STANDARD TAPE MANUAL

A data book for the AUDIO tape recordist, engineer or designer

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We have attempted to correct any errors in the data found in this book, however the use of the material herein will be at the sole risk of the user.

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TABLE OF CONTENTS

SECTION 1 – HEAD LOSSES
Gap losses, Core losses, Spacing losses.

SECTION 2 – FLUX LEVELS
Normal, Elevated, and relative difference chart.

SECTION 3 – AZIMUTH:
Determination, results of misalignment on phase error in various track configurations, level losses due to azimuth disagreement, five charts.

SECTION 4 – REPRODUCE AMPLIFIER RESPONSE:
Definition of induction loop response, and amplifier characteristics.

SECTION 5 – AMPLIFIER CURVES, INDUCTION LOOP RESPONSE CURVES, IDEAL RESPONSE CHARTS.

SECTION 6 – WAVELENGTH CHARTS: English and metric.

SECTION 7 – PRACTICAL TECHNIQUES OF MEASUREMENT:

- (A) HOW TO MAKE INDUCTION LOOP MEASUREMENTS
- (B) HOW TO MEASURE CONSTANT CURRENT THROUGH THE RECORD HEAD:
  Low end calibration
- (C) HOW TO MEASURE TRACK WIDTHS:
  Charts for formats 150 mil through 2"
- (D) LOSSES TO RECORDED SIGNALS:
  Storage, bending loss, oxide abrasion, demagnetization.
- (E) HOW TO MEASURE DISTORTION:
  Importance of separating second and third harmonic content from total readings.
- (F) HOW TO CHECK FOR MAGNETIZED COMPONENTS AND OTHER ELECTRICAL FIELDS CAUSING UNWANTED ERASURE AND NOISE:
  Measurement equipment illustrated: simple magnetometers, Hall effect magnetometer, indicator fluids, and magnetic viewers.
- (G) HOW TO CHECK FOR HEAD RESONANCE:
  Including, cable and core loss effects.
- (H) HOW TO CHECK FOR STATIC NOISE CAUSED BY UNGROUNDED HEADS, AND HOW TO REMEDY.
- (I) WEAR PATTERNS:
  Illustrations of wear patterns to heads, guides, and idlers, and how to initially insure that your equipment will not suffer from instability caused by uneven wear to these components.

INTRODUCTION

This data book will, we hope, be useful to those who must have the basic information necessary to standardize, maintain, or design audio magnetic tape reproducing systems. It is a book for those who are familiar with the fundamentals of magnetic recording and simply require a quick source of reference data to "plug in" to their routine endeavors.

The intent in compiling this lab manual was to provide that material not readily available in the many texts treating magnetic recording.

In the process of helping users of magnetic recording equipment to select appropriate test tapes and to interpret correctly the results obtained with these tapes, it has become evident what sorts of information are required by users of such equipment.

Consider the possible need to design a suitable reproducer for four track ¼" tapes having CCIR equalization and response to 20 kHz at 7.5 ips (19.05 cm/s). One could proceed as follows:

(1) Select appropriate response chart from Section #5.

(2) Note proper track dimensions for head selection in Section #7.

(3) Determine shortest wavelength to be encountered (See chart, Section #6)

(4) Consult Section #1 to obtain a practical gap specification for a suitable reproduce head for the response desired.

In the above four steps, requiring only a few minutes, one can determine the basic practical specifications needed to proceed with the job at hand. Other considerations such as the needed amplifier headroom will depend on the operating levels encountered. Section #2 will aid in this area, as will Section #3 in determining the minimum achievable phase error between tracks, as related to Azimuth error.

SECTION 1

Head Losses

CONSIDERATIONS CONCERNING THE REPRODUCE HEAD GAP:

The most significant losses due to gap effects occur in the reproduce head. As the wavelength of the signal to be reproduced approaches the effective length of the head gap, the flux induced in the head drops rapidly, nulling out when the gap is a multiple of the recorded wavelength.

At audio frequencies and normal tape speeds, the record head accounts for very little wavelength loss. The attached nomograph indicates losses caused by the playback head at various wavelengths. Since wavelength is determined by dividing the tape speed by the frequency involved, we can appreciate that very short wavelengths are encountered at high frequencies and slow tape speeds. (For example 10kHz at 1-7/8 ips is only 0.187 mils in length and therefore a short gap reproduce head is called for to reproduce material at this speed.) The term "gap length" of a magnetic head is often confused with the track dimension. Length refers to the distance between pole pieces established by the spacer. The thickness of the spacer determines the physical dimension of the gap length; however we must bear in mind that the physical gap length is not precisely the effective or magnetic gap length. Gap lengths are controlled during the manufacture of magnetic heads by selecting the desired spacer, or shim, and by measurement of the material by mechanical and optical means. Often the OPTICAL gap is less than the thickness of the original shim material, due to the result of compression during assembly. This is particularly true when the gap is made of paper or other soft material. The MAGNETIC GAP length is ALWAYS greater than the physical gap length. The difference can range from only a few percent to 15%. If one wishes to estimate the magnetic gap, a good conservative practice would be to use a factor of about 1.15. Therefore, if the playback head has a 100 micro-inch spacer, a maximum effective gap of 115 micro-inches may be used to obtain an approximate gap loss to be expected from this head at a specific wavelength. An accurate measurement of the actual or magnetic (i.e. effective) gap length can be accomplished through experimental means. A slowly rising sweep frequency is recorded, and the playback observed simultaneously. The null points of the reproduce head will be obvious and will appear at somewhat longer wavelengths than the thickness of the spacer material, as noted above.

CONSIDERATIONS CONCERNING THE RECORD HEAD GAP:

The efficiency of the record head at all wavelengths, depends upon its gap length. In audio work we tend to keep the gap length rather long for recording use, for example ½ to 1 mil. Where a combination record-reproduce head must be used, a compromise must be made to select a head with a gap long enough to be efficient for recording and yet not too long to be able to reproduce the necessary short wavelength information. Also where wide range Sel-Sync* response is required at moderate tape speeds, the gap length of the record head must be compromised. The shape of the bias field produced by a short gap record head causes such recording to be more susceptible to dropouts and a very short gap head is difficult to drive, so good practice is to avoid record gaps much shorter than ½ mil, unless other considerations specifically necessitate such a choice. (A specific exception to this very low speed recording such as in cassette and logging formats, where thin oxide tapes and quite short gap record heads ARE in order.)

In instrumentation work, the very short wavelength requirements often dictate the use of very short gap record and playback heads. As a matter of interest we have provided a chart showing the variation in an instrumentation system having fixed reproduce heads with various record heads having gap spacers ranging from 50 micro-inch to 200 micro-inch. Note that the six db spread occurs at very high frequency at the indicated speed which is 120 ips. Cassette and logging speeds have similar requirements as to wavelength so the chart can be used to directly apply to such systems. *Trademark of Ampex Corporation

PRACTICAL USE OF THE GAP LOSS NOMOGRAPH:

Before giving a practical example of the use of the nomograph, we should mention that there are other losses associated with the reproducer head, namely core losses and spacing losses. In audio these tend to be less of concern than the gap losses encountered in an average system. To determine the loss expected from the gap loss alone, one can use the nomograph thusly: For a given frequency, say 15kHz on a 7½ ips tape, the wavelength is determined from the wavelength chart or simply by dividing the tape speed by the frequency. In this case, the wavelength is 0.5 mils.

A straight edge is positioned to line up the gap length of the head (let us say for this example it is 130 micro-inches), with the wavelength of 0.5 mils. In this example, the loss from such a head at this frequency and tape speed would be expected to be 1.0 db.

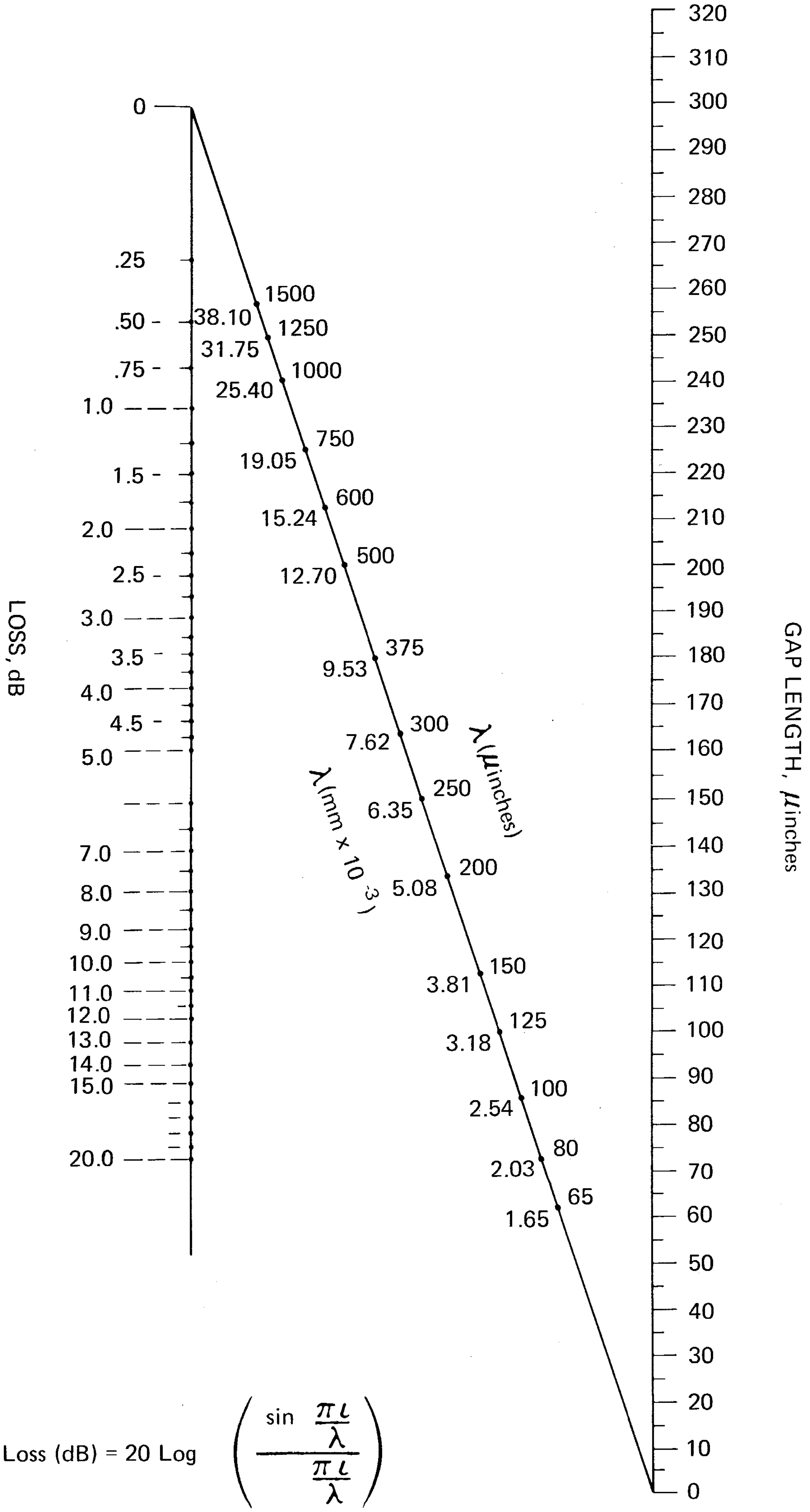
In designing a theoretically perfect reproduce channel for use with a head gap of 130 micro-inches, at a tape speed of 7½ ips with the upper limit of 15kHz, one would then equalize the reproduce channel to deviate from the appropriate curve selected from section #5, by one db at 15kHz, to compensate for gap loss.

CORE LOSSES

Core losses are a function of frequency, not wavelength as is the case with gap and spacing losses, and thus will affect a given head at the same point in the audio spectrum regardless of tape speed.

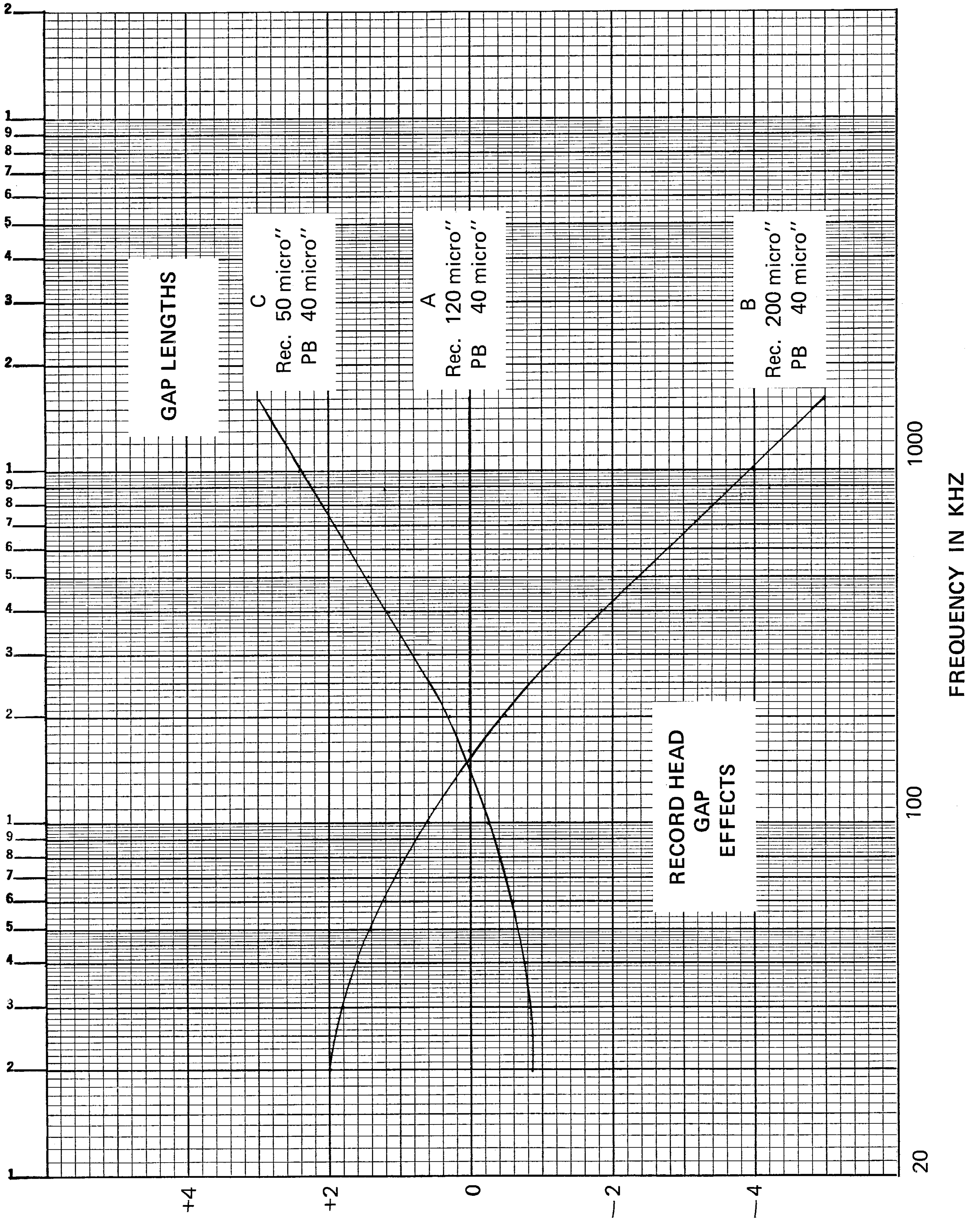
Core losses can result from excessively thick head laminations, or lack of proper insulation between laminations in the stack or between stack and frame. The core IS grounded to the frame to eliminate static buildup and discharge (see section #7), but at only one point. The overall efficiency of the core also depends

GAP LOSS NOMOGRAPH



$$\text{Loss (dB)} = 20 \text{ Log} \left(\frac{\sin \frac{\pi l}{\lambda}}{\frac{\pi l}{\lambda}} \right)$$

Note: $\frac{\pi l}{\lambda}$ *in Radians*



EFFECT OF RECORD GAP ON SHORTWAVE RESPONSE

upon the permeability of the core material after annealing.

Core losses found in modern magnetic heads used for audio usually are minimal over the normal audio spectrum; however, such losses can be significant in the case of duplicators or instrumentation systems where frequencies outside the normal audio band are encountered. To be specific, a typical audio head may show a small high frequency loss due to core effect at 20kHz while the same head could be deficient by several db at 120kHz if it were used in a medium speed duplication system. Core losses will show up during loop induction measurements of playback systems as described in section #7 dealing with practical measurements.

SPACING LOSS – formula: loss in db = 54.6(d/wavelength) where d = spacing distance

Any separation between oxide and tape head pole pieces results in spacing loss. The shorter the wavelength, the greater the loss for any given separation. The "55db" loss formula actually indicates a loss of 54.6 db for every one wavelength of separation. One can see, therefore, that a system suffering from a spacing problem of 100 micro-inches would cause a recorded signal of 7.5kHz recorded at 3.75 ips (wavelength of 0.5 mil) to lose in reproduction, 1/5th of 54.6 or 10.92 db!

An important caution to be observed in accounting for spacing loss is the fact that spacing losses due to oxide buildup on heads do not usually extend over the whole track area, and depending on head geometry and tape tension, the reproduce head will average the signal from the uncontaminated portion of the tape or head.

Thus a full track recording may reproduce reasonably satisfactorily despite a severe loss in one area across the wide reproduce head. Spacing losses are usually a more frequent problem in the case of narrow tracks as used in multiple track formats.

SECTION 2

Flux Levels

The importance of standardization of operating and reference levels is well understood. Calibration of equipment, for interchange of tapes and adjustment of noise reduction apparatus, requires accurate control of flux levels.

The expression FLUX LEVEL and the term Fluxivity represent the strength of the signal once it is recorded on magnetic tape. It is presently practical to express the degree of magnetization in absolute terms at medium wavelengths. The current practice is to state the signal strengths in billionths of a Weber per meter. Thus the most commonly encountered operating level today for 7½ ips reel to reel recording may be expressed as 185 nWb/m, at a given wavelength. (Often 700Hz or 10.7 mil wavelength at that speed).

EUROPEAN PRACTICE IS TO OFTEN STATE FLUX LEVELS IN MILLIMAXWELLS PER MILLIMETER.

Thus 100 nWb/m could be expressed as 10 millimaxwells per millimeter. To say it another way, when encountering a cassette standard for example indicating a peak level reference of 25 mMx/mm, we have only to add a zero to express the level in nanoWebers. (250nWb/m)

A brief mention should be made of the origin of choices for operating levels to be employed with the available tape and equipment. Before standards organizations addressed the subject, the industry, largely one company—determined experimentally that level which caused 3M 111 A tape to generate one per cent third harmonic distortion of a 15 mil wavelength signal when bias was adjusted for a maximum output of that signal. The 185 nWb/m flux level reference thus became "standard operating level" in U.S. practice, and is the standard from which most other recommendations have evolved. A word of warning: In the 50's and 60's several theoretically oriented writers took an interest in pinning down the absolute value of the empirically derived standard operating level and some published findings after measurement by very crude means. Anyone familiar with the literature of the time may remember figures ranging from 175 to 210 nWb/m, describing the *same* flux reference tape.

Fortunately the test tapes of the time were made using comparison tests to vault copies maintained for that purpose. Therefore, while our methods of "absolute" measurement were poor, the practical level references were held to very respectable tolerances. The professional test tapes of the time stayed within plus or minus ¼ db at medium wavelength reference set. The early attempts at absolute measurements with vibrating magnetometers, have largely been supplanted by measurement employing specially constructed flux measuring heads designed for measurement at medium wavelengths.*[1] The use of such a head requires a calibrated voltmeter, a frequency counter and means of determining exact width of the recorded track. The accuracy of such a system has been quoted as ranging from 3% to 5% depending upon the individual tolerances of the measurement components. In practice, this author has seen a spread of about 10% in measurements taken by professionals using the SAME reference tape, and even on occasion the same flux measurement head. The extra 5%, in my opinion, was due mostly to *mechanical* problems such as slight spacing losses and variance in technique of measurement of track widths encountered in different laboratories.

The above method, using the special flux measurement head, provides a voltage reading from the tape being measured, which is then applied in the formula along with the exact track width and wavelength. In making any of the measurements, we must remember that the recorded track may not be uniform across its width. The total flux will be averaged, and therefore, it is desirable to confirm that the tape is uniform across the track or tracks being measured. This can be checked in several ways: turning over the tape on multiple track equipment or scanning the tape with a narrow, vertically adjustable head are two methods. We should point out here, that the heads used to make test tapes are usually controlled to produce tapes having very little flux variation across the track. Record heads used in normal professional service often produce enough flux variation to indicate a spread of 1 or 2 db over a track width of 247 mils when scanned with a single 43 mil track, mounted on a "dove tail" assembly providing displacement of the head. Many ferrite record stacks with uneven core density show considerably more variation. It is for this reason that, up to now, the most successful special heads for wide format test tape use have been of stacked lamination construction with very carefully controlled evenness of gap depth to insure the most constant flux to the tape across its width.

Many cases of confusion have resulted from attempts to set up duplicators using peak reference test cassettes, on VU metered equipment, resulting in saturated tapes. What a VU meter detects and indicates is the general energy content of a program from moment to moment. The ballistic response of a true VU meter was carefully chosen and specified for ease of reading and accuracy of application to a wide range of normal speech and music material; the general understanding has been that at least 10 to 15 db of "headroom" in the recording or transmission medium is required between the zero VU level and the overload point, to accommodate the instantaneous peaks characteristic of speech and music. Thus, a reference level tone, for use with a recorder utilizing a VU meter would be chosen so that it would produce a flux level on the tape 10 to 15 db below tape saturation. If this tone were played back on a properly calibrated recorder equipped with a peak indicating meter, the meter would rise only to the level of the peak of the sine wave—far below the maximum permissible program peak level which produces reference deflection of a peak-indicating meter. If the meter calibration of such a machine were mistakenly sensitized to give a reading

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*1. The Measurement of Medium-Wavelength Flux on A Magnetic Tape Record. J. G. McKnight, 36th Convention AES April 28, 1969 Preprint 654 (H-3) of full modulation on the VU related reference tone, subsequent program recordings would be seriously under-recorded.

Correspondingly, the sine wave reference tone placed on a test tape intended for peak indicating meters is chosen so that its peak value is near the maximum capacity of the medium to handle, and if a VU metered machine were misadjusted to cause this tone to indicate Zero VU, subsequent recordings would be badly distorted.

From this it will be recognized that not all of the various reference flux levels encountered represent different choices of program operating level; each actual operating condition requires two different sine wave reference tones, to calibrate two different level indicating systems.

Note: It has been suggested that calibration tapes be recorded with a non sine wave reference tone of such character that its peak value bears such a relation to its RMS value that it could be used to calibrate either system. Though possible, this presently seems to have more drawbacks than advantages.

With the advent of newer tape oxides, it has become desirable to record at higher levels to increase signal to noise ratio. Some years ago, the (206 and 406) higher output tapes permitted a practical increase in level of 3 to 4 db over the older oxides, and therefore, an ELEVATED LEVEL became popular for mastering. The term ELEVATED LEVEL and the figure of plus 3 db were pretty much the writer's doing. (Remember that we are talking about VU meter readings as common in the U.S.A.) Round numbers are convenient, and 3 db above the established 185 nWb/m (261 nWb/m) was and remains a good increment. It would seem that this flux level has become the most popular for use in master recording in the U.S.A. It should be understood that these excellent high output tapes are best suited for use at the mastering speeds of 15 and 30 ips. At very slow speeds these mastering tapes are less suitable than thin oxide tapes intended to favor the short wavelengths encountered, for example, in logging machines running at 1-7/8 ips or slower.

The more recent mastering tapes (250, 456, etc.) provide another 3 db or better over the previously available tapes and therefore ELEVATED LEVEL EL6 (i.e. a level six db above the 185 nWb/m) has become used to some extent. EL6 represents 369 nWb/m. Much of the existing electronics in the field may limit the practical use of EL6 even though the tape itself is capable of satisfactory results. Some of the latest equipment is designed to operate at this level when using the appropriate tape. In practice, many of the studios have elected to stay with EL3 and, in so doing, retain the same approximate signal to noise ratio and at the same time enjoy the added "headroom" possible with the new tapes.

Some rather spectacular new oxides are in the offing and any equipment manufacturers would do well to consult the leading manufacturers of tape before proceeding with the design of any new tape equipment. Otherwise, the system may suffer in that it will be electronics limited rather than medium limited.

The following chart may be used to indicate various flux levels as they compare to a zero reference of 185 nWb/m. Formulae are also provided to allow slide rule and calculator computations for any flux level comparisons.

RELATIVE FLUX LEVELS

(Compared to the 185nWb/m Commonly Used Operating Level)

DB	Flux level in nWb/m
0	185
.5	196
1	208
1.5	220
2	233
2.5	247
3	261
3.5	277
4	293
4.5	311
5	329
5.5	348
6	369
6.5	390
7	414
7.5	439
8	465
8.5	492
9	521
9.5	552
10	585
10.5	620
11	656
11.5	695
12	736
12.5	780
13	826
13.5	875
14	927
14.5	982
15	1040

FLUX LEVELS FREQUENTLY CALLED OUT IN U.S. AND EUROPEAN STANDARDS:

referenced to 185nWb/m

100 nWb/m = −5.4 db
140 nWb/m = −2.5 db
160 nWb/m = −1.3 db
200 nWb/m = + .7 db
250 nWb/m = +2.6 db
320 nWb/m = +4.8 db
360 nWb/m = +5.8 db

$$\text{Flux Level} = 10^{\left[\frac{dB}{20} + \log_{10} 185\right]}$$

$$= 10^{\left[\frac{dB}{20} + 2.267\right]}$$

or may be written

$$\text{Flux Level} = \text{Antilog}_{10} \left[\frac{dB}{20} + \log_{10} 185\right]$$

SECTION 3

Azimuth

Direct magnetic recording produces "bars" made up of magnetized oxide particles. These lines or bars when produced by means of a record head gap of perfect straightness aligned to be exactly 90 degrees with reference to the edge of the tape, would constitute a recording having ZERO azimuth error. Such a recording would exhibit NO losses due to azimuth error when reproduced by another ideal head so aligned, and would provide perfect phase relationship of any one portion of the tape compared to any other portion. (A similarly perfect multi-track reproduce head would be required to demonstrate this condition). In practice, there of course must be tolerances. All heads have some deviation from straightness. Tape slitting tolerance contributes to varying skew of the tape as it plays across the heads. Machines without constant holdback tension will see a varying tension of the tape as the supply reel diameter changes. This also causes skew, with resultant azimuth changes. The narrower the track, the less critical the azimuth. The popular cassette format, with approximately 20 mil tracks, is "saved" by the narrow track at its low tape speed of 1-7/8 ips. A wider track at this speed would have much greater azimuth problems.

The determination of azimuth in the laboratory is quite well described in texts dealing with the general subject, however, we will briefly list the more practical methods.

(1) Pulse recording with recorded pattern made visible for readout on rather elaborate optical equipment capable of readings to within one minute of arc.

(2) "Mirror" image techniques, such as winding a high frequency recording on tape face to face with blank tape, exposing to a mild field to produce a printed mirror image. The two tapes are then each reproduced and the error halved, that is, the corrective arc is bisected. The experiment is continued until no correction of playback head azimuth is needed when comparing tapes. This method is cumbersome and seldom used.

(3) A head is built with accurately coplaner finished front and back gaps. Tape is drawn across one gap at a time. When maximum output is obtained at both gaps without altering azimuth, recording azimuth is shown to be vertical.

(4) A near perfect two track head is made to record and play two channels of recording. In this scheme the phase difference is noted when playing back the recording after the tape has been turned over oxide out and the signal is recovered through the base of the tape.

(5) A so called self proving azimuth tape has been produced having medium wavelength tones deliberately off azimuth by precisely the same amount in each direction. In playing back, the user bisects the error of the two tones, thus making the output equal for each tone. The tape can then be turned over and played through the backing to see if the two tones are still equal in level as they must necessarily be, assuming that the tape was made accurately. This method was also once used with variable density photographic recording where the inherent instability was more tolerable.

MISALIGNMENT AND PHASE ERROR IN TWO-TRACK SYSTEMS

The importance of proper alignment between the tracks in a two track system is critical if a situation arises in which one must sum the outputs of the tracks. Severe phase errors may occur, preventing proper signal summing and consequent distortion.

This particular analysis is limited to a consideration of two systems: (1) The new NAB cartridge (2) The standard two track stereo configuration. Results can be extended easily to multi-track systems by simply cascading the results in (2) above. In this analysis, several simplifying assumptions have been made, which are detailed below:

Assumption A: The angular offset is assumed to exist between the centers of the two tracks.

Assumption B: The angular misalignment is approximated, for the very small angles involved, by a section of circular arc.

Assumption C: The computed angular misalignment is linearly mapped into the sinusoidal flux distribution on the tape for the final result.

Assumption D: The calculations are for 1.01 mil recorded wavelength.

The effect of these assumptions is to introduce small errors in the final results which, however, are not measurable with typical resources available in the laboratory.

These results are summarized in Tables 1 and 2, following. The results have, in each case, been carried out to 20 minutes of arc (one third of a degree). The errors then begin to repeat as multiples of 360° (or close to it). It is instructive to note that misalignments of 17 minutes for the NAB cartridge and 10 minutes for the two track configuration will produce results close to a complete phase reversal. It, therefore, behooves the technician to be very careful when aligning heads and to use an oscilloscope to show lissajous figures. Also, he must ensure that the phase error does not exceed 360° (misalignments of more than 0.5 degrees will produce such gross errors).

TABLE 1

NAB 2 TRACK BROADCAST CARTRIDGE (2 Audio Tracks Plus 1 Cue Track)
1.0 MIL RECORDED WAVELENGTH (7.5 kHz @ 7½ ips)

Misalignment in minutes of arc	Resultant phase error in degrees between channels
1	11
2	21
3	31
4	42
5	52
6	63
7	73
8	84
9	94
10	105
11	115
12	126
13	136
14	147
15	157
16	168
17	178
18	189
19	200
20	209

TABLE 2

2 TRACK STEREO REEL TO REEL
1.0 MIL RECORDED WAVELENGTH

Misalignment in minutes of arc	Resultant phase error in degrees between channels
1	17.5
2	35.0
3	52.5
4	70.0
5	87.4
6	104.9
7	122.4
8	139.9
9	157.4
10	174.9
11	192.4
12	209.9
13	227.4
14	244.9
15	262.3
16	279.8
17	297.3
18	314.8
19	332.3
20	349.8

THE FOLLOWING CHARTS INDICATE THE LOSS DUE TO AZIMUTH MISALIGNMENT FOR VARIOUS TRACK WIDTHS.

ANY FORMAT MAY BE CALCULATED THROUGH USE OF THE FOLLOWING FORMULA

$$A = 20 \log_{10} \left[\frac{\sin \left(\frac{\pi b \tan a}{\lambda} \right)}{\left(\frac{\pi b \tan a}{\lambda} \right)} \right]$$

where A = loss in decibels;
b = width of sound track
a = angle of tilt
λ = wavelength of recorded signal.

Note: While a may be in degrees the quantity in parenthesis is in radians.

LOSS DUE TO AZIMUTH DISAGREEMENT
250 MIL FULL TRACK

1 Mil Wave Length		½ Mil Wave Length		¼ Mil Wave Length	
Loss in dB	Azimuth Error in Minutes	Loss in dB	Azimuth Error in Minutes	Loss in dB	Azimuth Error in Minutes
0.5 dB	2.5	0.5 dB	1.3	0.5 dB	0.64
1.0 dB	3.6	1.0 dB	1.8	1.0 dB	0.89
2.0 dB	5.0	2.0 dB	2.5	2.0 dB	1.25
3.0 dB	6.0	3.0 dB	3.0	3.0 dB	1.52
4.0 dB	6.9	4.0 dB	3.5	4.0 dB	1.73
5.0 dB	7.6	5.0 dB	3.8	5.0 dB	1.91
6.0 dB	8.3	6.0 dB	4.0	6.0 dB	2.07
7.0 dB	8.8	7.0 dB	4.4	7.0 dB	2.20
8.0 dB	9.3	8.0 dB	4.7	8.0 dB	2.33
9.0 dB	9.7	9.0 dB	4.9	9.0 dB	2.43
10.0 dB	10.0	10.0 dB	5.0	10.0 dB	2.53

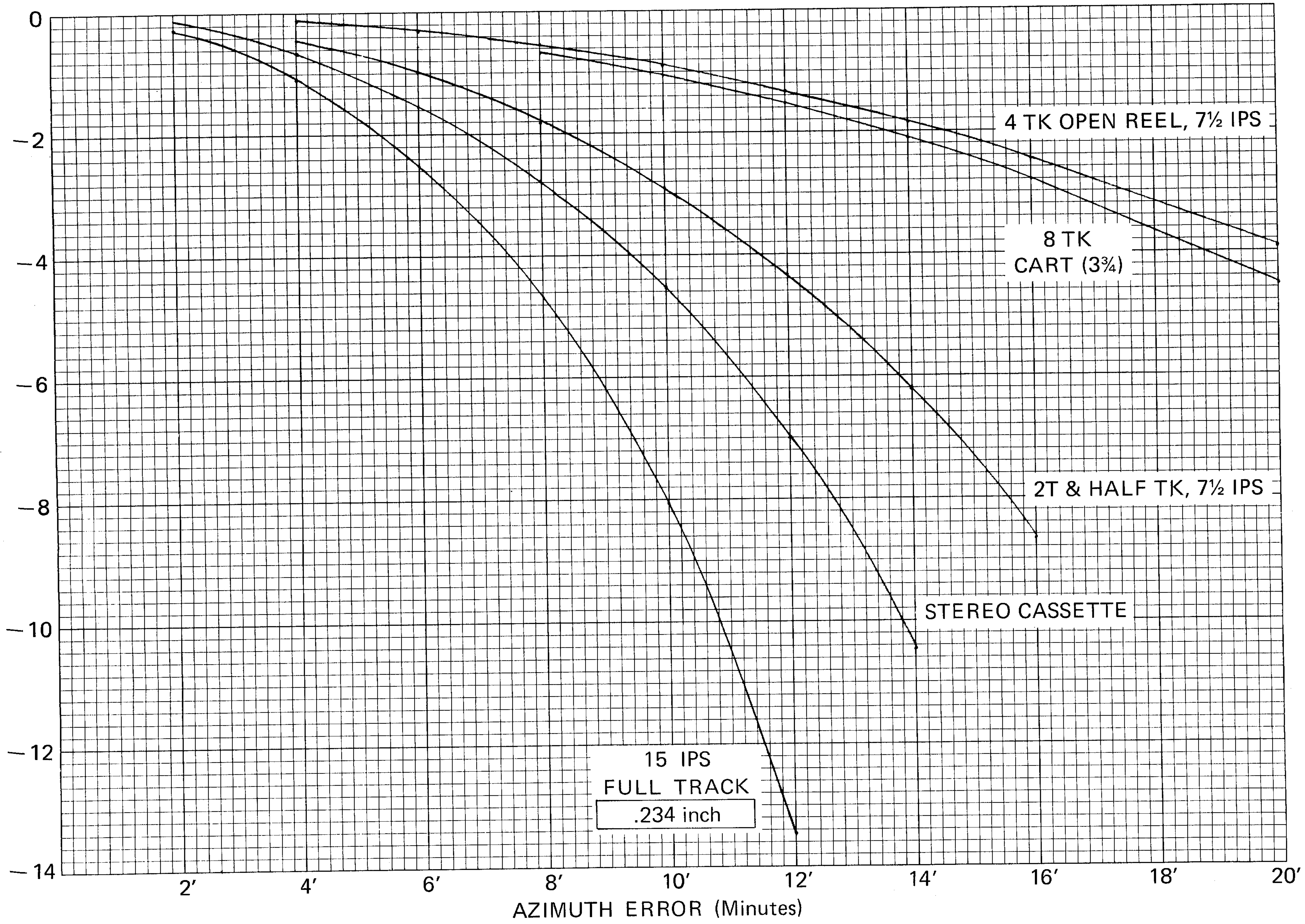
LOSS DUE TO AZIMUTH DISAGREEMENT
75 MIL TWO TRACK

1 Mil Wave Length		½ Mil Wave Length		¼ Mil Wave Length	
Loss in dB	Azimuth Error in Minutes	Loss in dB	Azimuth Error in Minutes	Loss in dB	Azimuth Error in Minutes
0.5 dB	8.52	0.5 dB	4.26	0.5 dB	2.13
1.0 dB	11.98	1.0 dB	5.99	1.0 dB	2.99
2.0 dB	16.75	2.0 dB	8.37	2.0 dB	4.18
3.0 dB	20.27	3.0 dB	10.13	3.0 dB	5.06
4.0 dB	23.12	4.0 dB	11.56	4.0 dB	5.78
5.0 dB	25.53	5.0 dB	12.76	5.0 dB	6.38
6.0 dB	27.61	6.0 dB	13.80	6.0 dB	6.90
7.0 dB	29.44	7.0 dB	14.72	7.0 dB	7.36
8.0 dB		8.0 dB	15.53	8.0 dB	7.76
9.0 dB		9.0 dB	16.26	9.0 dB	8.13
10.0 dB		10.0 dB	16.91	10.0 dB	8.45

LOSS DUE TO AZIMUTH DISAGREEMENT
43 MIL QUARTER TRACK

1 Mil Wave Length		½ Mil Wave Length		¼ Mil Wave Length	
Loss in dB	Azimuth Error in Minutes	Loss in dB	Azimuth Error in Minutes	Loss in dB	Azimuth Error in Minutes
0.5 dB	14.86	0.5 dB	7.43	0.5 dB	3.71
1.0 dB	20.90	1.0 dB	10.45	1.0 dB	5.22
2.0 dB	29.21	2.0 dB	14.60	2.0 dB	7.30
3.0 dB		3.0 dB	17.67	3.0 dB	8.83
4.0 dB		4.0 dB	20.16	4.0 dB	10.08
5.0 dB		5.0 dB	22.16	5.0 dB	11.13
6.0 dB		6.0 dB	24.08	6.0 dB	12.04
7.0 dB		7.0 dB	25.68	7.0 dB	12.84
8.0 dB		8.0 dB	27.09	8.0 dB	13.54
9.0 dB		9.0 dB	28.36	9.0 dB	14.18
10.0 dB		10.0 dB	29.50	10.0 dB	14.75

dB LOSS vs. MINUTES AZIMUTH ERROR AT 15kHz FOR SEVERAL COMMON RECORDING FORMATS



SECTION 4

Loop Response Measurements and Playback Amplifier Curves

The following pages present curves showing the standard induction loop response for various reproducer characteristics described in terms of time constants. Much confusion has occurred as to the relationship of the amplifier [alone] curve to the induction loop-head-amplifier curve. It is helpful to keep in mind that in a system having no gap, spacing, or recording process losses, a recording made by means of constant current, and subsequently reproduced through an amplifier having no frequency compensation, i.e. flat, would produce a signal rising 6 dB per octave. Normal repro. amplifiers are basically of the opposite characteristic, with a drop of 6 dB per octave over the audio spectrum *plus* whatever modification is called out in the particular standard for a given speed and application. The expression in "time constants" has been common in communications work (Radio, for example, 75 microsec. preemphasis in FM). The curve is defined by the time constant of the required values of resistor and capacitor components in the RC equalizer circuit. One must ALWAYS remember that the standard refers to equalization ADDED to the normal 6 dB/octave repro. curve. Therefore, the transition frequency reference is convenient to indicate where the curve DEPARTS from the 6 dB slope. (REFER TO THE 7.5 IPS 50 MICROSECOND AMPLIFIER CURVE* AND NOTE THE DEPARTURE FROM A STRAIGHT LINE AT 50Hz, AND AT 3200Hz.) The "3 dB" points can be expressed in terms of transition frequencies of 50Hz, and 3200Hz. To quickly illustrate the relationship of a loop response curve to an amplifier only curve, note that the loop response chart calls out plus 10.36 dB at 10kHz for the 7½-15 ips 3180 & 50 microsecond standard. Now look at the *amplifier only* response curve and note that the 10kHz point is NOT THE SAME. If you now place a straight edge along the straight part of the amplifier curve, and COUNT UP FROM THE STRAIGHT EDGE TO THE 10kHz POINT you will read the same 10.36 dB as shown in the induction-loop response. PLEASE forgive the harping on this point but MANY experienced people fail to realize that you cannot simply turn OVER the loop response chart and see the amplifier curve.

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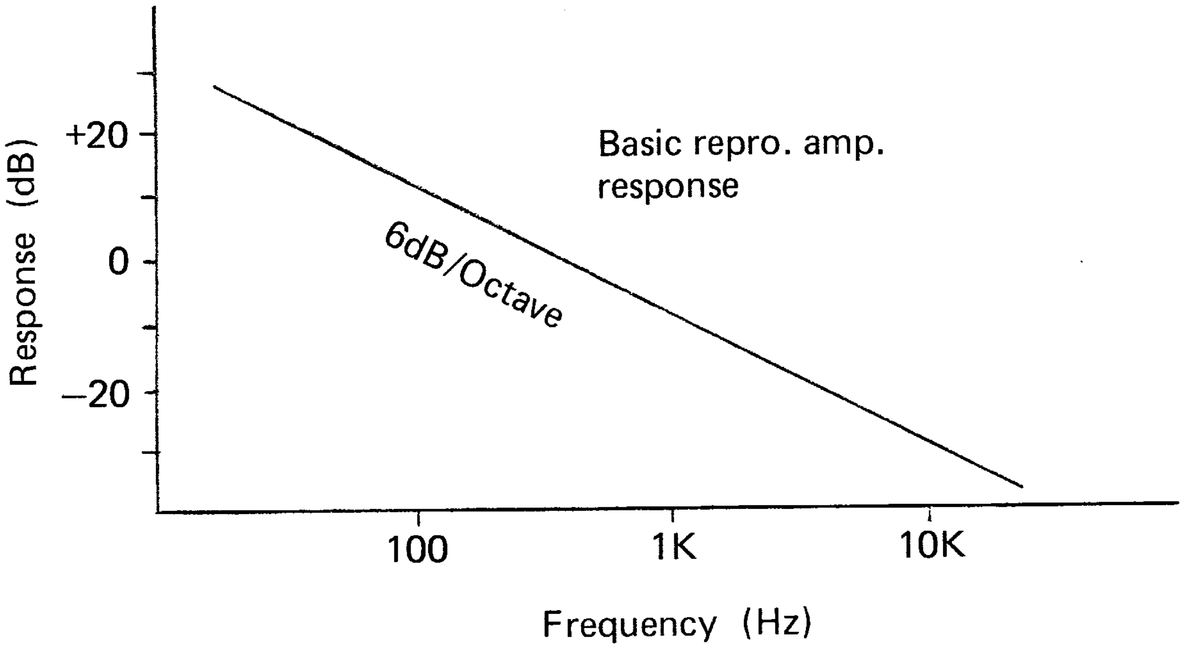
*Section 5

Amplifier response can be plotted from loop response by simply drawing a 6dB/octave line and adding to this line the amount by which the loop response figure deviates from the 0 dB reference. See examples below:



NOTE: in case of 50 microsecond response, PB amp. is displaced by 10.4dB from a straight 6dB/oct. slope at 10kHz. Loop response is 10.4dB above Zero reference.