# MAGNETIC RECORDING TECHNIQUES

W. EARL STEWART

McGraw-Hill Book Company, Inc.
NEW YORK TORONTO LONDON
1958

# 6 MAGNETIC RECORDING STANDARDS

In many applications of magnetic recording, it is desirable to produce a recorded medium on one piece of equipment and reproduce it on another, possibly even one made by another manufacturer. Several problems immediately present themselves to the equipment designer. For example, the physical form of the medium must be held within limits that are understood and acceptable to all manufacturers of this particular equipment; i.e., in tape recording, the size of the reel and its method of attachment to the machine must be standardized, and the width and thickness of the tape must be within certain limits. The speed of the medium is, of course, one of the important factors in interchangeability.

Another factor, for audio recording especially, is frequency response. Preferably, this should be standardized in terms of the recorded signal on the medium, since this is the item which must pass from one equipment to another. The NARTB standards in this chapter have accomplished this by specifying the response for an ideal reproducing system. In doing this they have, in effect, also specified the recorded signal on the tape.

During the years 1946 to 1953, when audio applications of magnetic recording were expanding rapidly, the need for standardization caused considerable activity in this field. Out of pure economic necessity, various industrial organizations formed committees which established the minimum standards needed to guide healthy growth in the new fields. In general, the standards established have been wisely chosen and rapidly adopted. They have allowed the industries to grow, yet they have not established limits to technical progress.

Economics plays a strong part in the growth of magnetic recording. It was the ability to use the media over and over again that made it





attractive to the Nazis for their propaganda program. This same factor has played an important part in its post–World War II growth. However, the ability to record and reproduce for long periods without interruption has also been very important. Disadvantages have included the high cost of storing a program on magnetic media and the high cost of duplicating a program on magnetic media for mass distribution. Hence, thinner tapes and slower speeds have been adopted as rapidly as the required performance could be obtained from them. Dual-track tapes were the result of this economic pressure, giving twice as much storage and playing time for the same piece of tape as a single, full-width track, at a small sacrifice in signal-to-noise ratio. In fact, the narrower track reduced the problems in the manufacture of a precise gap in the reproducing head and in maintaining azimuth alignment.

Standardization work will continue, but in general it will follow rather than lead the progress, and the standards presented here are likely to be augmented rather than changed. They are presented to give the designer the basic dimensions for his work in these fields. They may not, however, reflect the most advanced practice in a given field.

The applications of magnetic recording to such fields as data recording, computers, dictating machines, and automation have not required the free interchange of the media from a machine of one manufacturer to that of another. Hence, standardization has not been of great importance, and few standards have been adopted.

The following standards have been reproduced through the courtesy and cooperation of the agencies which established them.

# NAB (NARTB) RECORDING AND REPRODUCING STANDARDS *†

*For Mechanical, Magnetic and Optical Recording and Reproducing including a Glossary of Terms and Definitions*

The NARTB Recording and Reproducing Standards Committee was originally organized in 1941. Standards proposals issuing from the Committee have been adopted by the Board of Directors in 1942, 1949, and 1950. Standards as contained herein were adopted by the Board on June 19, 1953.

These standards and recommended good engineering practices are for the benefit and welfare of the broadcasting industry, and represent the contributions of more than 100 of the nation's authorities on the various phases of recording as used by the industry. The NARTB Recording and Reproducing Standards Committee has also benefited by contributions made by the administrations belonging to the International Radio Consultative Committee (Study Group X). The approach taken to many of the problems in the development of these standards was suggested by the work of CCIR Study Group X, particularly in the case of the methods of measuring the magnetization of a tape. The committee is open to participation by any interested individual or organization and consists of representatives from the manufacturers, broadcasters and producers. Close liaison has been maintained with other organizations (as well as foreign countries) to insure the maximum degree of coordinated understanding and recommended standardization, to permit interchangeability and, at the same time, to embrace the latest technological advances of the art.

Nothing in these standards prohibits or discourages continued progress or advancement of the art. On the contrary, the standards are so molded as to provide a stimulus for continued scientific exploration in the field of recording. It is anticipated that when necessary the NARTB Recording and Reproducing Standards Committee will review its work of the past decade, looking toward any needed amendments and additions to keep pace with the art as it affects all forms of broadcasting—AM, FM, and Television.



† The following pages contain Section 2, Magnetic Recording and Reproducing Standards, in its entirety; and selected items from Sections 3 and 4 which appear to apply to magnetic recording.



## Section 2. Magnetic Recording and Reproducing Standards

### *Magnetic Tape Dimensions*

**2.05** Thickness. It shall be standard that the thickness of magnetic tape shall not exceed 0.0022 inches.

**2.10** Width. It shall be standard that the width of magnetic tape shall not exceed 0.250 inches nor shall it be less than 0.244 inches.

### *Magnetic Tape Speed*

*Definition.* Magnetic tape speed for recording and reproducing is the velocity of the magnetic tape recording medium with respect to the recording or reproducing device.

**2.15** Primary standard. It shall be standard that the primary standard magnetic tape speed shall be 15 inches per second.

**2.20** Secondary standard. It shall be standard that the secondary magnetic tape speed shall be 7.5 inches per second.

**2.25** Supplementary standard. It shall be standard that the supplementary magnetic tape speed shall be 30 inches per second.

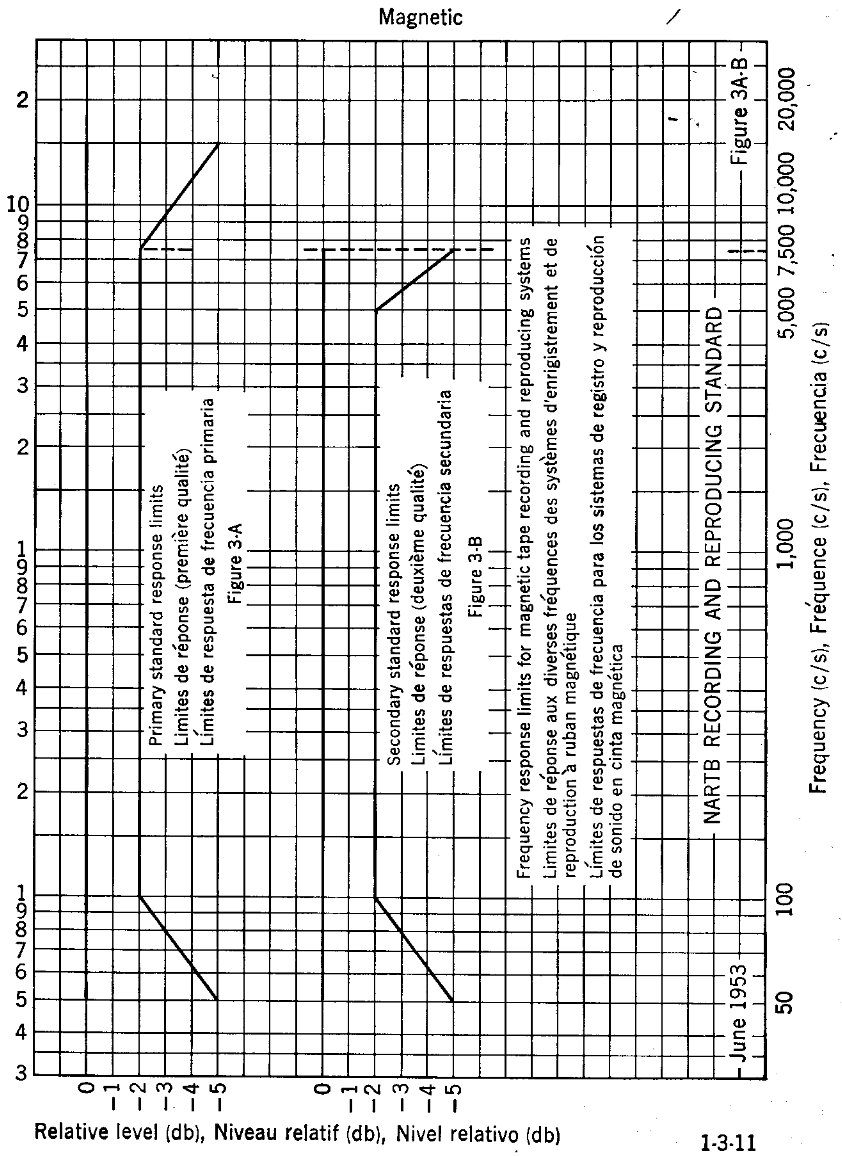
### *Frequency Response Limits*

**2.30** Primary Frequency Response Limits. It shall be standard that the primary frequency response shall lie between two limits. (See Figure 3-A.) [Text Fig. 6-6] The upper of these limits shall be uniform from 50 to 15,000 cps. The lower shall be uniform from 100 to 7500 cps and 2 db below the upper limit. In addition, the lower limit shall be an additional amount down at 50 and 15,000 cps determined by decrease at a uniform rate of 3 db per octave below 100 cps and above 7500 cps.

**2.35** Secondary Frequency Response Limits (for applications where a restricted frequency response may be tolerated). It shall be standard that the secondary frequency response shall lie between two limits. (See Figure 3-B.) The upper of these limits shall be uniform from 50 to 7500 cps. The lower shall be uniform from 100 to 5000 cps and 2 db below the upper limit. In addition, the lower limit shall be an additional amount down at 50 and 7500 cps determined by a uniform 3 db decrease from 100 to 50 cycles and from 5000 to 7500 cycles.

### *Flutter and Wow*

**2.40** It shall be standard that the instantaneous peak flutter and wow shall not exceed 0.2% (peak to peak 0.4%) when recording and reproducing on the same equipment.



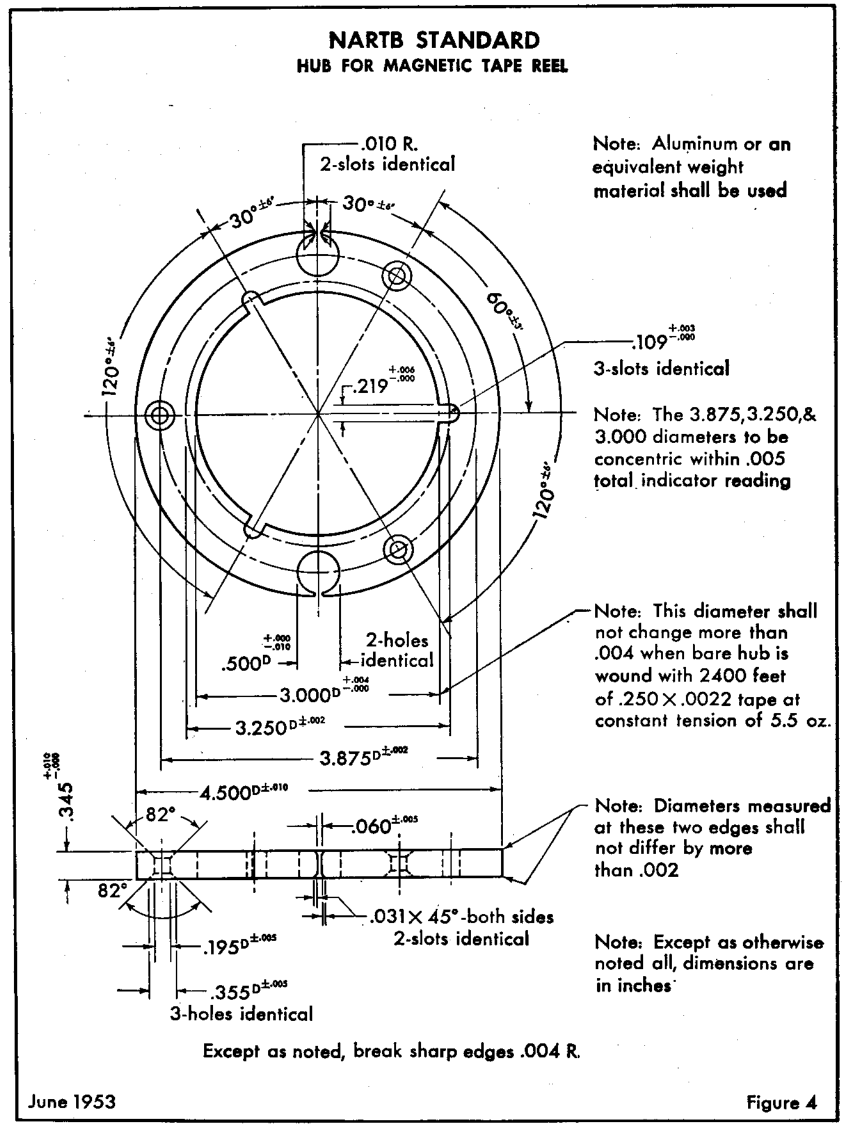

[Fig. 6-6]





*Magnetic Tape Reel*

**2.45** It shall be standard that the hub carrying magnetic tape shall be in accordance with Figure 4. [Text Fig. 6-7]




[Fig. 6-7]

*Tape Wind*

**2.46** It shall be standard that magnetic tape, when supplied on reels ready for use, shall be wound with the active magnetic surface on each layer facing toward the center of the reels.

**2.50** Primary standard. It shall be standard where flanges are used that the primary standard flange shall be in accordance with Figure 5. [Text Fig. 6-8]

**2.50.01** The primary standard flange provides for the accommodation of sufficient magnetic tape of standard thickness for a nominal 30 minutes of recording.

*Erasing Function*

**2.55** It shall be standard that the erasing function shall be applied to the entire width of the tape.

*Magnetic Tape Length*

**2.60** Length—Primary standard. It shall be standard that the primary standard length of magnetic tape shall be 2,400 feet, + 50 feet, − 0 feet.

**2.60.01** The primary standard length of magnetic tape provides the nominal amount of maximum thickness magnetic tape for the primary standard flange as well as a nominal recording time of 30 minutes (plus a starting and stopping margin) when recording with the primary standard magnetic tape speed.

**2.65** Length—Secondary standard. It shall be standard that the secondary standard length of magnetic tape shall be 1,200 feet, + 25 feet, − 0 feet.

**2.65.01** The secondary standard length of magnetic tape provides a nominal recording time of 30 minutes (plus a starting and stopping margin) when recording with the secondary standard magnetic tape speed.

*Magnetic Sound Track Position*

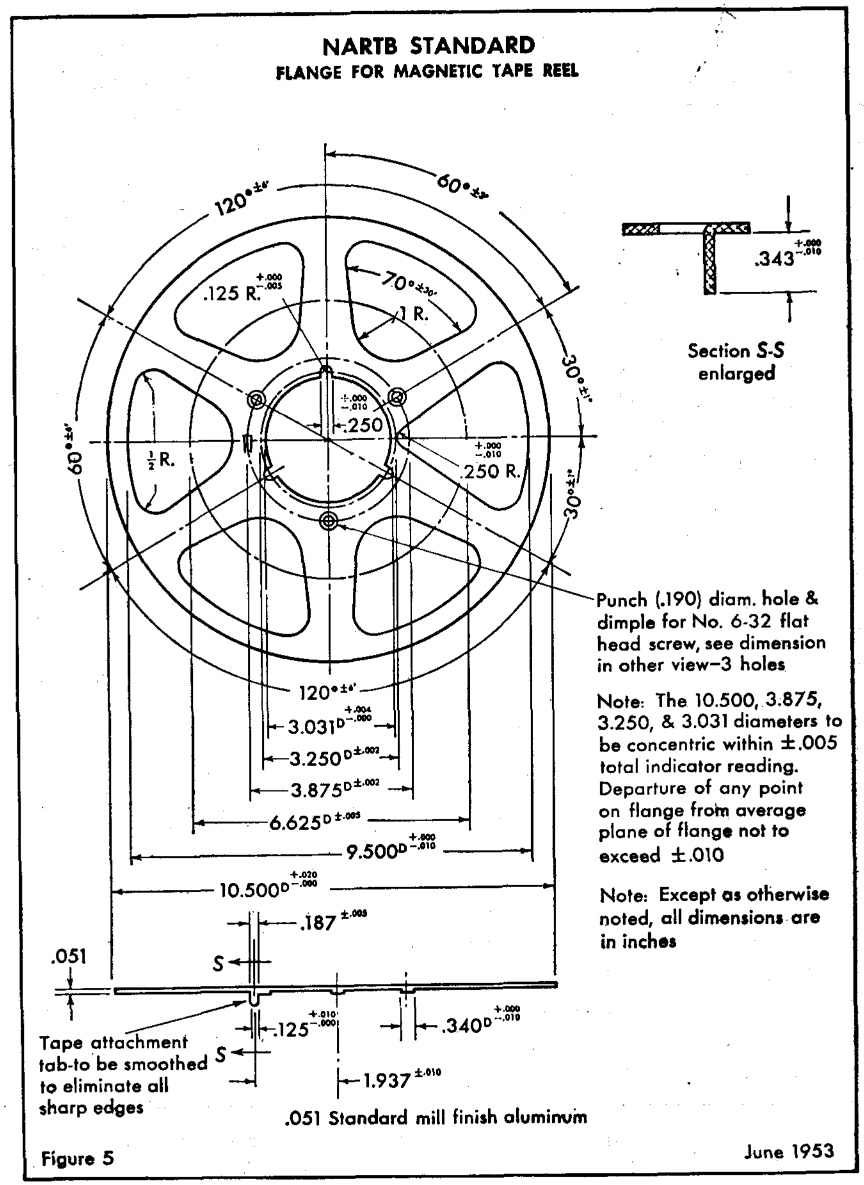
**2.75** It shall be standard that the magnetic sound track shall be symmetrically located with respect to the center line of the tape.

*Standard Reproducing Characteristic*

**2.80** It shall be standard that a Standard Reproducing System is one having an "ideal" reproducing head,* the EMF of which is am-

* An "ideal" reproducing head is defined as a reproducing head the losses of which are negligible. With a normal ferromagnetic head this means that the gap is short and the arc of contact with the tape is long compared to the relevant






[Fig. 6-8]

plified in an amplifier with a response curve having the following characteristic:

> At a tape speed of 15″/second: The response curve shall be that which results from the superposition of three curves; one that falls with increase of frequency at the rate of 6 db per octave; this curve to be modified at low audio frequencies by a curve that falls with decrease of frequency in conformity with the admittance of a series combination of a capacity and a resistance having a time constant of 3180 microseconds; and this same curve to be modified at high audio frequencies by a curve that rises with increase of frequency in conformity with the admittance of a parallel combination of a capacitance and a resistance having a time constant of 50 microseconds. The combined curve is shown in Figure 6. [Text Fig. 6-9]

### *Methods of Establishing the Standard Reproducing System*

**2.85** The relative surface inductions at different frequencies on a tape can be measured by at least three methods that are described in the Annex [p. 182]. From such measurements the departure of the response of a reproducing head from the "ideal" can be deduced and consequently a Standard Reproducing System can be established as a primary standard. Test tapes can then be made which can serve as secondary standards for use in normal operation.

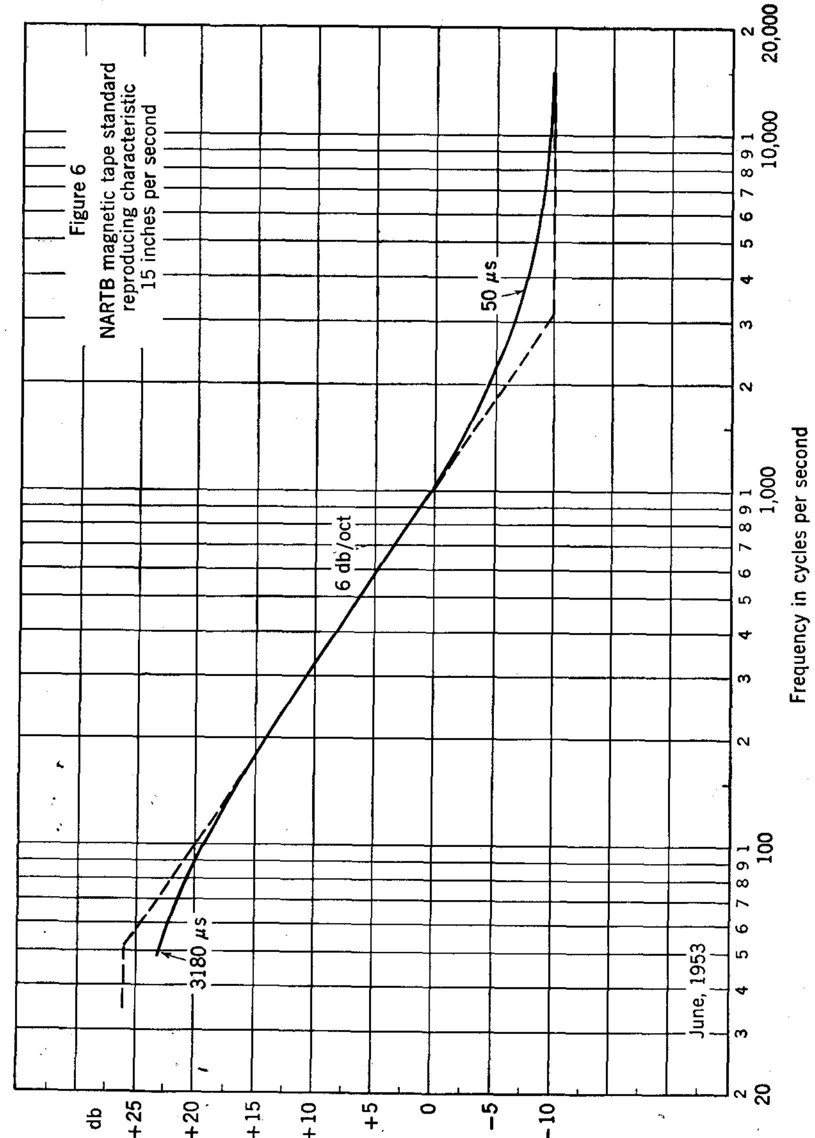
### *Signal-to-Noise Ratio*

**2.90** It shall be standard that the signal-to-noise ratio of a recording system shall be at least 55 db referred to the Standard Reference Level. All frequencies between 50 and 15,000 cycles are to be included in the measurement of the noise. (The standard reference level for signal-to-noise measurements shall be the output level obtained by reproducing tape, produced by a recording system operating under normal conditions, at which two per cent total harmonic distortion of the recorded 400 cycle tone occurs using tape that is normally available.)

---

wavelengths, and the losses in the material of the head are small. With the reproducing heads used in practice, an equalization to compensate for the head losses must be added to the replay amplifier.






[Fig. 6-9]

1-3-14

## Annex

*Methods of Measuring the Magnetization of a Tape* *

There are two general ways in which the surface induction † vs. frequency characteristic of a tape may be determined:

1. By means which do not affect the surface induction. This implies the use of a nonmagnetic reproducing device. For example, reproduction by means of a simple nonmagnetic conductor placed in the field at the surface of the moving tape appears to be practicable as a laboratory method and might therefore be used to establish a primary standard which could be used to determine the relative change of surface induction with wavelength created by the presence of a magnetic head.

2. By means of a magnetic reproducing device, which necessarily affects the surface induction of the tape in a manner dependent on recorded wavelength. In this category there are two ways in which conventional magnetic heads have been used, one method involving heads with a short gap, the other involving heads with a long gap. In both cases the gap in the reproducing head must be sufficiently accurate, magnetically, to give well-defined minima of reproduced level, one in the short gap method or several in the long gap method.

(*a*) *The "Short Gap" head method.* The longest wavelength at which a minimum of reproduced level occurs is the effective gap length (d). The necessary correction for the gap length is calculated on the assumption that output is proportional to

$$\frac{\sin \dfrac{\pi d}{\lambda}}{\dfrac{\pi d}{\lambda}}$$

This correction must not exceed 5 db at the shortest wavelength considered. Any necessary correction for eddy current losses must also be determined, for example, by comparing output at various tape speeds or by the use of an inducing loop. It appears that if the correction for

* These methods resulted from experiments undertaken by members of the NARTB Recording and Reproducing Standards Committee following the original work in CCIR Study Group X on the subject.

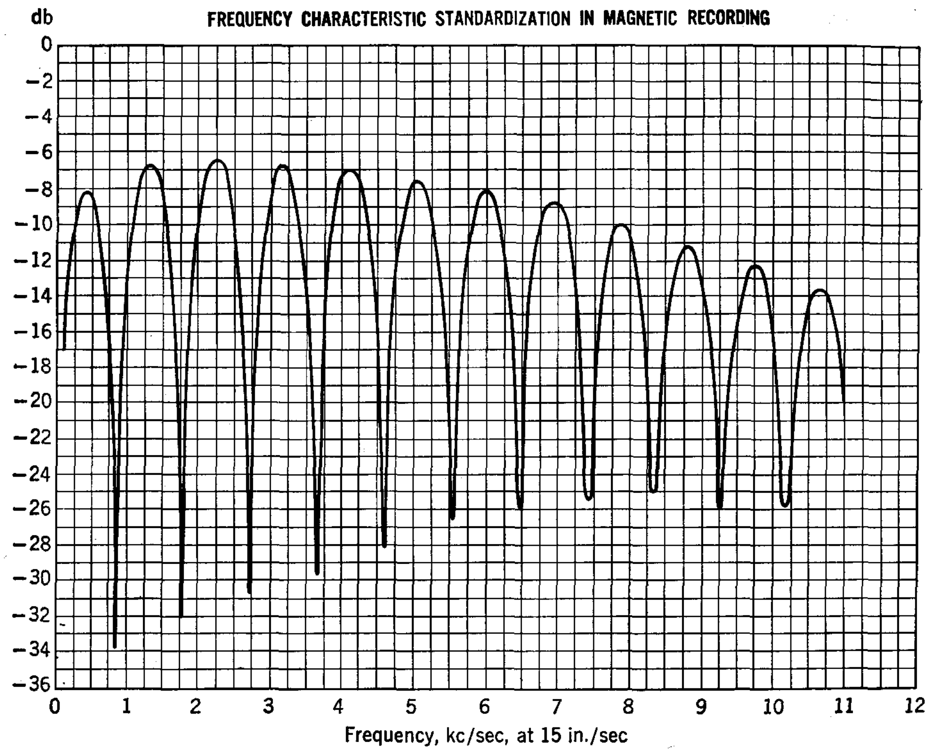
† In general terms, surface induction is the flux density ($B$) at right angles to the surface of the tape. It depends not only on the magnetization of the tape but also on the properties of the reproducing device. In the following, surface induction means the surface induction of the tape in space and not in contact with a reproducing device.



gap length does not exceed 5 db, then the surface induction is altered, due to the presence of the head, by an approximately constant factor over the whole range of wavelengths and may therefore be neglected. Once these corrections are known and applied, the head may be used as an "ideal" head to measure relative surface inductions on the tape

Figure 7

FREQUENCY CHARACTERISTIC STANDARDIZATION IN MAGNETIC RECORDING




[Fig. 6-10]

over the wavelength range considered. Since surface induction is a measure of flux density, it is proportional to the open circuit induced voltage of an "ideal" short gap head.

(*b*) *The "Long Gap" method.* In this method a head is used with a gap some 50 times as long as that of the normal reproducing head. In practice an erase head can usually be adapted for the purpose. The response of such a head should show a series of well-defined maxima and minima as shown in Figure 7. [Text Fig. 6-10]

A curve through the successive maxima is a measure of the surface induction on the tape when the necessary corrections for eddy current losses of the head have been made. This curve falls at approximately 4 db per octave compared with the curve of surface induction vs. frequency in air as determined by a non-magnetic reproducing device, or by a "short-gap" head. This correction must be explored further before this method can be applied.

NOTE 1: The "Long Gap" method is included here because of its use in other countries and its possible future use in the U.S.A. The uncertainty of the correction factor makes it unusable as a standard method of measurement at present.

The precise steps by which the procedures of (2) (*a*) and (*b*) may be applied in practice are outlined in the following.

*Standardization by the "Short Gap" Magnetic Head*

Using the "Short Gap" method a recording equipment is set to the standard condition in the following way:

1. A "gliding tone" is recorded on a tape and reproduced by means of the head to be used for the measurements. The longest wavelength at which the output disappears is noted. This wavelength will be equal to the effective gap length, from which the necessary gap correction may be deduced. If this correction exceeds 5 db, the head is unsuitable for this measurement. Since the measurement must take place at a very short recorded wavelength, a high coercivity tape should be used, and a certain amount of pre-emphasis will be found useful. In order to avoid making the measurements at an unnecessarily high frequency, the lowest tape speed available should be used.

2. The tape with the gliding tone is reproduced at two different speeds and the output curves compared. If the curve can be brought to coincidence by displacing one frequency scale so that equal wavelengths coincide it may be assumed that frequency-dependent losses are negligible. If not, these losses may be deduced from the two curves mentioned or, alternatively, from a measurement with an inducing loop.

3. The frequency response of the reproducing amplifier is now adjusted to consist of the sum of the following:

(*a*) Compensation for the gap loss noted in (1) above.

(*b*) Any compensation for the frequency-dependent losses noted in (2) that may be required.

(*c*) The response curve specified for a Standard Reproducing System with an "ideal" reproducing head and shown in Figure 6.

4. The recording equalization is then adjusted so that a flat overall response is obtained.



*Standardization by the "Long Gap" Magnetic Head*

Using the "Long Gap" method a recording equipment is set to the standard condition in the following way:

1. The reproducing head used has a well-defined gap long enough to give successive maxima of response at intervals of 1 kc/s or less in the audio frequency range. (With a tape speed of 30 in/sec the gap length required would be about 800 microns.) If the successive minima in the response curve are not equally well defined, the head is not suitable for this measurement. A short preliminary experiment is carried out to determine the exact frequencies at which the successive maxima occur at the standard tape speed.

2. A "gliding tone" test tape of the audio frequencies of maximum level is then recorded with constant voltage input to the recording chain and the tape is reproduced using the long gap head. The open circuit voltage of the head around these frequencies is then plotted against frequency, and a smooth curve is drawn through the successive maxima.

3. The tape with the gliding tone is reproduced at two different speeds using the long gap head and the output curves compared. If the curves can be brought to coincide by displacing one frequency scale so that equal wavelengths coincide it may be assumed that frequency-dependent losses are negligible. If not, these losses may be deduced from the two curves mentioned, or, alternatively, from a measurement with an inducing loop.

4. When the curve drawn in (2) has been corrected by a 6 db/octave rise with increase in frequency, together with the compensation for frequency-dependent losses and a correction of 1 to 2 db/octave falling with increase of frequency, the result defines the surface induction of the tape.

5. The equalization of the recording amplifier is now altered to obtain a characteristic of surface induction vs. frequency that is the inverse of the equalization specified for the reproducing system (without allowance for the reproducing head losses).

6. The reproducing amplifier equalization is then adjusted so that a flat overall response is obtained when using a normal reproducing head.

## Section 4. Glossary of Mechanical, Magnetic, and Optical Terms and Definitions (Selected Terms)

**4.105** Equalization (Corrective Equalization). Equalization is the effect of all corrective means employed in the recording and reproducing process to obtain a desired over-all frequency response.

**4.110** Erasing Head. An erasing head is a device for obliterating any previous recordings. It may be used for preconditioning the magnetic media for recording purposes.

**4.115** Erasing Head, A-C. An a-c erasing head is a magnetic head which uses alternating current to produce the magnetic field necessary for erasing.

NOTE: A-c erasing is achieved by subjecting the medium to a number of cycles of a magnetic field of a decreasing magnitude. The medium is, therefore, essentially magnetically neutralized.

**4.120** Erasing Head, D-C. A d-c erasing head is a magnetic head which utilizes direct current to produce the magnetic field necessary for erasing.

NOTE: D-c erasing is achieved by subjecting the medium to a unidirectional field. Such a medium is, therefore, in a different magnetic state than one erased by alternating current.

**4.125** Erasing Head, P-M. A p-m erasing head uses the fields of one or more permanent magnets for erasing.

**4.150** Flutter (WOW) (Drift). In recording and reproducing, flutter is the deviation of frequency which results in general from irregular motion during recording, duplication, or reproduction.

NOTE: The term "flutter" usually refers to cyclic deviations occurring at a relatively high rate, as for example, 10 cycles per second. The term "wow" usually refers to cyclic deviations occurring at a relatively low rate, as for example, a once-per-revolution speed variation of a phonograph turntable. The term "drift" usually refers to a random rate close to zero cycles per second.

**4.155** Flutter Rate. Flutter rate is the number of cyclical variations per second of the flutter.

**4.175** Gap Length. In longitudinal magnetic recording, the gap length is the physical distance between adjacent surfaces of the poles of a magnetic head. (See Magnetic Head.)

NOTE: The effective gap length is usually greater than the physical length and can be experimentally determined in some cases.



**4.245** Ground Noise. Ground noise is the residual system noise in the absence of the signal. It is usually caused by inhomogeneity in the recording and reproducing media, but may also include amplifier noise such as tube noise or noise generated in resistive elements in the input of the reproducer amplifier system.

**4.310** Magnetic Biasing. Magnetic biasing is the simultaneous conditioning of the magnetic recording medium during recording by superposing an additional magnetic field upon the signal magnetic field.

NOTE: In general, magnetic biasing is used to obtain a substantially linear relationship between the amplitude of the signal and the remanent flux density in the recording medium.

**4.315** Magnetic Biasing, A-C. A-c magnetic biasing is magnetic biasing accomplished by the use of an alternating current, usually well above the signal frequency range.

**4.320** Magnetic Biasing, D-C. D-c magnetic biasing is magnetic biasing accomplished by the use of direct current.

**4.330** Magnetic Head. In magnetic recording, a magnetic head is a transducer for converting electric variations into magnetic variations for storage on magnetic media, for reconverting energy so stored into electric energy, or for erasing such stored energy.

**4.335** Magnetic Head, Double Pole-Piece. A double pole-piece magnetic head is a magnetic head having two separate pole pieces in which pole faces of opposite polarity contact the medium on opposite sides. Either both or only one of these pole pieces may be provided with an energizing winding.

**4.340** Magnetic Head, Single Pole-Piece. A single pole-piece magnetic head is a magnetic head having a single pole piece which contacts the recording medium on one side.

**4.345** Magnetic Plated Wire. Magnetic plated wire is a magnetic wire having a core of nonmagnetic material and a plated surface of ferromagnetic material.

**4.350** Magnetic Powder-Coated Tape (Coated Tape). Magnetic powder-coated tape is a tape consisting of a coating of uniformly dispersed, powdered ferromagnetic material on a nonmagnetic base.

**4.355** Magnetic Powder-Impregnated Tape (Impregnated Tape) (Dispersed Magnetic Powder Tape). Magnetic powder-impregnated tape is a magnetic tape which consists of magnetic particles uniformly dispersed in a nonmagnetic material.

**4.360** Magnetic Printing (Crosstalk *). Magnetic printing is the permanent transfer of a recorded signal from a section of a magnetic

* Deprecated.

recording medium to another section of the same or a different medium when these sections are brought in proximity.

**4.365** Magnetic Recorder. A magnetic recorder is equipment incorporating an electromagnetic transducer and means for moving a ferromagnetic recording medium relative to the transducer for recording electric signals as magnetic variations in the medium.

NOTE: The generic term "magnetic recorder" can also be applied to an instrument which has not only facilities for recording electric signals as magnetic variations, but also for converting such magnetic variations back into electric variations.

**4.370** Magnetic Recording Head. In magnetic recording, a magnetic recording head is a magnetic head for transforming electric variations into magnetic variations for storage on magnetic media.

**4.375** Magnetic Recording Medium. A magnetic recording medium is a magnetizable material used in a magnetic recorder for retaining the magnetic variations imparted during the recording process. It may have the form of a wire, tape, cylinder, disk, etc.

**4.380** Magnetic Recording Reproducer. A magnetic recording reproducer is equipment for converting magnetic variations on magnetic recording media into electric variations.

**4.385** Magnetic Reproducing Head. In magnetic recording, a magnetic reproducing head is a magnetic head for converting magnetic variations on magnetic media into electric variations.

**4.390** Magnetic Tape. Magnetic tape is a magnetic recording medium having a width greater than approximately 10 times the thickness. This tape may be homogeneous or coated.

**4.395** Magnetic Wire. Magnetic wire is a magnetic recording medium, approximately circular in cross section.

**4.400** Magnetization, Longitudinal. Longitudinal magnetization in magnetic recording is magnetization of the recording medium in a direction essentially parallel to the line of travel.

**4.405** Magnetization, Perpendicular. Perpendicular magnetization in magnetic recording is magnetization of the recording medium in a direction perpendicular to the line of travel, and parallel to the smallest cross-sectional dimension of the medium.

NOTE: In this type of magnetization, either single pole-piece or double pole-piece magnetic heads may be used.

**4.410** Magnetization, Transverse. Transverse magnetization in magnetic recording is magnetization of the recording medium in a direction perpendicular to the line of travel and parallel to the greatest cross-sectional dimension.



**4.440** Modulation Noise (Noise Behind the Signal). The modulation noise is the noise caused by the signal. The signal is not to be included as part of the noise.

NOTE: The term is used where the noise level is a function of the strength of the signal.

**4.460** Multitrack Magnetic Recording System. A multitrack magnetic recording system is a recording system which provides, on a medium such as magnetic tape, two or more recording paths which are parallel to each other, and which may carry either related or unrelated program material in common time relationship.

**4.565** Playback. A playback is an expression used to denote reproduction of a recording.

**4.575** Post-emphasis (De-emphasis) (Post Equalization). Post-emphasis is usually a form of equalization complementary to pre-emphasis.

**4.580** Pre-emphasis (Pre-equalization). In recording, pre-emphasis is an arbitrary change in the frequency response of a recording system from its basic response (such as constant velocity or amplitude) for the purpose of improvement in signal-to-noise ratio, or the reduction of distortion.