SECTION 7

Practical Techniques of Measurement

HOW TO MAKE INDUCTION LOOP MEASUREMENTS OF A REPRODUCE CHANNEL

Induction loop response measurements utilizing a single turn of wire parallel to the reproduce head gap are frequently mentioned in standards recommendations and the literature in general. Before describing the technique, and practical methods of performing the measurements, we should state what the test will and will NOT achieve. Properly performed induction loop response measurements *will* provide data relative to the electrical characteristics of the system. Included will be useful data pertinent to head resonance, playback amplifier response, and core losses of a specific head. The technique will NOT provide data relative to spacing loss, (i.e. tape to head contact), gap loss of the head itself, "head bumps" due to the physical design of the head, nor losses due to misalignment. The distinction between a "standardized" reproduce channel with an IDEAL repro. head, and a channel adjusted to vary from the ideal electrical characteristic to compensate for the imperfections of a practical head must be understood. The common 7½ ips 50 and 3180 micro sec, NAB curve would call for an induction loop response showing a 13.6 dB rise at 15kHz referenced to 400Hz, and a 3 dB drop at 50Hz. In employing a practical head, there will usually be some gap loss and this must be compensated for, although the deviation from "ideal" in repro. heads is becoming quite small. A good head supplied for the purpose above might show a deviation of only a dB or two at the upper and lower frequency extremes. The present tendency with the shorter gap spacers being employed is to find most of the deviation at the low end—due to head bumps resulting from core design shape. Some core loss is to be expected, but this will show up in the induction loop measurements.

The following technique for loop response measurements may be conveniently employed in most laboratory or shop environments. In addition to the reproduce amplifier and playback head, you will need the following:

Two VTVM's

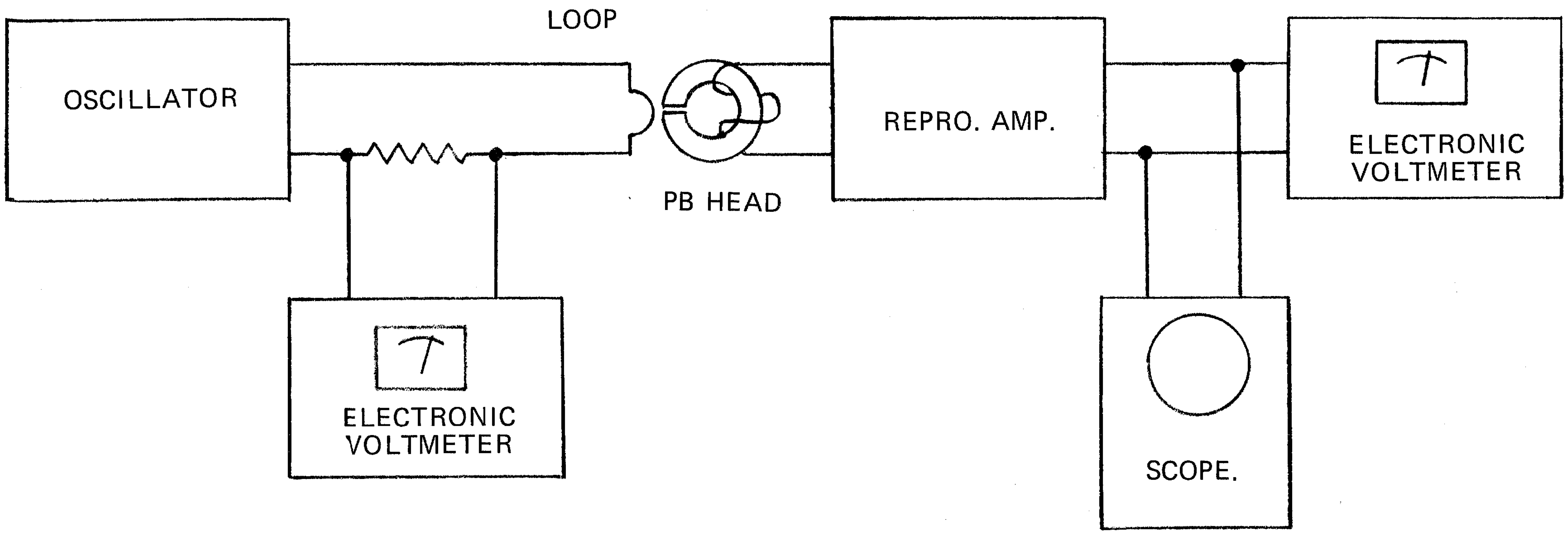
A short piece of small diameter enameled wire

A resistor (10 ohms is fine)

An audio oscillator

Leads to connect as follows:
(See drawing)

METHOD FOR INDUCTION LOOP MEASUREMENT



A single piece of wire is positioned up against the head with attention given to secure it in a parallel relationship to the gap. It should be as close as possible to the gap. Obviously, care should be taken not to scratch the head, and therefore, you may want to put a layer of masking tape over the head's surface and then secure the wire with another piece of tape. If loop measurements are to be made frequently, you will appreciate the convenience of a spring clip jig or holder for the wire such as the one illustrated on page 5. Such a device can be easily fabricated and quickly attached or detached. Since heads come in many sizes, you will have to make a loop holder to fit the type of head stack involved. Notice that the wire can be laid in a groove of plastic material in such a way to insure that the head surface cannot be scratched. A piece of masking tape can be permanently left on the holder to protect the head.

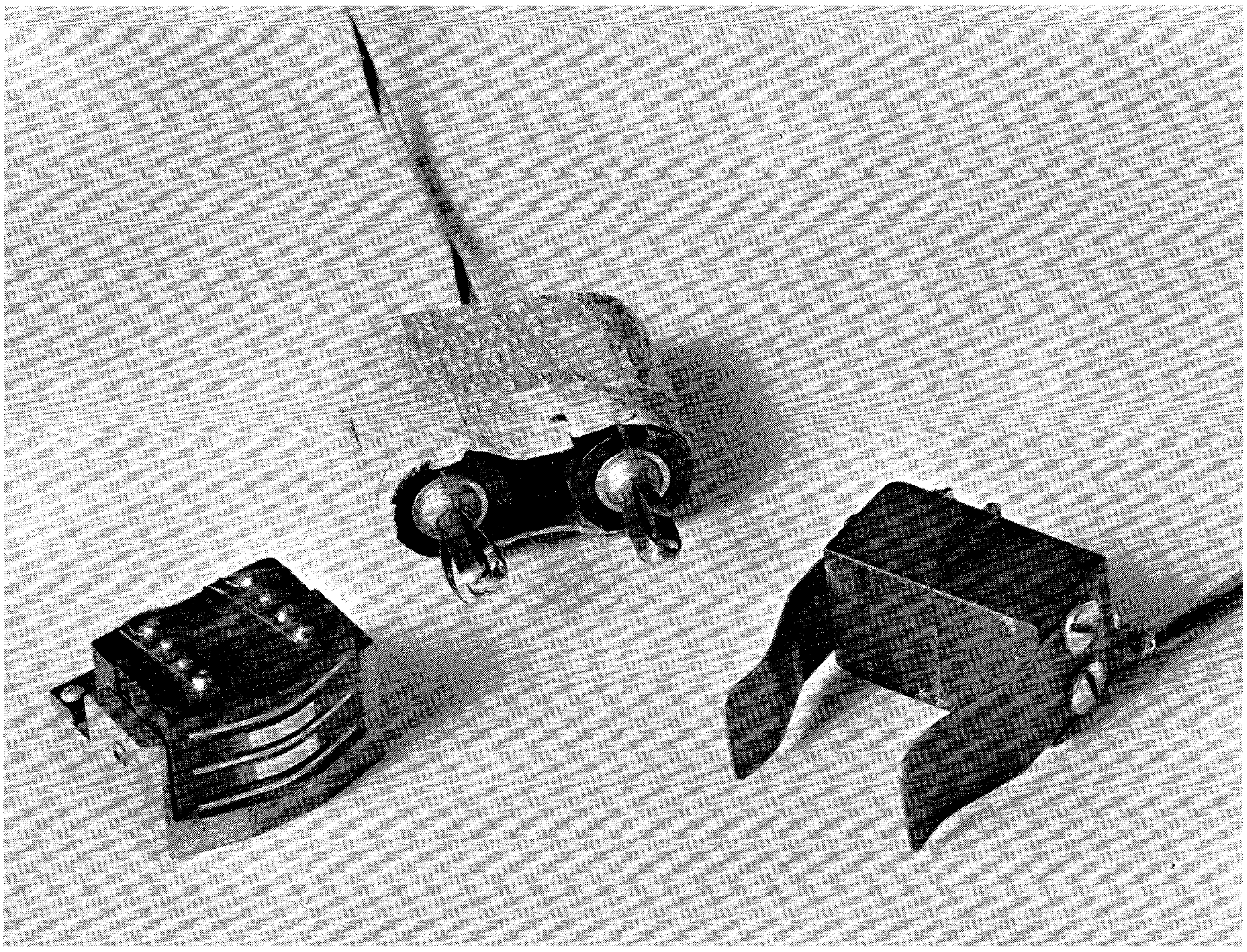
Some added considerations:

(1) The response is not affected by the "azimuth" relationship of the wire to the tape head gap, however maximum signal will result from careful placement as above.

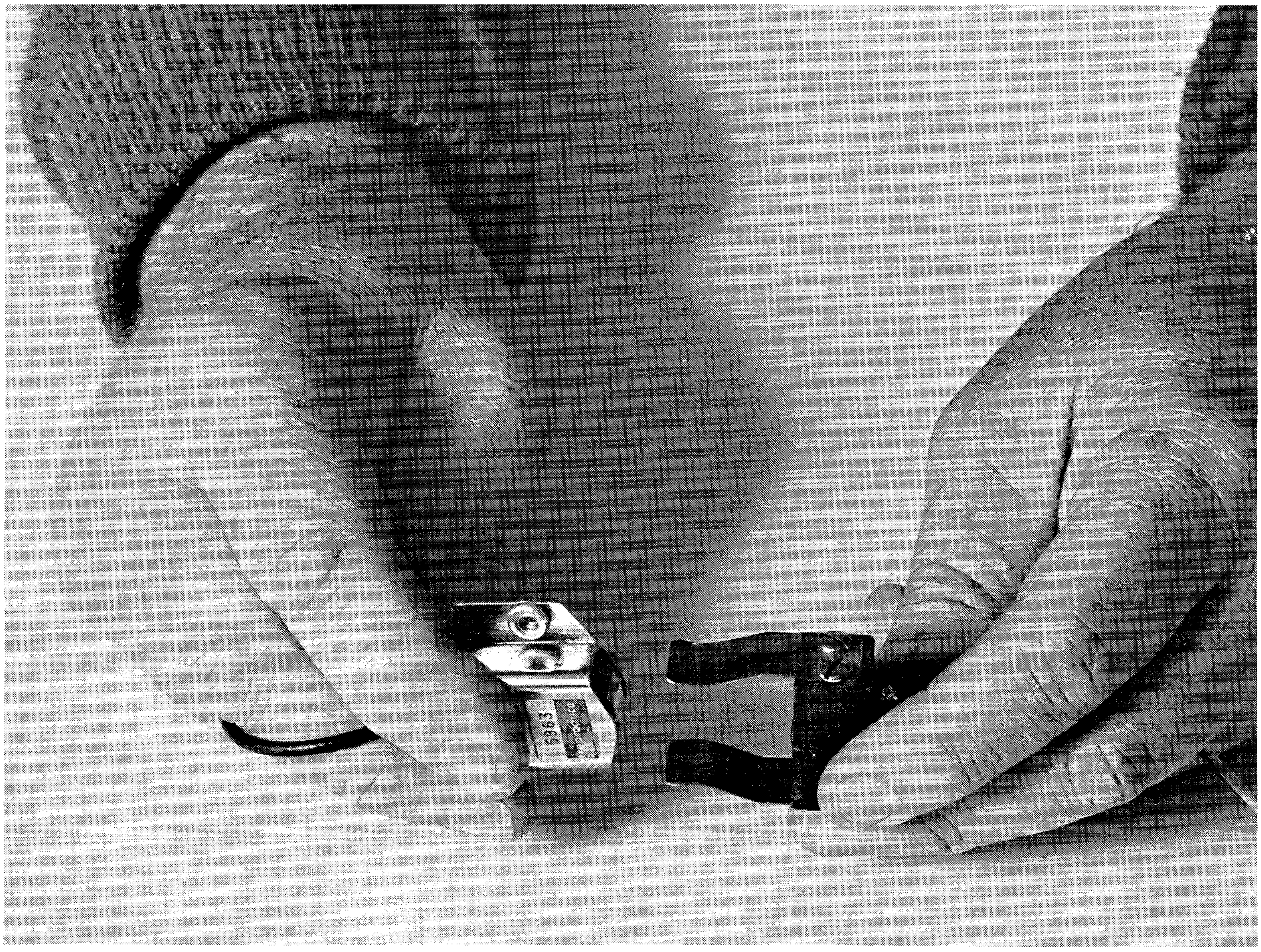
(2) The usual audio oscillator will only provide a signal at 400Hz of sufficient strength to produce a ZERO reading on about the –30 dB scale of the voltmeter which is connected to the output of the playback amplifier.

(3) It is best to make the measurements with the level control on the playback amplifier set in the normal position for two reasons: (a) Some equipment may vary slightly in response at different level settings. (b) The induction loop will show a rising response with frequency, and if the 400Hz reference were set to ZERO on equipment having a time constant of say 120 microsec, the high frequency region of measurement could easily produce amplifier clipping resulting in a misleading reading. I have personally encountered two such cases resulting from the above problem; both happened in professional areas, one a laboratory, the other a large recording company's engineering facility. The best policy is to include a 'scope at the amplifier output and watch for any clipping. You may wish to measure a channel that has been adjusted to reproduce a test tape with flat response. Provided the tape is accurate, the result of a loop response test will indicate how much compensation was necessary to make up for gap, spacing, core, and geometric losses in the head.

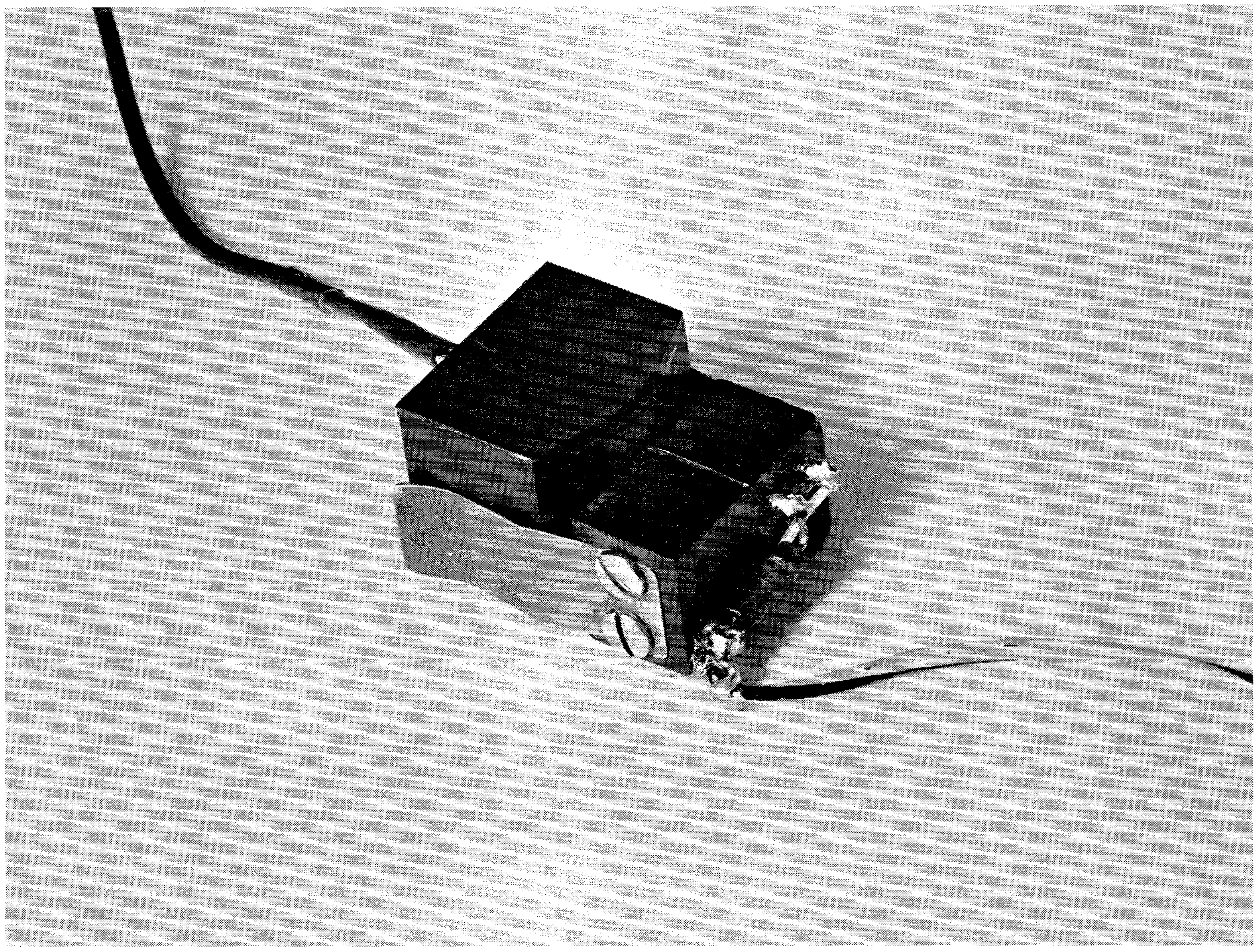
Another possible use for the loop response test would involve the calibration of a reproduce alignment tape by means of a known reproduce head. By "known", we mean a head that has been measured carefully to determine its actual core, gap and contour deviations from ideal. With such a head connected to a repro. amp which has been corrected for these head losses, a reproduce alignment tape can be examined for agreement. We have found, incidentally, that the most reliable data result from use of heads which are made to be as near "ideal" as possible. One reason, other than the fact that any error involving a large correction factor usually results in a large error, is that heads departing from "ideal" by a wide margin often make measurements very uncertain. Best case in point would be the use of a 300 micro inch repro. head to calibrate a tape's short wavelength recordings. The readings would be unsteady and the measurement, therefore, uncertain. There was a tendency, unfortunately, for some standards committees, in the past, to use components with gross deficiencies when determining measurements of recorded materials. Often the corrections, each with its own inevitable error of measurement, compounded to provide a mathematical treatise of many pages, representing an experiment that was probably un-



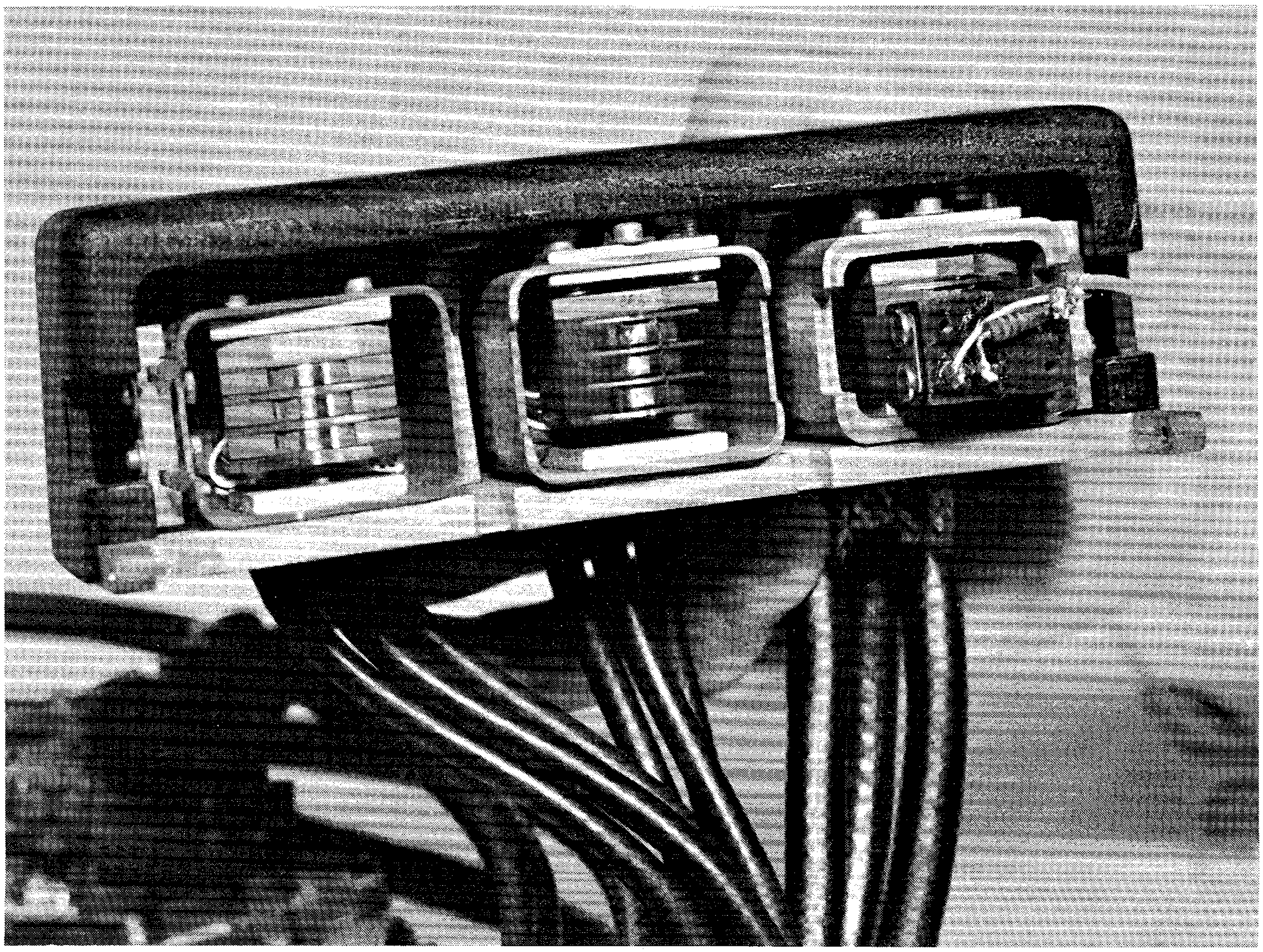
One turn wire fits in groove in plastic block.



Induction loop jig is held in place by means of spring clips.



Resistor and extra leads facilitate current measurement.



Jig in place on reproduce assembly.

repeatable. The best agreement and repeatability of loop measurement tests as related to response tapes can be achieved by use of a repro. head as close to ideal as the state of the art allows.

In actual use the loop test is simple:

A mid frequency reference tone is supplied to the wire. (400Hz is most often used for the reason that the major American standards committees have shown 400Hz as the zero reference on their charts). The level from the oscillator is adjusted to produce the zero reference on the voltmeter scale (actually about –30 dB as stated above). This meter is connected to the OUTPUT of the repro. amplifier. An additional voltmeter is bridged across the ten ohm resistor in series with the wire. The voltage drop is noted and all subsequent tones are fed to the wire at the same level. In this way we can be sure that the current through the induction wire is the same at all frequencies. Remember, in making any of these measurements that you are seeing the electrical response of the head, plus the cable, plus the amplifier. You can, by sweeping the oscillator, quickly determine the resonance of the system. The cable capacitance will often affect the resonance, so it is well to employ the SAME type of cable from head to amplifier as will be used in practice, when you make loop measurements.

Your attention is called to the introductory remarks heading Section 5. Much confusion occurs when playback amplifier curves are compared to loop response curves. They are NOT the same, but are directly related. How they relate will be found in Section 5.

HOW TO MEASURE CONSTANT CURRENT THROUGH THE RECORD HEAD AND MEASURE HEAD CONTOUR EFFECTS:

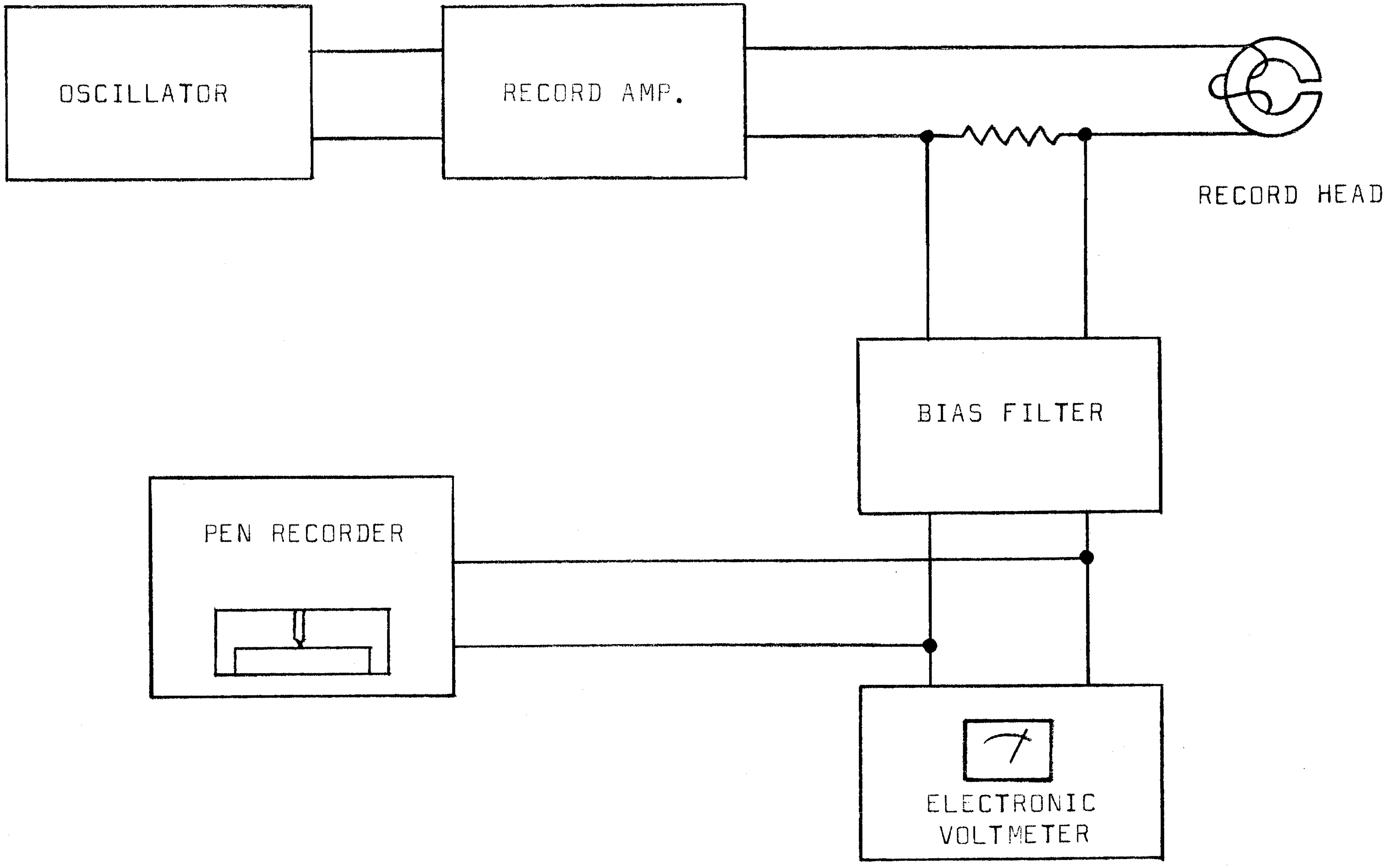
It is often convenient to make constant current recordings to evaluate raw tape stock differences, to calibrate low end playback head effects, or to set up a system intended to record constant current with a variable high frequency repro. equalization. Perhaps the most often encountered need for constant current techniques involves the measurement and separation of the contour, fringing and low frequency equalization variables which occur in the same part of the audio spectrum.

Consider the need to determine the head bump (contour effect) of a given reproduce head. Using a good quality record head having the SAME track width as the repro. head to be used, a test tape having a series of tones, or even better, a slow sweep of, for example, 30Hz to 500Hz is recorded with constant current, through the record head coils at each frequency. The resultant tape may now be played back with the head to be measured connected to a FLAT amplifier (electronic voltmeter). Since an ideal head under such conditions will produce a signal rising 6 dB per octave, any variation from this result will indicate effects due to contour design of the playback head.

If the track recorded corresponds to the track width of the playback head, no fringing effect will be noted, and as no low end characteristic is added in recording the constant current tape, these two elements of consideration are removed. Several precautions should be noted: In making such constant current measurements, a record stack of good quality with proper core design should be used to avoid losses at low frequency.

Long wavelength "peaks" and "valleys" will be best shown when spot tones are recorded at very close frequency intervals, or where a pen recorder can be employed to track on frequency paper the reproducer output. Constant current does not imply constant flux level on the tape at all frequencies; however at long wavelengths, constant current through the record head will produce recordings of

METHOD FOR PLOTTING RECORD CURRENT — DURING RECORD MODE

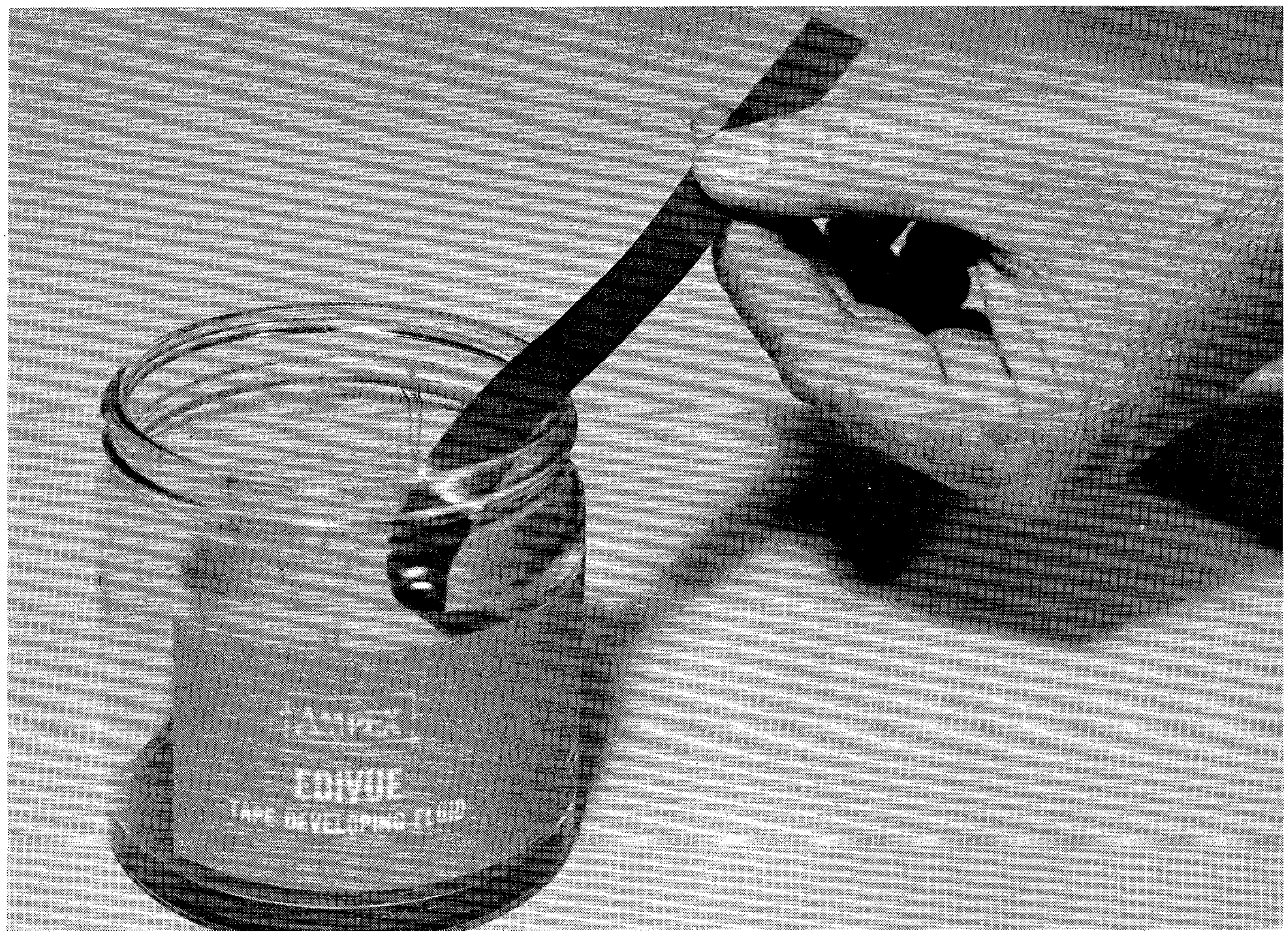


constant flux level within the needs of practicality. Above medium wavelengths, the tape oxide and thickness differences cause differing results depending on the tape used.

To set up for constant current measurement: Determine the current through the record head required to produce a normal level signal at 700Hz or 1000Hz. A 100 ohm resistor can be inserted in one leg to the record head and the voltage drop across the resistor noted. The same voltage drop should be maintained for all tones supplied to the head individually or during a slow sweep either from a pen recorder oscillator unit, or manually with marker or voice identification included. Care must be taken to insure that the bias current signal is not reaching the meter reading across the series resistor during the recording process. On many machines the easiest expedient is to pull out the oscillator tube, or card, and pre measure the current through the head in record mode to insure that it is flat, and then put the tube or card back in and proceed to record the tape "blind". Of course filters, if available, can be used to make possible simultaneous monitoring while recording. Please note that most American made tape recording equipment has some low frequency compensation in the record channel. The "NAB" low end, i.e. 3180 microsec., provides a bass boost of 3 dB at 50Hz with 1 dB at 100Hz. Therefore a true constant current recording will be found to roll off by this amount when played on such a reproducer. This tape would play back flat on a machine without low frequency compensation, as for instance one incorporating European standards.

HOW TO MEASURE TRACK WIDTHS:

It is often necessary to know the exact track width of a recording, such as when measuring a flux level using the "direct method" with a special flux measuring head. As indicated in Section #2, the track width is one of the required items to use the formula.

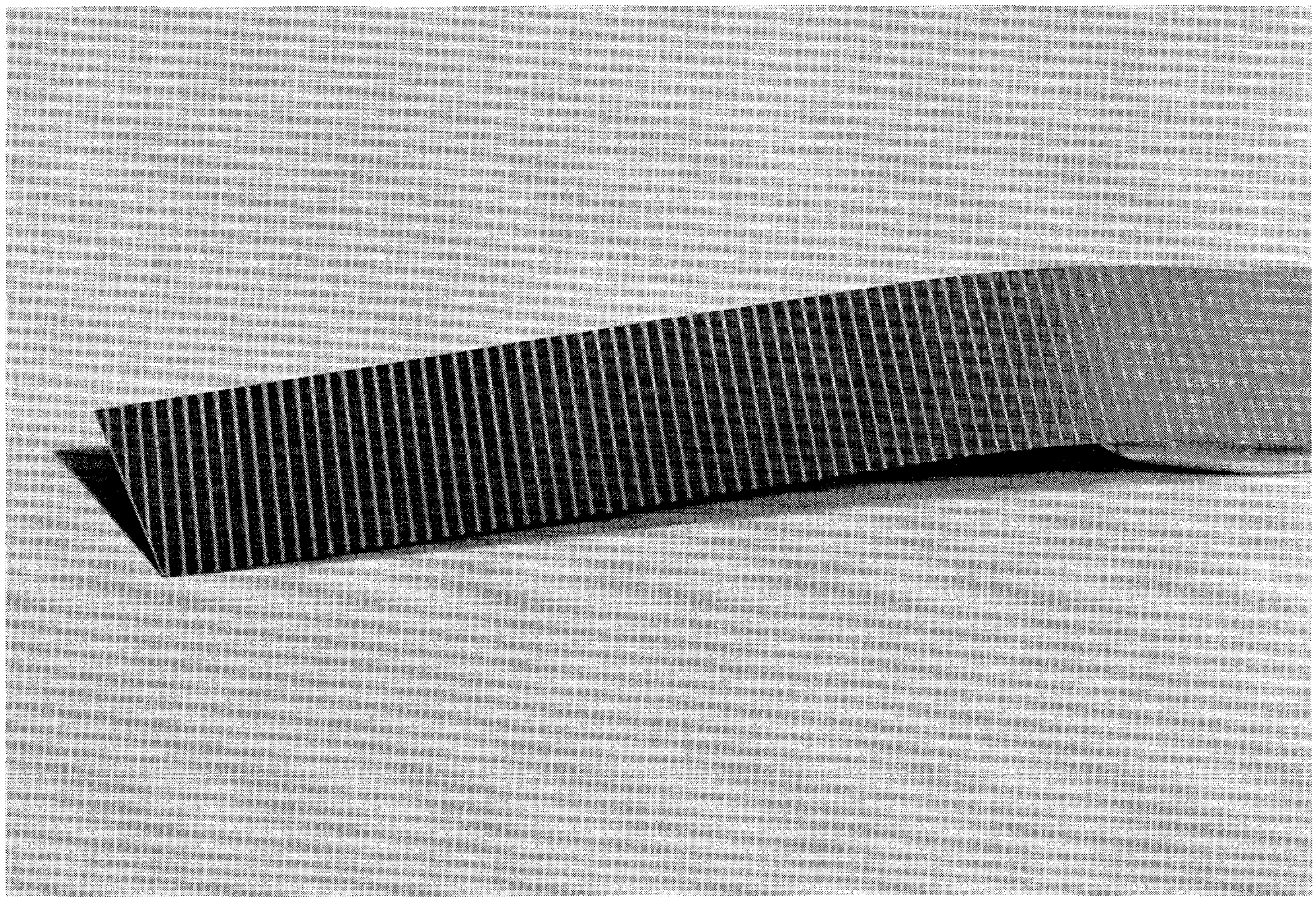


Tape is dipped into indicator fluid.

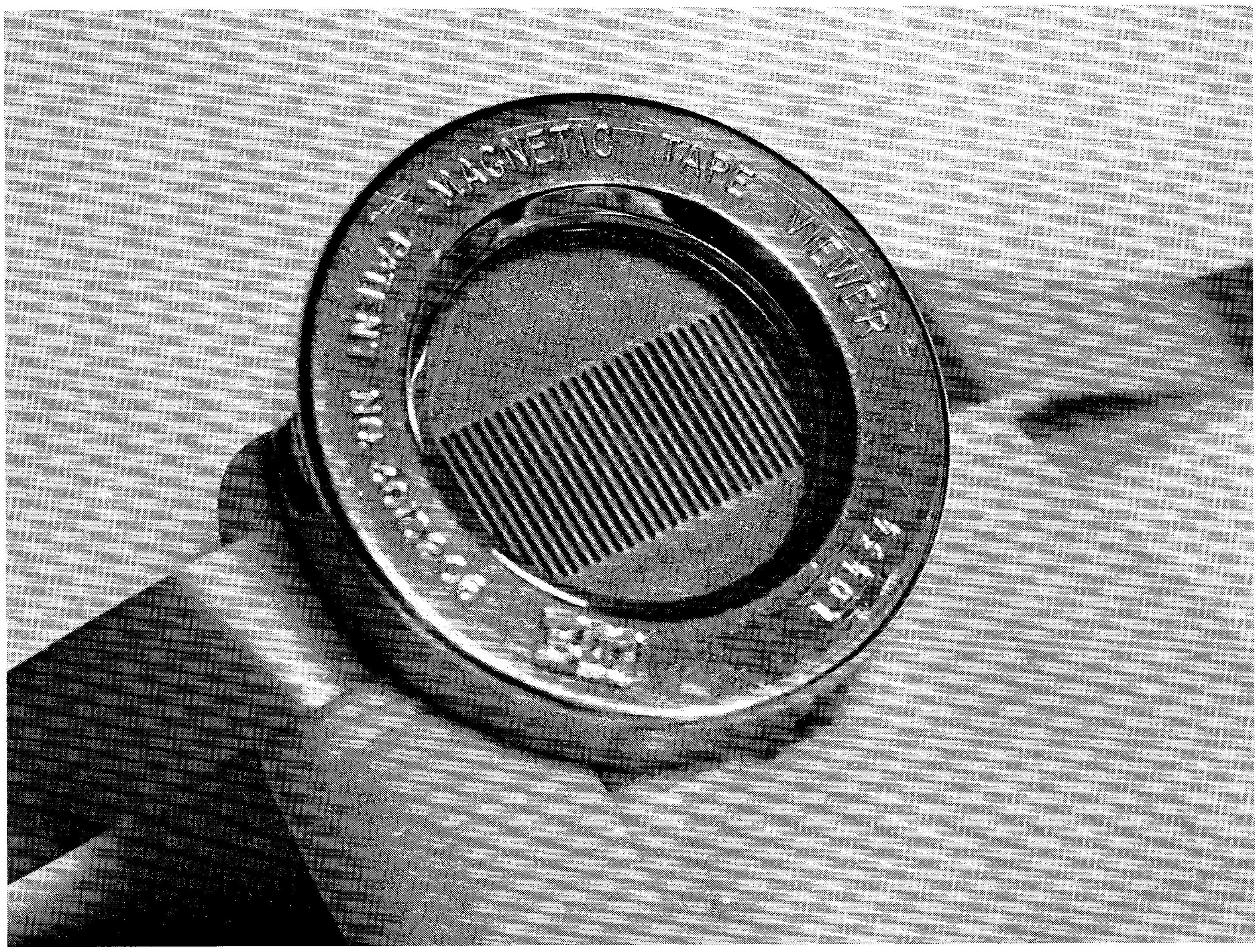
The vertical location of a record head may be determined by means of edge track width measurement.

The most commonly encountered means of track width measurement involves use of indicator fluids made of carbonyl iron particles in evaporative solution. The resultant pattern is then measured with a tool maker's microscope, optical comparator or other optical device. These instruments are capable of very accurate measurements, PROVIDED THE PATTERN IS ACCURATE AND OF GOOD RESOLUTION. How could the pattern NOT be accurate? The iron particle solution has several drawbacks: (1) Only fairly long wavelengths recorded on tape can be made visible. (2) There is often some "pull back" from the edge of the tape while the material is still in solution, before complete evaporation. Part of this is due often to slight "turn up" of the tape edge. The effect can be shown when making comparisons with indicator fluid, and captive particle viewers. (See illustration) The same edge track may show a narrower pattern on examples treated with indicator fluid, than displayed in the captive particle viewer. Both the viewer and the indicator fluid measurements suffer from a lack of perfect edge definition. With accurate optical readout equipment, (See illustration) it is my opinion that the repeatability of a given track sample can be accomplished within approx. 1 mil.

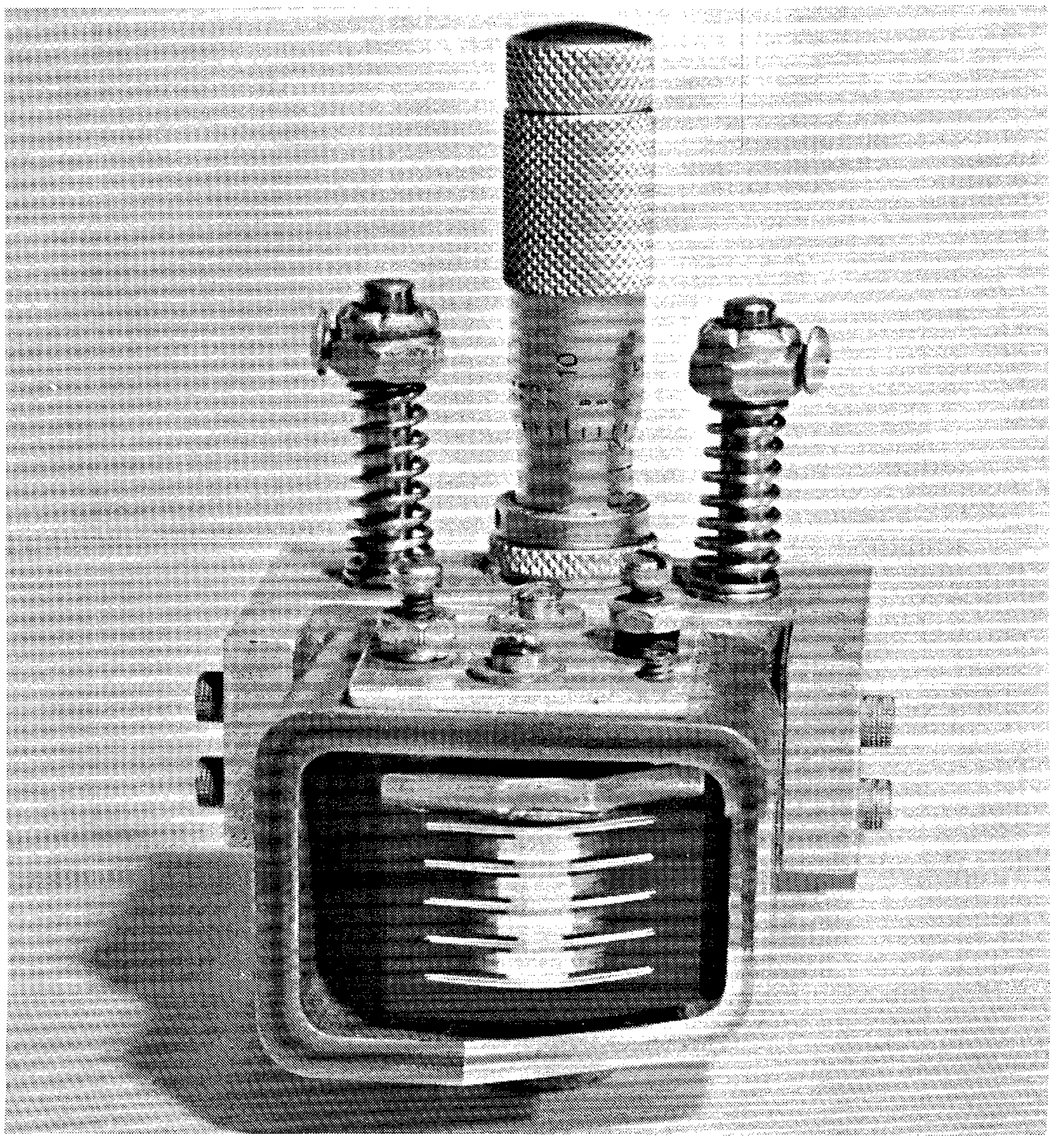
Another method of measurement, most useful in a laboratory, utilizes a special head assembly having a precise dove tail mechanism coupled to an accurate micrometer stem. The head used for this purpose is specially made up to have only one lamination. Here the recording is "played" to indicate vertical reference points. Such a laboratory set up can provide useful measurements of shorter wavelengths than possible with the normal indicator fluids. Each method has its particular applications and the special head is not as useful in determining track PLACEMENT, where tape edge is the reference from which indicated tracks are referenced.



Visible pattern – long wave length recording.



Magnetic pattern as seen with 3M viewer.



Vertical dovetail assembly.

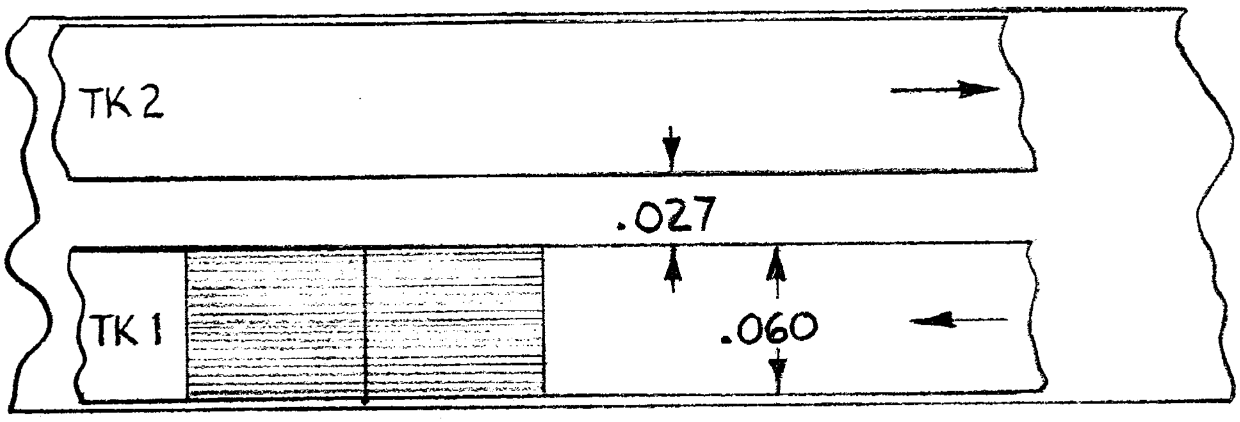
TYPICAL TRACK DIMENSIONS (Professional Equipment)

Note: Engineering dimension specifications are called out to accommodate the permissible manufacturing tolerances and to avoid "double dimensioning"; thus the foremost specifications published by standardizing committees, which must conform to this practice, do not show all the data of interest in easily digested form. The format presented here, represents nominal patterns for well made heads in accordance with current professional practice.

CASSETTE TAPE FORMATS

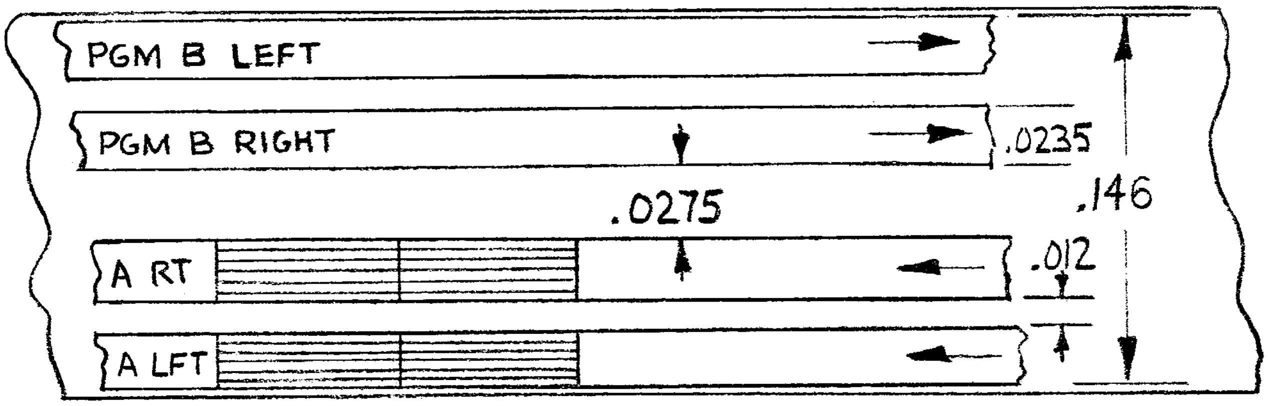
Tape .144 – .150 in. (3.66 – 3.81mm)

MONO



	INCHES	mm
TRACK WIDTH	.060	1.52
GUARD BAND	.027	.69
TRACK CENTER SPACING	.087	2.21

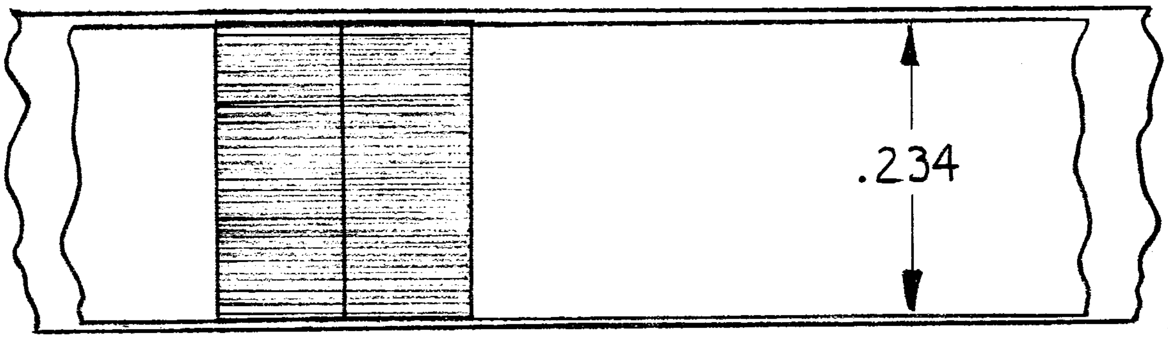
STEREO



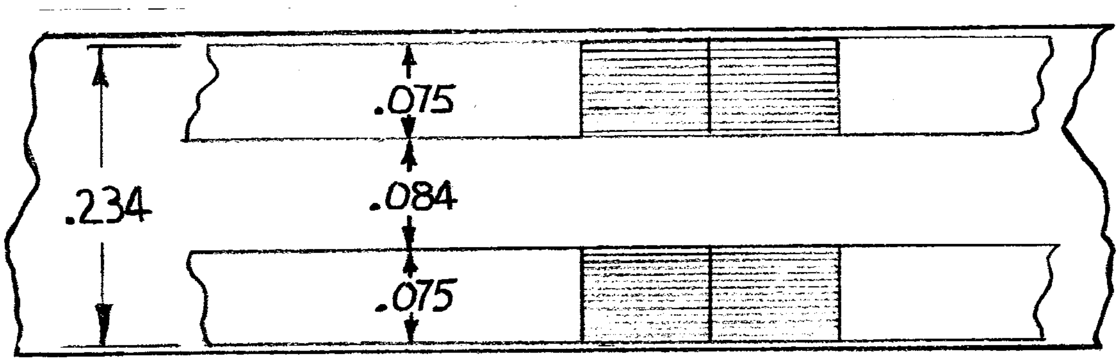
	INCHES	mm
TRACK WIDTH	.0235	.597
GUARD BAND (PAIR)	.012	.30
GUARD BAND (CENTER)	.0275	.699
STEREO PAIR CENTERS	.0355	.902

PROFESSIONAL ¼" TAPE FORMATS
Tape .244 – .248 in. (6.198 – 6.299 mm)

FULL TRACK



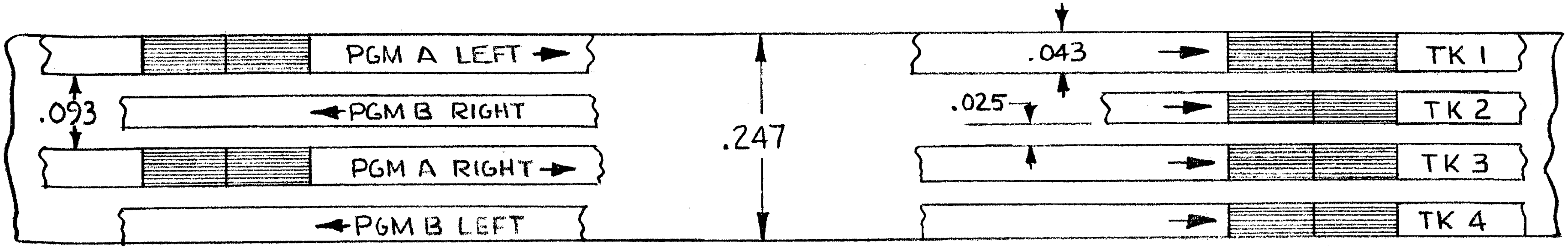
HALF TRACK & 2 TRACK



	INCHES	mm
TRACK WIDTH	.075	1.91
GUARD BAND	.084	2.13
TRACK CENTER SPACING	.159	4.04

NARROW TRACK ¼" TAPE FORMATS
Tape .244 — .248 in. (6.198 — 6.299mm)

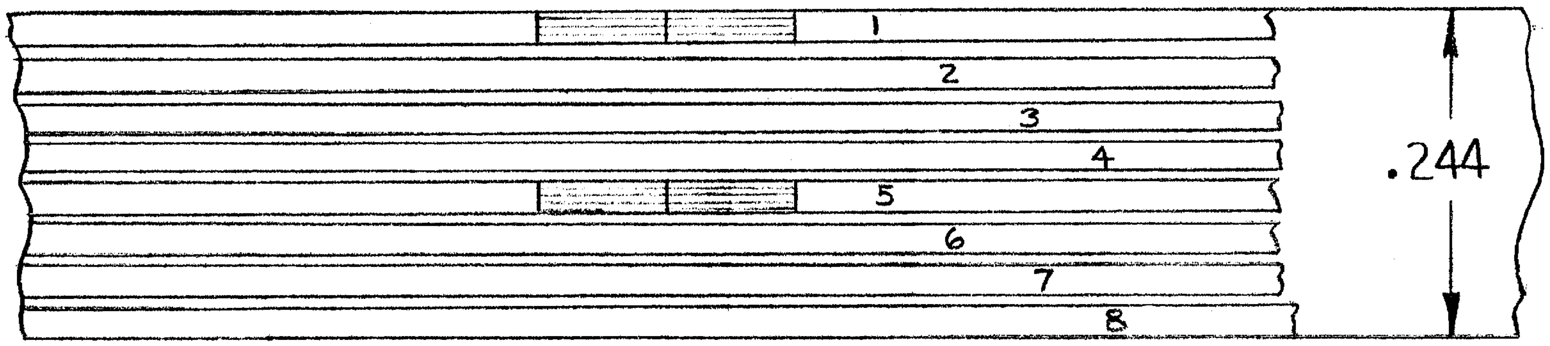
	INCHES	mm
TRACK WIDTH	.043	1.09
GUARD BAND	.025	.64
STEREO PAIR CENTERS	.136	3.45
ADJACENT TRACK "	.068	1.72



QUARTER TRACK STEREO

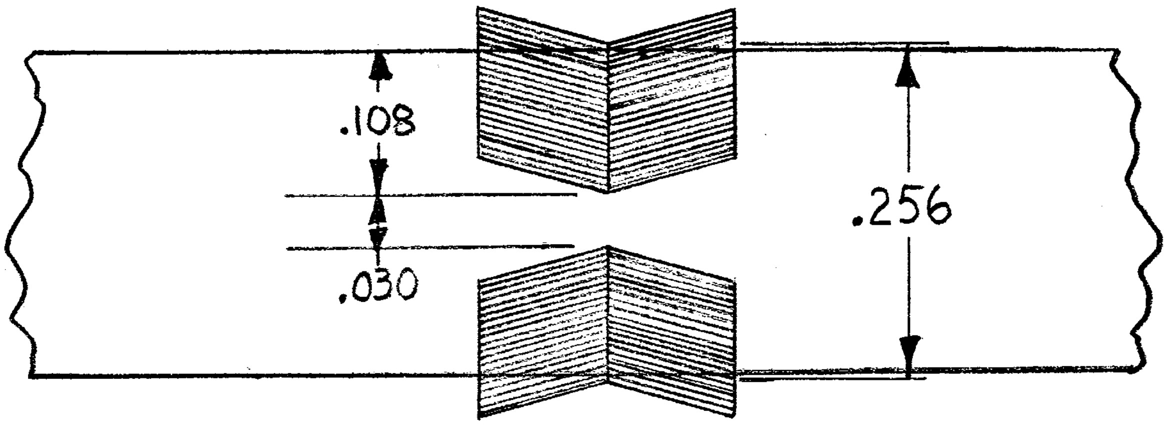
4 TRACK

8 TRACK CARTRIDGE



	INCHES	mm
TRACK WIDTH	.022	.56
GUARD BAND	.0097	.246
STEREO PAIR CENTERS	.127	3.22
ADJACENT TRACK "	.0318	.806

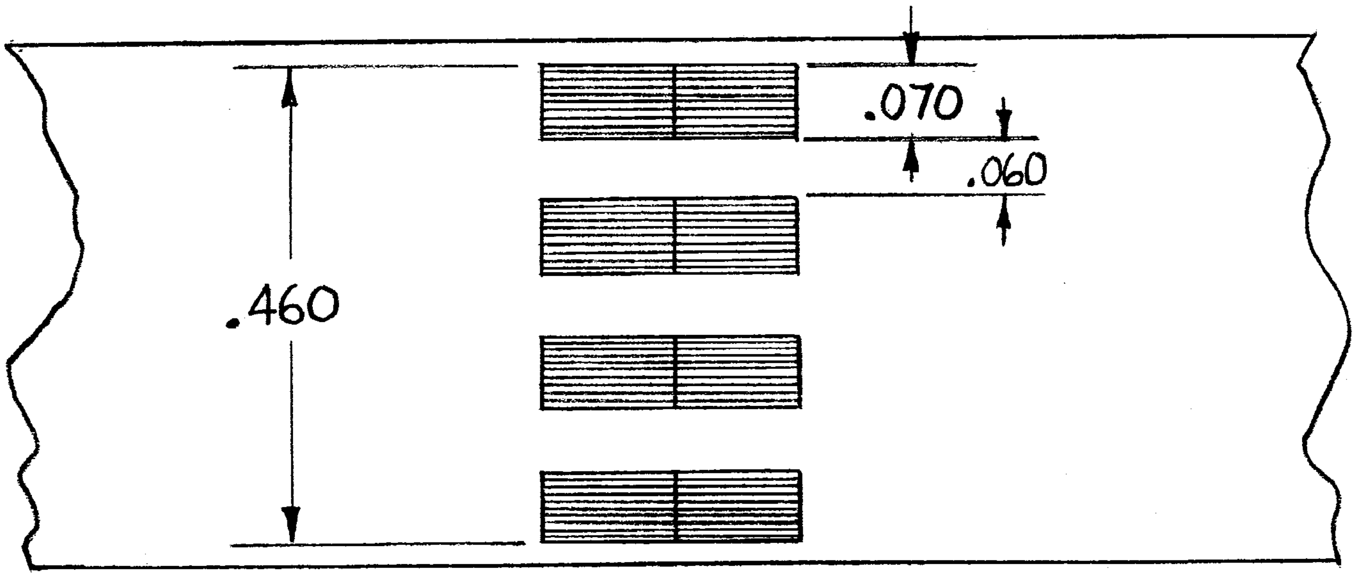
EUROPEAN ¼" 2-TRACK FORMAT



	INCHES	mm
TRACK WIDTH	.108	2.75
GUARD BAND	.030	.75
TRACK CENTER SPACING	.148	3.76

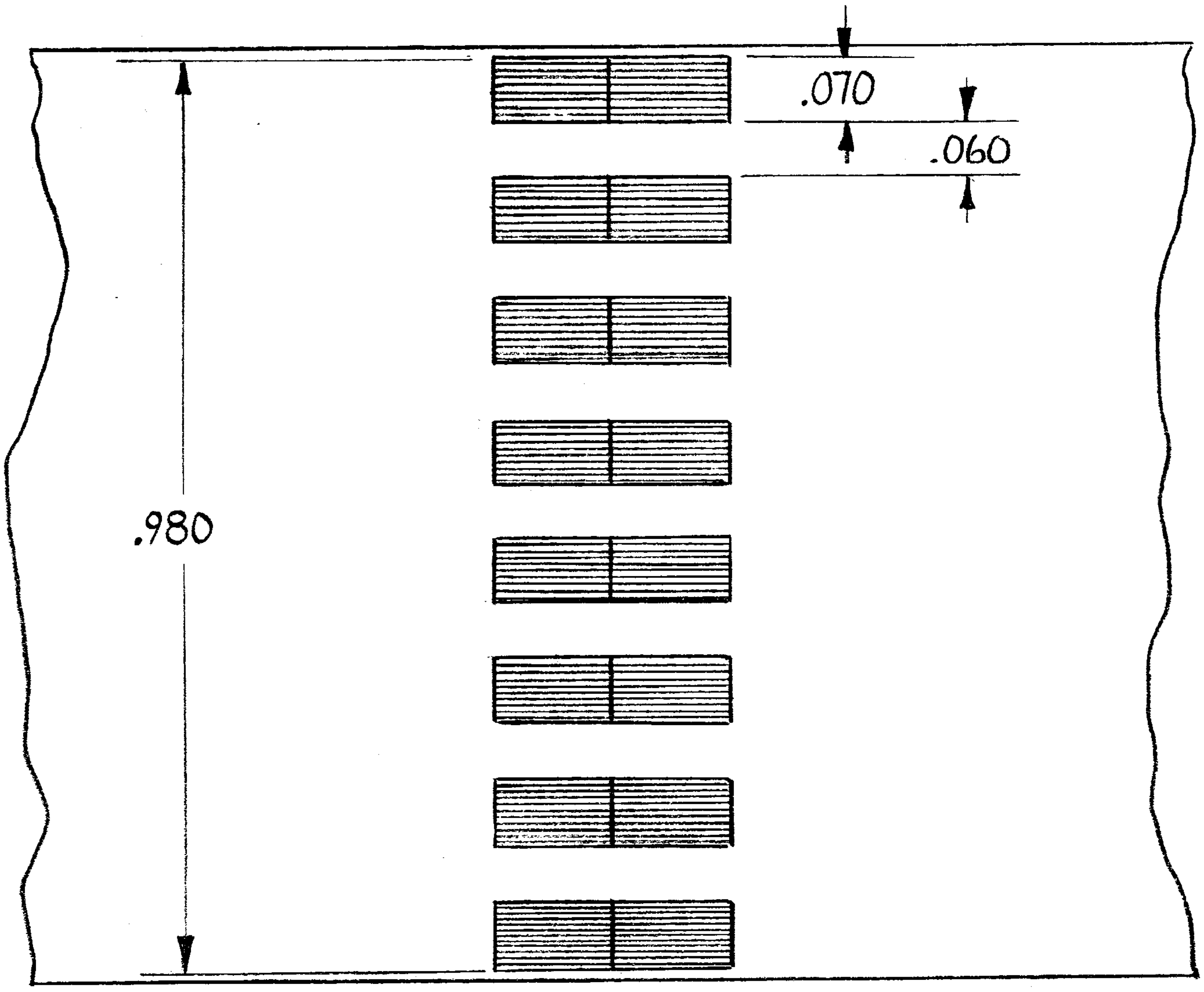
HALF INCH, 4 TRACK FORMAT

Tape .496 – .500 in. (12.598 – 12.700mm))



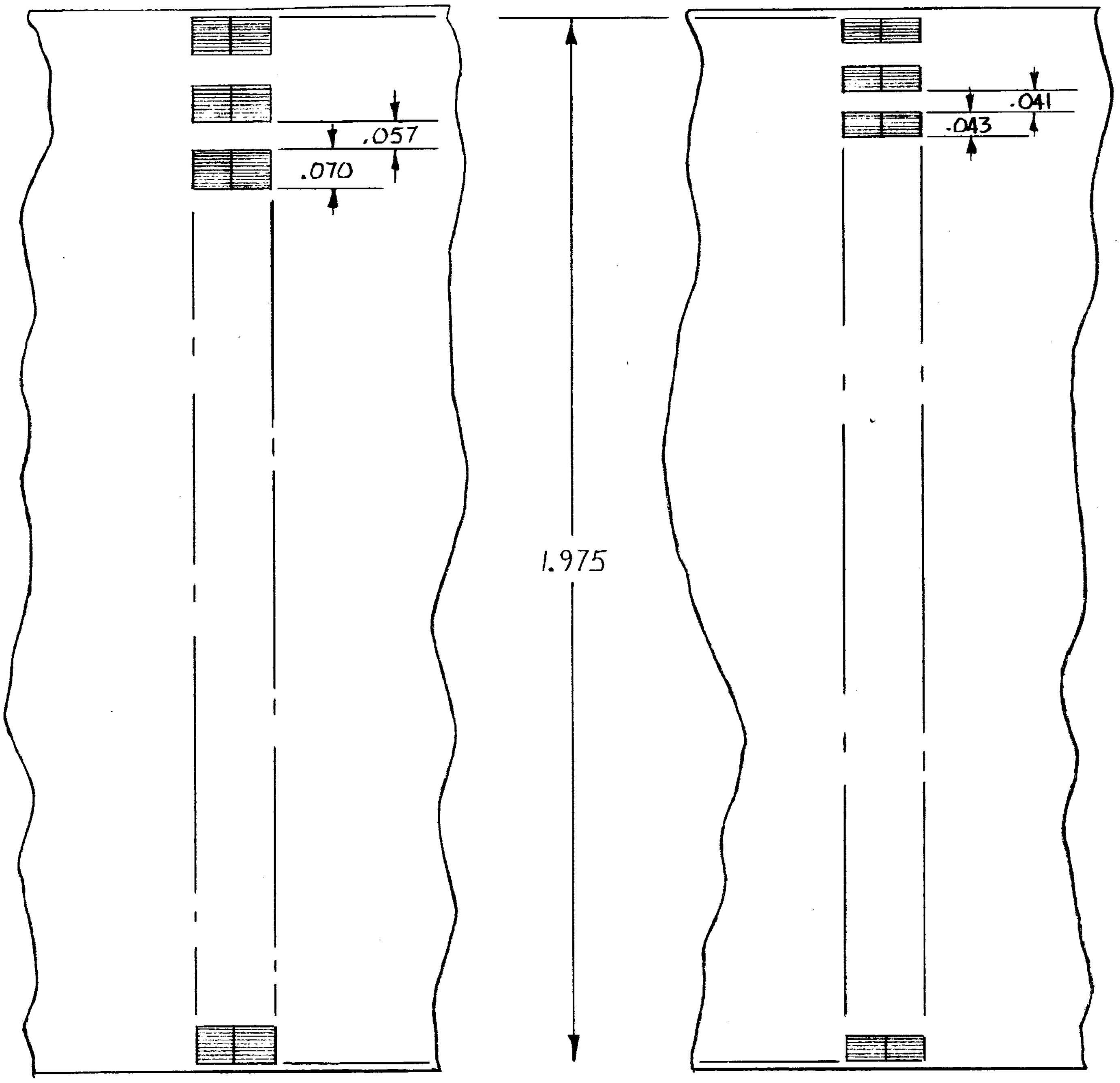
	INCHES	mm
TRACK WIDTH	.070	1.78
GUARD BAND	.060	1.52
ADJACENT TK CENTERS	.130	3.30

ONE INCH, 8 TRACK FORMAT
Tape .996 – 1.000 in. (25.298 – 25.400mm)



	INCHES	mm
TRACK WIDTH	.070	1.78
GUARD BAND	.060	1.52
ADJACENT TK CENTERS	.130	3.30

TWO INCH TAPE FORMATS
Tape 1.996 — 2.000 in. (50.698 — 50.800mm)



16 TRACK

	INCHES	mm
TRACK WIDTH	.070	1.78
GUARD BAND	.057	1.45
ADJACENT TK CENTERS	.127	3.23

24 TRACK

	INCHES	mm
TRACK WIDTH	.043	1.09
GUARD BAND	.041	1.04
ADJACENT TK CENTERS	.084	2.13

LOSSES TO RECORDED SIGNALS:

The most often asked question the test tape producer must contend with is, how long or how many plays is my reference tape good for? To my knowledge, no one has ever been able to collect enough reliable data to satisfactorily answer in absolute terms loss figures to apply to the many differing conditions, and environments effecting the tape. We do know that there are a number of factors contributing to losses in recorded tapes. These can be listed in two groups:

(A) Losses resulting from changes occurring in the recorded tape while UNPLAYED, i.e. stored on the shelf. These storage losses can be the result of temperature cycling, magnetic fields and chemical changes in the adhesive binder peculiar to a particular oxide formulation. Some oxides lose flux more readily than others and much has been said about the tendency of cobalt doped oxide to lose short wavelength signals readily.

(B) Losses resulting after repeated use. Here the various physical changes affecting the tape can be summarized as:

(1) Bending loss: The flexing of the tape particularly around capstans and guides of small diameter. Capstan idler pressure can contribute to the amount of loss as applied to small diameter capstans. Possibly the losses to some tapes as a result of shock stresses, as can occur with equipment designed to fast rewind after an abrupt start, should be included in the category with bending loss. Just as a permanent magnet can be partially demagnetized by striking with a hammer, a tape may be partially demagnetized by stretching, bending sharply, or winding around a small diameter. Unfortunately, this effect appears to vary with the particular tape oxide and binder. Figures are, in this case, dangerous, however; we have seen losses of ½ dB to recordings of ½ mil wavelength, after ten playings on equipment having a very small diameter capstan. (3.75 ips & 7.5 ips direct drive capstan)

(2) Oxide abrasion: Actual removal of oxide particles due to abrasion caused by heads, guides, counters or anything contacting the tape's surface.

An interesting sidelight to abrasion is the fact that often with the smoothest head surface the most highly polished tape oxide suffers greatly. The smooth tape and smooth metal surfaces can "stick", causing in addition to "squeal", oxide pull-off, with resultant signal loss.

An excellent method of experiment presented itself a few years ago. A tape had been produced especially to appeal to Audio Visual people, where the student was expected to use a recorded tape on equipment unattended. The tape had a very thin plastic film OVER the oxide. It was reasoned that while there would be considerable spacing loss due to the protective film, the head would remain clean, as no oxide could be removed to contaminate the head. Another advantage was a reduction in head wear, since the film was less abrasive than oxide. There were some disadvantages including the downgraded frequency response caused by the 20 micro-inch film, and resultant spacing-loss and static discharge problems. The tape, however, allowed us to make short wavelength recordings and submit them to normal wear cycles. The results were surprising in that the oxide (similar to 3M 190) showed only about one fourth the losses after 100 plays as did tape without the protective film. Tension and bending arc were identical in testing both normal and coated tape. The interpretation of the results could easily be misdirected to indicate that all the improvement was due to the fact that the oxide lost not one precious acicular needle, however, we must also recognize that the other variable is the separation itself, which could protect the tape slightly from a magnetized surface. My own opinion is that the erosion factor is an important one in describing losses to magnetic tapes, and next to unwanted magnetic fields, the most neglected.

(3) Magnetic effects causing losses: Elsewhere in the lab manual, we have described how to check for unwanted magnetic fields. As with all the losses to tape, the shorter the wavelength, the greater the loss. This is especially true in the case of magnetized guides, heads, etc. Here are some figures which you may find interesting, and if you have the equipment handy you can duplicate the conditions. As a matter of fact, it is difficult not to duplicate the conditions (or worse) with most of the equipment available today.

10kHz is recorded at 1 7/8 ips, on 150 mil cassette tape. Tape is passed over a guide showing a 4 Gauss reading taken on a Hall effect magnetometer. The high frequency loss becomes 2 to 2.5 dB when replayed. Four or five passes reduced the signal some 5½ to 6 dB!

A word of caution here, when taking readings on components. Not only is the strength of magnetization important but also the shape of the field. As an example we have seen two guides of different proportions producing the same reading on the Hall effect instrument. The loss cuased by one guide was almost twice that of the other.

In the example given above, the wavelength was short, 0.187 mils to be exact. The 2 dB loss would be much less, probably ½ dB if the recording were made at 7.5 ips. In such a case the loss might go unnoticed; however, the accumulative effect would definitely downgrade a test tape or program material after repeated replays. In short, 4, 5, or 10 Gauss fields are NOT all right despite what equipment manufacturers may say. Very probably many manufacturers are not even properly equipped to measure the magnetic contamination of the equipment they design and sell.

Stainless steel is normally used for guides and capstans. Steel designated as #440 is quite hard; however it has poor magnetic properties in that it will magnetize and can be difficult to demagnetize. Once degaussed it may not stay clean. This is the most popular stainless used in commercial audio tape equipment. In wide band instrumentation equipment, the type #303 stainless has been found to be the solution to some of the magnetic problems encountered with short wavelength recording. (125kHz at 7.5 ips, for example) Type #303 is soft, but has good, i.e. antimagnetic properties. With this type of metal, the surface must be hardened by electrolizing. A hard chrome finish is applied to the surface, after machining. We point out the above to indicate that you may NOT BE ABLE to demagnetize certain stainless steel components.

SOME PRACTICAL EXAMPLES OF LOSSES SEEN USING VARIOUS OXIDES UNDER CONTROLLED CONDITIONS:

One extensive experiment produced the following results.

3M 111 – 1 mil wavelength

NUMBER OF SHUTTLES	LOSS IN DB
10	0
25	0
50	0
100	0

3M 111 – ½ mil wavelength

NUMBER OF SHUTTLES	LOSS IN DB
10	–0.17
25	–0.17
50	–0.72
100	–1.10

3M 206 – 1 mil wavelength

NUMBER OF SHUTTLES	LOSS IN DB
10	0
25	0
50	–0.26
100	–0.54

3M 206 ½ mil wavelength

NUMBER OF SHUTTLES	LOSS IN DB
10	0
25	–0.26
50	–0.45
100	–0.72

Maxell A50-10 – 1 mil wavelength

NUMBER OF SHUTTLES	LOSS IN DB
10	0
25	0
50	0
100	0

Maxell A50-10 – ½ mil wavelength

NUMBER OF SHUTTLES	LOSS IN DB
10	0
25	0
50	–0.17
100	–0.17

In the above tests made several years ago, the already obsolete 3M 111 tape was used as control reference as it had played such an important part in arriving at a number of the early standards and still remains in vault reference form in many laboratories. It also represented an example of a coarse, non doped, low output oxide.

The results on the previous page were taken on equipment carefully controlled to insure minimum magnetic contamination.

The data are shown to indicate that even under carefully controlled conditions, some short wavelength loss must be expected. We could perhaps conclude here that in the case of 15 ips music masters, 15kHz material (i.e. 1 mil wavelength) should suffer less than 1 dB after 100 plays on well maintained equipment. It also says that your test tape will likely suffer to the same extent.

It should be noted that certain equipment or methods of operation can cause losses of a greater magnitude to recorded material than would be experienced on carefully maintained magnetic tape recorders.

Operations in editing or rewinding which put severe physical strains on the tape should be avoided.

Some equipment providing very fast rewind cycles may accelerate from stop to rewind at a rate which can stretch or snap the tape.

Such sudden tensioning can produce short wave length losses to the recorded tape. Other conditions contributing to problems are:

Editing with counters or other equipment having sharp guide paths or abrasive surfaces.

Proximity of magnetically contaminated items—electric clocks, etc.

In practice, we can minimize "storage losses" through attention to proper, non-magnetic shelving, and by stabilizing temperature and humidity of the environment. Too low an humidity should be avoided as it can accelerate print-through problems and may produce some static problems. (60 to 70 degrees F, and 40 to 60% humidity, has proven satisfactory)

The main concern should be directed to the reproduction equipment. One should avoid "pin sized" capstans, sharp tape path bends, and particularly transports and heads that magnetize easily.

HOW TO MEASURE DISTORTION:

The most useful instrument for measuring distortion in tape equipment is the wave analyzer. Only with such an instrument can the various contributors to even and odd harmonics be separated. For example, amplifier problems and MAGNETIZED HEADS will contribute to the second harmonic, while the proper record bias current relates to the third harmonic for a given tape. The total harmonic distortion meters such as seen in most broadcast installations show everything excluding the fundamental, and therefore, all harmonics as well as noise and flutter show up in the total. As the broadcast market is a big one in the audio magnetic field, such equipment—particularly the cartridge machine—is often specified as to total harmonic content. 1.5% is an often quoted figure. Head magnetization, noise and flutter may produce the remaining figure as read out on a total analyzer. Actual distortion content for a quality broadcast machine using average lubricated tape would be approximately 0.7% third harmonic and 0.2% to 0.4% second harmonic. The total harmonic analyzer will combine these figures along with noise and flutter to produce a higher reading than the true distortion on the tape. The above assumes a low distortion oscillator as a test signal source. We should caution also that use of a total harmonic analyzer is difficult with any system having flutter components, which will cause irregular meter readings. A satisfactory procedure to follow in setting and maintaining tape equipment as related to distortion is as follows:

(1) After calibrating the reproduce channel to the desired reference level, record a 15 mil wavelength signal (1000Hz at 15 ips, or 700Hz is satisfactory at 15 ips and 7.5 ips) on the TAPE TO BE USED. Adjust bias current to produce highest output and re-adjust record level control to produce your ZERO reference.

(2) Calibrate wave analyzer and measure the distortion of the oscillator being used. (Look at second, third, etc harmonics)

(3) Calibrate wave analyzer to tape machine output with output switch in tape position and take third harmonic reading. (For example, 2100Hz for a 700Hz signal) Modern tape oxides at normal audio speeds and operating levels range generally in the region of .3% to .8% third harmonic for levels of 185 nWb/m to 261 nWb/m.

(4) Shift wave analyzer to read second harmonic, i.e. 1400Hz as above and IF the record amplifier has noise balance control, adjust for minimum second harmonic. (The range of noise balance controls on some equipment can cause changes ranging from 1% or 1½% second harmonic to a null approximating the oscillator content). IF the second harmonic remains anything but very low, the head stack should be demagnetized, also one should re-adjust noise balance control for minimum second harmonic and the reading repeated. PM magnetic fields in the head stack cause second harmonic. THE VALUE OF THE ABOVE PROCEDURE CAN HARDLY BE OVER EMPHASIZED, FOR THE SECOND HARMONIC IN MANY MACHINES BEING USED FOR MASTERING IS A MAJOR FACTOR IN INCONSISTENT QUALITY. We have seen extreme cases of magnetized heads causing 3% and 4% second, and that can, of course, be heard in the program.

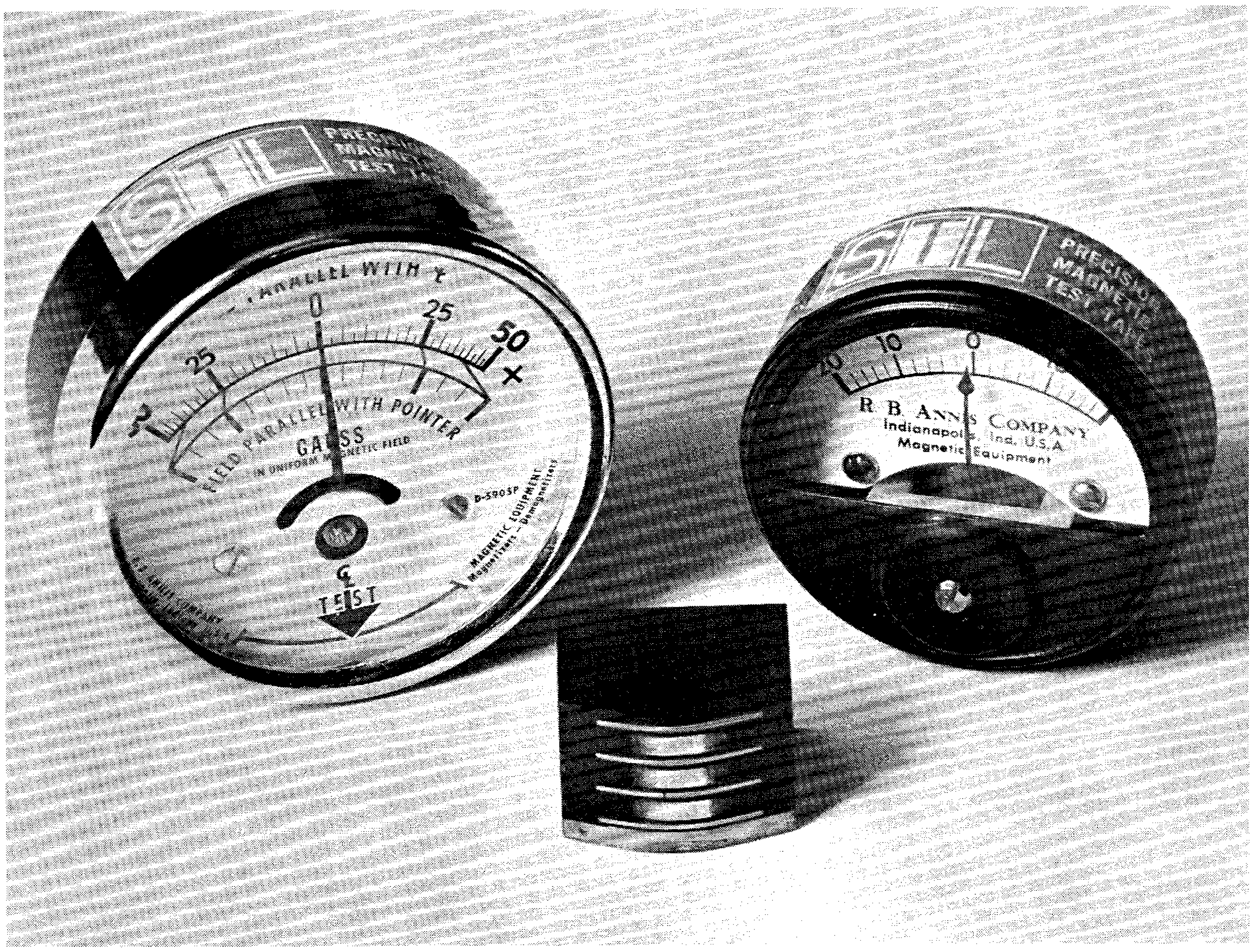
If a sensitive magnetometer is at hand, this would be a good time to scan the head stacks for PM "contamination" as related to the second harmonic readings taken. Also it should be pointed out that some head demagnetizers can, depending on use, i.e. how fast the tip is withdrawn, etc. produce a field in a head stack. Switching transients and other factors can also be a problem in this respect. One of the most interesting conditions came to the author's attention some years ago when we noticed that a certain big name professional machine used primarily in broadcast service, built up a strong permanent magnetic field in its playback stack in a short time after the head had been carefully degaussed and harmonic measurements taken. Invariably the playback stack "took on" about 4 or 5 gauss, with the result being a high distortion reading. The nature of the head laminations and the head coil being directly fed with DC in the transistor circuit caused the problem and, for all I know, still does in this still available "professional" machine.

HOW TO CHECK FOR MAGNETIZED COMPONENTS AND OTHER ELECTRICAL FIELDS CAUSING UNWANTED ERASURE AND NOISE:

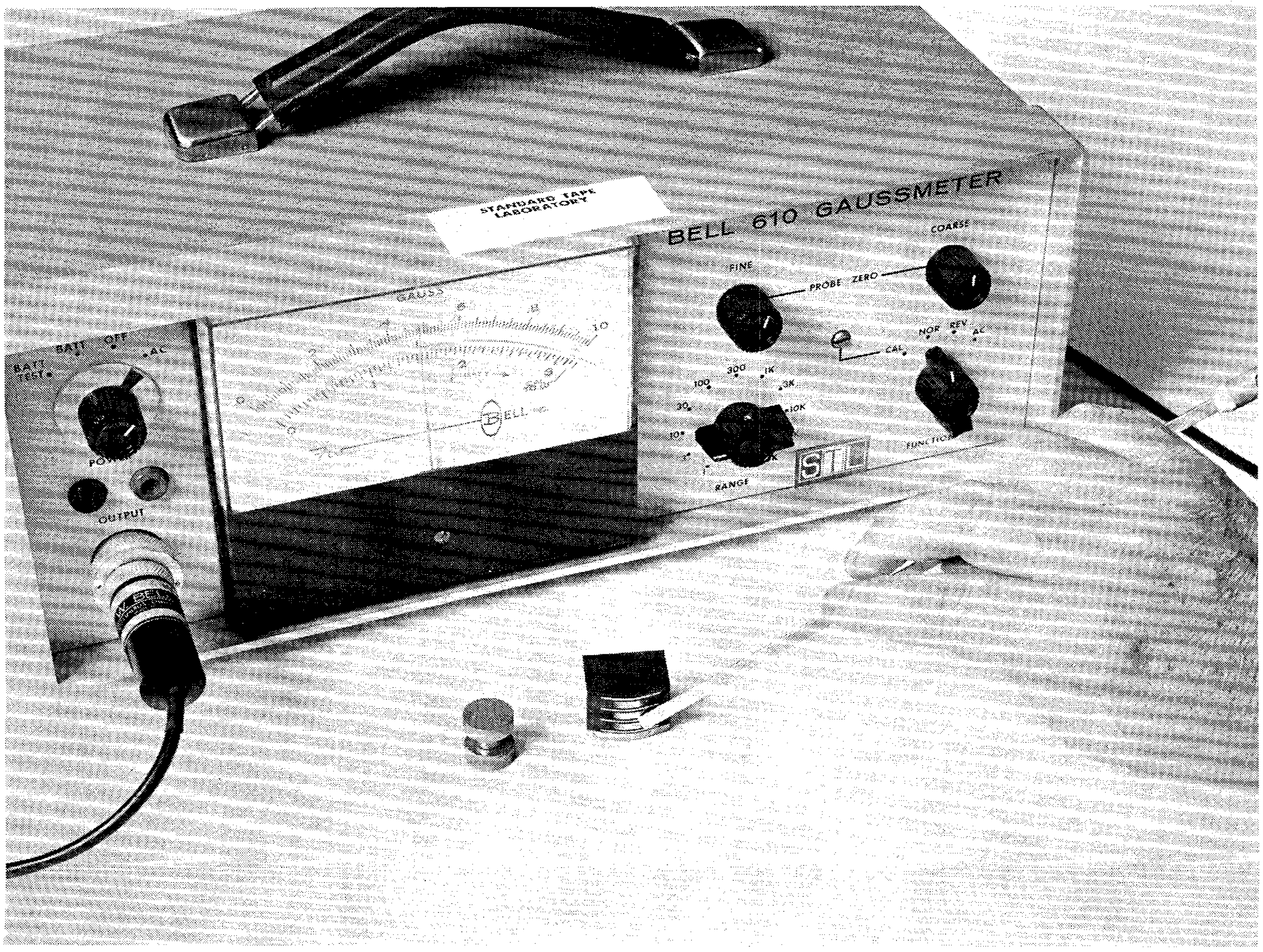
On page 23 we indicated the relationship of second harmonic distortion to PM fields in a reproduce head. The same PM contamination of the head can cause severe short wavelength erasure to recorded tapes. The slower the tape speed employed, the greater the top end loss to be expected from magnetized components. In the last section of this manual, several types of simple and elaborate magnetometers are illustrated. The simple meters are inexpensive and are highly recommended, however, they only indicate PM FIELDS. AC fields often are the culprit. One professional machine actually showed an AC field caused by a misplaced solenoid of 34 GAUSS with the machine in a rewind mode and the tape lifters actuated. The field was concentrated at the supply reel side of the transport at the flutter idler guide. Many top selling machines have been designed and sold without any consideration by the engineering departments as to AC magnetic field contamination. A poorly filtered DC supply may carry enough AC ripple to do a lot of damage to a tape passing near a solenoid or relay coil. The simple magnetometer may only show a field of a few gauss under the same conditions. The minimum equipment needed to look for catastrophic conditions due to magnetic fields would be one of the simple magnetometers such as the ANNIS 5-0-5 Gauss model and one of the magnetic viewers as indicated for track width measurement in Section C. Ideally a "Hall effect" type of magnetometer with a variety of crystal probes can be used to indicate very small magnetic fields, AC as well as DC. Such an instrument is more expensive as it requires its own set of electronics, but has the added advantage of being able to calibrate for the earth's field. In looking for magnetic contamination it must be remembered that there is about 0.5 gauss due to the earth's own field, and on measurement equipment of the most sensitive variety, this field will show up in the reading, depending on "compass" orientation of the meter or probe during use. To check for magnetized heads: measure second harmonic of recording; if high, measure field at head with magnetometer. If questionable, degauss and remeasure. Similarly examine the guides, the capstan and any metallic surface to contact the tape. Even "Stainless" materials called non magnetic are capable of retaining some field and are, therefore, suspect. If a magnetometer is not available but a magnetic "Viewer" is, use this to observe any darkening of the magnetic particle suspension as the viewer is brought *as close to the object as possible without touching it.* These tools are responsive to pressure of the diaphragm as well as fields so care must be taken not to touch the indicator to the object.

If none of the above equipment is available, a rough test can be made as follows: Record a fairly short wavelength, say, 15kHz at 7.5 ips. Observe playback level and reproduce ten times, observing any change. Losses can be result of demagnetization by the transport components. Any pops or noise noticed as a result of stops and starts would lend suspicion.

The most often asked question concerning magnetized parts and resultant losses is "HOW MUCH IS TOO MUCH"? To provide a given amount of high frequency loss for a given field is difficult for several reasons. The SHAPE of the field bears on the result as well as the measured strength as shown on a magnetometer. The nature of the tape oxide is also of importance, as is the spacing between tape and component. The particular machine mentioned earlier with the highly magnetized guide caused a deterioration of about 3.5 dB to a 15kHz signal recorded at 7.5 ips after twenty plays. The above experiment was made on 206 tape and the same experiment repeated in another laboratory on transports of a different design showing almost no stray AC or PM fields in the



Inexpensive self contained Gaussmeters.



Hall effect Gaussmeter — Note: Head shows almost 5 Gauss field.

tape path. The result showed no loss at twenty-five plays, with a loss of ¼ dB at fifty plays and ½ dB at one hundred plays. These loss figures would represent a "norm" to be expected in the reproduction of normal oxide tapes at ½ mil wavelength.

We know from the above that a guide showing about 10 or 11 gauss on a PM type magnetometer and some 34 gauss on a Hall effect meter was TOO much. An old Library of Congress document*[1] states that maximum flux density permitted should be 10 gauss. We feel that this is also too much, and that any direct exposure of a recorded tape to more than 3 or 4 gauss will show up as loss. Ten passes over a head stack showing 4 gauss PM, resulted in a loss of 0.75 dB.

We recognize that other factors contribute to high frequency loss as well and all these including bending loss, abrasion, and self demagnetization can contribute to the total, thereby obscuring the individual components. In the above remarks concerning degree of loss due to magnetization, allowance has been made for variations in tape tension, arc of wind, capstan to idler pressure, capstan diameter, etc. The SAME transport without adjustment can be used to show the changes occurring WITH and WITHOUT a magnetized component when playing sections of the same short wavelength recording.

OTHER CAUSES OF UNWANTED ERASURE:

In systems where a single master bias oscillator is kept "running" and is switched to various tracks at appropriate times, it is well to make sure that no bias current is flowing through the record head during playback mode. Here we are dealing with RF, and some designs found in tape electronics are less than perfect. A "buffer card" may be shorted out during playback mode; however, since bias is "RF", the "loop" in the wiring may couple to the circuit to allow a small amount of bias to leak through during playback. A multiple track instrument recently came to our attention after it mysteriously dropped the level on the high frequency section of a one inch test tape only on two channels. A scope showed about 3.5 to 4 volts of bias on the two record head tracks during *playback.* The program track being added-to, also suffered audibly with repeated playbacks. Here we can say that for this machine, 4 volts of bias through the record coils was too much during playback!

One other test found useful should be mentioned: With the scope across the record head, and the machine in playback mode, the start-stop-rewind modes should be actuated and any record coil signal observed. Only the poorest designed machines will suffer in this respect, however; THEY ARE OUT THERE!

HOW TO CHECK FOR HEAD RESONANCE (and cable and core loss effects)

With the same loop setup as described in Section 7 A, an oscillator is slowly swept as the output is read on meter or scope. As the system passes through resonance, the response will cease to rise and will fall rapidly. As we recognize that the lower the inductance of the head, the higher will be its resonant point, we can choose the appropriate head for the job. It is usually good practice to choose the head having a resonance well outside the frequency band of interest. For example, if we desire only 15kHz response, then a head having a resonance of only 17kHz could be used, and, as a matter of fact, the beginning rise at 15kHz could be part of the playback eq. It is more common in audio machines nowadays to choose a head with a resonance of 22kHz or more. For standards work most prefer a head well outside the audio band, say 27kHz or more. At frequencies at the upper end

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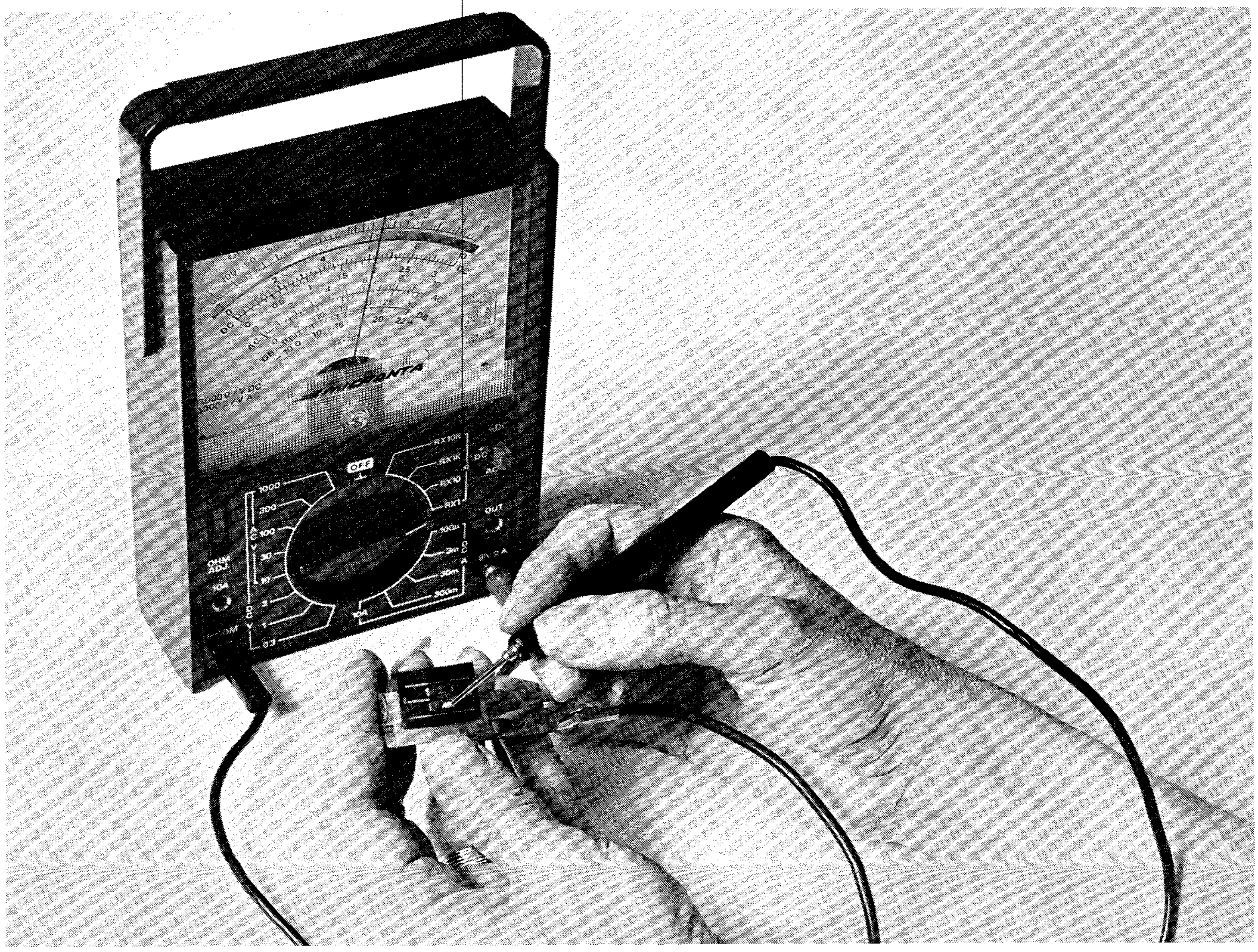
*1. Preservation and Storage of Sound Recordings, A. G. Pickett, M. M. Lemcoe 1959.

of the audio band the head may suffer from core losses caused by shorted laminations, improper insulation of cores, or the lamination material itself. We mention this because in the case of duplicators, for example, where very high frequencies are encountered, a situation can occur where the inductance is chosen to be quite low to provide high resonance, but the core losses cause the head to roll off at a much lower frequency than its expected resonance. Another caution: A head is commonly measured on an inductance bridge, to determine inductance and "Q" by means of clip leads attached to the head's terminals. The cable capacitance is, therefore, not seen. THE CAPACITANCE OF THE REPRO. HEAD CABLE IS OFTEN THE CULPRIT IN CAUSING LOWER THAN DESIRED RESONANCE. Changing the cable to a lower capacitance type, if available, or shortening it, may be required. In head production or checking work, the most convenient method of charting head resonance is through the use of an oscillator/pen recorder unit supplying signal to the head WITH ITS NORMAL CABLE, and into a 6 dB/oct integrating amplifier of the same input impedance. The result then reflects the combined effects of head resonance with cable, and core loss effects.

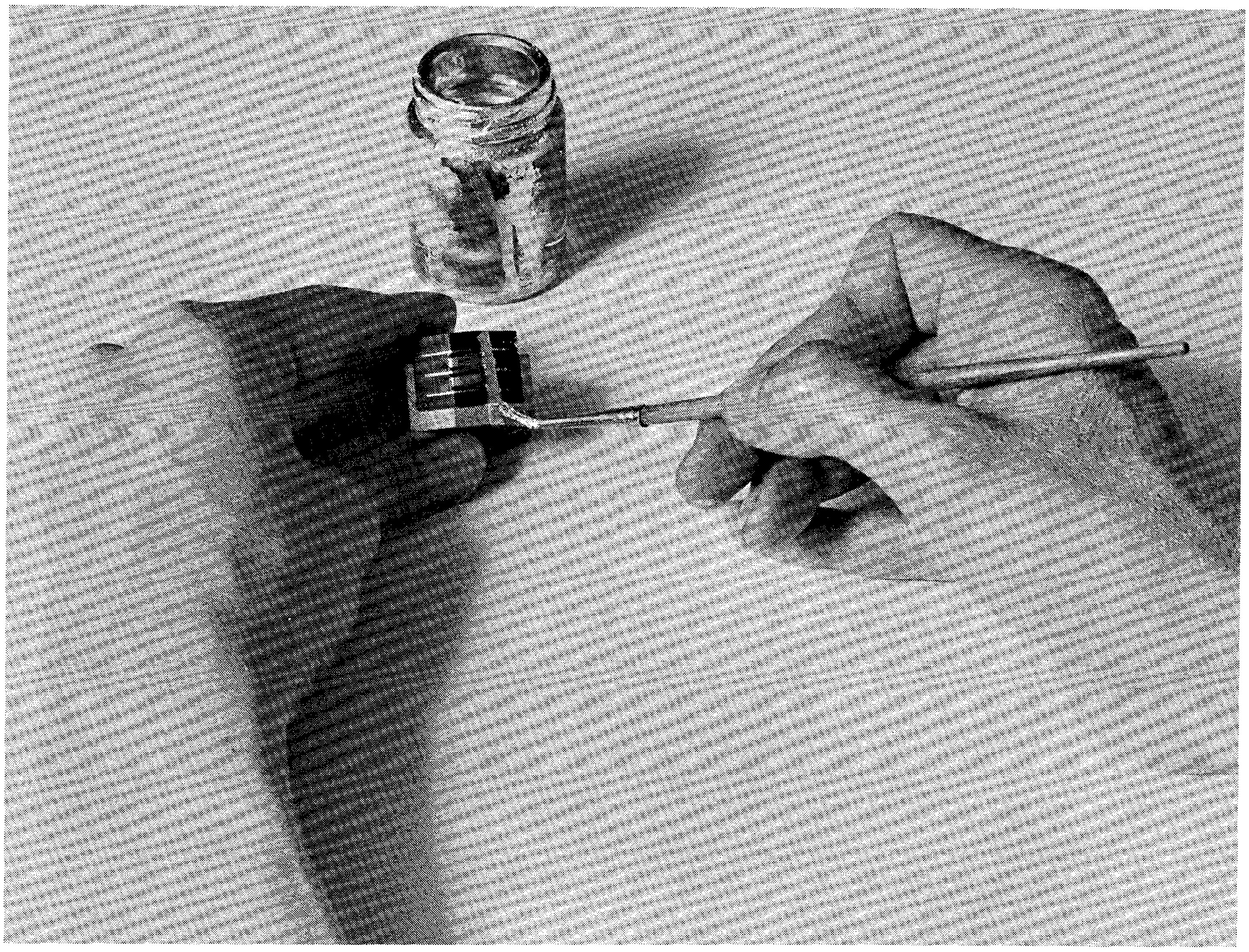
CHECKING FOR UNGROUNDED HEADS

Static noise may be added to valuable program tapes, if any of the head cores are not properly grounded to the frame of the head stack. While stacked head laminations must be insulated from one another as well as from the side pieces of the head to eliminate unwanted core losses, the stack should be grounded to the frame at ONE point to prevent static build up.

The effect is particularly troublesome with high speed equipment such as in



Checking for resistance between core and frame.



"Painting" a ground with conductive silver paint.

duplication. Plastic or paper leader tape traveling across an ungrounded stack can cause discharges producing pops and thereby render the master useless. The resistance from core to head frame must be practically nil to be satisfactory. The accompanying illustration shows a two track head having about 6 ohms from core to ground. This is an actual example and is not faked. This head caused noise and was removed from service for that reason.

Silver conducting paint is often used as shown to ground the core to frame. During initial manufacture, heads are usually grounded at the rear, rather than at the front; however "repairs" can be carefully made on the front as shown in the picture. The stripe must be applied to one side of the gap, far enough from the tape wear pattern, not to cause spacing loss.

Remember to wait a sufficiently long period of time after striping the head for the solvents to evaporate, rechecking resistance of core to ground. Depending on the conductive paint used, 10 to 20 minutes should be adequate.

An old technique which we do NOT recommend was to score the core down one side with a screwdriver and ground the last lamination to the frame. The silver paint is the better way and the only excuse for the violent approach might be in a situation where desperation dictates such action.

In checking core grounding, take care not to touch the meter prods to the gap itself or area of wear-pattern, always aim for one side.

WEAR PATTERNS:

It is very important that the heads are set at the outset, i.e. before any wear pattern develops, for proper zenith, and meridian as well as azimuth. A new, unworn head may be set to operate within specs even though it tilts forward, or back, or is turned too much to one side or the other. The problems arising after a poor wear pattern develops, cannot then be corrected, for any adjustment will cause instability of the tape as it tries to climb a trapezoidal wear pattern or fight a groove in a head which is acting as a guide.

A properly adjusted head will have an even pattern with the gap near the middle of a rectangularly worn "flat". Illustration "A" shows an average fair wear pattern. Illustration "B" shows the head disassembled to indicate a rather even core depth after considerable wear.

Not only is the proper wear pattern desirable as contributing to stability of tape travel during usage, but even core wear in record stacks maintains the best flux distribution across the track width.

The following illustrations show wear patterns resulting from improper zenith adjustment. The resulting trapezoidal pattern, in the case of the full track head was caused by the head being tilted backward in the assembly. The lower part of the stack wore more than the top area, and the head height was wrong. Illustration "D" is a highly magnified view of a half track head as found in a duplicator. The trapezoidal pattern here was not the result of improper zenith adjustment but rather to the fact that the head is constructed of normal mu metal core with a brass "shoe" to support the tape. The brass, being softer, wore sooner, thus producing the wear pattern.

A highly recommended method of initially setting up head assemblies is as follows: Using either a soft wax pencil or felt tip pen, color the front of the head with a light even coat. Then thread the tape and run a hundred feet or so in play mode, to produce a "wear" pattern. In this way you will be able to predict the

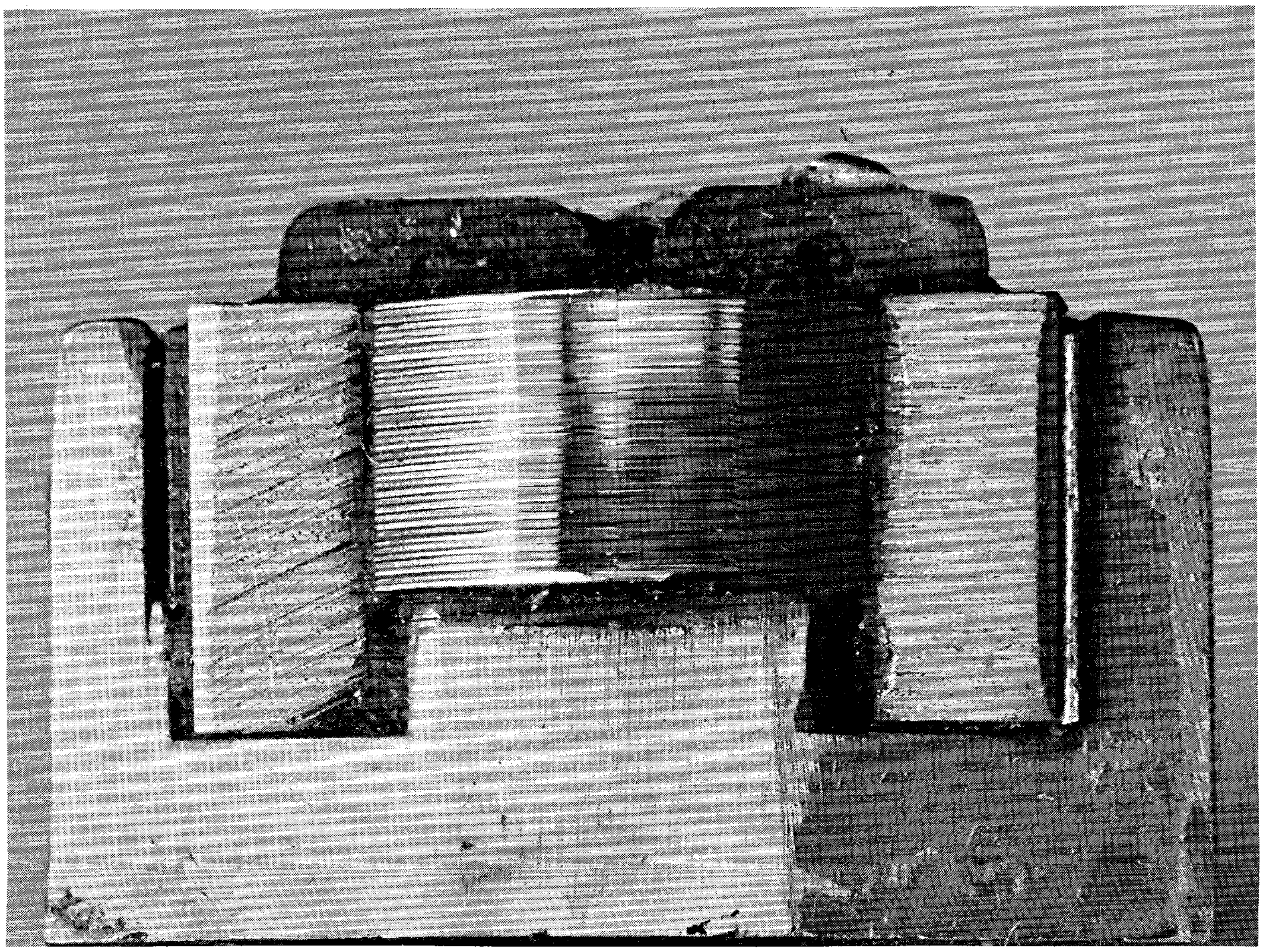


Figure A – Average wear pattern.

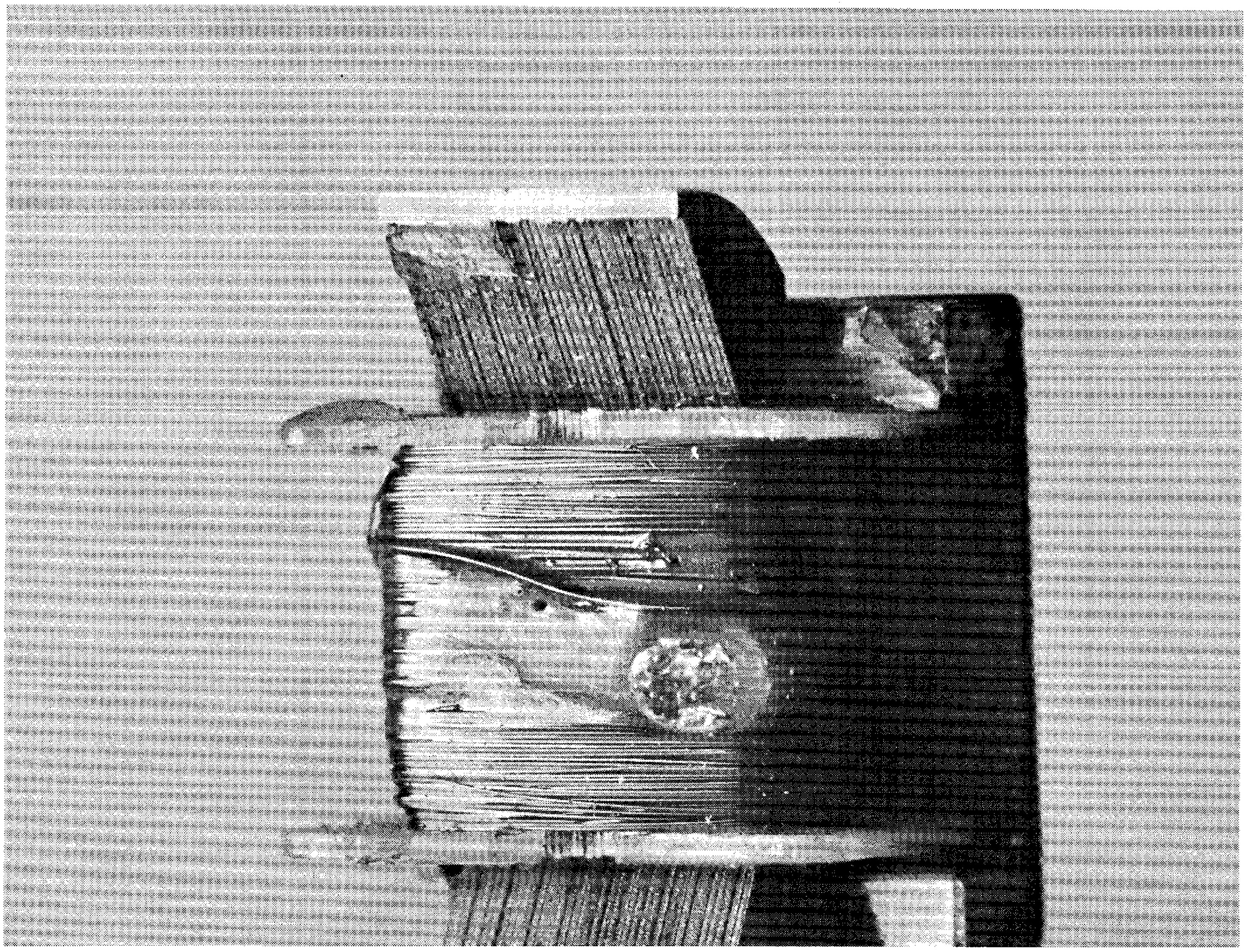


Figure B – Even core depth – head disassembled.

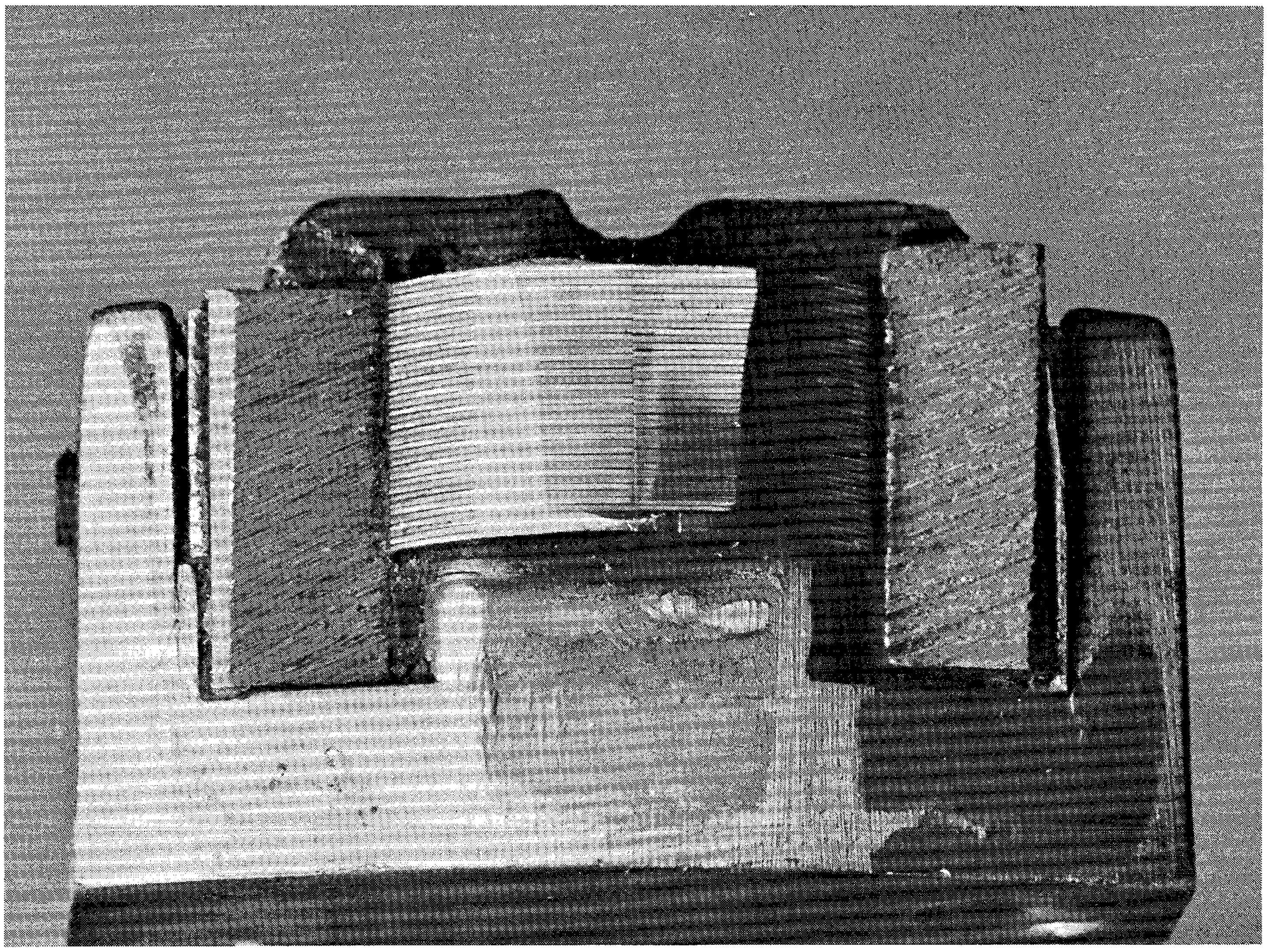


Figure C – Trapazoidal wear pattern.

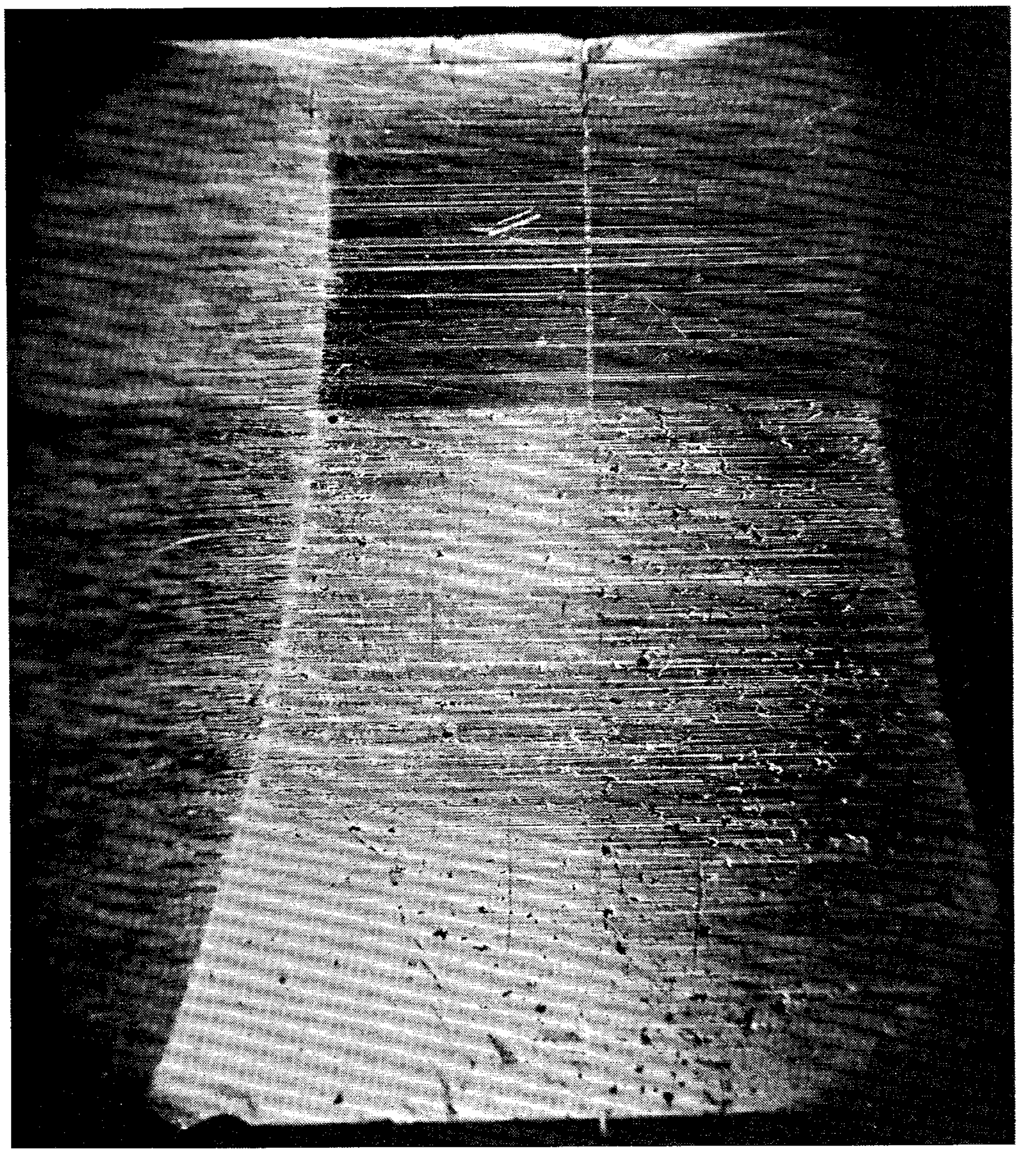


Figure D –
Highly enlarged ½ track head with trapezoidal pattern.

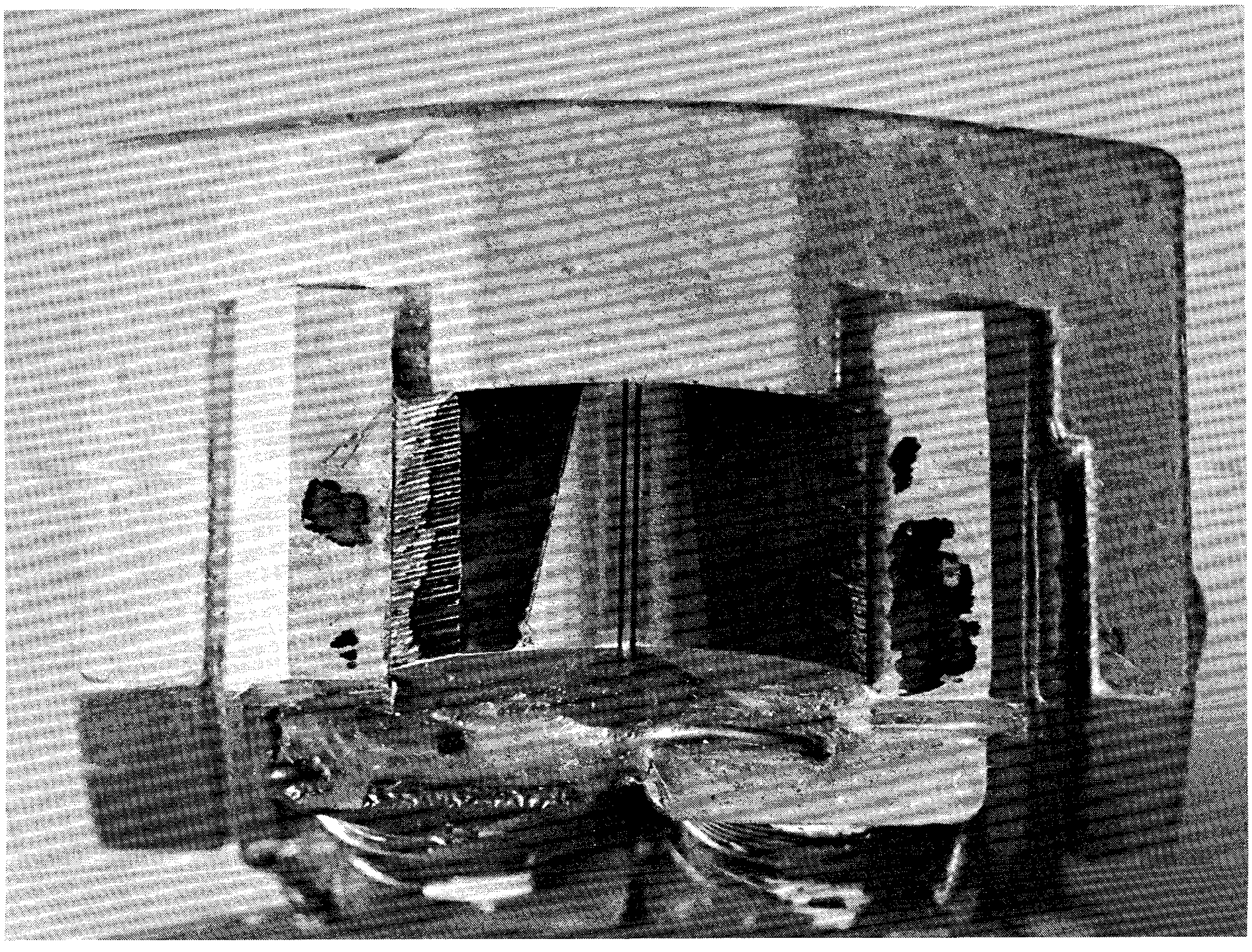


Figure E – Pattern after felt tip pen ink is worn away indicates improper "Zenith."

type of pattern to expect before an actual wear pattern occurs. As in figure "E" an improper zenith will be apparent. Repeating the experiment after adjustment reveals in fig "F" a meridian problem, that is the gap is to one side of the pattern, and there is still some zenith error. We have used an erase head with large gap in this example, so that the gap may be easily seen in the picture.

A commonly encountered mistake results from the assumption that only the record and reproduce heads are of concern as to meridian and zenith, since "anyone knows that erase heads work all right however they are adjusted." The wear pattern on the erase head as well as any other component in the tape path contributes to the continued stability of the tracking of the tape, and therefore erase heads should also be set up properly as to attitude.

Guides, particularly glass guides, often groove in more than one area. These multiple grooves can come from effects of rewinding, with partial tape lifting, fast forwarding after the head wear patterns cause steering dependent on speed, or from the use of various "white box" tapes having differing slitting dimensions. (One reason white box tape may be the worst "bargain" a recorder user may ever encounter.) Once a tape guide develops multiple wear grooves it is a matter of Russian Roulette as to which groove the tape will follow on which pass.

Capstan and idler wear patterns see Fig. "H" also contribute to tape instability and skew. A machine having wear patterns similar to those shown cannot be realigned for optimum performance. Where for example critical phase control, as in two track stereo broadcasting is called for, there is no alternative but to replace or have relapped the head stacks along with worn guides or idlers. Any attempt to skimp here is futile. The aforementioned wear patterns are those seen on standard tape recorder type head bridges. Motion picture projectors and

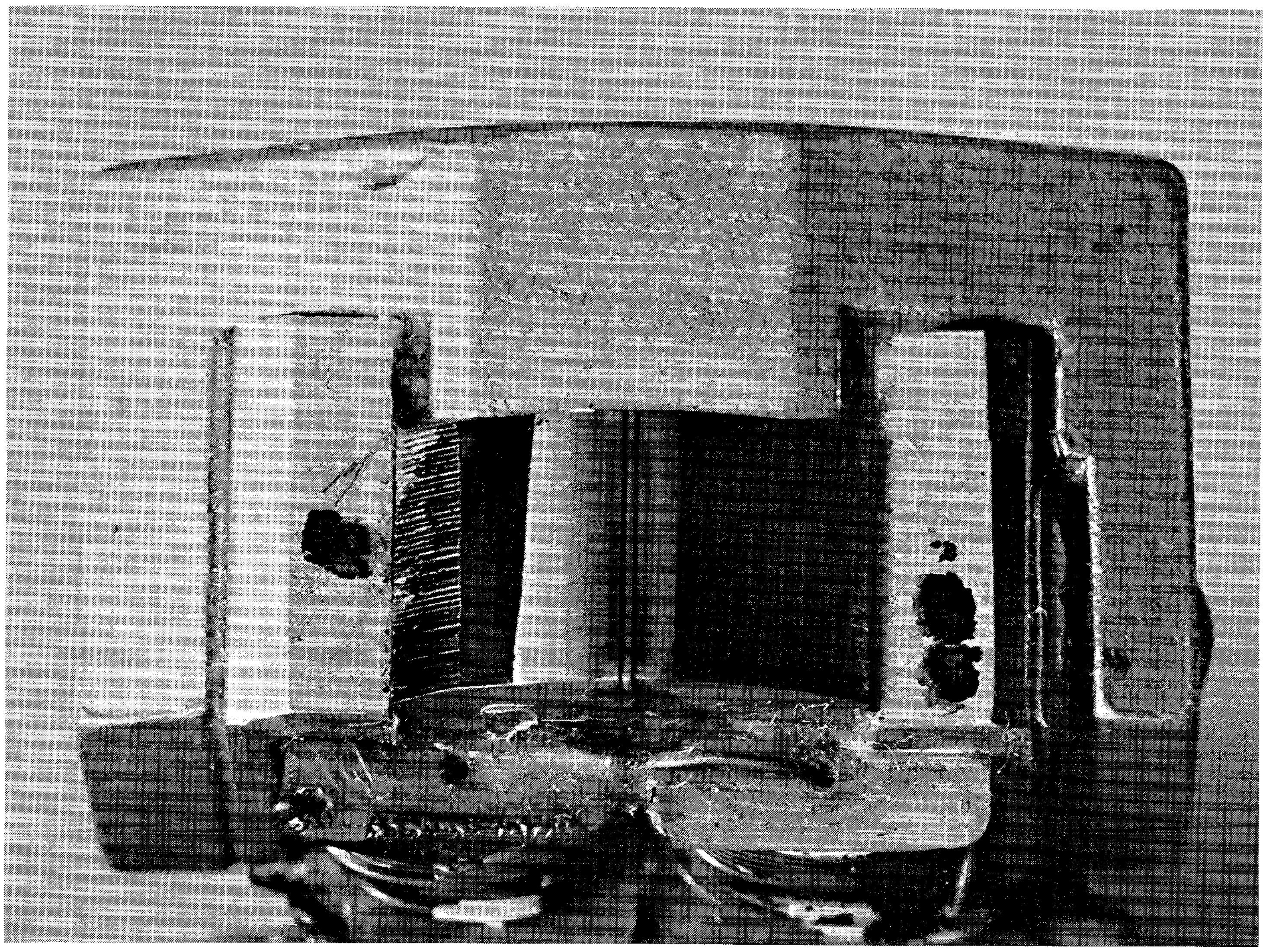


Figure F – Improper "Meridian."

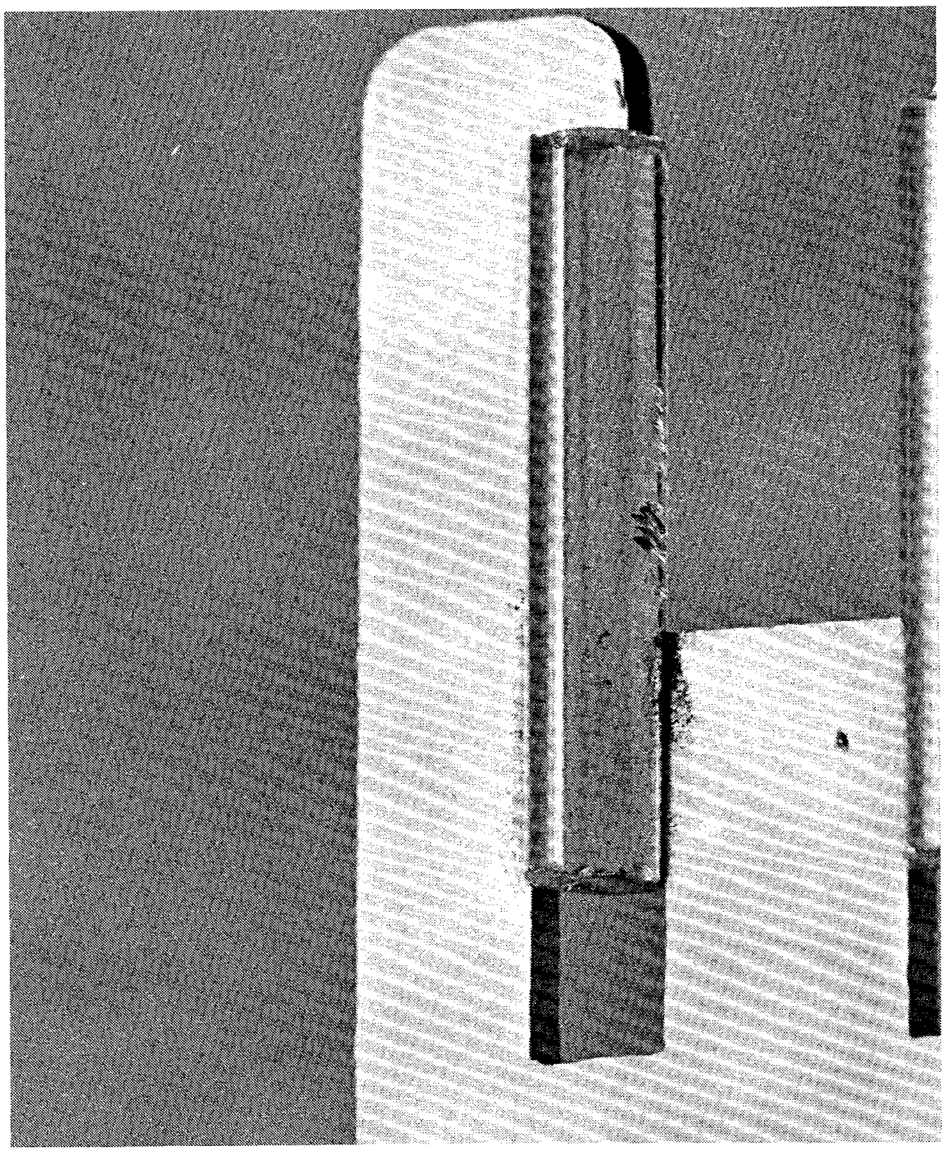


Figure G –
Glass guide with multiple grooving.

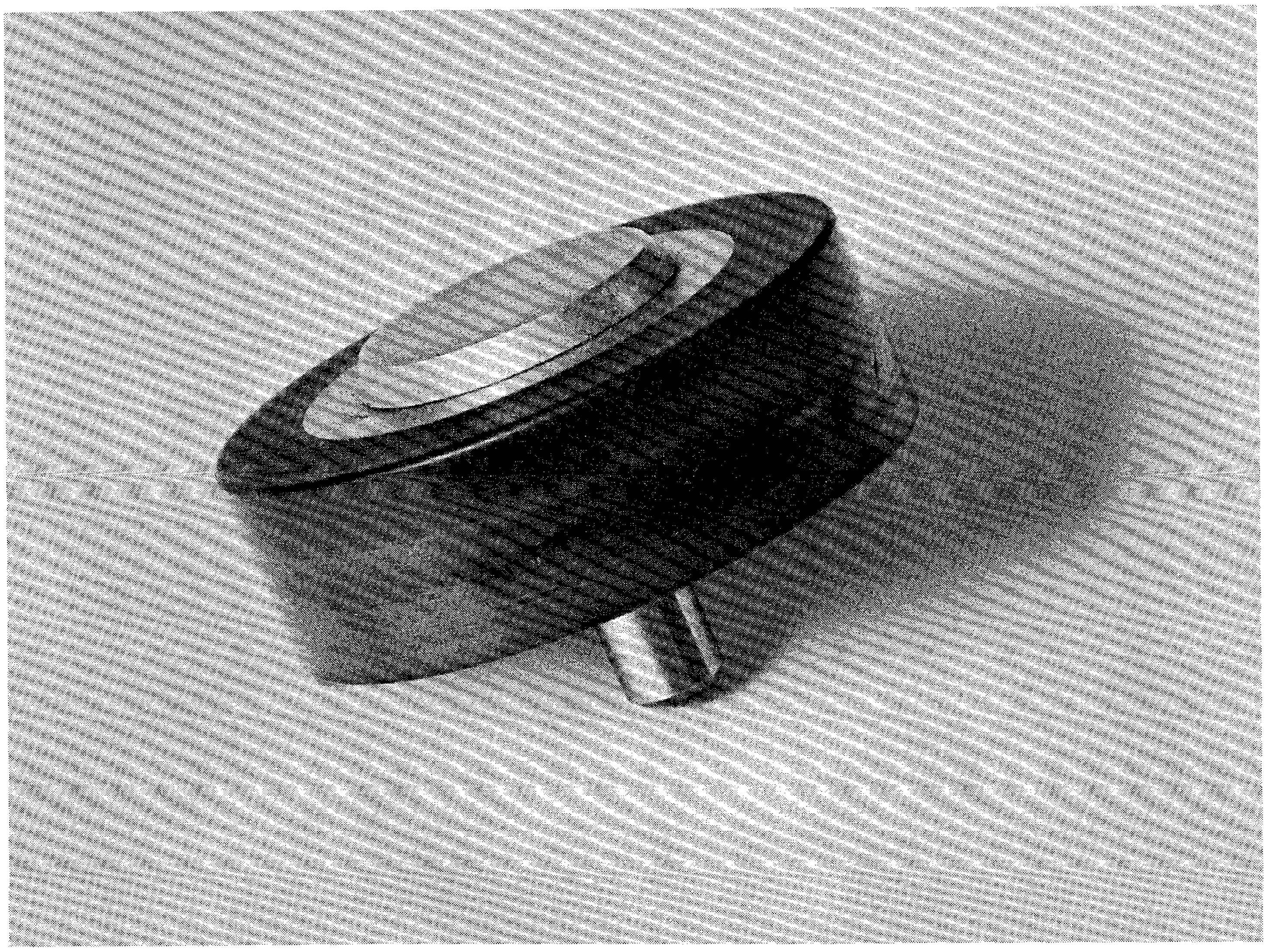


Figure H – Grooved capstan idler can cause steering with resulting skew

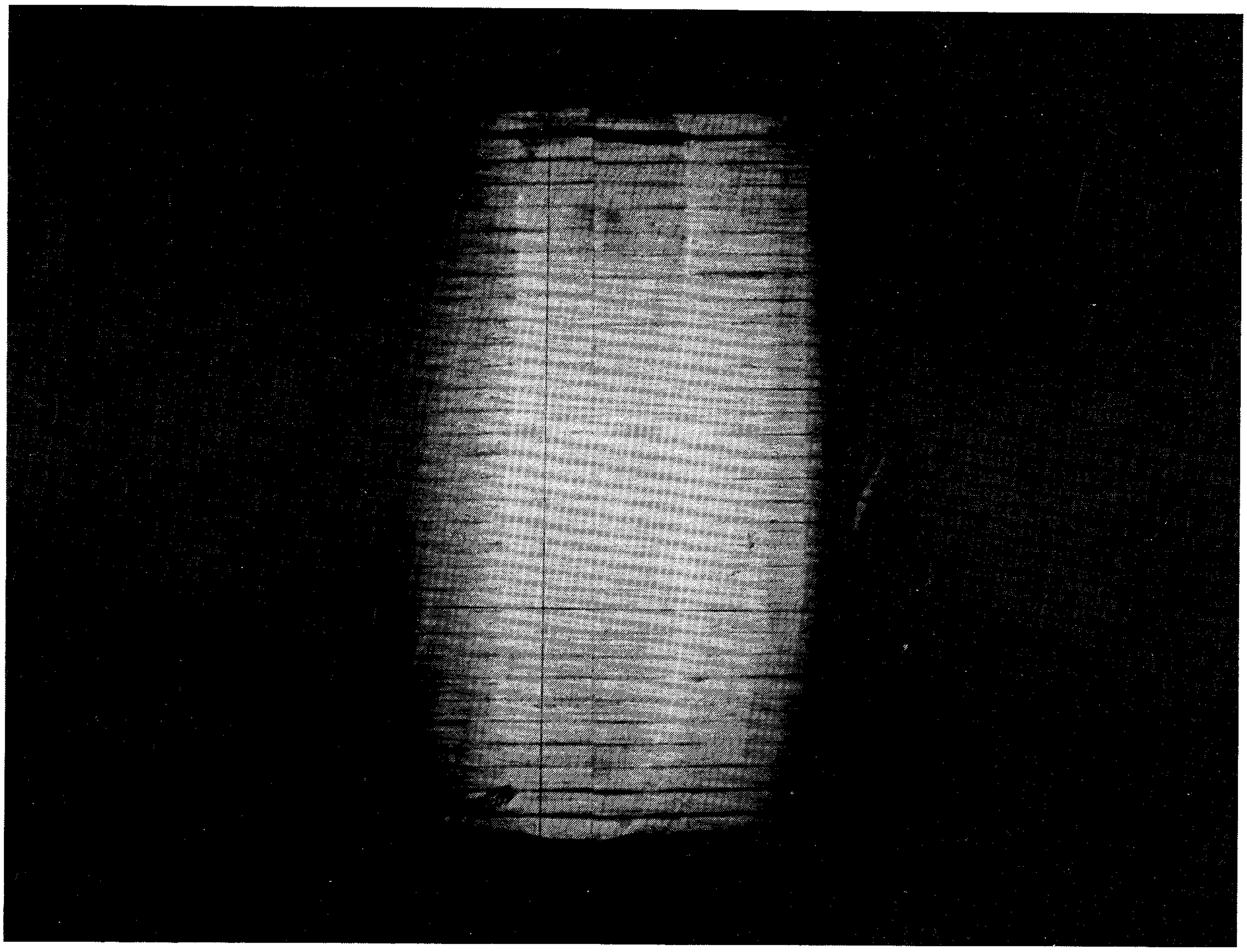


Figure I – Drumhead wear pattern.

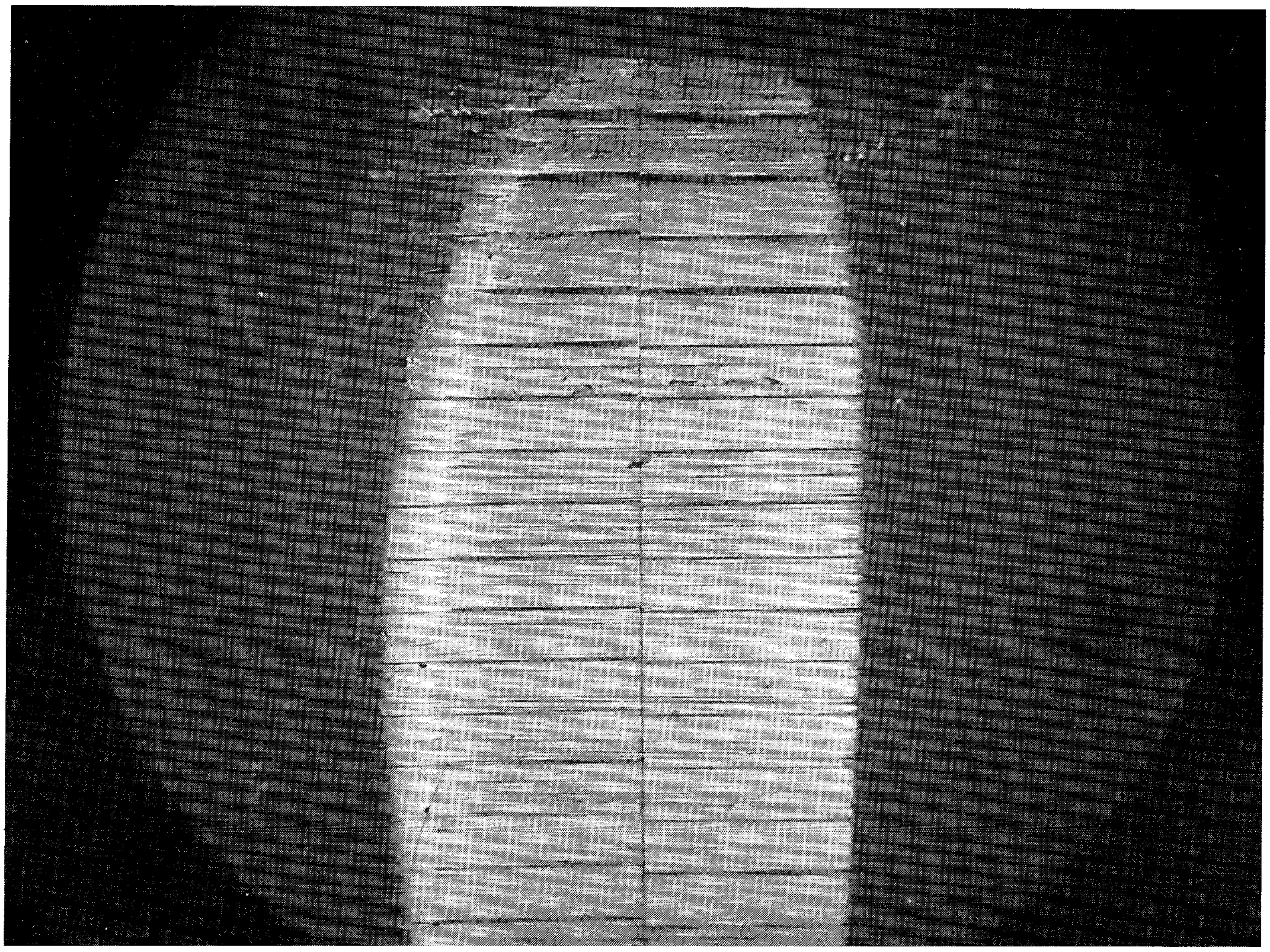


Figure J – Drumhead wear pattern.

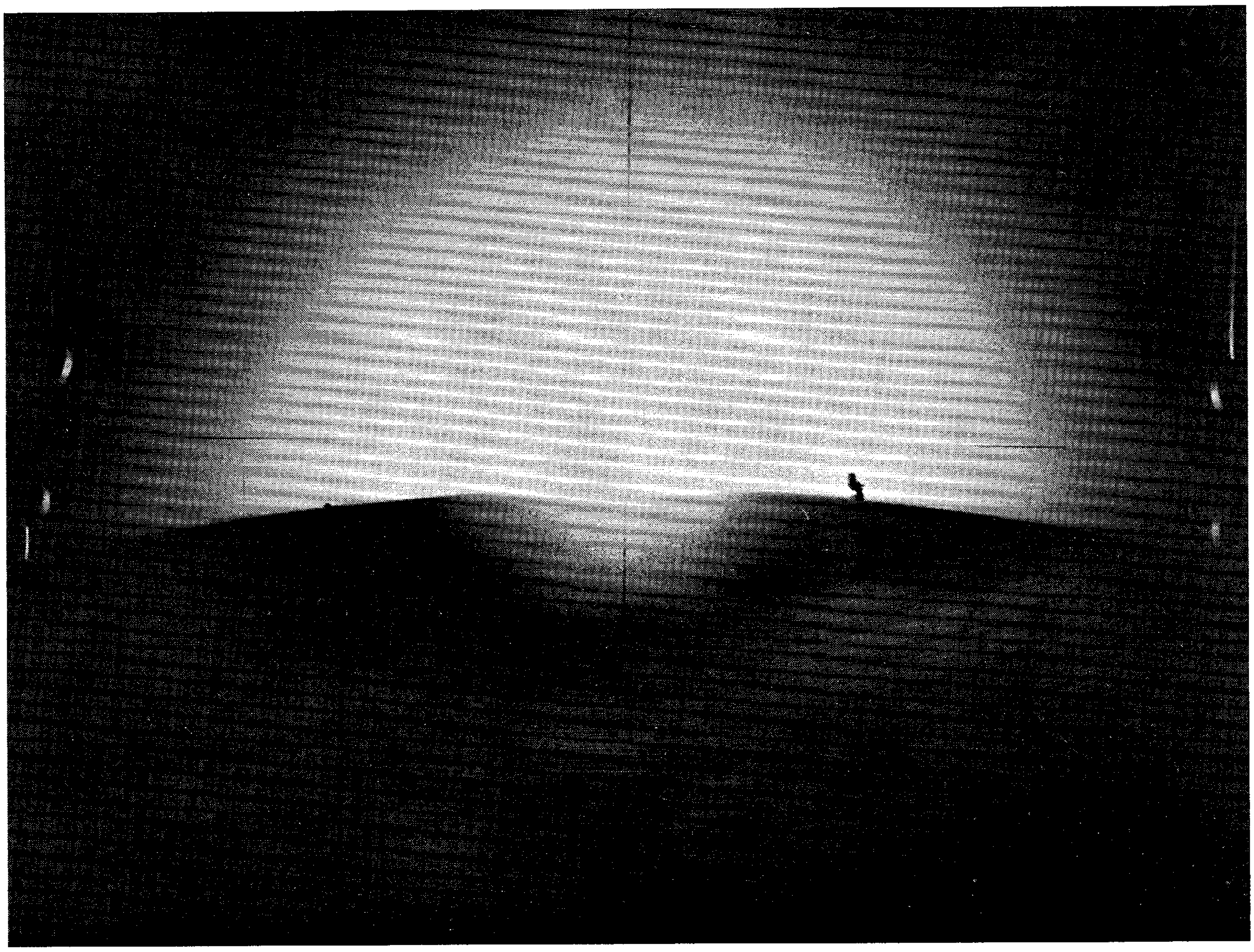


Figure K – Shadow graph of worn drumhead showing concave area at gap.

some double system drum head recorders operate with a spring loaded head which bears upon the magnetic film as it wraps around a drum. This arrangement produces a different type of wear pattern. Figures I, J and K indicate the concave pattern resulting from this system. Fig. K is a shadowgraph view taken from where the edge of the film would travel.