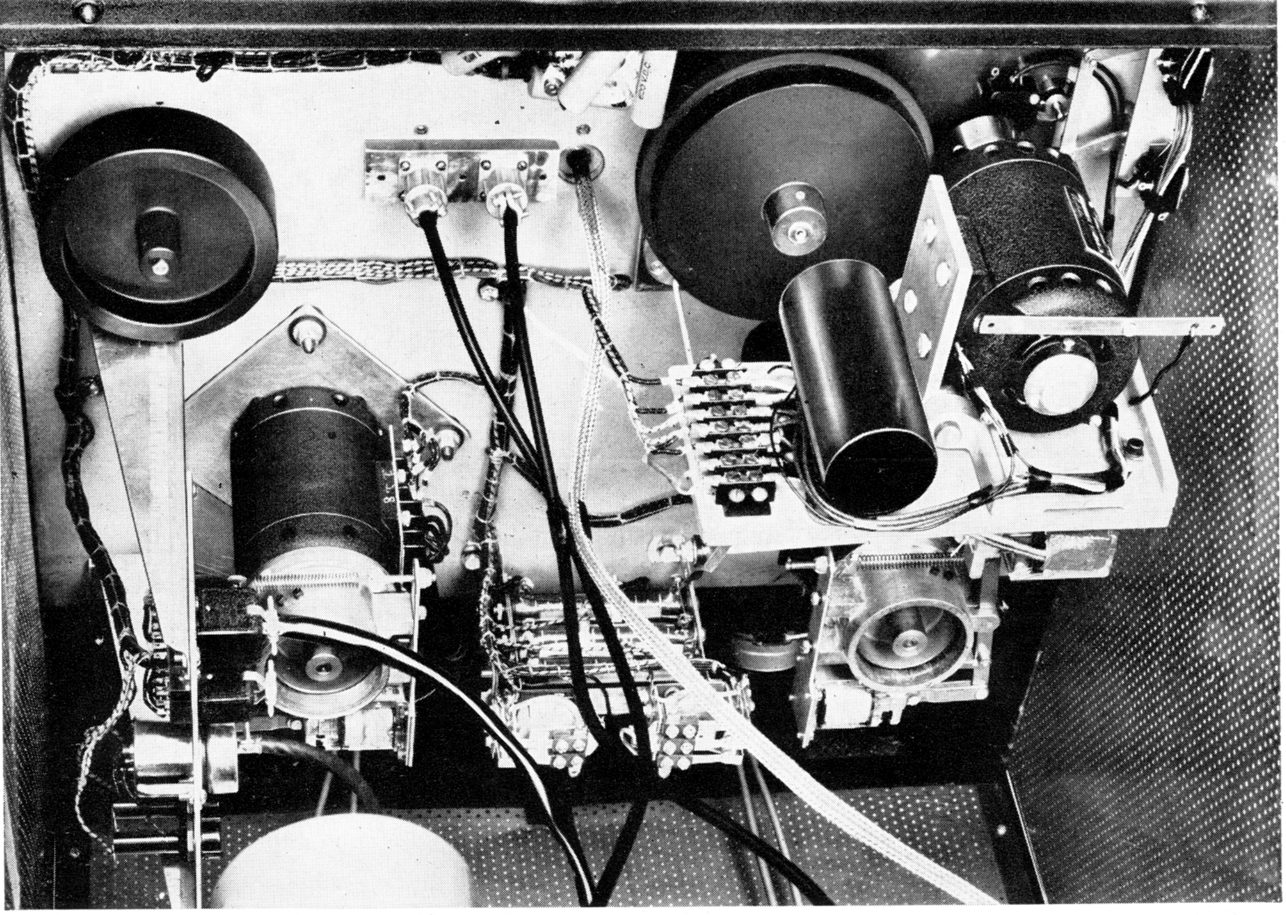


Fig. 1—Underside of recorder top plate showing tape transport assemblies. Rewind assembly with two-phase capacitor type induction motor, square mounting flange, and solenoid-operated brake assembly, is visible to the left. Capstan-drive synchronous hysteresis motor is shown at the extreme right. At the upper left is the reel idler flywheel.

reel idler; and compensating tension arms; three drive motors, one for the capstan drive and the other two on the reel assemblies. All motors are very compact, lightweight, and were designed for this application.

Rewind or supply-reel assembly located at left rear of the top plate of the recorder (see Fig. 1) consists of a vertically mounted ball-bearing two-phase capacitor-type induction motor with double shaft extensions. Electrical design of motor is such that maximum torque is developed at or near zero speed. Upper shaft extension has a die-cast turntable pinned directly to it with the exposed surface resiliently covered with a pad of 1/16-in. neoprene-cork adhesive-backed sheet. Reels are secured to this turntable by a "hold-down" which is so constructed as to center and lock the standard NAB reel, as well as the standard RTMA reels.

Reels of varying thickness are always firmly held because of a spring-loading feature built into the hold-down and combined with a pinch-locking "trigger" to allow positive gripping at any location along the smooth shaft extension. Instant release is afforded by simply grasping the hold-down and lifting the trigger with the thumb.

A 3/16-in. thick aluminum stamping fastened by means of the motor end bell screws to the upper end bell provides a suitable mounting flange for the entire subassembly: latter is resiliently mounted with soft-rubber stem bushings on four 1/4-in. studs and retained by self-locking nuts. This mounting system was developed not only for quieter operation, but also to conveniently provide means for critically aligning the unit in final assembly. Lower end-bell screws were utilized as fasteners for the brake assembly.

Brakes are spring-applied and solenoid-released external-band-and-drum type, the drum being carried on lower motor shaft extension. The brake design effects a differential braking ratio of approximately 2:1, making use of the self-energizing effect of band-wrap. Rewind and take-up assemblies (which otherwise are substantially identical) are arranged so that their brakes are self-energizing in opposite directions of rotation and in such order that, regardless of tape travel direction, the tape-supply reel will always receive the stronger braking action. Brake drums are made from drawn-steel cups with staked-on hubs and are turned true to shaft bore. Attachment to shaft is by means of a steel "roll-pin."

Remaining parts of the brake assembly are mounted on a die-cast housing cast in a die with a removable and reversible slot core. This dual-purpose die permitted casting of both right- and left-handed housings with respect to the brake band exit slot at a considerable saving in tooling cost. Brake bands are punched from 0.006-in. x 1/2-in. wide blued clock-spring steel and carry a special felt lining securely cemented to one side. Solenoid and brake spring-mounting bracket, as well as the brake arm, solenoid linkages and band clamps, are all steel stampings.

Solenoid control of the brakes assures their operation in unison. This, together with the differential action allows smooth and rapid stops to be made without undue tape tensions and without formation of slack. Importance of proper braking action is more readily appreciated when it is realized that a full reel of 2500 ft tape is rewound in 1 min. Early in the design, dynamic braking by applying direct current to the motor windings was carefully investigated; while this system appeared attractive because of its simplicity, it was dropped because of the objectionable looseness of the tape when at rest. With the mechanical system herein described, reels are not too free to turn when standing with brakes applied, but offer some resistance to the removal of tape. This is particularly important when the machines are used in remote operation where, at rest, the tape will lose tension and stall the machine through operation of the tape-runout switch associated with the take-up tension arm.

Function of the capstan-drive assembly (see Fig. 1 again) is to maintain constancy of tape velocity during recording and playback operations. This system was the subject of the most extensive investigation of any part of the recorder. Different types of drives were constructed in experimental form and studied. Methods of electromechanical analogy, wherein the mechanical elements were set up as electrical-circuit analogs, proved of great value in this development. Result is a remarkably wow-free and flutter-free drive with a minimum of precise, close-tolerance parts. Specifications guarantee maximum of 0.1 per cent rms flutter at the 15-in. speed and 0.2 per cent rms flutter at 7.5-in. speed; however, the average measurements, as recorded in final production check-out, are about half.

Tape drive is accomplished by clamping the tape between a rubber-tired idler and a precision-ground and lapped capstan shaft. Runout of the hardened steel shaft is maintained within 0.0001 in. total indicator reading. Capstan shaft runs in a bronze, grooved and graphite-filled upper bearing with a generous oil supply. The lower bearing carrying the end thrust is a selected precision ball bearing. Flywheel mounted on lower shaft extension has a cemented-on rubber molded tire of especially compounded rubber of high uniformity and then ground true on assembly after mounting.

Fig. 2—Recorder in operation: Tape tension has been relaxed to facilitate tape editing, after which open gate of head housing is again ready to receive the tape. Note the 20-deg sloping skirts of reel guards, reel idler and other projecting parts. The sloping bases cause slack tape to draw up into running position when tension has been restored.

Capstan assembly is driven by a dual-speed sleeve-bearing hysteresis synchronous motor on which is mounted a ground-in-place stainless steel pulley. Disengagement of the motor pulley and the rubber tire, when the machine is not in use, is effected by a hinged motor mounting combined with an actuating solenoid. A second solenoid serves to swing the rubber-tired idler against the capstan for tape driving. Entire assembly is mounted on a $\frac{5}{16}$-in. thick dural plate suspended on the under side of the top plate on threaded studs with spring loading and secured with self-locking nuts.

Special feature of the drive system is instant starting, particularly desirable in editing and in cueing programs. When the machine is threaded, the take-up tension arm is pulled away from its rest position by the tape which causes the capstan-drive motor to start. When the start button is depressed the rubber-tired idler clutches the tape against the running capstan and tape is brought to full speed in less than 0.1 sec.

Spring-loaded compensating tension arms carrying hardened steel guides at their ends are located to either side of the head housing (Fig. 2) and serve to momentarily equalize sudden changes in tension during starting or stopping and to reduce the lesser fluctuations resulting from the passage of a splice. They also preserve tension on the tape while the equipment is at rest. A switch operating in conjunction with the take-up tension arm stops the machine when tape runs out or when tape breaks. The left-hand tension arm is associated with the reel idler and swings coaxially about its shaft. It has the additional function of increasing the angular wrap of the tape about the reel-idler pulley.

The reel-idler assembly has a dual purpose: (1) it causes the angle of approach of the tape to the head housing to remain constant, though the angle from the supply reel continuously changes as tape is paid out; and (2) it functions as a filter system to smooth out minute disturbances in tape tension which might otherwise be noticeable in the recording. The second function, in particular, makes this subassembly one of the most critical to produce.

Control buttons and switches have been so located that when the top-plate assembly is mounted on the console cabinet or portable case they are conveniently positioned along the front edge. A three-position rotary selector switch controls "play," "rewind" or "fast forward" operations while pushbuttons govern "start," "stop" and "record" functions. Since the pushbutton-controlled functions are relay operated (see Fig. 3 for the control-circuit diagram) they may be manipulated remotely.

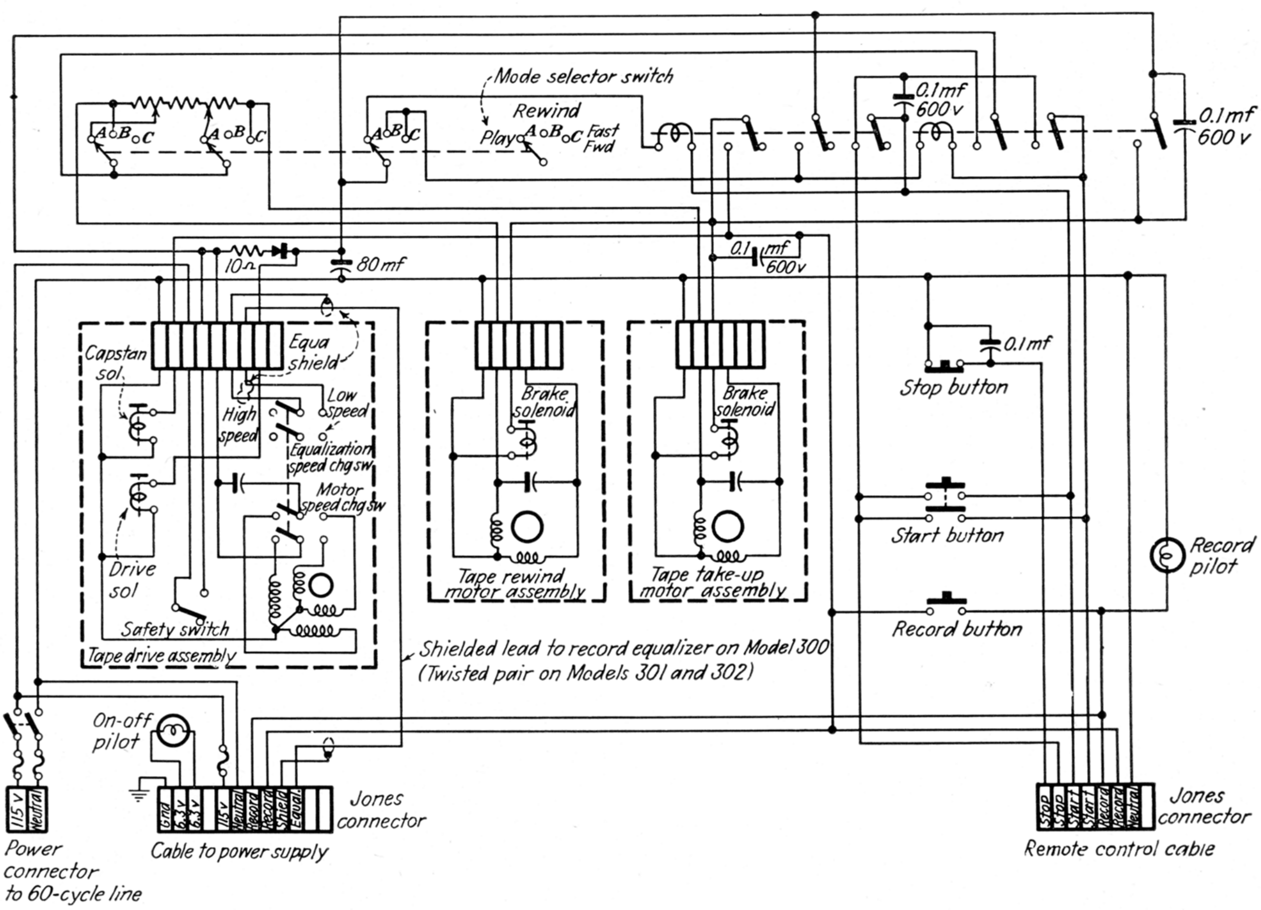
After once initiating tape motion by depressing the start button, operation may be shifted readily from one mode to another with the exception that in returning from "fast forward" or "rewind" to "play" the machine automatically stops to avoid breakage of the fast-moving tape which would occur by clamping it to the relatively slow-moving capstan. The ability to shift at will facilitates editing.

An outstanding feature is the head assembly, which comprises a housing containing erase, record and playback heads with the necessary head shielding and tape guides. It mounts as a self-contained unit by means of two concealed socket-head cap screws to the top plate. Head cables with their respective connectors remain a permanent part of the head assembly allowing the unit to be broken free for replacement.

New heads were designed which have improved performance characteristics and are of smaller size. The compactness along with a modified "ring" core design and the balanced windings all contribute to a considerable reduction in susceptibility to hum pick-up.

Extreme precision in head construction must be maintained to insure interchangeability of recordings between machines without loss of high-frequency response. The accuracy required to maintain ±2 db limits of deviation in frequency response is exacting; assuming for the purposes of illustration, that the associated amplifier has a perfectly flat frequency response, then one edge of the gap must be held in alignment with respect to the other within ±0.0003 in. In actual practice, however, this tolerance must be reduced since it is not practical to attempt to hold the amplifier response to closer than ±¼ db. To maintain this order of accuracy in manufacturing, the mating

Fig. 3—Control circuits of Ampex professional magnetic tape recorder; tape drive, rewind, and take-up assemblies are indicated within heavy broken lines. Start, stop, record functions are relay-actuated and may be remotely operated.



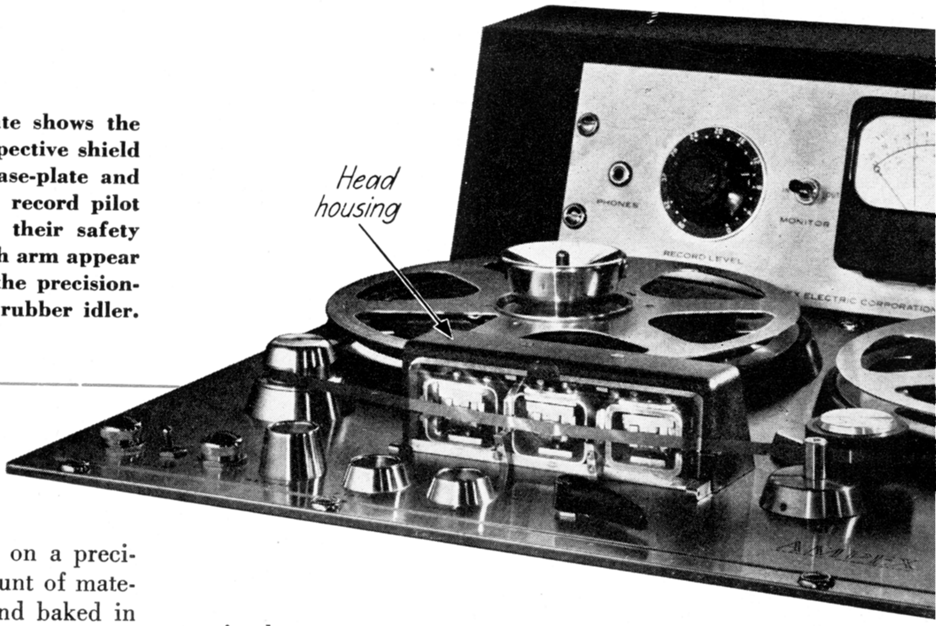


Fig. 4—Phantom view of head-housing gate shows the three magnetic heads mounted in their respective shield cans, which are clamped to the die-cast base-plate and enclosed by the die-cast cover. Power and record pilot lights, power switch, control buttons with their safety escutcheons and the operation selector switch arm appear along the front. Projecting up at right is the precision-ground capstan shaft with ground-surface rubber idler.

surfaces of the split-ring core are lapped on a precision lapping machine. To reduce the amount of material removal, laminations are cemented and baked in a precision-ground stacking fixture.

Coil forms are of a split-spool design to allow mounting on the finished core stacks, and are injection molded from high-temperature-resisting nylon plastic. Wound cores with their respective gap shims are finished by careful hand work and machine lapping.

Unique element of the head assembly is the thorough shielding provided for the three heads. (See Fig. 4.) Each head is mounted in a drawn sheet metal can. The erase head is mounted in a copper can for electrostatic shielding, while the record head is mounted in a single can of Permalloy. Since the playback head naturally requires the greater amount of magnetic shielding, it is mounted in a dual-alloy shield consisting of nesting cans—an inner and outer can of Permalloy with an intermediate copper can. The hinged cover, or "gate," for the head housing carries matching shield caps for the record and playback heads. Mating surfaces of cans and caps are lapped to insure maximum shielding efficiency. Cans and their spring-loaded covers are, of course, provided with appropriate slots to form openings for the entrance and exit of tape. The record and playback heads are mounted within the cans by a system of spring-loaded screws which allows azimuth adjustment of the gaps in each head while the machine is running.

Lateral guiding of the tape through the head housing is accomplished by a set of Pyrex glass rods properly spaced and mounted close to the entrance and exit openings of the assembly. An additional set of Pyrex guides is mounted on the over-center spring-loaded gate so that in opening the gate the tape is removed from contact with the heads, thereby avoiding head wear during fast reeling operations. Threading is extremely simple.

Considerable development work preceded the final production design of the electronic assembly. Purpose was to simplify all components and reduce cost and size. Transformers were kept to the minimum consistent with performance, and dual tubes used where advantageous. A well-filtered bias and erase power supply leaves the tape remarkably quiet. It is stable to adjustment and supply voltage variations.

Record amplifier takes signal from microphone or radio input directly to a bridging input transformer or in the optional form with a matching input transformer. There are two stages of amplification through resistance-coupled 6C5 triodes and a third stage through a resistance-coupled 6SN7 with grids and plates operated in parallel. There is sufficient gain to operate from a line level as low as —30 volume units. Normally, the units are set up by means of the screwdriver gain control provided to operate from a line level of +4 vu. Additional screwdriver-adjusted controls provide high-frequency equalization, bias current, erase trimmer, and noise-balance adjustments. Power rating of the amplifier is such that no distortion is introduced well beyond the tape-saturation current.

Playback amplifier feeds signal from tape through two stages of resistance-coupled amplifiers, one a 12SJ7 pentode, the other a 6J7 pentode. Amplified signal goes through a playback level control to a 6SN7 tube which acts as a phase inverter for another 6SN7 double triode arranged in a push-pull circuit with the output transformer. The playback amplifier has sufficient power to deliver +25 dbm (decibels stated in terms of a zero level of 1 milliwatt) at 1 percent total harmonic distortion into a 150- or 600-ohm line, which is ample reserve for the normal operating level of +4 vu to +8 vu. Screwdriver-adjusted controls provide high-frequency equalization as well as overall gain adjustments.

Overall performance characteristics fall well within the proposed NAB standards. Frequency response is ±2 db from 50 to 15,000 cps at 15 in. per sec and ±2 db from 50 to 7500 cps at 7.5 in. per sec. Signal-to-noise ratio is better than 60 db, unweighted, and in accordance with the NAB definition (ratio of peak-recording level to total unweighted noise-level recording zero signal; peak-recording level is that point at which the overall total harmonic distortion does not exceed 3 per cent measured on a 400-cps tone).

Final acceptance must of necessity rest strongly on the results of a critical listening test, such as the "A-B" test which compares a "live" musical program of the most exacting nature with a recording. Results of such tests show that it is impossible to distinguish recorded material on the Model 300 from the original performance, and indicate that the original design objectives were satisfactorily achieved. □ □ □

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