MAGNETIC TAPE TRENDS

AMPEX

BULLETIN NO. 10 SEPT. 1965

APPLICATION ENGINEERING BULLETIN

RECORDING THEORY AND TECHNIQUES AS APPLIED TO TAPE

PART IV - WIDE BAND INSTRUMENTATION

Today's requirement for full spectrum recording places a most critical demand on the resolution capability of wide band instrumentation tape. An instrumentation system recording 1.5 mc at 120 ips requires a wavelength resolution of 80 μin.- the shortest wavelength in magnetic recording history. To accomplish such a task, broad new concepts in hardware technology were developed, and an entirely new approach in precision tape design accompanied system innovations. This article will discuss the unique tape parameters comprising precision tape for wide band instrumentation systems.

RECORDING PROCESS

Two basic recording techniques are employed in wide band systems - Analog and Pulse. Wide band FM is sometimes used in a variation of Analog recording.

ANALOG

Trends No. 7 discussed the recording process as related to the internal construction of tape, and the basic principles set forth also apply to wide band recording. Certain generalizations will also be made for purposes of this discussion such as each oxide particle representing a separate domain. In practice, these particles are approximately 20 μin. long and 5 μin. in diameter. This means that an 80 μin. wavelength signal must be supported by a relatively small number of individual particles.

From this analogy, it is apparent why absolute perfection is required in oxide dispersion and uniformity. The slightest degree of oxide particle size distribution, orientation deviation, or imperfect dispersion will result in significant signal degradation. It is also obvious that under these short wavelength conditions essentially all the energy is supported in a fraction of the total coating thickness. Standard coating thickness for instrumentation tape is 400 μin. nominal, and thincoat instrumentation tape coating thickness is 200 μin.

 Litho in U.S.A. -- 1694/10 -- 9-65

nominal. Thincoat is wholly adequate for such recording tasks, and for all practical purposes will perform in an identical manner to tape having standard coating thickness.

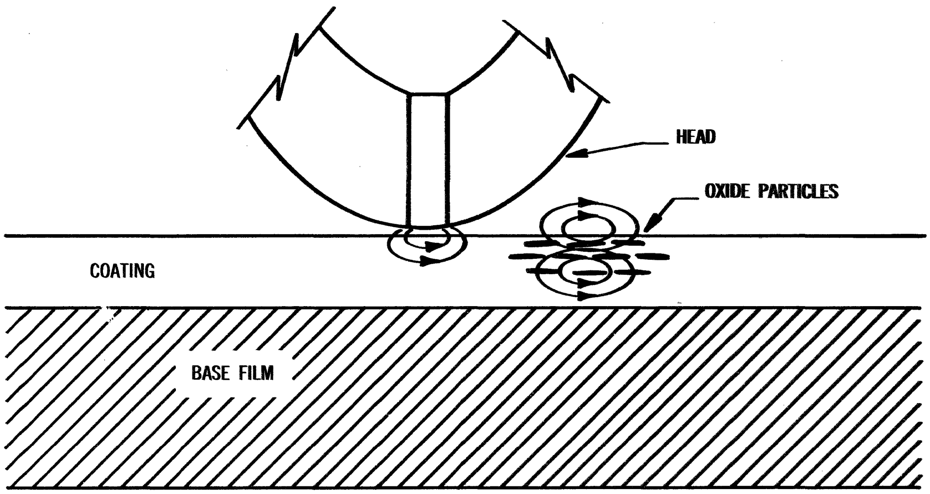


FIG. 1 RELATION OF 80 MICROINCH FLUX PATTERNS AND OXIDE PARTICLES

BANDWIDTH LIMITATIONS

Precision tape resolution capability has been extended at a steady rate as new systems have been developed. A logical question is "just how far can it go?" Tape does not see frequency per se, it understands only wavelength. For example, a tape doesn't know if it is recording 500 KC @ 60 ips or 1.0 mc @ 120 ips. All it knows is that it must handle a 120 μin. wavelength:

$$\left(\frac{120 \text{ ips}}{1 \times 10^{6} \text{ cps}} = 120 \times 10^{-6} \text{ in.} \right)$$

So, to increase bandwidth from 1.5 mc to 6.0 mc, all that is necessary is to increase tape speed from 120 ips to 480 ips. This has obvious drawbacks, so to extend the bandwidth in a practical manner, it is necessary to work with shorter wavelengths. Now, let's investigate what happens to the tape at a 20 μin. wavelength for example (6.0 mc @ 120ips). To begin with, practical limitations on tape surface finish are reached at about 5 μin., so it is safe to assume that the record gap "floats" at least 5 μin. above the oxide particles. Secondly, the smallest sized oxide particles being reliably dispersed in production tapes measure about 20 μin. Previously, it was pointed out that extreme difficulty was encountered in supporting an 80 μin. wavelength with 20 μin. particles, and it follows that a 20 μin. wavelength will be impractical under such conditions. This is not to say that magnetic tape is at the end of its rope, but magnetic tape as we know it today cannot be pushed much farther. It will be necessary to develop new oxide types with different physical characteristics, along with innovations in coating and dispersing technology. Surface finishing must be improved to an absolute level of smoothness without compromising physical parameters such as layer-to-layer adhesion.

TAPE SURFACE

Longitudinal wide band systems demand the absolute epitome of surface smoothness to adequately resolve and play back short wavelength signals. Intimate tape-to-head contact must be maintained at all times. This is pointed out in the following relation:

$$\text{Loss in signal (db)} = \frac{55d}{\lambda}$$

where:

λ = wavelength
d = tape-to-head separation

For example, a 1.5 mc signal @ 120 ips with a 25 microinch tape-to-head separation would be down 17.2 db. This is more significant when it is realized that the diameter of an average particle of cigarette smoke is 25 microinches.

Typical wide band tape has a surface finish in the order of magnitude of 6 - 8 microinches peak to valley. This presents unique problems from the standpoint of layer-to-layer adhesion, and is one of the reasons why such tape should be protected from wide ranges of temperature and humidity. (See section on Care and Storage.)

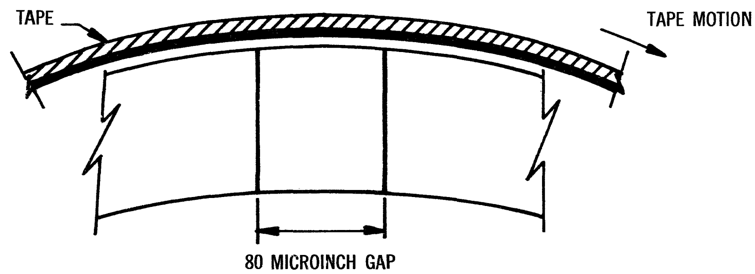
DROPOUTS

Wide band instrumentation tape dropouts are similar in nature to those experienced in video, audio, and computer. By basic definition, a dropout is any tape caused phenomena that results in temporary loss of signal for a specified length of time. The most prominent cause of dropouts is surface contamination, where a piece of oxide shed or foreign particle adheres to the surface of the tape and lifts the tape from the head. As pointed out in the discussion on surface smoothness, it takes only a very small particle to completely lose the signal. Since most instrumentation recorders operate at high tape speeds, "tape flap" aggravates and prolongs the dropout problem.

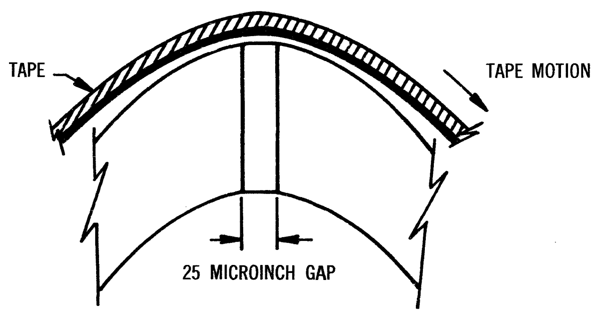
HEAD WEAR CONSIDERATIONS

Tape abrasiveness and associated head wear has long been an important consideration, but with the advent of extended bandwidth recording techniques it has become paramount in importance. This has been the result of many system changes and improvements, one of which has been head design. Previous generations of instrumentation recorders have utilized heads with relatively large gaps. In addition to the wider gaps, the head construction presented a wider angle of tape approach and departure. Such systems had the capability of easily resolving wavelengths of 240 microinches (250 KC @ 60 ips). In order for the later systems to resolve 80 microinch wavelengths (1.5 MC @ 120 ips) head construction took on a slightly different configuration, as shown in Fig. 2.

First, the head gap was reduced to 25 microinches from 80 microinches, and secondly, the tape wrap angle was altered to provide more intimate tape-to-head contact at the gap. (This angle has been great-



GENERAL HEAD CONFIGURATION FOR 240 MICROINCH RESOLUTION



GENERAL HEAD CONFIGURATION FOR 80 MICROINCH RESOLUTION

FIG. 2

ly exaggerated in the sketch for clarity.) With this configuration, a new head/tape parameter was introduced, which may be referred to as gap integrity. Conventional tapes used on wide band systems destroy the gap integrity and create a "gapsmear" condition. (Not to be confused with "crap in the gap" which is a computer tape phenomenon resulting from spurious noise signals remaining on the tape in the inter-record gaps of written characters.) Gap smear is the result of material being worn from the leading edge of the pole pieces and forced into the gap, creating a magnetic short.

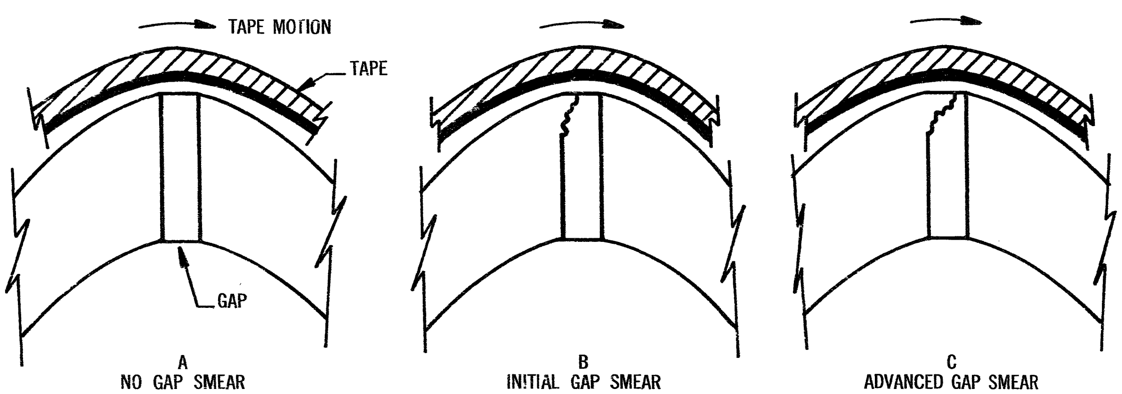


FIG. 3 GAP SMEAR

There are three classes of tape abrasiveness quality relating to gap smear: very low abrasive tape, moderately abrasive tape, and highly abrasive tape. A highly abrasive tape will not necessarily cause gap smear because it will wear off both sides of the gap cleanly, and thus preserve gap integrity. A moderately abrasive tape will wear the leading edge and set up a coldflow condition, thereby forcing head material into the gap, creating an effective magnetic short.

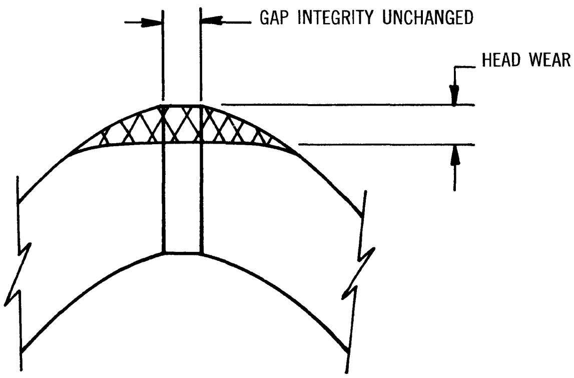


FIG. 4 HIGHLY ABRASIVE TAPE

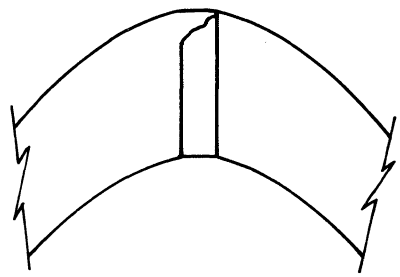


FIG. 5 MODERATELY ABRASIVE TAPE WITH RESULTING GAP SMEAR

A tape that is very low in abrasive characteristics will wear the head evenly, but at a very low rate. Gap integrity is preserved, and head life is extended as well.

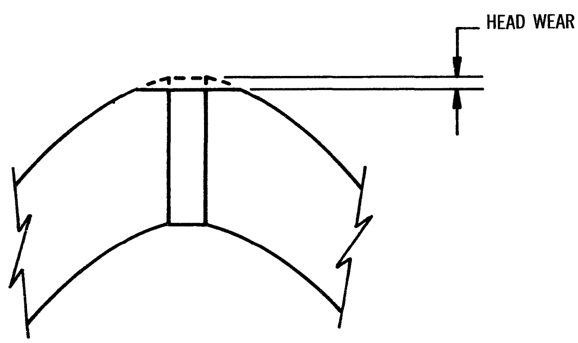


FIG. 6 LOW ABRASIVE TAPE-NO GAP SMEAR

The obvious disadvantage of the highly abrasive tape is excessive head wear, and reduced head life. Moderately abrasive tape will make reliable recording impossible. An interesting sidelight is that as the gap of a particular track progresses into the smeared or shorted condition the output at shorter wavelengths sometimes increases abruptly prior to its falling off completely. This is caused by the effective gap width becoming more and more narrow.

The previous discussion should not be confused with other tape/head maladies such as head clogging and oxide buildup. Head clogging is the result of tape binder system breaking down to where a gummy residue is deposited on the head. Such deposits will lift the tape from the head and substantially reduce the output. Normally this will occur on the trailing edge of the reproduce gap, because the reproduce heads have a more critical gap configuration than the record heads. This buildup is called "rooster tails". Dry, powdery buildup normally occurs at the leading edge of either record or reproduce gaps.

All tapes can be expected to exhibit a slight amount of shed for this is the normal wear pattern of tape. Such shed should be of a fine powdery nature. In most tapes, this shed is more noticeable on the first 3 or 4 passes, until the tape wears in.

HEAD WEAR MEASUREMENT AND EVALUATION

Wide band tape abrasiveness and associated head wear is a complex phenomenon involving many variables related to the system as a whole. Some of the more important parameters are head construction, tape speed, tension, wrap angle, ambient conditions, and tape path. For this reason, it is impractical to conduct a meaningful evaluation on an accelerated basis. The only true assessment of abrasive quality of tape is a test conducted on a standard transport using actual heads. Since this has severe economical limitations, many users have developed abbreviated tests utilizing brass cylinders, metal shims, etc. Such an approach is relatively simple, but the results are incomplete at best. Tape is pulled over a brass cylinder for a given number of passes, and the brass is weighed before and after to determine amount of material worn away. Such a test measures the tape's reaction to brass and has no bearing on the tape's abrasive qualities as related to actual heads under normal (or abnormal) operating conditions.

A precision instrumentation head consists of a laminated structure employing different materials, each having different wear rates. It is erroneous to assume that wear results based on one metal can be used to predict wear rates of a complex assembly of 3 or more different metals.

The only valid evaluation is one conducted as follows. A standard transport properly adjusted to manufacturer's specifications is to be used with a head contoured to original head specifications. A trace of the head should be taken with a profilometer at beginning of the test and the head installed on the transport for an end-to-end shuttle conducted for a given number of passes, say 100. The head is then re-profiled, and the two traces compared:

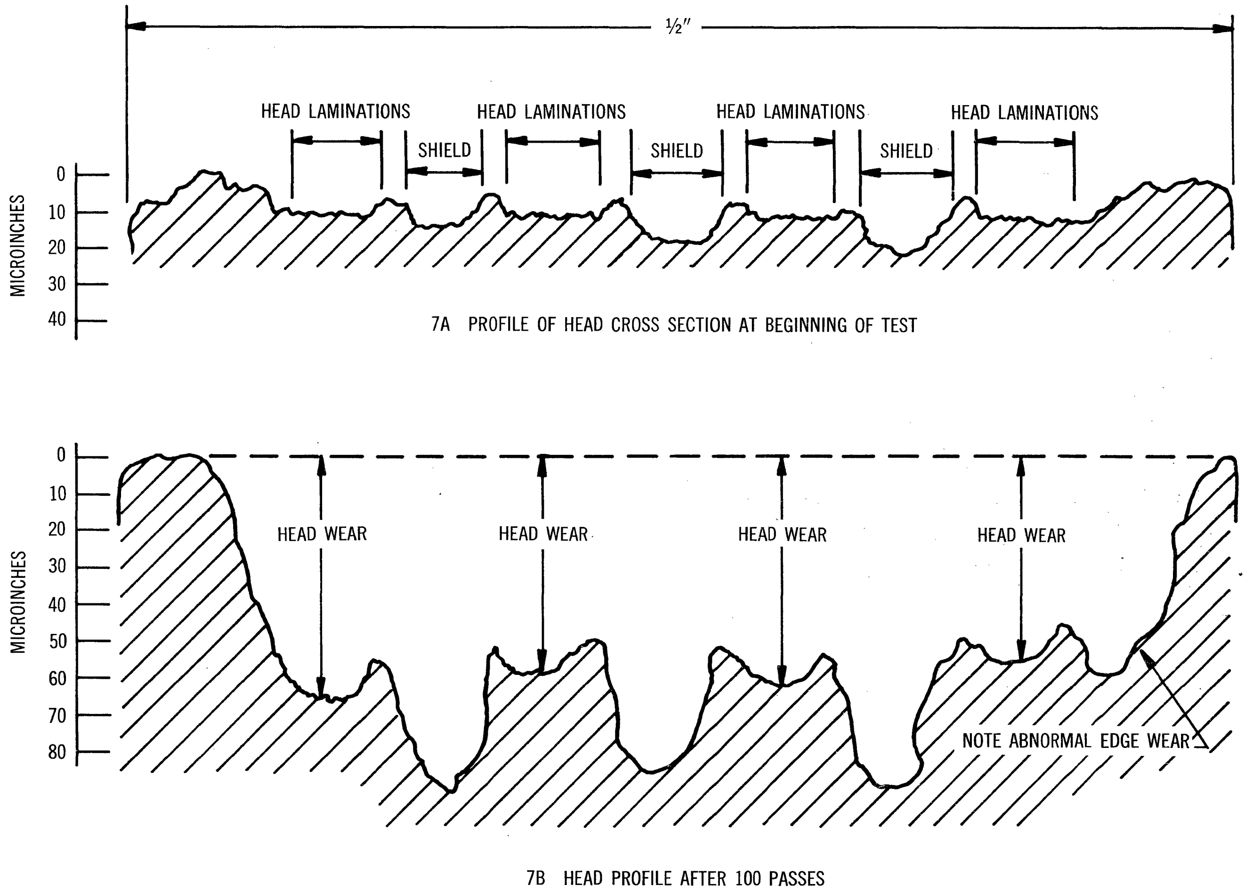


FIG. 7 HEAD PROFILES

This type of evaluation not only shows absolute level of head wear, but it points out unique wear characteristics peculiar to a given tape. For example, Fig. 7 reveals a tape that has excessive wear concentrated along one edge.

CARE AND STORAGE

Proper care and handling of precision tape is a well recognized requirement, and most users fully appreciate its relation to reliable performance. In the case of wide band tape, this requirement becomes more critical as a result of the extremely tight physical tolerances. Specifically, wide band tape surfaces are much smoother than other precision tapes such as computer and video. Secondly, tape lengths are longer for wide band tape than computer and video. The standard instrumentation length is 7200' (9200' for thincoat) as opposed to 2400' for computer and 4800' for video. Dynamic aspects of flutter and skew are definitely more critical in wide band instrumentation recording than any other precision tape application. This demands the absolute ultimate in the physical integrity of the tape, i.e., perfect slitting and edge conditions.

When tape is exposed to wide fluctuations of temperature and humidity, the base film expands or contracts, setting up tremendous internal stresses in the tape pack. The degree of stress is a function of the length of tape, and may become excessive in a 9200' reel. This stress will induce distortion beyond the elastic limits of the base film which in turn renders the tape useless for its intended purpose. The ultra smooth surface characteristics have a greater propensity for layer-to-layer adhesion under exposure to uncontrolled environment. Optimum ambient conditions are 70°F and 60% RH. Any departure from the optimum will increase the possibility of tape damage. Absolute maximum limitations are:

	Operating	Storage
Temperature	+40°F to 125°F	-20°F to 140°F
Humidity	25% RH to 95% RH	25% RH to 95% RH

Tapes stored in an ambient different from that of the operating ambient should be normalized for a minimum period of 8 hours and a maximum period of 24 hours.

Head wear is substantially influenced by low humidity and dusty, contaminated ambients. Extreme care should be taken to minimize these effects. Tape should be handled as little as possible. Remember, each complete pass of the tape exposes the entire working surface of the tape to ambient conditions, and the possibilities of surface contamination, edge abrasion, and physical distortion occurring are present.

Experience shows that more self generated contamination from tape edges occurs during the first 3 or 4 passes. Normally the absolute level of this shed is small enough to be of no serious consequence, but it points up the importance of thorough transport cleaning after each pass.