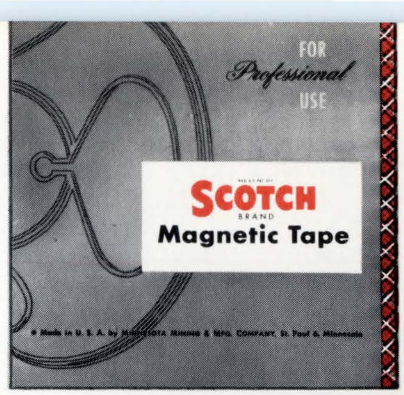
Sound Talk



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SCOTCH BRAND Magnetic Tape

Bulletin No. 37

REDUCTION OF DROPOUT ERRORS IN MAGNETIC RECORDING SYSTEMS

By

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The past few years have witnessed a coming-of-age for magnetic recording methods in the field of data acquisition and storage. Digital tapes are now as well accepted as either written documents or punched cards as reliable records in the data processing field, and tape analog records have all but replaced oscillographic records as the first line storage media for high speed data acquisition. However, the success of these operational magnetic tape systems has spurred the quest for even more efficient equipment and methods. System engineers are seriously asking the question of whether data cannot be recorded on magnetic tape 10 or even 100 times as rapidly and as compactly as on present equipment. While there are many problems to be solved in accomplishing such an objective, perhaps the most serious is the increase in signal dropouts normally associated with higher information densities on the tape. Therefore a careful study of the causes of dropouts is the first step towards more efficient data recording systems.

Dropout studies made a few years ago revealed a large number of coated-in defects in magnetic tape. These may be exemplified by the large oxide clump and the coated-in fiber shown in figure 1. However, since 3M's new production facilities went on stream in 1957 this kind of gross defect has been virtually eliminated. Success in this endeavor is due in large measure to engineering advances in tape coating machines, a portion of which is shown in figure 2. Dust control measures in these areas rival those employed in transistor and gyro assembly rooms. However, in spite of the great reductions in gross tape flaws brought about by improvements in coating methods, smaller dropouts continue to be a problem in highly critical applications.

When viewing the envelope of signals reproduced from tape, these dropouts appear to be remarkably similar in shape. Indeed, it might be said that severe dropouts in which the signal amplitude falls nearly to zero are invariably of considerable time duration, whereas small dropouts in which the signal amplitude drops only slightly are invariably of short duration. This suggests that dropout areas on the tape are roughly circular, having about the

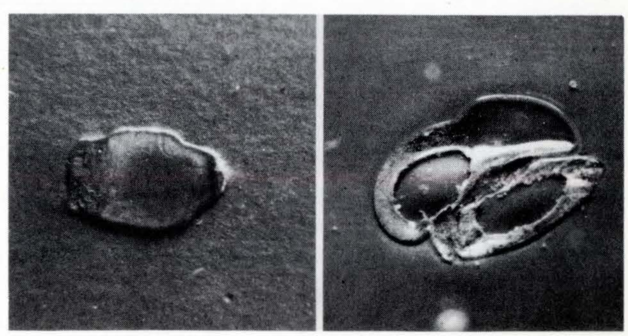


FIGURE 1.

Photo-micrographs of two common types of coated-in tape flaws which have been largely eliminated by modern coating methods.

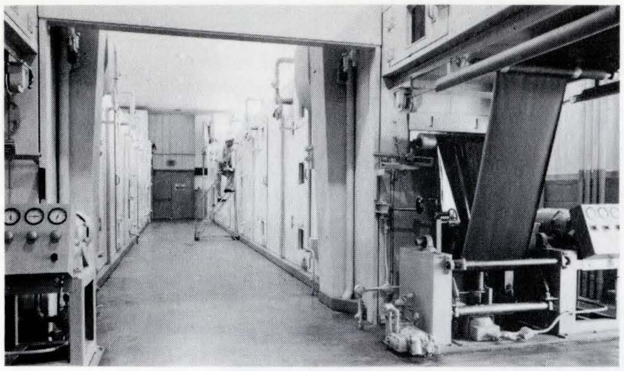
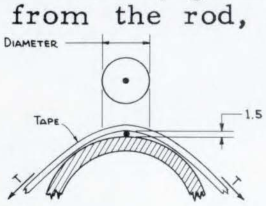


FIGURE 2.
View of modern tape coating machine. Note the hospital cleanliness throughout.

same length (time duration) as width (amount of signal lost from a recorded track). It should be possible then, to form some sort of graphic conception of these circular dropout areas.

Careful observations of dropout areas on the tape failed to reveal any absence of magnetic material causing dropouts. However, in a large number of cases, extremely small bits of foreign matter were found lying on the tape surface, which suggested that the small dropouts may be due to separation of the tape from the head. A simple experiment was set up to investigate the effect of small bits of matter lifting the tape from the head. A 1" diameter glass rod was used in place of a recording head so that contact areas could be viewed directly through the transparent surface. Standard half inch wide instrumentation tape was wrapped around the rod and held at various tensions. Small bits of film of known thickness were inserted between the tape and the rod and the effect on the contact area noted.

The effect of the small bits of film was to lift a considerably greater area of tape away from the rod, leaving in



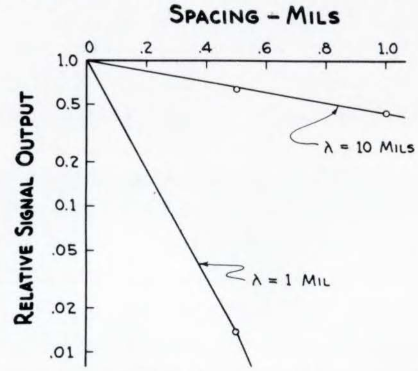
Backing Thickness	Tension	Diameter
1.0 Mil	2 oz	.13
	8 oz	.08
1.5 Mil	2 oz	.18
	8 oz	.10

Optically Measured Size of Dropout Area Caused by 1.5 Mil Protuberance on ½" Tape Wrapped on a 1" Dia. Rod.

FIGURE 3.

each case a circular "hole" in the contact pattern. The size of the "hole" is of course, greater for the stiffer 1.5 mil backings than for the 1 mil, and also is greater for low tape tensions than for high. The size of the "hole" for various tape thicknesses and tensions is tabulated in figure 3. It is interesting to note that even the smallest "hole" noted for 1.5 mils separation (half the thickness of a human hair) is more than double the width of the usual recorded track (about 35 mils), indicating that such separation would be intolerable.

The above analysis assumes that perfect contact is required between the head and tape in order to perform the recording and reproducing functions, and that areas of the tape which are not in perfect contact do not contribute



Curves Showing Fall Off of Reproduced Signals vs Spacing from Reproduce Head

FIGURE 4.

to the reproduced signal. This is obviously not quite true, so it is necessary to examine the efficiency of both the recording and reproducing processes with respect to separation from the head. The reproducing process lends itself to calculation, and the separation loss for sinusoidal signals has been shown by several investigators to be 54 db per wavelength separation. The actual measured losses shown in figure 4 for 1 mil and 10 mil wavelengths were very close to this theoretical prediction. It is apparent that information recorded at high density on the tape is extremely susceptible to spacing loss during reproduction.

The recording process is complicated by the non linear nature of magnetic materials, and the theory can only be given in broad outline. Figure 5 shows

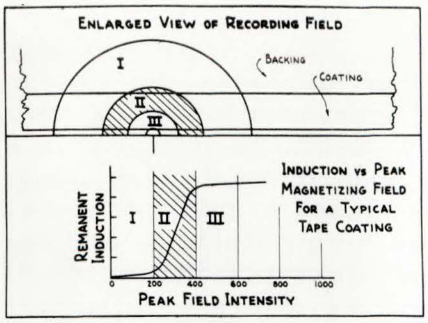


FIGURE 5.

Diagram showing magnetic field pattern near the recording head (above). Below is a graph showing the relation of the recording field intensities to the magnetization curve of the tape coating.

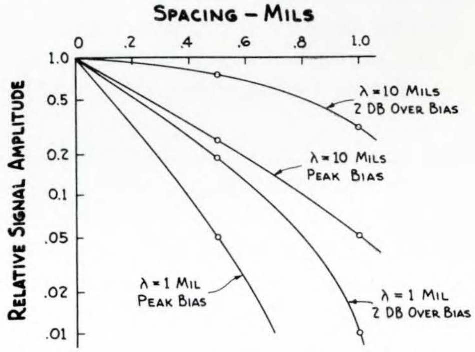
a simplified diagram of the fields encountered by the tape in recording. If the recording gap is idealized to an infinitesimal slit, the recording field can be represented by half circles. In region I at considerable distance from the recording slit, the field intensity is so low that the magnetic material of the tape is unaffected. In region III very close to the head gap, fields are so high that the tape coating is completely saturated on each excursion of the signal, and hence small changes in signal amplitude have no effect on the ultimate magnetization on the tape.

In region II, however, the tape is subjected to fields which are neither inconsequential nor saturating, and hence the ultimate signal left on the tape is determined by the signal excursions as it passes out of this region. It can be seen that in this simplified example, if the tape is spaced away from the head an amount equal to the thickness of the coating (about 0.5 mil), the recorded signal will be very low since only a small portion of the tape encounters fields of the sufficient amplitude for recording (i.e. passes through region II).

Let us consider what happens when the amplitude of the recording signal is doubled. Region I now has sufficient field intensity for recording, and the size of the recording region is extended considerably. This means that the resolution of the recording process will not be as great as in the former case, and therefore the density of information on the tape may have to be curtailed. However, separating the tape from the head by the distance equivalent to the coating thickness no longer brings the tape outside of the effective recording area and recording can be performed without serious loss.

This simplified model indicates that at low levels of recording signal, the recording process is critical to spacing (regardless of wavelength) and that spacing loss can be reduced considerably by increasing the recording signal, but only at the expense of resolution. It is understood, of course, that the signal level referred to includes supersonic bias where applicable, and indeed, the bias amplitude is usually so much greater than the information components that it is the determining factor in considering separation loss during recording.

Experimental verification of these concepts is given in figure 6 which shows separation loss vs. wavelength and bias. Note that a small increase in bias (2 db over bias is only 30% greater than peak bias) results in about 4 times the reduction in separation loss. The effect of poorer resolution is apparent in the curves for 1 mil wavelength, but it is also noted that even at low bias, the recording separation loss is not as



CURVES SHOWING FALL OFF OF RECORDED SIGNALS vs SPACING FROM RECORDING HEAD

FIGURE 6

great as the reproducing loss.

From the above analysis it is apparent that while long wavelength signals can be made rather stable with respect to separation loss by choosing a large recording signal, there is little hope of improving the situation for short wavelengths. Moreover, for short recorded wavelengths, the amount of separation which can be tolerated is very small indeed, amounting to only about 0.1 mil for 1 mil wavelength signals. This fact would tend to substantiate the earlier

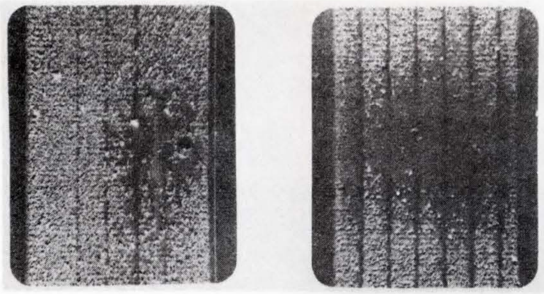


FIGURE 7.
Photo-micrographs showing the effect of small dust specks on recorded data tracks. The wavelength is 3 mils and the track width 35 mils.

assumption that the entire area of non-contact caused by a small inclusion can be considered as a dropout.

A number of dropouts were located and examined using colloidal magnetite to indicate the recorded areas. Typical dropout areas are indicated in the photomicrographs of figure 7. The size scale may be estimated from the fact that the recorded wavelength is 3 mils and the entire track is about 35 mils wide. The unrecorded vertical lines are the spaces between laminations in the recording head. The specks of white dust (probably backing chips broken off from the edge of the tape) in the center of the unrecorded areas are undoubtedly the cause of the dropout. It is obvious that the dropout area is many times the size of the contaminating particle.

While the majority of the dropouts noted in instrumentation tape were of this kind (i.e. specks of dust and other contaminants), the next most significant group were caused by dents and creases in the backing. Dents can be caused either by foreign particles becoming wound up tightly in the roll, or by roughness in the surface of the hub on which the tape is wound. These may cause a permanent set in many layers of the tape which cannot be stretched out flat as the tape passes over the heads. In most cases, the creases were caused by handling the tape (i.e. threading, making splices, removing the tape from the guides, etc.) or by damage to the edges of the tape because of uneven winding.

Many of these handling problems can be obviated by the use of precision reels, shown in the cutaway view of figure 8. These reels have heavy flanges 0.10" thick at the root, tapering to .05" thick at the rim. This construction increases the flange stiffness 10 times over standard reels while holding the movement of inertia to only 1.8 times that of the standard reels. The flanges are closely spaced to minimize scattering of turns during winding, and the solid sideplates (except for three small holes for threading) afford greatly increased protection against dust and crushing of the tape edges. The hub surface is devoid of threading slots which cause distortion of the inner turns and is instead covered by a rubber friction ring to aid in threading. This ring also acts as a cushion for the innermost tape layers and prevents distortion.

It would appear from the above analysis of dropouts that future systems will require even closer attention to cleanliness, and careful handling of the tape if reliable operation is to be achieved. The tape contact situation is so critical for short wavelength signals it would seem that special techniques to provide more positive contact between the head and tape, such as the vacuum guide system of the Ampex video recorder, will be mandatory in future systems. Since contamination and tape distortion is also critical, better storage and handling of tape is also indicated. The use of sealed tape cartridges might provide a very good answer for the dropout problems of the future. However, if these problems can be solved, there is every reason to believe that the information storage capabilities of magnetic tape can easily be extended 10 or 100 fold.

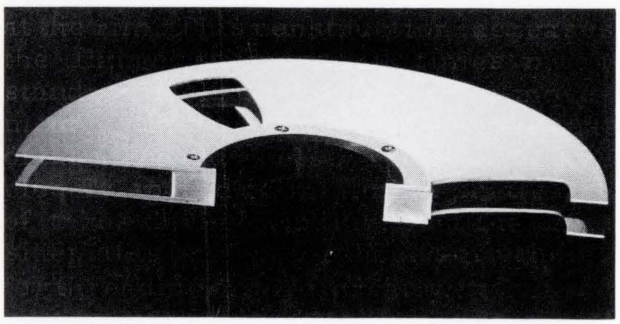


FIGURE 8.
Cutaway view of new precision reel. Note tapered flange section and solid hub with rubber friction ring.