Sound Talk®

Scotch Magnetic Tape

Volume II
No. 1
1969

POLYESTER AND ACETATE FOR MAGNETIC RECORDING TAPE BACKINGS

Within the magnetic recording industry, only audible range recording tape is available with both polyester and acetate as a backing material. It is interesting to note that the recording tapes used for other applications such as video, instrumentation, and computer rely almost entirely on polyester backing materials. For these applications polyester is the preferred substrate because of two basic properties, stability and strength. These properties are also of definite interest to the audible range recording industry, so this issue of SOUND TALK will compare the performance of both polyester and cellulose acetate film in terms of their use as backing materials. Some of the physical parameters which define the basic properties will also be discussed.

During its extensive life, magnetic recording tape may be subjected to a variety of environmental changes. The temperature and humidity, which are constantly changing, will affect the backing material used in all recording tapes. The tape backing, during these changes, will expand or contract. This change in physical dimension affects its wind-stability and ultimately its overall life expectancy. These finite variations created by environmental changes are reflected in the basic property of stability which, as we will describe, is different for the two backing materials. During the use of recording tape, the stresses and strains which the tape receives will vary. The ability to withstand these forces is determined by the physical strength of the backing material. The two materials being examined exhibit subtle differences that we can observe by various testing techniques.

STABILITY

A basic requirement of a backing material is to maintain its dimensional stability when subjected to changes of temperature and humidity. Differences which do occur and can be measured when comparing the two materials are expansion, cupping, and wind stability.

EXPANSION COEFFICIENTS

The thermal and hygroscopic coefficients of expansion of each material define some of the differences between them. The thermal coefficient of polyester is 2×10^{-5} in/in/°F. The coefficient of acetate is 3×10^{-5} in/in/°F. We must conclude that neither material is detrimentally sensitive to temperature changes. Even though polyester expands only two-thirds as much as acetate, the numbers are so small that the result is rather unimportant.

The significant difference in materials, however, lies in their moisture or hygroscopic coefficients. Polyester expands or contracts at the rate of 6×10^{-6} in/in/%R.H. Acetate on the other hand has a coefficient of 50×10^{-6} in/in/%R.H. Although these, too, are rather small numbers, notice that polyester is 8 times *less* sensitive than acetate to changes in relative humidity. As an example, let's use these expansion or contraction rates to determine how the length of two 7200 foot rolls of tape will change when the RH changes 60%. The thickness and width will also change the same percentage, but this change will be negligible when compared to the absolute change in length. One of the rolls will be 1 mil polyester and the other 1 mil acetate.

From the following computation, notice that a 60% change in Relative Humidity creates a change in length of the polyester tape of about 2½ feet.

Length (Poly.)

$$= [6\,(10^{-6})\text{ unit change/\%R.H.}] \times 7200\text{ ft.} \times 60\%\text{ R.H.}$$

$$= 6\,(7.2)\,(6)\,(10^{-2})\text{ ft.}$$

$$= 2.59\text{ ft.}$$

Using the same formula, notice that under the same conditions the acetate sample changed over 21½ feet.

Length (Acet.)

$= [50\ (10^{-6})$ unit change/% R.H.$]\ \times 7200$ ft. $\times$ 60% R.H.

$= 0.5\ (7.2)\ (6)$ ft.

$= 21.60$ ft.

At 15 ips, this would amount to a 2 sec. difference, a negligible change, in the running time of the polyester roll. The acetate, however, changes about 17 seconds.

CUPPING

The moisture sensitivity of acetate also shows up in another manner. A short, single strand of acetate tape, if exposed to a wide range of Relative Humidity, will not remain flat through this range. The tape will have a tendency to curl across its width. Observing a cross-sectional view of the tape end, as in Figure 1, you would note the amount of cupping is measured in degrees of arc (flat tape is taken as zero). Samples tested at 15, 50, and 85% R.H. showed the amount of cupping is related to the relative humidity level. A typical 1½ mil acetate tape measures 4° at 15%, 8° at 50%, and 16° at 85%. Thus the acetate may cup badly at high humidities while remaining relatively flat below 50%. The acetate's change in cupping throughout this 70% R.H. range was 12° while the polyester changes less than 1°. The reason for acetate's change is its absorption and loss of moisture that causes a differential in expansion and contraction when compared to the magnetic layer.

Another type of cupping apparatus measures the height of the arc. This distance can be ascertained by viewing the edge of the sample through a calibrated microscope eyepiece. Regardless of the measurement, cupping is considered detrimental because it disrupts head to tape contact.

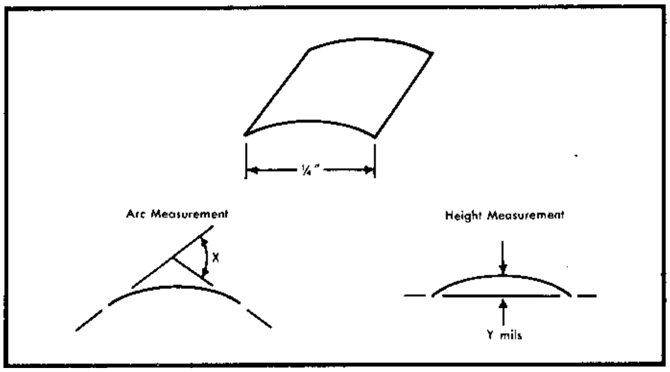

FIGURE 1. CUPPING

WIND STABILITY

Another important humidity effect is apparent in the tightness of a roll of tape. An acetate roll wound at moderate tensions with constant torque at 50% R.H. and normal room temperature will become very loose when the R.H. is raised to 95%. At 5% R.H. and normal room temperature the same roll becomes very tight. For a duplicator with a 7200 foot bulk roll, a loose wind makes the roll quite difficult to handle because the roll may fall apart. A tight wind may cause the roll to become dished, making it difficult to handle on the duplicating slaves. The tight wind could cause stresses within the roll that may result in permanent physical distortion.

A roll of polyester will not exhibit these changes after being submitted to the same range of conditions. Seasonal changes may create either loose and tight winds of acetate bulkpack rolls because of the day to day changes in relative humidity. Some users may consider environmentally regulated storage areas for acetate tape. The wind stability of polyester, with respect to changes in relative humidity, is much more predictable than acetate.

STRENGTH

Another important property of magnetic recording tape is its ability to withstand stresses and strains which occur during use. The simplest method of a comparison between the two backing materials is to subject them both to a series of tests which determine tensile strength during tension and their shock tensile strength to withstand a sudden application of stress. Still another strength parameter is the ability of the backing to withstand minor damage and aging and still remain in usable condition.

TENSILE STRENGTH

The tensile strength test is accomplished by attaching a tape strand to two fixtures or jaws, one is stationary and one is capable of being moved at a constant speed (figure 2). The tension imposed on the stationary jaw is measured by a force transducer as the movable jaw pulls on the sample. The output of the transducer provides an electrical signal which deflects the pen of a chart recorder in proportion to the force. The chart paper is moved in proportion to the distance the movable jaw travels, thus generating a force versus elongation curve. The curve shows the backing's strength when subjected to a constant rate of elongation.

Figure 3 is a graph of typical samples of 1½ mil polyester and acetate tested on the apparatus at 50% R.H. Even though this curve represents 50% R.H. the polyester would be essentially the same at any humidity because polyester's strength is virtually unaffected by the presence or absence of moisture. During this test a typical polyester sample elongates 100%. This is a deceiving figure, however, because magnetic recording tape is useless once it has stretched beyond 5%. The knee of the curve appears at approximately this 5% point. Below 5%, the backing's elasticity allows it to return to essentially the same length and shape as when it was under no tension. Beyond this knee at 5%, the film is permanently distorted. After the 5% point, the tape continues to lengthen without additional force for a short time, then more force is required to reach the breaking point. Finally, breakage occurs at approximately 100%. This percentage can vary from about 90 to 150%, but 100% is typical.

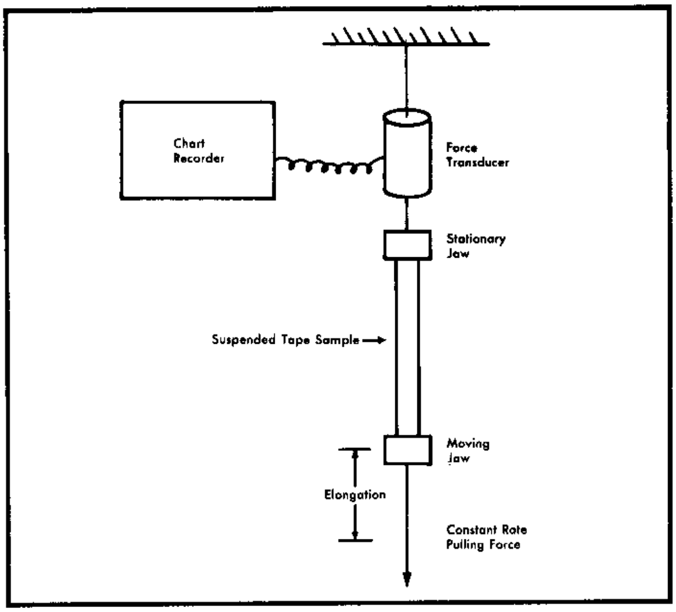

FIGURE 2. TENSILE STRENGTH TESTING APPARATUS DIAGRAM

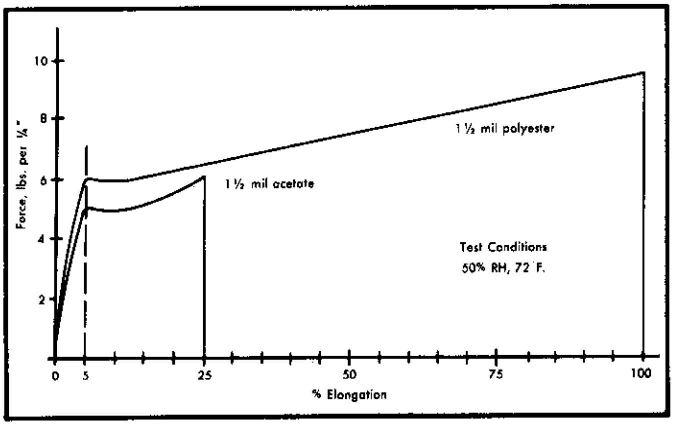

FIGURE 3. TENSILE PROPERTIES OF 1½ MIL BACKING

During the comparison test of a 1½ mil acetate tape sample, notice that the acetate also stretches, but not nearly as much as polyester. Breakage occurs after 25% elongation. Also, this breakage figure varies considerably depending on both the edge quality of the tape and the relative humidity. The permanent deformation point (yield point), is again approximately 5%; the same as polyester. But about 15 to 20% less force is required to permanently distort acetate. For 1½ mil polyester bases, the 5% point is reached at about 6 lbs. per ¼ inch. For 1½ mil acetate, it is only about 5 lbs. per ¼ inch. Notice that under the conditions of test (normal room temperature and 50% R.H.), acetate and polyester both stretch, but the acetate sample is permanently deformed at 20% lower force.

Figure 4 shows how 1 mil polyester and acetate tapes compare. The same general relationship exists between the two different 1 mil bases as with the 1½ mil bases as previously illustrated. The major difference lies in the forces required to stretch and break the tapes. Since the base materials will withstand an established constant force per cross-sectional area, the thinner caliper tapes, having reduced cross-sectional areas, will stretch and break at lower forces.

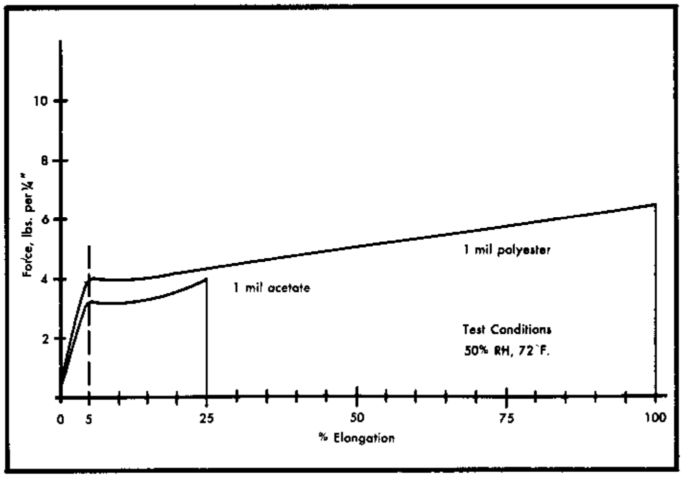

FIGURE 4. TENSILE PROPERTIES 1 MIL BACKING

The effect of temperature on the 5% yield point of 1½ mil acetate and polyester is shown in Figure 5. At low temperatures, both tapes require more force to reach permanent deformation than they do at room temperature. The higher the temperature, the lower the required force. Notice the two lines are parallel, indicating that both materials are affected to about the same degree.

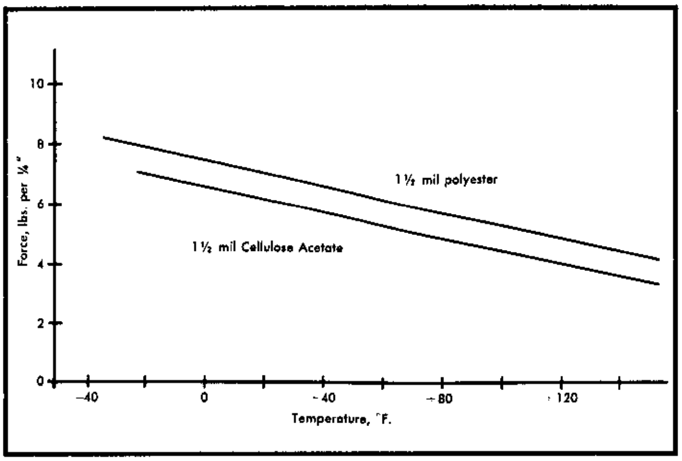

FIGURE 5. TEMPERATURE EFFECTS ON 5% ELONGATION POINT

Since acetate is hygroscopic (absorbs moisture), it has different tensile properties at different humidities. As an example, Figure 6 illustrates the tensile properties of 1½ mil acetate at three different humidities. The tests were made at 15%, 50%, and 80% R.H. with a constant 72°F. temperature. At 85% R.H., acetate stretches much easier and elongates much further than it does at 50% R.H. At 15% R.H., acetate becomes more brittle and will break sooner although it requires a slightly higher force to reach permanent deformation. At high humidities the acetate absorbs moisture which "plasticizes" the backing, allowing it to become more flexible; and, therefore, it is more subject to stretching.

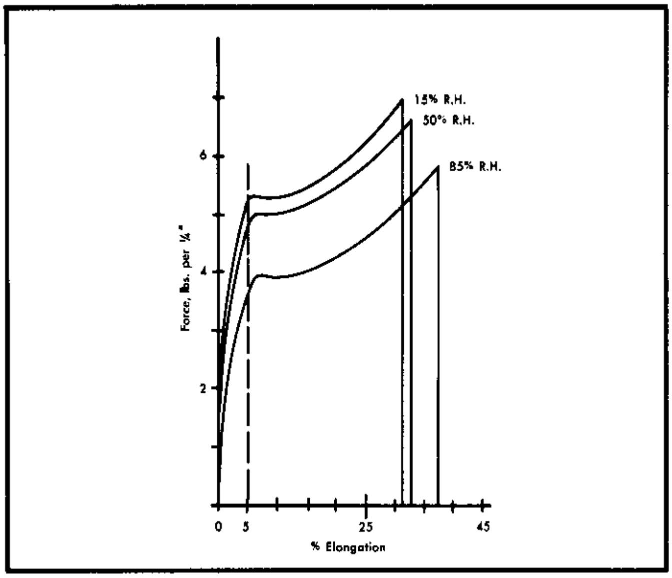

FIGURE 6. ACETATE TENSILE PROPERTIES AT DIFFERENT RELATIVE HUMIDITIES

SHOCK TENSILE STRENGTH

Shock tensile is a test that evaluates how tapes will react to sudden stresses which often can be the cause of breakage. A special instrument is used to apply the forces required during the test. Figure 7 is a simplified drawing of the stress application which corresponds to the Military Specification W-T-0070 testing methods. A weight (or pendulum), attached to a radial arm, is raised a number of degrees and allowed to fall and strike a tape sample. The weight, angle, and radius are determined so that the tape sample at the bottom of the arc is struck with 0.59 ft.-lbs. of energy.

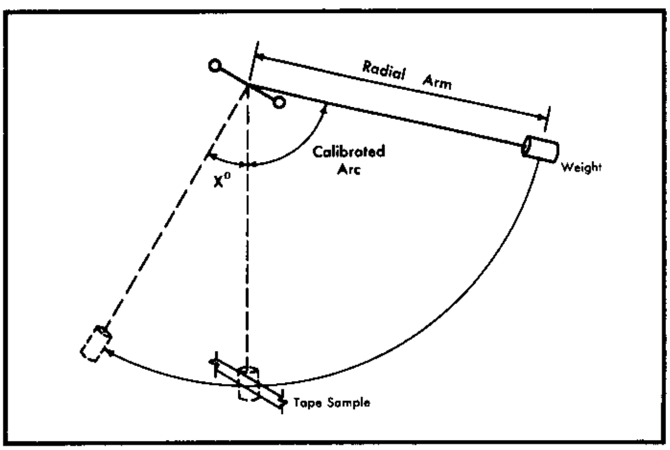

FIGURE 7. SHOCK TENSILE TEST APPARATUS DIAGRAM

The comparison of tapes tested on this apparatus is done by measuring the distance the weight travels after breaking the tape sample (angle X°). If the sample breaks without absorbing any energy, neglecting the frictional losses in the apparatus, the weight will swing to the same height (or angle) as that of its initial position. The difference in the angles, before and after striking the tape, allowing for frictional losses, yields a calculable amount of energy that is absorbed by the tape before it breaks.

The average energy absorption figures for acetate are 0.43 ft.-lbs. for 1½ mil thickness and 0.30 ft.-lbs. for 1 mil. As previously mentioned, because of plasticizing, these figures are extremely dependent upon the Relative Humidity. At lower humidities acetate will absorb less energy and at higher humidities it absorbs more. Depending on ambient conditions, the tape will tend to either plasticize or embrittle. The more moisture, the more plasticized it becomes and the more it stretches before breaking. The stretching action of the tape absorbs the energy of the falling pendulum. At 95% R.H., both 1 mil and 1½ mil acetate material will stretch enough to absorb 100% of the pendulum force and will not break.

During this test comparison, the polyester material of both 1½ mil and 1 mil thickness absorbed the entire pendulum force without breaking, regardless of the relative humidity.

"WEAK" EDGES

A "weak edge" can occur if a tape has been poorly slit during manufacture or damaged in handling. The edge is apparently minutely broken or nicked, and, therefore, has a weak point. To evaluate the effect of the damage to the strength of tape, we took a known good sample roll of 1½ mil acetate. Preliminary tests were performed to assure that it would absorb a minimum of 0.43 ft.-lbs. and stretch normally before breaking. The tapes' edge was then deliberately damaged with a 5 mil nick, using a sharp razor blade and a microscope with a calibrated eyepiece. The edge-nicked samples were then tested. The damaged tape absorbed only 0.07 ft.-lbs. of energy before breaking. No stretching was observed, and the break occurred where the edge nick had been placed. With 5 mils of edge damage, the tape absorbed less than 20% of the energy that it would have if it had good edges. Repeating the same experiment with 1½ mil polyester samples, it was found that the damaged samples did *not* break.

To additionally verify the effect of minor edge damage, static tensile tests were made on samples of the same acetate and polyester rolls. The polyester samples exceeded the 5% permanent deformation point. The acetate samples broke after they elongated about 3%.

Edge damage may be the result of substandard slitting, as occasionally is found in poor quality recording tape. Weak edges also can be the result of improper transport guiding, causing the tape to scrape a reel flange. Damage can also be caused by the bending over of a slightly exposed tape edge in a scattered wind, or by rough handling during thread-up and editing. In all probability, the main cause of acetate breakage is attributable to damaged edges — the direct result of improper handling.

AGING

Cellulose acetate film, as used in magnetic recording tape, contains a plasticizer which is necessary to provide the required flexibility at all relative humidities. It was discovered that old acetate tapes become brittle because of the gradual loss of the moisture and plasticizer over many years time. In an attempt to verify this effect, shock tensile tests were made on artificially aged rolls of tape. The rolls were aged by placing them in a 150°F. oven for 1,000 hours, which, in the chemical industry, is known to be the equivalent of about 2 to 3 years of normal aging. In a comparison between these "aged" rolls and "un-aged" control rolls from the same lot, it was discovered that the strength of the aged rolls was almost ⅓ *less* than that of the un-aged rolls. This verifies previous theories about aging and the loss of plasticizer, causing the acetate to become more brittle. It was found that moisture can be returned to the tape but that the acetate film would never be as flexible or as strong as it was originally. Since polyester does not contain a plasticizer, it does not exhibit this "aging" phenomenon.

CONCLUSION

Because of the greater stability and strength, polyester film is the preferred type of backing for many applications. Although acetate type backings are considered by some as preferable for editing purposes, the polyester must be considered better for operational reasons. For original mastering and duplicating masters, it is important that a recorded tape remain useable in spite of relatively rough handling. Physical distortion caused by changes in humidity that could be encountered during storage cannot be tolerated in conditions which require precise playback. In duplication, it is important that breakage does not occur either during start-up or during operation. Generally speaking, polyester backing materials offer greater reliability and a larger safety factor against problems that can be both time consuming and costly.

If at any time additional information on this topic is desired, it is available by simply writing to:

Technical Service
Magnetic Products Division
3M Company
3M Center
St. Paul, Minnesota 55101

Additional copies of this paper are available from your 3M representative, or by writing to the address above.

Magnetic Products Division 3M COMPANY

LITHO IN U.S.A. WITH 3M OFFST PLATES