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A NEW CONCEPT FOR RADIO BROADCASTING
OF COMMERCIALS

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INTRODUCTION

Short duration recording and reproducing media are essential in radio broadcasting. The 45's paved the way for the current top 40 format; similarly, a convenient, reliable, and economical means of playing commercial messages has long been sought.

Broadcasters have tried various methods of improving quality and simplifying operation in this area -- including ET's, reel-to-reel tape, and endless loop tape cartridges of various designs.

ET's could be mailed by the advertiser and played directly on the air with reasonable confidence that they would provide good quality. However, constant cueing resulted in noisy lead-ins, and variable lead-in time. Cueing was inconvenient and quality suffered with increasing number of plays.

In an effort to retain the quality, reel-to-reel tape was tried. An intermediate transfer process from ET's to tape was generally required. Although quality was improved, the inconvenience of threading and cueing was more than many could cope with.

The advent of cartridge recorders provided a more convenient method of cueing. Several problems existed which are constantly being improved upon. Transfer from ET's to cartridge is necessary. Despite the problems, a majority of broadcasters have switched to cartridges. Several cartridge designs exist and interchangeability still poses problems. The NAB has established a standard for cartridges in an attempt to correct the situation.

Many broadcasters approached Ampex in search of an improved cartridge recorder or a new system tailored to their requirements. Ampex felt that a significant contribution could be made to the broadcasting industry in the area of short duration recording.

With this interest in mind, Ampex ventured into a development program which resulted in the Cue-Matic* Recorder-Reproducer, whose concept and design will be discussed in this paper.

DESIGN GOALS AND PHILOSOPHY

Before we embarked on this major development program, a survey was made to establish the extent and the requirements of the proposed market. This survey showed the need for a more reliable unit which would provide higher quality than the equipment then being used. A set of basic criteria was then established. The design goals were general so as not to restrict creative thinking, but reflected the needs of the user as determined by the market survey.

After careful deliberation, the following objectives were established:

1) The recording media should have no moving part.
2) The media should be inexpensive and easy to mail.
3) The equipment should provide simple operation, with only one start button (if possible) and automatic cueing and stopping.
4) Minimum space should be required for media storage, and easy access should be furnished.

* TM, Ampex Corporation

BASIC APPROACH

At the start of the project, the first consideration was to determine the size and shape of the recording media, because, obviously, this would in turn determine the design of the transport.

There are many considerations in designing a medium acceptable to broadcasters, advertisers, and to those in the master recording field. Ideally, we desired one which the advertiser could record with his commercial spot and send to the broadcaster for direct replay. This would avoid the re-recording or transferring processes necessary with cartridges. Among other considerations were price, and ease of handling, mailing, and storing.

From a performance standpoint, it was felt that frequency response to 10 kHz, a signal-to-noise ratio of 50 db (or better), and sufficient playing time to allow the recording of pop tunes as well as commercial spots were necessary.

Many different configurations, each with advantages and disadvantages, were considered -- including conventional reel-to-reel, endless loop cartridges, belts, sleeves, and sheets. In light of the considerations previously mentioned, it was felt that the sheet offered the most acceptable medium.

It was decided that the sheet should be in a circular form, resembling the LP disc familiar to broadcasters. Mailing would be simplified by using LP mailers currently existing.

The cost was dictated by the 3-mil thickness of the medium, which gives satisfactory performance and acceptable handling. The cost would be less than for endless loop cartridges, but more than for standard 1/4-inch tape, for a given length program.

To distinguish the circular sheets from records or discs, they have been trade-named CUE-MATS.

Figure 1 shows the dimensions of the Cue-Mat. The following operational data were established:

Rotational speed:	12 rpm
Track width:	43 mils
Center-to-center track spacing:	62 1/2 mils

The 12-rpm rotation results in a linear head-to-Cue-Mat speed of 7 ips on the outside track and 3 1/2 ips on the inside track. A playing time of 3 minutes 45 seconds, which seems adequate for at least 95 percent of current pop tunes, is provided.

With the form factor for the medium established, the design of the machine for proper Cue-Matic handling, and for signal processing, could continue.

DESIGN DETAILS

One of the first considerations in the actual design of the recorder was the magnetic head. To meet the operating requirements previously stated, the following magnetic head criteria were established.

1) It must play back 1/3-mil wavelength with minimum gap loss.
2) It must record the medium to saturation without saturating the head (using a 100-kHz bias frequency at peak bias current).
3) Easy replacement was required.
4) Low hum pick up from extraneous fields was essential.
5) It must exhibit minimum head bumps.
6) It must have minimum cross talk between tracks.
7) Head wear must be minimum, to provide long head life.

To achieve high output with minimum gap loss for playback to 1/3-mil wavelength, a 100-microinch gap was selected. This also gave satisfactory operation with the 100-kHz bias frequency to be used. A 10-mil gap depth was chosen as optimum for long head life and required bias power.

The shape of the head was designed for minimum head bumps, with a symmetrical head structure to balance out stray hum fields. A metal shield can around the entire head further reduced hum pick up.

With this close shielding around the head gap, the cross talk from adjacent tracks exhibits the familiar low frequency "fringe" effect. A graph of the measured cross talk is provided in Figure 2. Since it occurs at low frequencies, where the ear is least sensitive, it is practically inaudible when program material is played back.

To provide proper head-to-mat contact, the head must protrude from the shield can. Since the gap depth was 10 mils, which represents the head life, the head was made to protrude from the can by that amount.

A precise mounting surface is provided to facilitate changing the head assembly. To remove the head it is necessary only to remove two finger-tight screws, and unplug the head cable.

Transport. For the transport itself, the head placement and head movement mechanism were of prime concern. The head must be mounted and moved with the head gap on a line precisely on a Cue-Mat radius, in a similar manner to that used on disc recording lathes. The requirement for consistently high sound quality makes the head placement most critical. A slight displacement at the outside will cause the azimuth error to increase by an order of magnitude at the inside of the mat. Figure 3 shows the geometry involved.

The method of moving the head accurately across the Cue-Mat is also critical. Any thermal expansion or contraction of the media could cause a misalignment of the head in relation to the recorded track. To compensate for the thermal coefficient of the media, the head is moved across the Cue-Mat by a strip of the same material used for the mat. Any expansion or contraction of the mat due to temperature will therefore be offset by a similar change in the positioning strip. The unit can be operated with considerable latitude in regard to temperature, with negligible loss due to head positioning.

Head-to-mat contact is also critical. This requirement is the same for any reel-to-reel machine -- that is, high frequency losses and dropouts can occur due to spacing. The 3-mil thickness of the media is at least twice that of ordinary 1/4-inch tape. This reduces the compliance of the media, and head-to-mat contact becomes more difficult to maintain. To obtain satisfactory results , a force of 20 grams was found necessary (approximately 10 psi). However, a fixed head position with respect to the medium would cause variations in pressure with head wear. A spring loaded head mounting arrangement overcomes this problem, and provides increased head life.

Positioning the mat in the unit was of next concern. In the final position of the mat, the locating hole must be accurately centered around a spindle. When the mat is inserted into the unit, a rough positioning is first necessary to assure that the center hole will not be deformed when the mat is later clamped around the spindle. This is achieved, as shown in Figure 4, by two end stops, and by shaping the top of the spindle to allow for slight misalignment.

Clamping the mat is accomplished in two stages. As the mat is inserted, a micro switch is actuated. This brings the clamping disc down far enough to provide drag between the mat and the turntable for cueing purposes. During this phase the mat is accurately centered on the spindle. For the actual recording or playback mode, the clamping disc is lowered still further, tightly clamping the mat to the turntable (see Figure 5). The mat then is driven by the turntable, with the clamp driven by the frictional force between it and the mat. In this manner any disturbance or stoppage of the mat due to external forces will not cause misalignment between the head and mat.

At the instant the clamp is seated in its final clamped position, the cue bar is released. Simultaneously, a clutch is engaged. The clutch drives a drum which in turn winds in the polyester strip and starts to move the head.

The method for driving the turntable was next considered. Coupling a drive motor to the turntable created a problem, because of the required high reduction in speed. To provide the necessary speed reduction ratio an intermediate pulley, fitted with a heavy flywheel, was provided. The rotational speed of this pulley is 480 rpm, compared with 12 rpm at the turntable, and the resultant high effective inertia provided by the tightly coupled flywheel reduces wow and flutter, and allows the use of a lighter turntable to achieve the necessary results.

Figure 6 shows the drive system. A capstan drive against the rim of the turntable provides the 40:1 speed reduction from the intermediate pulley to the turntable. A rubber belt around the periphery of the turntable was first used as a frictional surface. However, trying to drive against this surface alone caused errors in timing due to creep and wow and flutter due to irregularity in the rubber. An endless polyester belt, cemented to the rubber, provided a more consistent drive surface, as can be seen in Figure 7.

During the design phase it was decided that a mechanical cueing device would be more reliable than an electrical system. The Cue-Mat has a rectangular hole which is used for cueing purposes. This cueing slot is used to position the mat precisely with respect to the head, so that all mats start at the same point. This cueing is accomplished automatically when the mat is inserted.

Because program material would vary in length, a tone sensing system is used for stopping the equipment. A 30-Hz signal, which is used as a stop tone, is generated by a simple magnetic pick-up located adjacent to the drive motor shaft. A two-pole, ferrite ring magnet is mounted on this shaft, and the 30-Hz signal is generated by the magnetic flux induced in the pick-up. A hysteresis synchronous drive motor is employed, so the stop tone is as accurate and stable as the frequency of the power line.

Electronics. Since only one head is used, the electronics does not require separate record and playback circuitry. Much of the circuit is combined, with switching to select either the record or playback modes.

A block diagram of the record amplifier is shown in Figure 8. Provision is made for microphone inputs, as well as for balanced and unbalanced line inputs. After suitable amplification, a sharp dip filter attenuates (approximately 50 db) any 30-Hz component in the program material to eliminate false stopping caused by low frequency components in the program material. The signal is further amplified and equalized prior to recording.

The vu meter is fed by a separate amplifier, which presents the proper impedance for correct ballistics of the vu meter.

When the stop button is pressed in the record mode, the program source is disconnected and the 30-Hz stop signal is automatically recorded.

When the record/play switch is placed in the record position, a red warning light next to the start button is illuminated. As a further precaution, a record cue interlock control must be actuated to initiate the cueing process. When the interlock is actuated, the vu meter indicates the bias current through the head. When the stop button is pressed at the end of the recording, the meter will indicate the record pilot tone level.

The maximum (clip) level of the record amplifier is 20 db minimum above operating level, to provide adequate margin for transient peaks. The limitation in maximum recording level is media saturation, which is defined as 14 db above operating level at mid-audio frequencies. The third harmonic distortion from the media at operating level is just under 1 percent. The record amplifier distortion is shown in Figure 9.

A variable record equalization method was necessary to compensate for the change with time in linear head-to-mat speed. Both continuous and step type equalization were tried. For ease of adjustment and repeatability, the step type was selected, using a leaf switch with five leaves to provide the steps. The drum which winds in the polyester strip (to which the head assembly is attached) has a direct relationship to the head position on the Cue-Mat. Therefore the actuating cam for the equalizer switch could be designed as an integral part of the drum.

Equalization is in approximately 3-db steps at 10 kHz (much less at lower frequencies). Figure 10 shows a graph of 1 kHz, 3 kHz, and 10 kHz tones recorded throughout the mat. Because very little change occurs in the mid-frequency band, where the ear sensitivity is the greatest, the switching is practically inaudible on program material.

A block diagram of the playback amplifier is shown in Figure 11. An input transformer is used because of the low impedance of the head. The transformer is designed so its losses (series copper loss and parallel eddy current losses) are low in comparison to the head, so it does not add to the thermal noise of the head.

The signal is fed in two separate paths after going through an equalized preamplifier. One path is through a 30-Hz dip filter and a line amplifier to the output terminals. The other path is provided for the automatic 30-Hz tone stopping feature. The signal is fed through a diode clipper and a 30-Hz emphasis filter to the switching transistors. Actuation of the relay places the transport in the stop mode and releases the mat. Shutoff sensitivity versus frequency is shown in Figure 12.

A muting switch, actuated by the head carrier movement, opens the output line to prevent switching transients from appearing on the line. An additional contact on this switch prevents accidental stop when cueing a mat with less than 5 seconds of message (such stoppage could occur if the mat curled up enough to contact the head).

Playback amplifier distortion is shown in Figure 13.

Overall record/reproduce response is shown in Figure 14.

FIELD TEST

The object of the field test was three-fold -- to test the concept, reliability, and acceptability of the unit.

Testing the concept was of major importance, because the equipment represented a totally new method of operation. The concept had to be tested not only with broadcasters, but also with advertising agencies and master recording studios. Both the large networks and the small stations using combo men and engineer-announcers were to be considered.

The field test also had to provide information as to the reliability and maintainability of the unit. Further information on mat life, handling, and mailing was felt necessary. And finally, the acceptance of the machine by the proposed user had to be demonstrated.

It was originally felt that 10 machines, field tested for 3 to 4 months, would be sufficient. As it turned out, 15 units were placed in the field to cover all facets of the test. Six were placed with two networks, six with two top-40 stations (one combo and one engineer-announcer operation), two in a duplicating facility for advertising agencies, and one with a master recording studio to determine if duplicating problems existed.

The field test was conducted for as long as a year (in one instance) at station KYA in San Francisco. At this station, it was felt that a total conversion of all records to Cue-Mats would offer advantages. Three more units were provided to KYA, making a total of six, and all but a few records were dubbed on Cue-Mats.

The field test was limited to two areas, New York and San Francisco, because of the lack of properly trained service personnel for wider coverage.

Results of the field test were encouraging. Several problem areas that developed during the test resulted in design changes. The most significant of these changes were:

1) Playing time was increased from the original 3 minutes 5 seconds to 3 minutes 45 seconds.
2) The clutch was redesigned to provide greater reliability.
3) The head carrier and mounting mechanism were redesigned to assure longer head life and more consistent head-to-mat contact.

The durability of the mat was well demonstrated. Tests in the lab had indicated that mat life should be in excess of 30,000 plays. Under actual operating conditions, a mat was played more than 27,000 times with little deterioration in quality.

One operating problem discovered was degaussing the mat so that a 30-Hz tone was not introduced from the degausser. Introduction of such a tone, of course, caused the machine to stop, when it was reproduced, and rendered the recording useless. Proper care in the degaussing process quickly cured this problem. As a result of this problem, a simple semi-automatic degausser is now on the way.

The final, production, model of the Cue-Matic recorder is shown in Figure 15.

APPLICATIONS

This unit was designed primarily for the broadcaster. Aside from classical music, live news, and personality segments, the most repetitive portion of broadcasting is concerned with:

1) Spot commercials.
2) News and program introductions.
3) News and program inserts.
4) Promo's.

5) Jingles.

6) Station ID's.

7) Top tunes.

The Cue-Matic can be used in all of these short-term program requirements, and offers a more flexible and more consistently timed format. Once the cue time is set during the recording process, it will not change -- dead time will not vary with different engineers. The mat is immediately released after play, ready for the next message with no need to wait for an entire cycle as with cartridges. Instant recueing is possible to allow for repeated messages or for previewing.

Life of acetate discs is short and deterioration of quality is noticeable after several plays. Cue-Mats can be recorded with greater ease, and handled and played, without loss of quality.

If sufficient interest is manifested, advertising agencies may provide commercials on Cue-Mats, thus avoiding the transfer process at the station. Another possible application could be using Cue-Mats for record prereleases; these are currently sent to disc jockeys on acetate discs.

CONCLUSION

The final design of the Cue-Matic unit has met the design goals established at the start of the program. We feel that the equipment should provide a valuable tool for the broadcaster in program or commercial material of short duration. The simplicity of operation and precise timing should increase efficiency and profits.

REFERENCE

Skov and Vogel, AES Preprint Nr.354, October 1964. This paper gives further technical details.

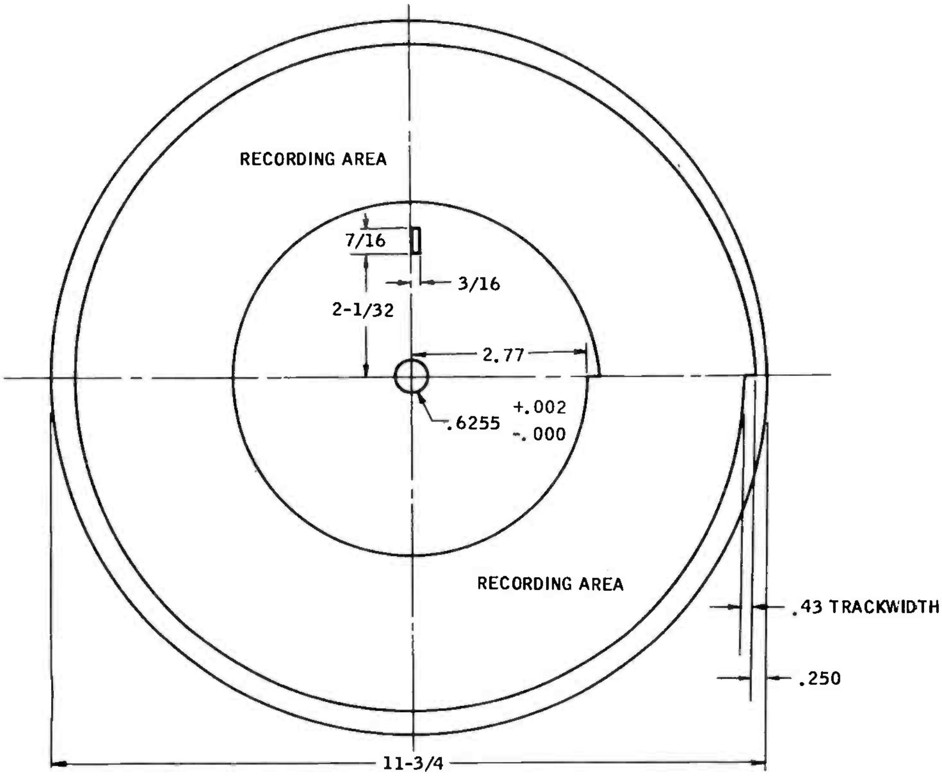


Fig. 1 AMPEX CUE MAT - THICKNESS 3 MILS

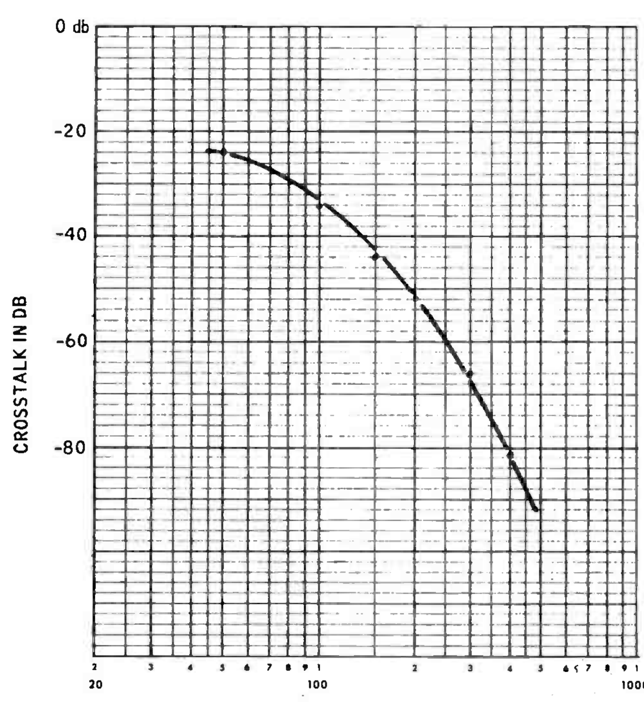


Fig. 2 TRACK-TO-TRACK CROSSTALK VERSUS FREQUENCY

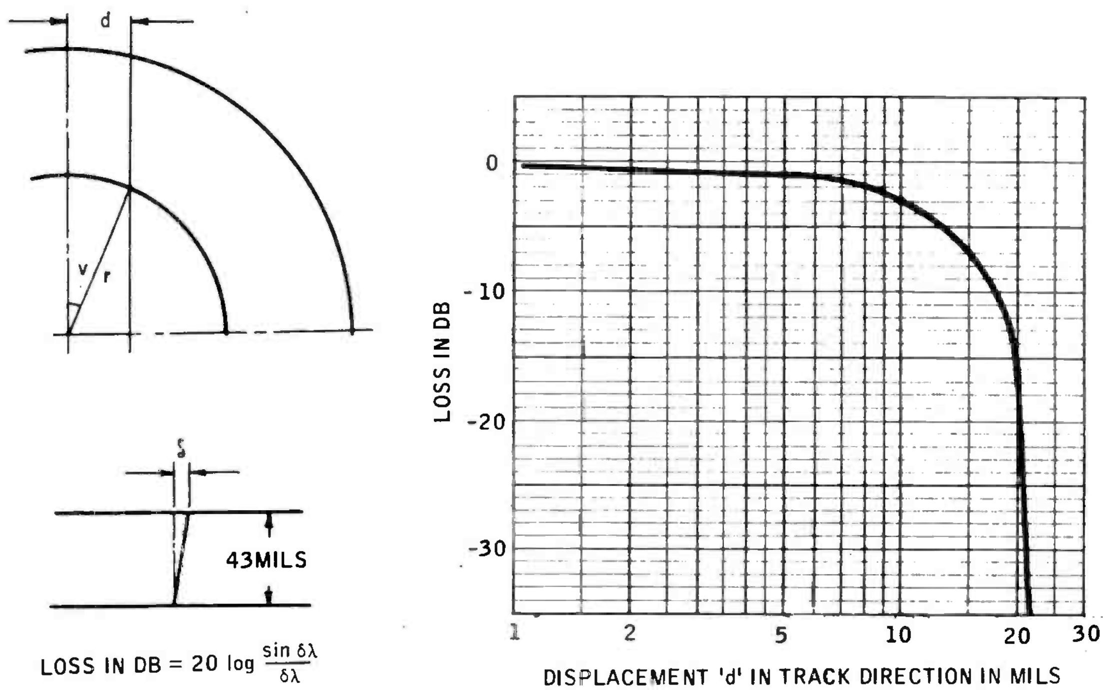


Fig. 3 GEOMETRY OF HEAD MOTION AND 10-KC INSIDE TRACK LOSS VS HEAD DISPLACEMENT IN TRACK DIRECTION

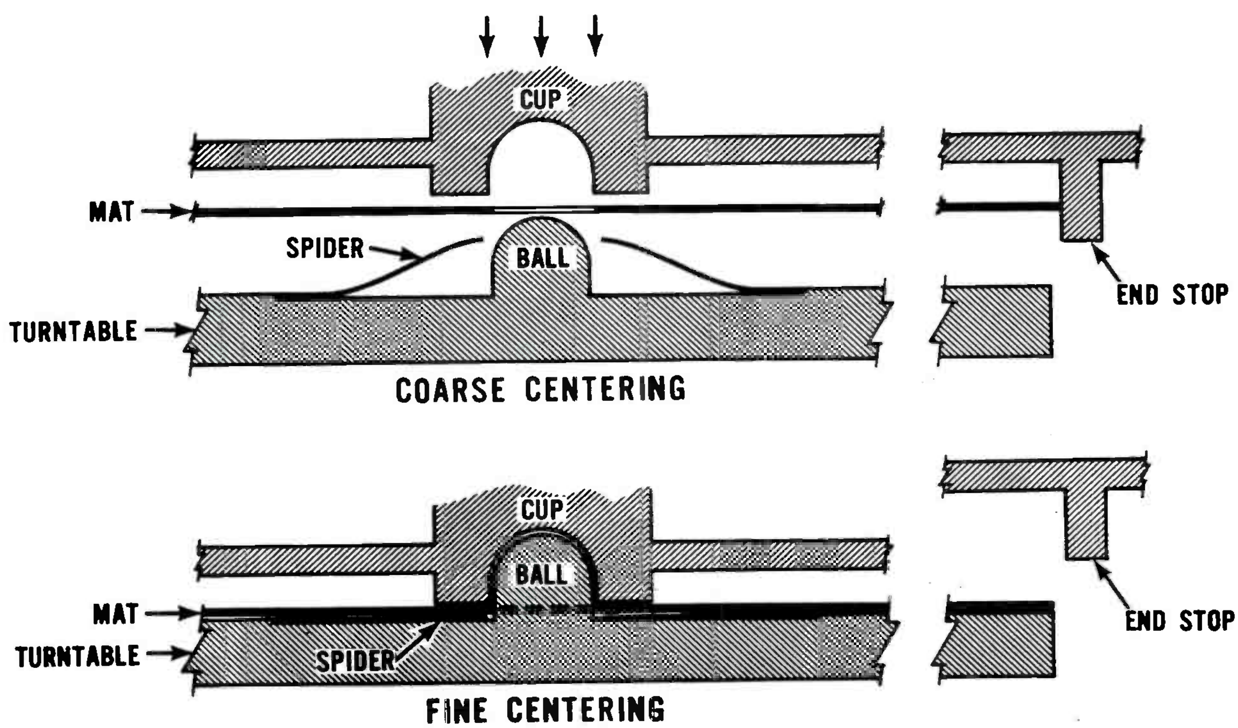


Fig. 4 POSITIONING OF THE MAT

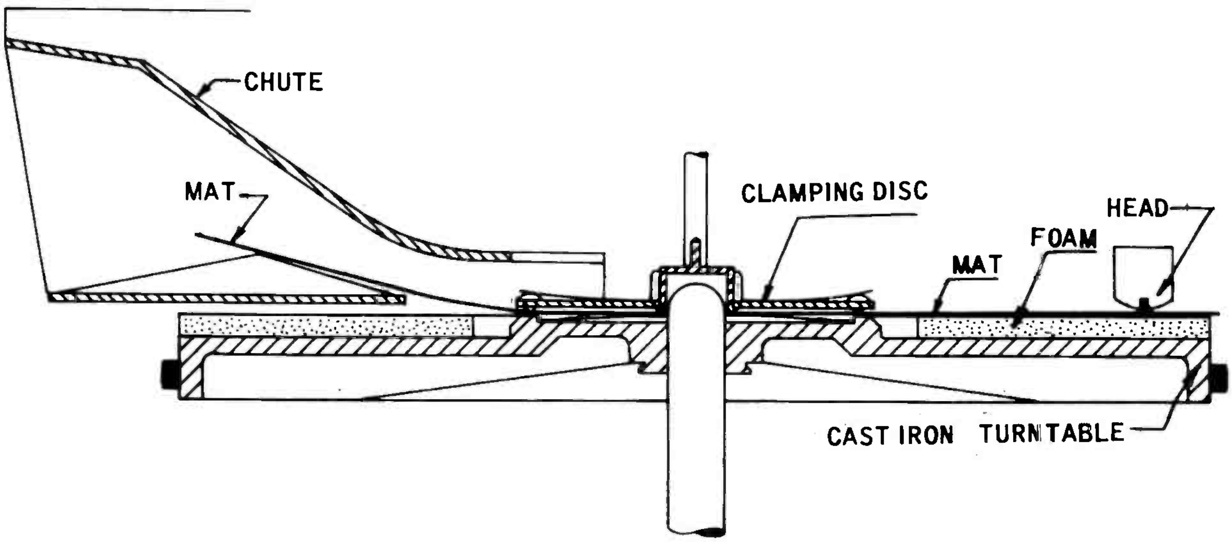


Fig. 5 SECTIONAL VIEW SHOWING POSITION OF MAT AND HEAD IN PLAY MODE

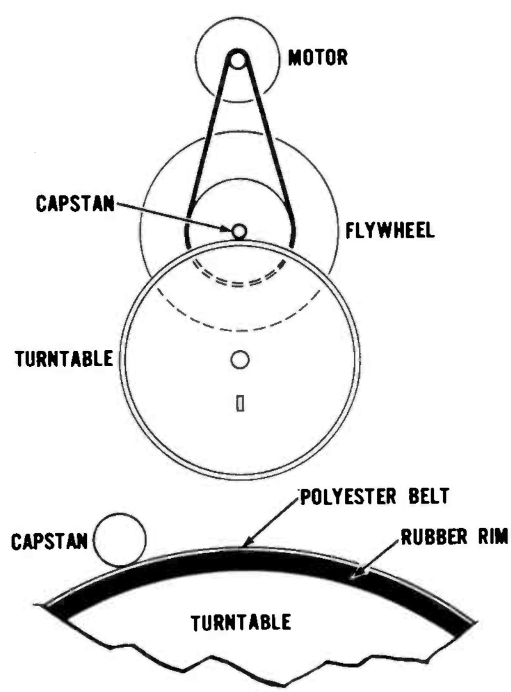


Fig. 6 BASIC DRIVE SYSTEM

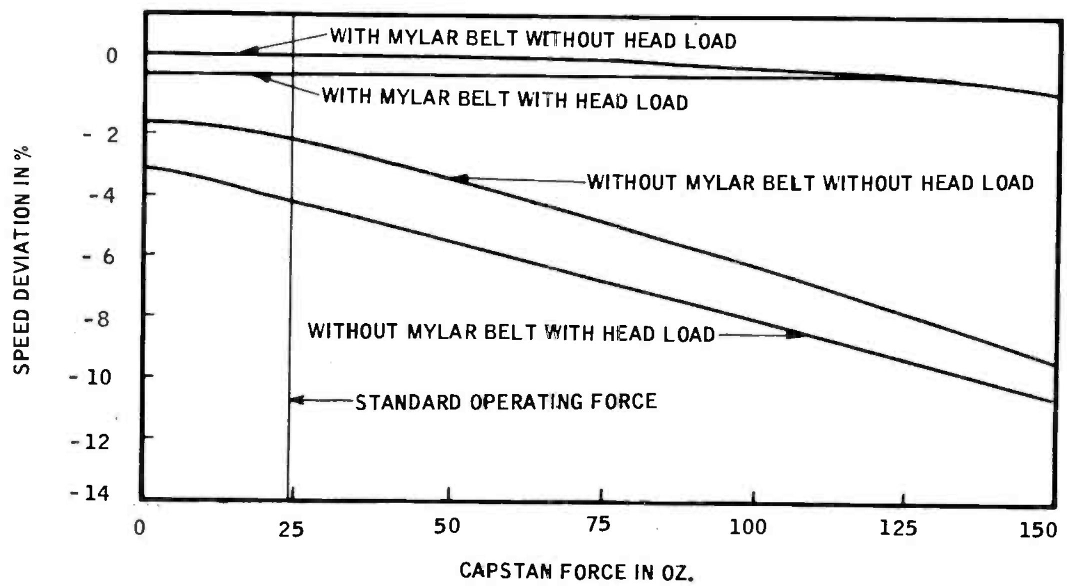


Fig. 7 TURNTABLE SPEED VARIATION VERSUS CAPSTAN FORCE

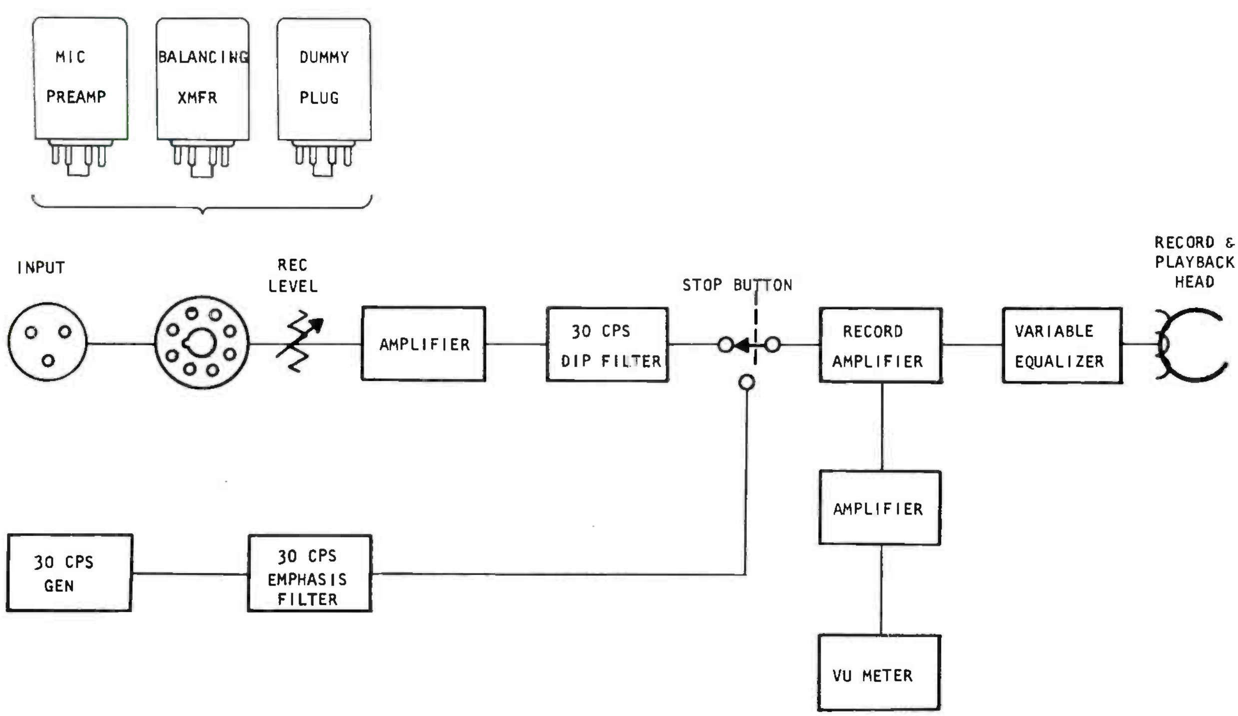
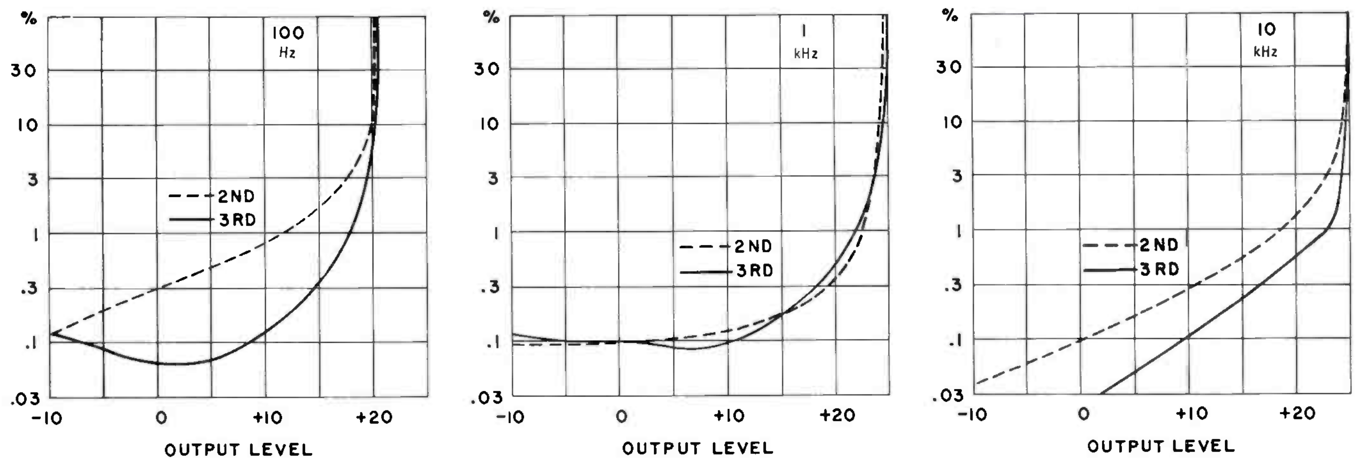


Fig. 8 RECORD CIRCUIT BLOCK DIAGRAM



OUTPUT LEVELS ARE REFERENCED TO OPERATING LEVELS

Fig. 9 AG-100 RECORD AMPLIFIER DISTORTION

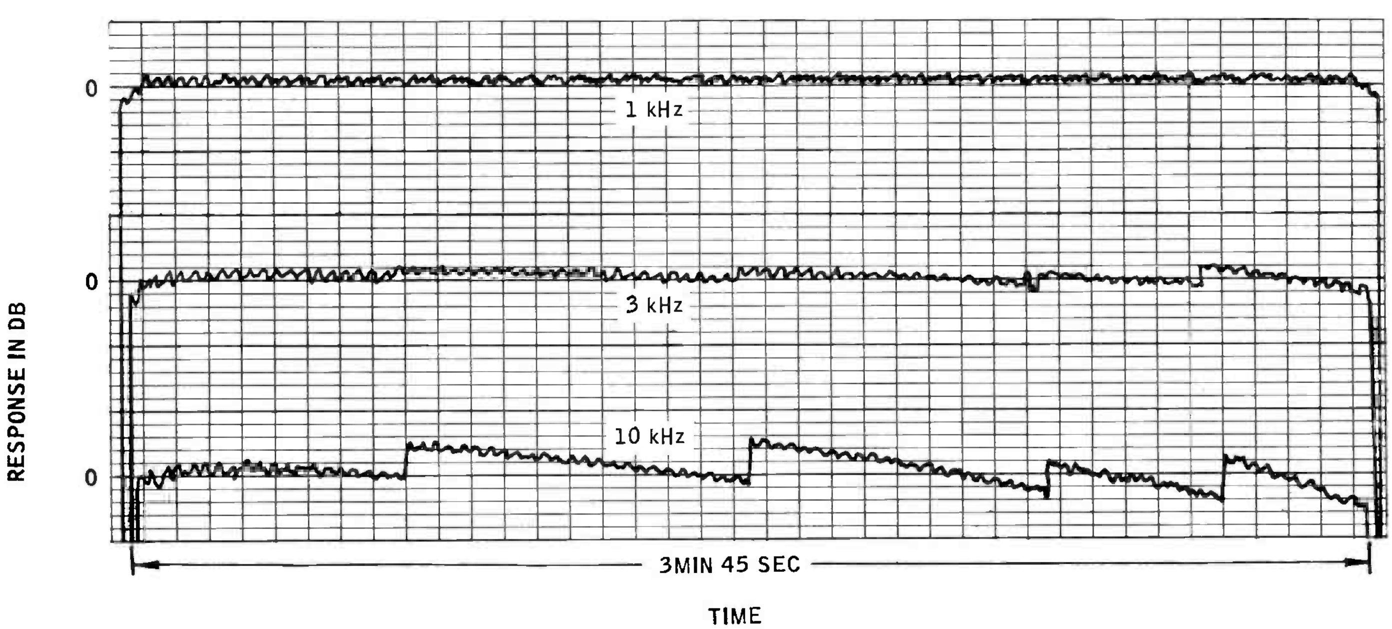


Fig. 10 1 kHz, 3 kHz, and 10 kHz RESPONSE VERSUS TIME

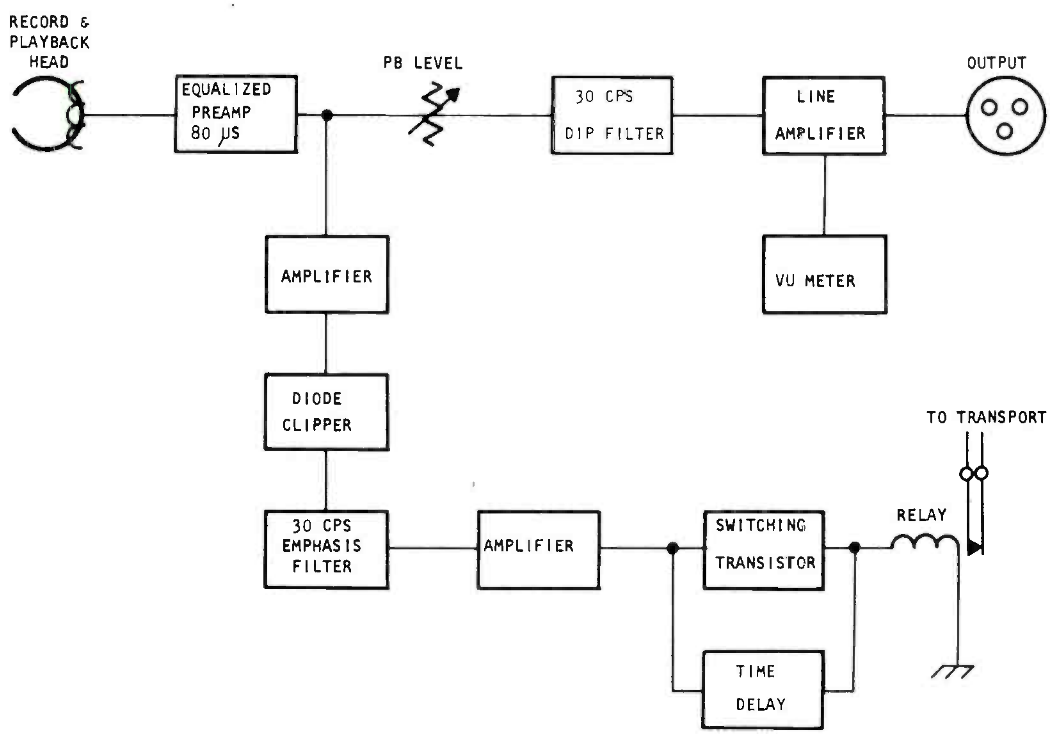


Fig. 11 REPRODUCE CIRCUIT BLOCK DIAGRAM

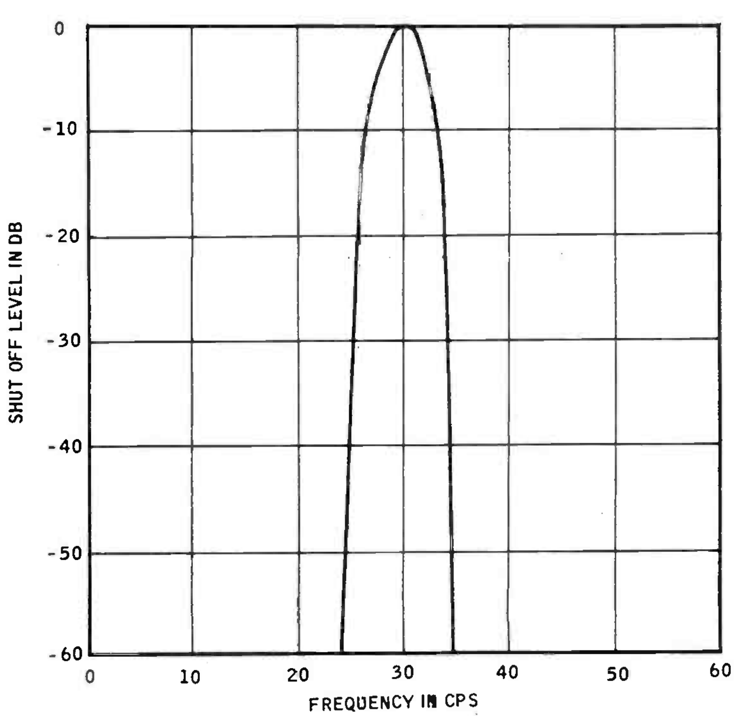
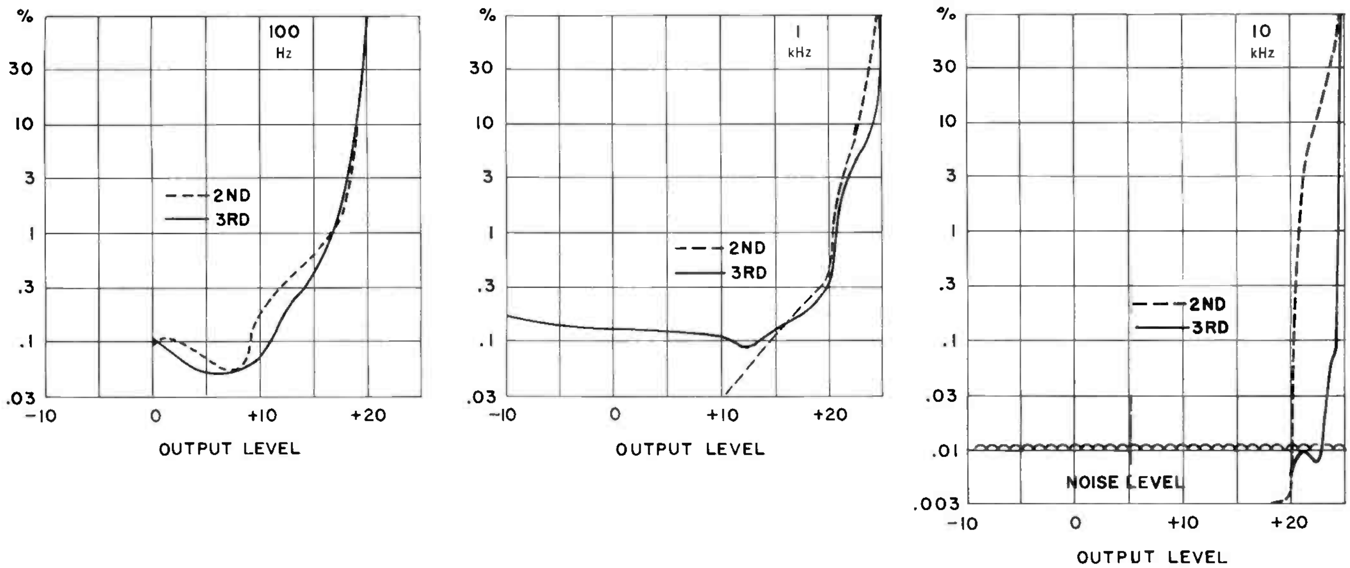


Fig. 12 PILOT TONE SHUT OFF SENSITIVITY VERSUS FREQUENCY



OUTPUT LEVELS ARE REFERENCED TO OPERATING LEVELS

Fig. 13 AG-100 PLAYBACK AMPLIFIER DISTORTION

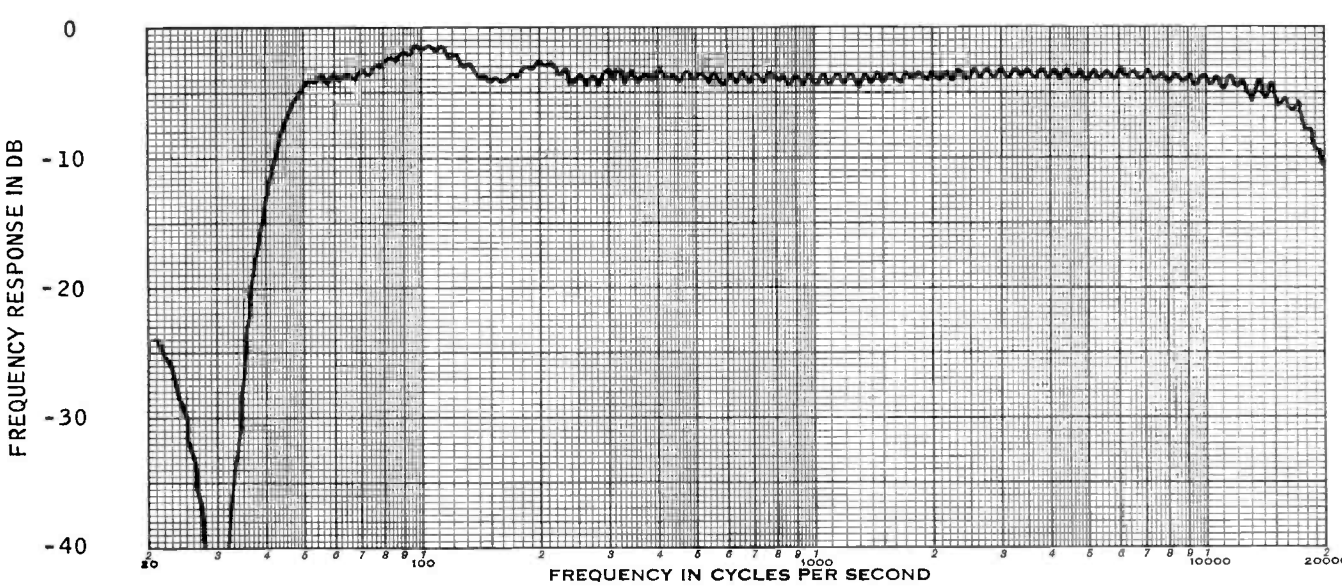


Fig. 14 FREQUENCY RESPONSE AT OPERATING LEVEL

Fig. 15 PRODUCTION MODEL OF CUE-MATIC RECORDER/REPRODUCER