THE INFLUENCE OF AN AMBIENT MAGNETIC FIELD ON MAGNETIC TAPE RECORDERS

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Introduction

Magnetic recorders are susceptible to external magnetic fields and hence prone to data degradation. This is primarily observed in instrumentation (space and ground) and computer recorders, where little or no shielding of the heads is provided.

The magnetic core material in the heads attracts flux lines and will with certain orientations concentrate these in the record, play back or erase gaps. During recordings a foreign field may therefore be superimposed on the intended recording field and may cause errors in the form of phase shift and dc offset; these affects are agravated when AC bias is used in the recording process. If an external field is present during playback only, partial or complete erasure may take place.

One external field is always present: The earth s magnetic field which has a magnitude of roughly one Gauss (or Oersted). The writer is not aware of any errors per se caused by this field, but it has numerous times caused difficulties in achieving a perfect demagnetization of heads (An oscillating and simultaneously decreasing field from a degausser does then in essence record a permanent magnetization into the heads, which in turn will result in noisy and distorted recordings).

Other fields are man made, such as originating from heavy currents in cable harnesses. The analysis presented in this paper was undertaken to establish susceptibility limits for a field generated by a magnetic attitude control system for spacecrafts. This is illustrated in Figure 1, where three orthogonal electromagnets on board a spacecraft generate a magnetic moment (M), variable in magnitude and orientation. The attitude correcting torque (T) on the spacecraft is expressed as the cross product between this moment and the earth’s field.

Recording equipment may be located within a few feet of the center of the attitude control field, which must be limited in magnitude or the recorder shielded to avoid data errors and/or erasure.

Examination of Susceptible Components

A tape recorder is shown in Figure 2, and the susceptible magnetic components illustrated in Figure 3. The effect of a field on the motor, tachometer and relays are discussed briefly later.

The magnetic heads are fabricated from high permeable (μ - 10^4) material and will attract flux lines through them. The magnetic tape has a 0.2 mil thick coating consisting of roughly 30% minute permanent magnet particles dispersed in a plastic binder. The effective permeability is very low (1-3), and the tape packs on the reels will have negligible effect on the external field.

Figures 3, 4 and 5 show how three different field orientations are deflected by passage through the recorder. From these we can deduct the following information:

Deflection of Field by Magnetic Heads

The perpendicular field causes no contribution to the useful longitudinal field in the gap, i.e., it should no affect erasure, recording or playback. The side-to-side field does concentrate the field in the head gaps, and off-set an otherwise symmetrical recording field or cause partial erasure at the playback gap. It could further DC magnetize the tape at any of the gaps.

The front-to-back field gives the largest field concentration in the gaps and the effects mentioned in the preceding paragraph are accentuated. The fields in the gaps are moreover longitudinal and will hence interfere directly with the intended fields in the magnetic erase, record and playback heads.

An order-of-magnitude estimate is in order. Assume the external field has a strength of H_0 Oersted and roughly approximating the core structure with a sphere, then the internal flux is

$$B = \mu \times H_0$$

where μ is the permeability of the core. The bulk permeability, after head fabrication, is in the order of 10^3. The presence of gaps in the core reduces this to an effective value of 30 (for a typical record head). The internal flux is further reduced by the demagnetization factor of the approximated sphere structure which is 1/3.

An external field of magnitude H_0 will therefore produce a core flux of roughly 10 x H_0, a fact we shall use later.

Deflection of Field by Magnetic Tape Pack

The effective permeability of the tape pack is so low (1 to 3) that the field deflections are minor, but the field direction will however, have influence on the magnitude of potential erasure.

The perpendicular field will be reduced inside the tape pack due to demagnetization:

$$H = H_0 - N \times J,$$

where H is the inside field, N the demagnetization factor and J the magnetic intensity formed on the outside layer of the pack. The magnitude of N is approximately One for a field perpendicular to a plate, and we can therefore, predict reduced erasure of inside recorded tracks as compared to edge tracks, i.e., the tape pack serves as a shield for its own tracks.

The side-to-side or front-tobback fields do penetrate the tape pack since the demagnetization factor is less than 10^{-1} for a disc in these field orientations. Partial or complete erasure may therefore, result from fields that are not perpendicular to the tape pack; this effect will be magnified when the reels are turning and the relative effect is an alternating field.

Erasure of Magnetic Tape

We can, from the foregoing, anticipate accidental erasure of magnetic tape in an unshielded recorder. This has indeed been reported in the past, and MMM Co., experimented to find the amount of erasure for a given field strength; their data are plotted in Figure 5. A quantative analysis of the effects of an external field is easily made by using geometric projections to and from the hysteresis loop for the magnetic tape coating.

The hysteresis loop for a prerecorded tape is shown in Figure 7, as an example. The remanences are $-B_s$ and $+B_s$ (saturation recording). Exposure to an external "positive" field has no effect on the $+B_s$ state while increasing field strengths will cause the $-B_s$ magnetization to shift toward and into positive values $-B'_s$, $-B'''_s$ by following the major hysteresis loop in the 4th and 1st quadrant. The corresponding remanence values are (after removal of the external field): $-B'_r$, $-B''_r$ and $=B'''_r$, by following minor loops. The net result of plotting remanences after maximum fields is shown in Figure 8, that shows signal degradation and partial erasure for increasing fields. Erasure is not complete except for very large fields (H> 1000 Gauss), but the drastic increase in erasure above 250 Gauss is evident.

The erasure of a recording made at a level of 6 dB below saturation can be analyzed in a similar manner and the result is shown in Figure 9; Both positive $+B_r$ and negative $-B_r$ magnetizations are affected and complete erasure occurs above H = 500 Gauss.

If the recorded tape is subject to an alternating field, as is the case when the tape loops through a recorder (see Figures 4 and 5, bottom), or the reels are turning, then the degradation may be even worse. The result is shown in figure 10, constructed from hysteresis loops similar to the example in Figure 11.

The transition between minimal and maximal erasure is quite pronounced, occurring around 270 Gauss, which also is the value for the coercivity H_c of the magnetic tape used in the above example.

We can hence conclude that a 6 dB - below - saturation recording will be affected at field strengths of 50 - 100 Gauss, and will be severely erased above 300 Gauss. And we have seen that this field can be brought about by a 10 times smaller external field, if picked up and focussed by the heads. We can therefore, expect signal degradation of pre-recorded data at 5 - 10 Gauss, and severe erasure at 30 Gauss and above.

Distortion of Recordings

Recording of Magnetic Tapes in the Presence Of an External Magnetic Field

Most digital recorders operate with saturation recordings, while newer, high packing density units utilize AC-bias during recording.

The transfer curves for the two techniques are shown in Figure 12. It is evident that the AC bias technique is extremely sensitive to even a small biasing (superimposed) DC field, while saturation recording is relatively insensitive to fields less than 100 Gauss.

An example is a 6 dB - below - saturation recording made with a data field of ± 50 Gauss. The recording will be totally asymmertrical for a DC bias field of 50 Gauss, which in turn can be caused by a 5 Gauss external field due to head focussing.

Recording of DC Magnetized Tapes

We have seen that an external field can saturate the magnetic tape into the $+B_r$ or $-B_r$ direction when it passes over the erase head (which actually reords the external field onto the tape). This magnetized tape will present a DC flux at the record head and cause a DC off-set (or bias) of the transfer curve with resulting distortion. It is difficult to assess the field value that will cause trouble, since the tape remanence will be to low to affect the recording field, but strong enough to “re-record” itself across the gap with resulting distortion. This distortion will, during playback, cause zero-crossing (and phase) shifts which may cause bit errors.

Experiments

Verification of the presented predictions were carried out by experiments using an instrumentation set-up as shown in Figure 13. The field in the center of the large coil was measured with a Hall element prove, prior to insertion of the recorder. All following field readings were made with the probe located as shown.

The recorder contained a pre-recorded tape which allowed us to make the first tests a determination of signal degradation due to an external field during playback only. The recorder was identical to the unit shown in Figures 2 and 3. The packing density was 6 kbpi, the recording speed 4 IPS and the playback speed 32 IPS.

Playback of Pre-Recorded Data in an External Field

The unit was oriented for the worst case field orientation-, front-to-back. The playback signal was monitored on an oscilloscope, prior to limiting, and signal degradation judged on the amount of erasure.

The signal amplitude started dropping at 5 - 7 Gauss and then decreased linearly with increasing field strength. At 28 - 30 Gauss the amount of erasure was 20 dB, and bit errors began to appear. Phase distortion became pronounced, and at 35 Gauss the errors were in abundance and the played back data at total loss.

Recording of Data in External Field, Playback without Field

In this test a combination of magnetized tape and DC biasing of the record field was tested. Signal degradation was noticed at 10 - 14 Gauss and at 30 Gauss the played back data were a total loss.

Recording and Playback of Data in an External Field.

All degrading affects of the external field were acting in this test: DC magnetized tape, a DC biased recording field and partial erasure of the recorded tape. And signal degradation was observed above 5 Gauss, and the played back data total loss above 25 Gauss.

Effect of Field Orientation

The recorder was sensitive to all field orientations except one: perpendicular (as predicted). This preferred orientation allowed recording and playback in the maximum possible field, 160 Gauss. The playback level was only reduced 1 dB, and there were no errors.

However, this orientation is very critical. By turning the unit only a few degrees, signal deterioration started rapidly. Since the direction of the anticipated field from the attitude control subsystem will shift in magnitude and orientation as well, advantage cannot be taken of this particular recorder orientation.

Effect of External Field upon Motors, Relays, etc.

Motors and relays are closed magnetic circuits, and no performance degradation anticipated. Reed relays may be exceptions, and we found that the magnetic tachometer in the servo drive system was highly susceptible: The superimposed external field distorted the tachometer signal so speed synchronization was very poor at 30 Gauss, and complete loss of phase lock occured at and above 34 Gauss.

Remanent Magnetization of the Recorder Unit after Exposure to External Field

The magnetization of the recorder was measured before and after the tests and the results plotted in figures 14 and 25. The curves show the magnetic field from the recorder during a 360° rotation, with a field probe located 0.5, 0.7 and 1.0 meters from the center of the unit.

At a distance of 0.5 meters the maximum field was 0.002 Gauss prior to test, and 0.011 Gauss after. This is largely attributed to DC magnetization of the tape packs. .

CONCLUSIONS

An unshielded tape recorder is susceptible to external magnetic fields, Predicted and measured degradation of the record and playback signal correlate and rank as follows:

Above 5 Gauss:	The amplitude of recorded data is reduced.
Above 25 Gauss:	Loss of digital playback when external field is present during both recording and playback.
Above 30 Gauss:	Loss of digital playback when external field is present during recording only.

Above 35 Gauss: Loss of digital playback when external field is present during playback only.

These figures are typical and will vary among different recorders, configurations and head constructions.

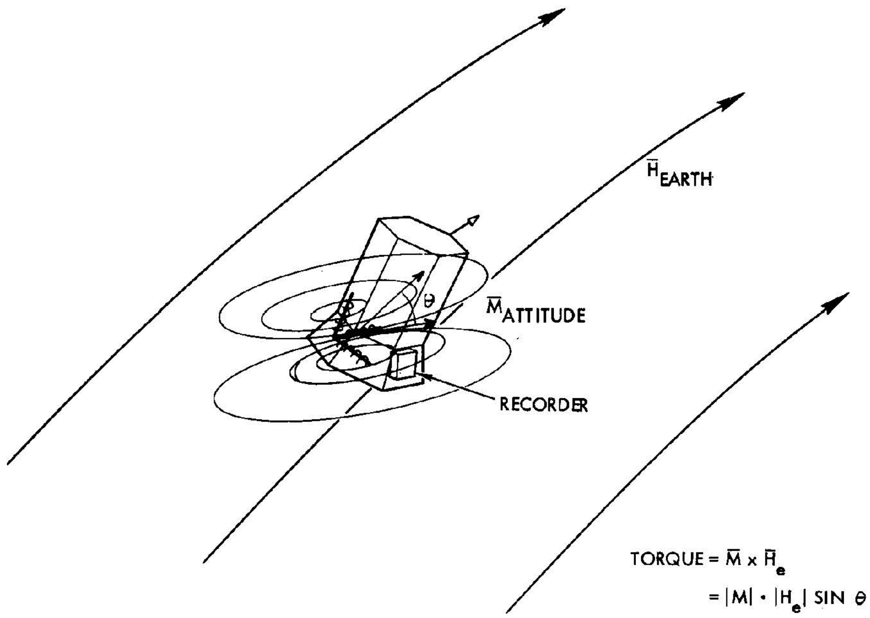

Figure 1. Magnetic Attitude Correction for Spacecraft

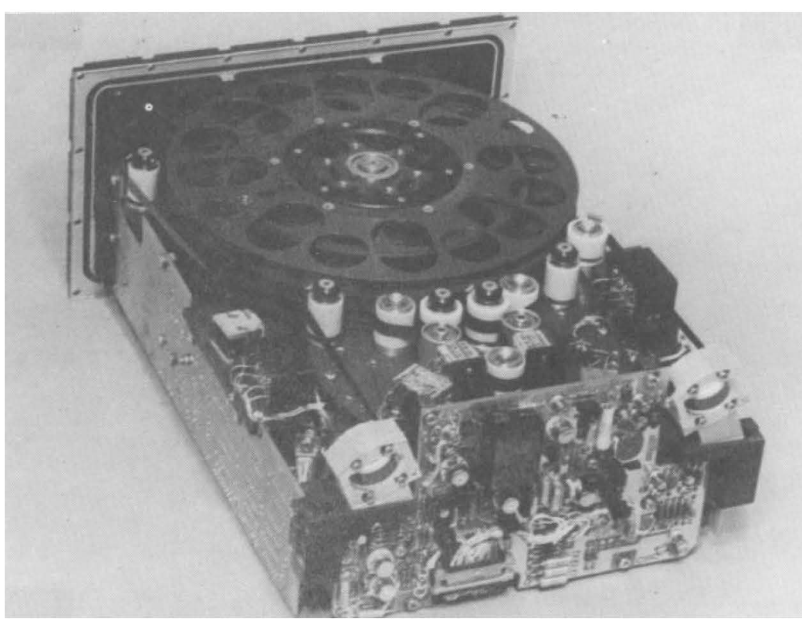

Figure 2. Tape Recorder Out of Enclosure (Courtesy, Odetics, Inc.)

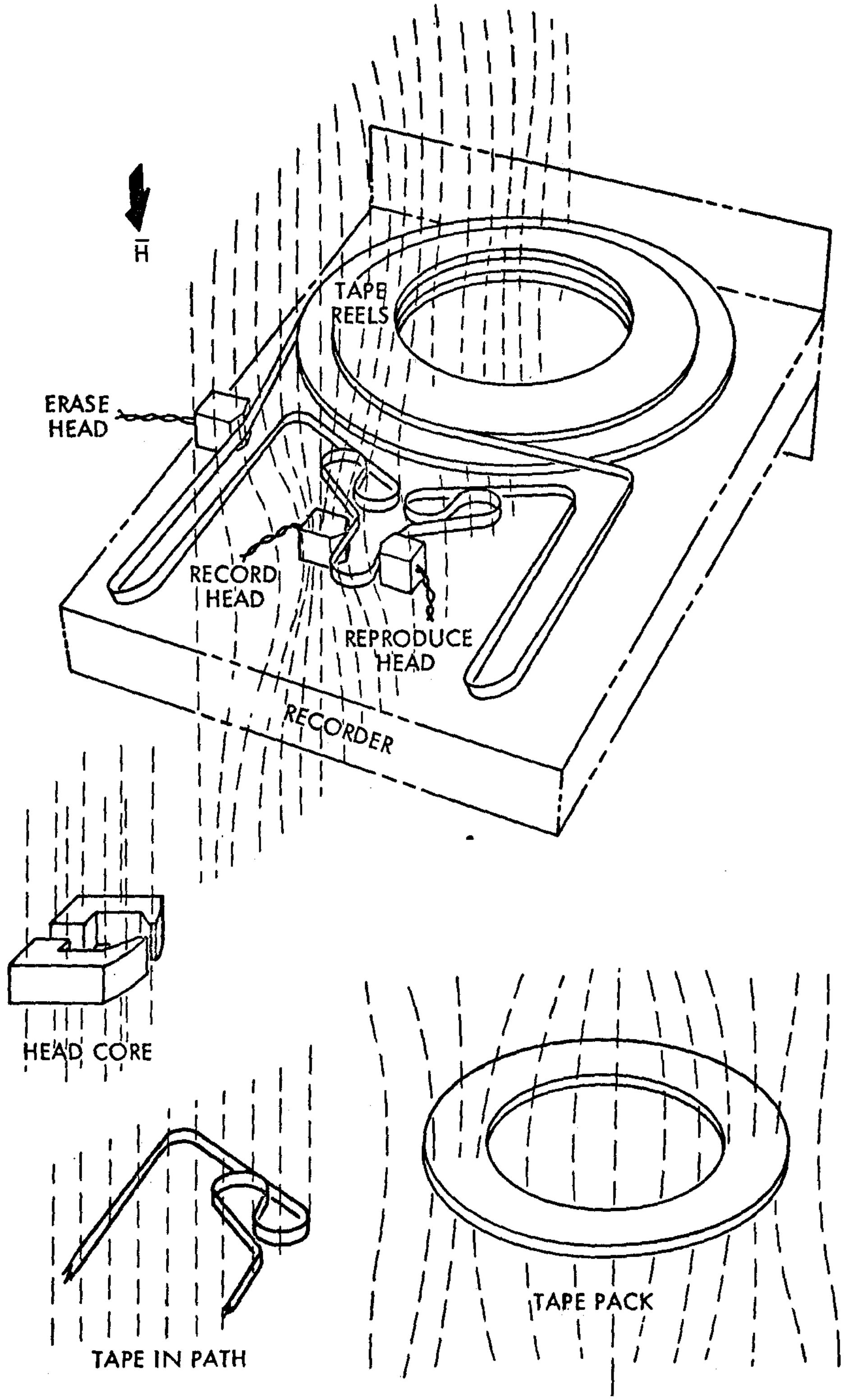

Figure 3. Deflection of a Perpendicular Magnetic Field

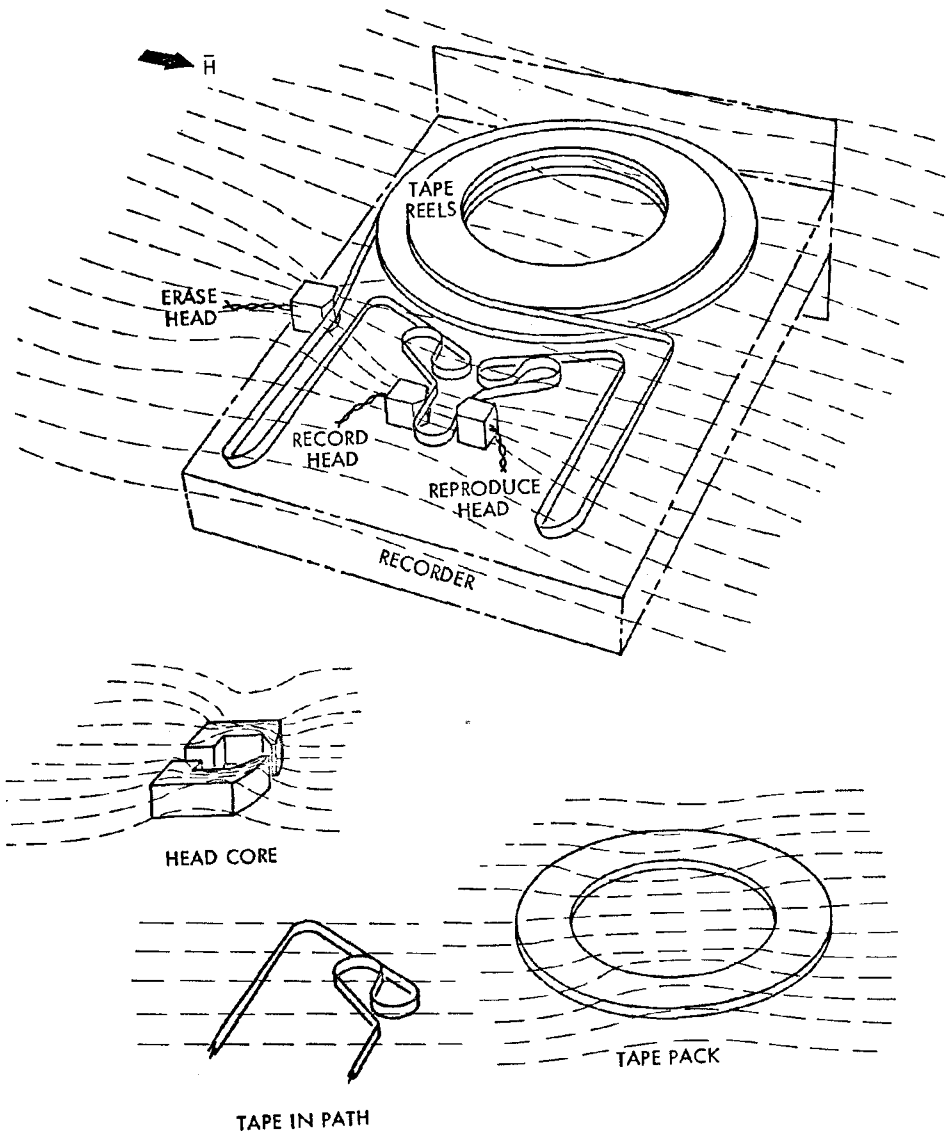

Figure 4. Deflection of a Transverse Magnetic Field

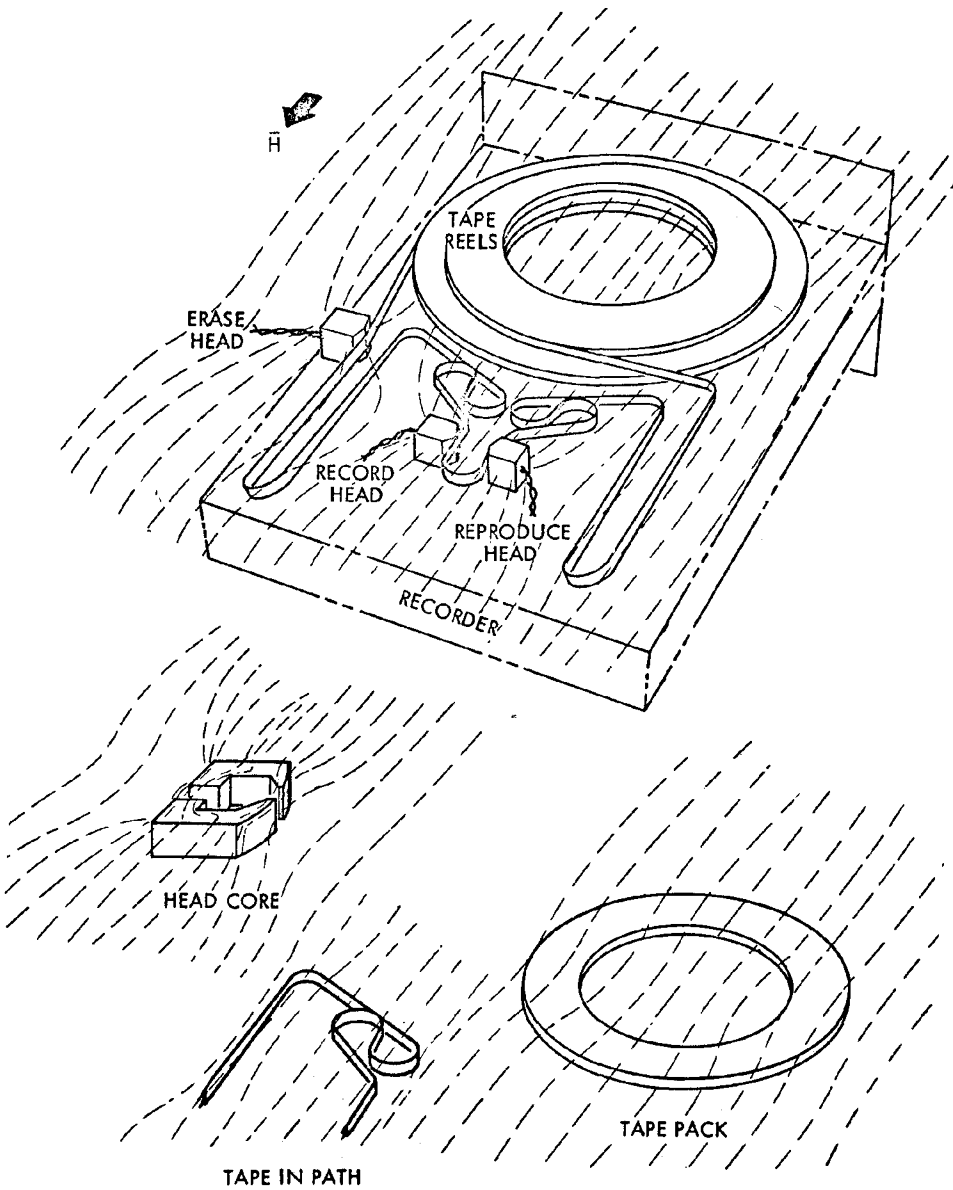

Figure 5. Deflection of a Front-to-Back Magnetic Field

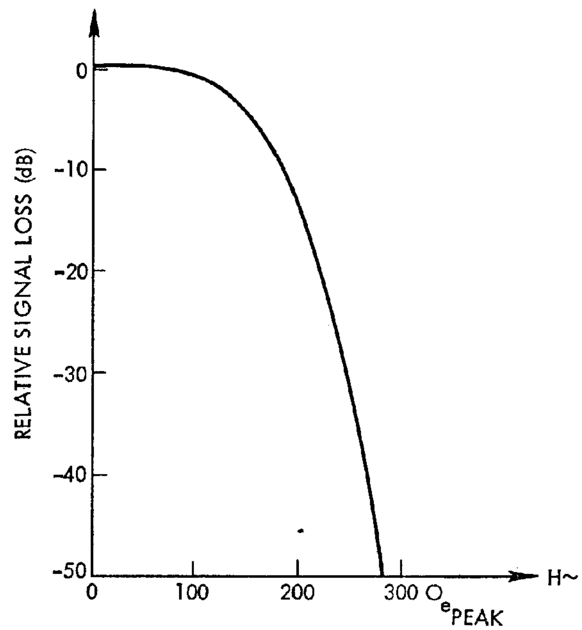

Figure 6. Erasure of Magnetic Tape in an A.C. Magnetic Field (after 3MC$_0$)

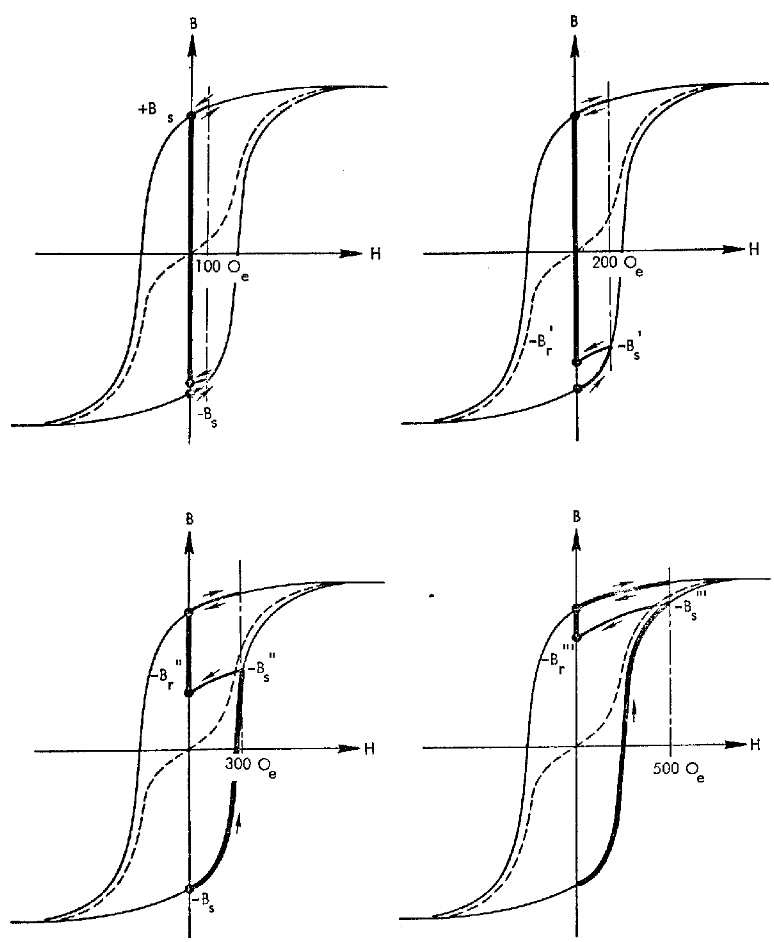

Figure 7: Distortion of Recorded Data in a DC Magnetic Field of Strengths 100, 200, 300 and 500 Oersted. Original Recorded Saturation

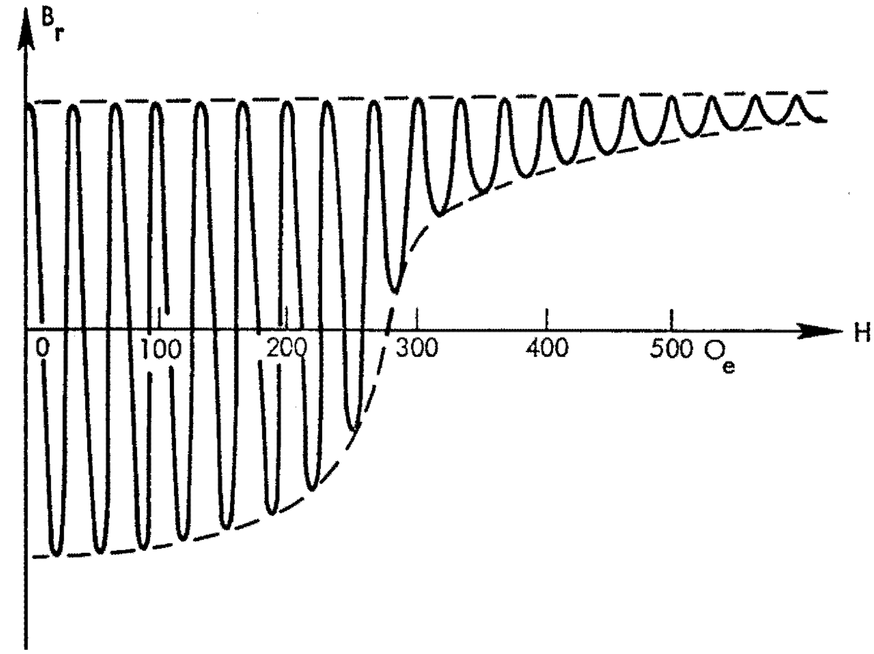

Figure 8. Distortion and Erasure of Saturation Recording by an External Field H

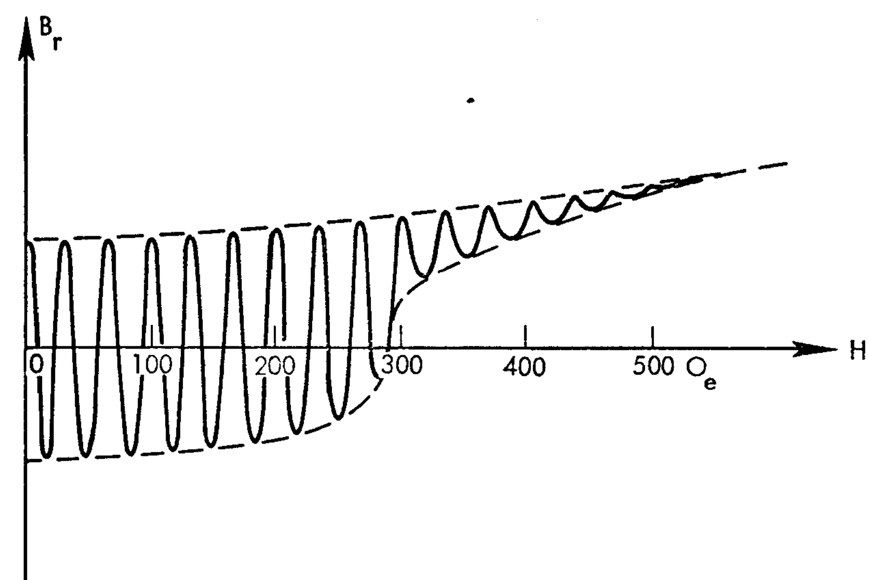

Figure 9: Distortion and Erasure of 6 DB-Below-Saturation Recording by an External Field H

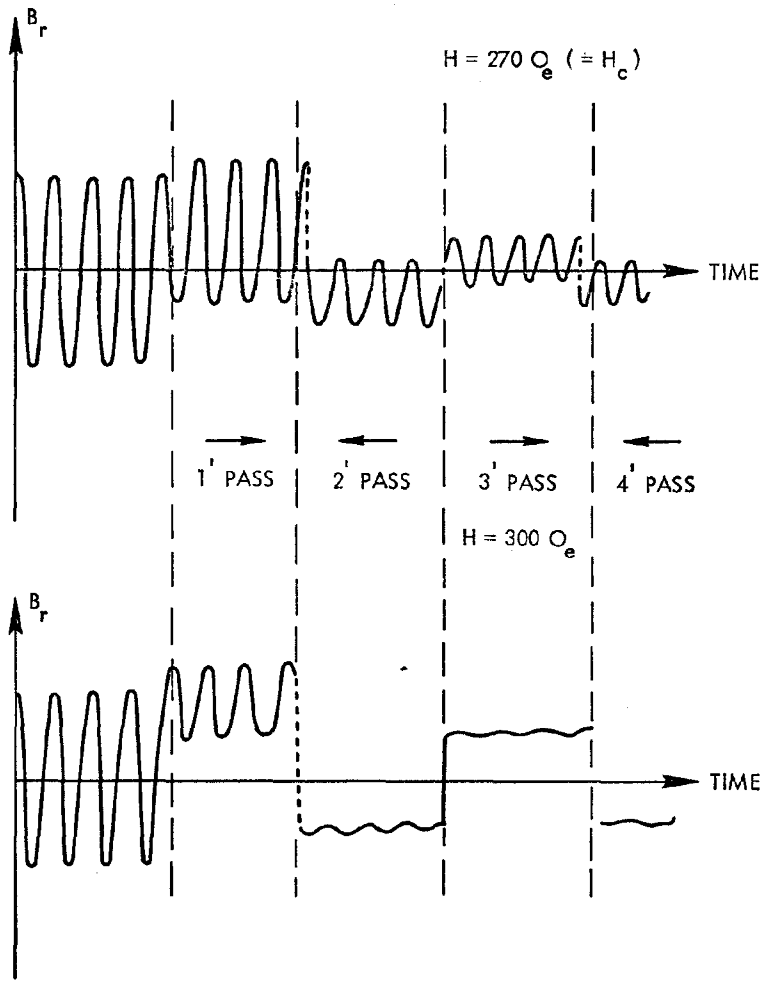

Figure 10. Distortion and Erasure of a 6 DB-Below-Saturation Recording by an Alternating Field

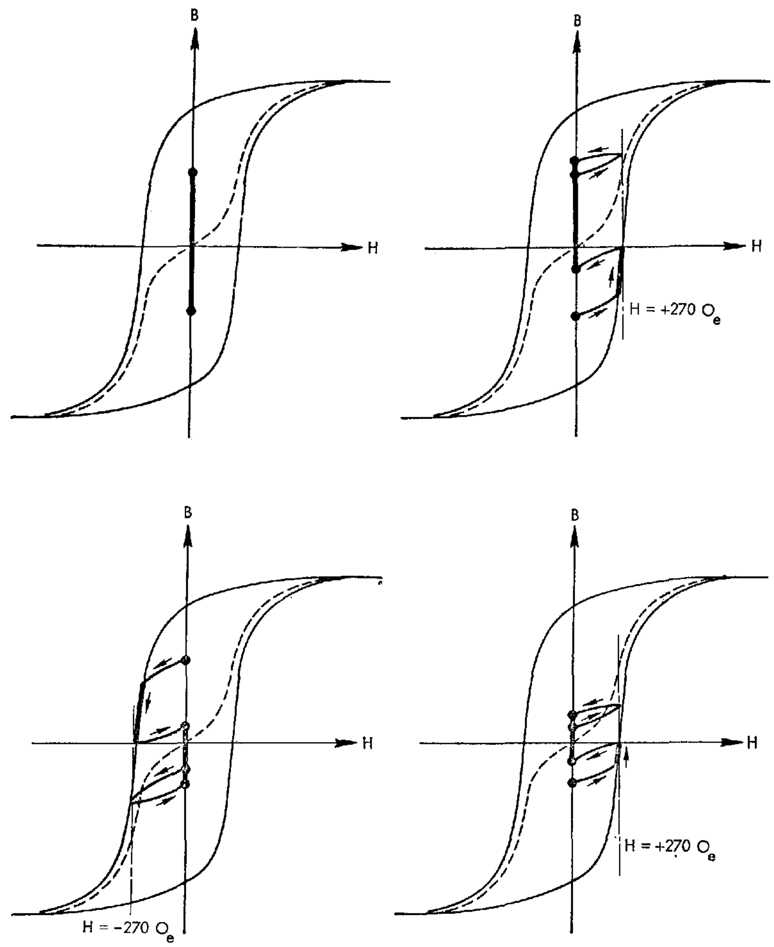

Figure 11. Distortion and Erasure of a 6 dB - below Saturation Recording by an Alternating Field of Strength ± 270 Gauss

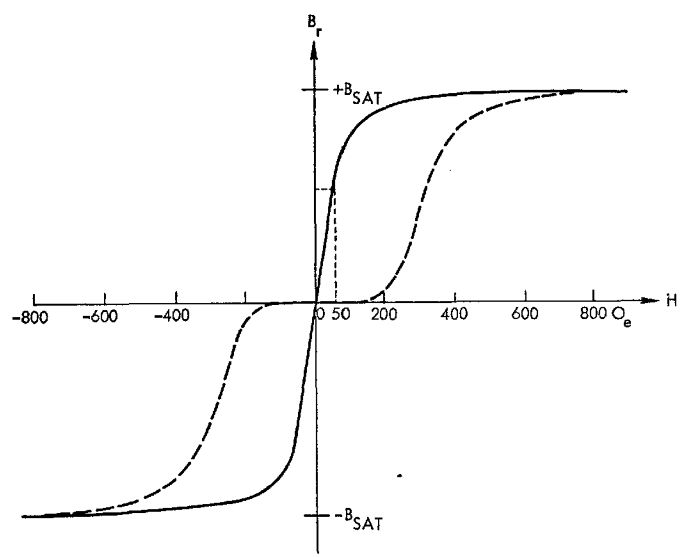

Figure 12. Saturation Recording Transfer Curve ----, and AC-Bias Transfer Curve.

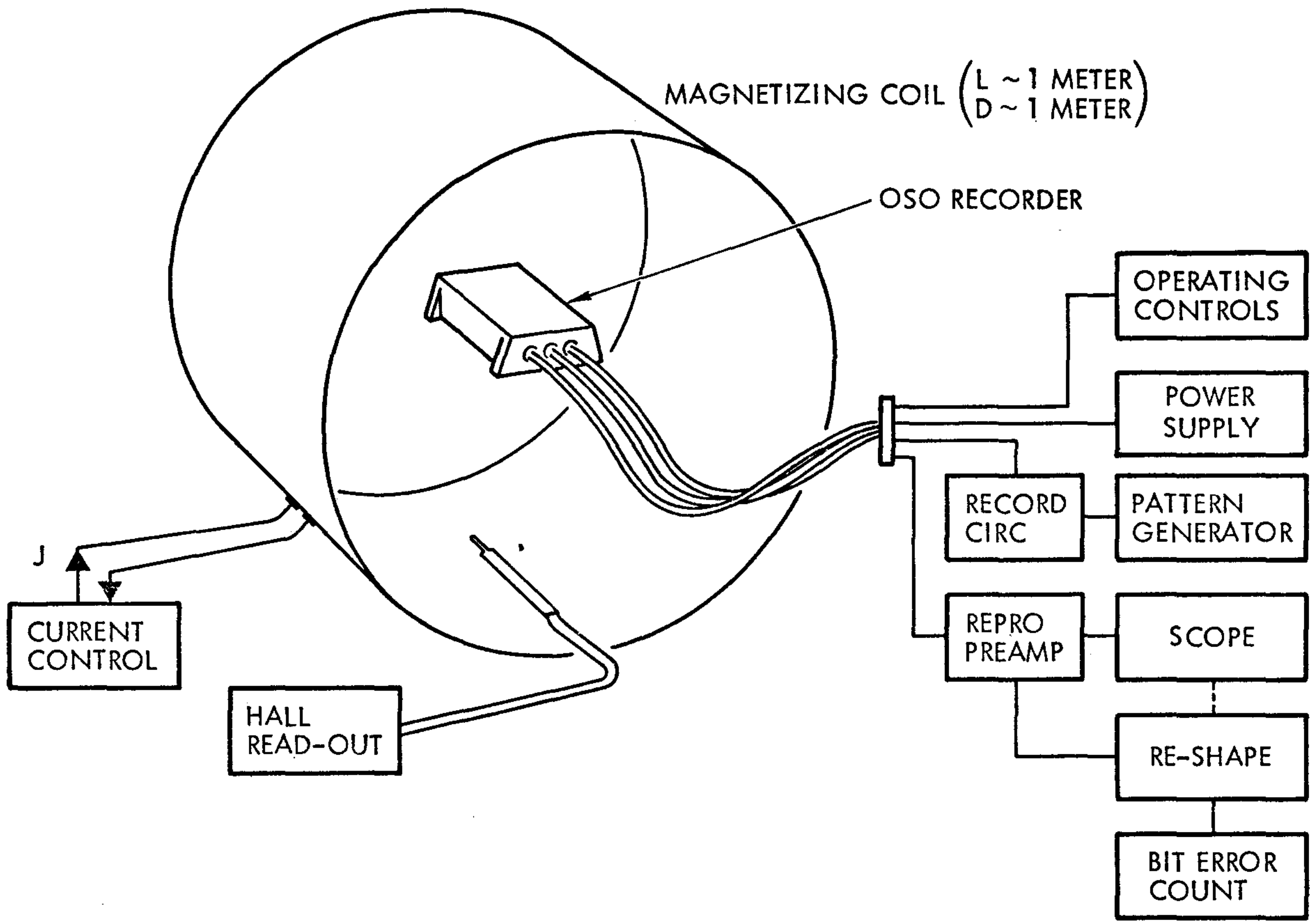

Figure 13. Instrumentation for Measurement of Tape Recorder Performance in an External Magnetic Field

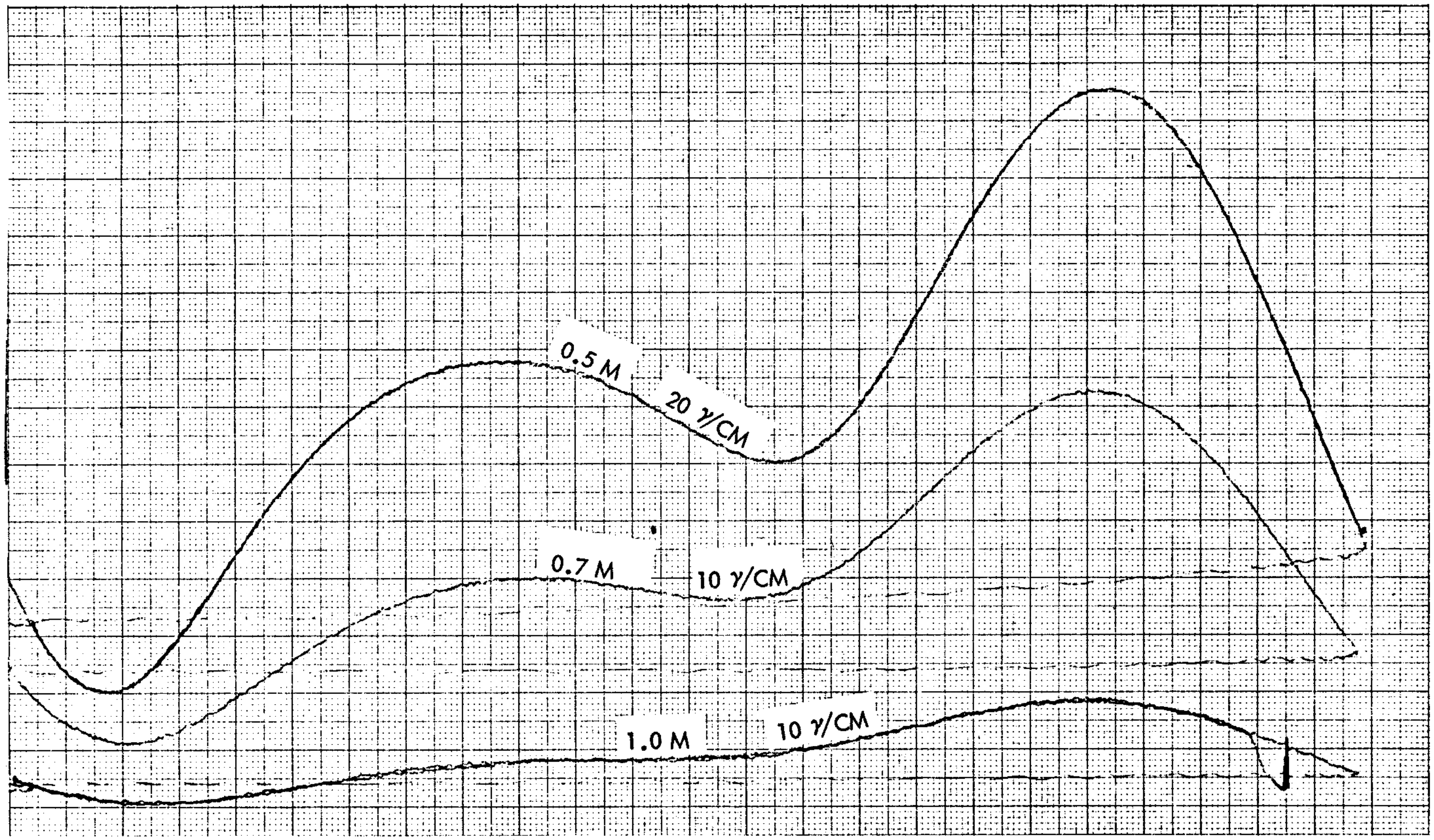

Figure 14. Residual Magnetization of Recorder <u>Prior</u> to Tests

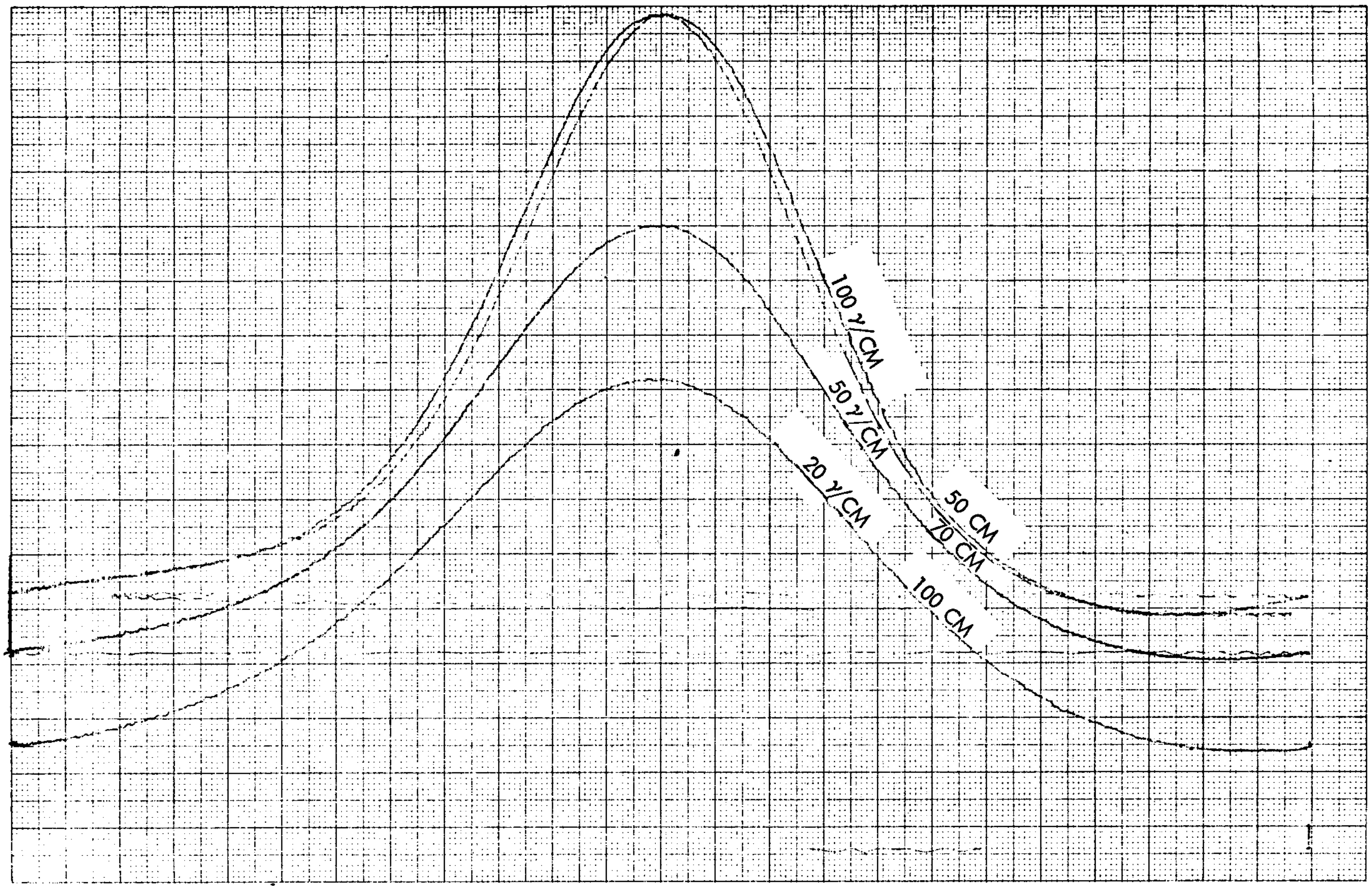

Figure 15. Residual Magnetization of Recorder After Test