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# Causes of Failure in Magnetic Tape

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## Causes of Failure in Magnetic Tape

by Donald F. Eldridge

*The factors which lead to performance deterioration and end of life of magnetic tape are discussed. Two types of failure are described: that attributable to normal use and that produced by accidental damage. Normal wear occurs when material that has been slowly abraded from the tape by various fixed surfaces is suddenly redeposited on the recording surface. Accidental failure may come from a number of sources, including the tape handler, the operator, shipping or even storage conditions. Specific factors which can shorten or extend tape life are discussed, with the object of assisting the user to obtain maximum utilization and reliability in the use of magnetic tape.*

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## Causes of Tape Failure

When a tape is re-used many times its performance will eventually deteriorate so that it no longer fulfills the requirements of the particular application. This is considered "tape failure," and the point at which it occurs will vary widely with the application and the type of tape used. Tape failure may result from "natural causes" such as normal wear during use, or it may occur prematurely due to accidental damage. Specific causes of both types of failure are discussed below.

### Normal Wear

Normal wear occurs because, in order to be recorded and replayed, the tape must make sliding contact with the heads. In many types of recorders sliding contact also occurs between a number of fixed surfaces and the tape surface, edges and backing. Deterioration of performance is not, as might be supposed, caused by the removal of the magnetic coating and consequent loss of signal. Instead, it is the redeposition of wear products onto the tape surface which causes deterioration and ultimate failure. These wear products consist of small pieces of the coating and the base film which are removed from the tape by normal abrasion. These particles may collect on any fixed surface such as the heads and will slowly build up to form a projecting lump. At some point the combination of pressure, velocity and surface temperature caused by the moving tape will cause a lump to become re-attached to the tape surface as shown in Fig. 1. The redeposited lumps are often more firmly attached to the tape than is the original magnetic coating, indicating that considerable heat may be involved in the redeposition process. It is these lumps which produce the performance degradation by causing separation between tape and heads. Individual lumps will cause single dropouts as they pass over the record and reproduce heads. When redeposition becomes severe, the tape surface is studded with lumps so that the recording surface is almost continuously out of contact with the heads. In digital recording the redeposited lumps will cause dropout errors when they are of sufficient size. In a typical computer

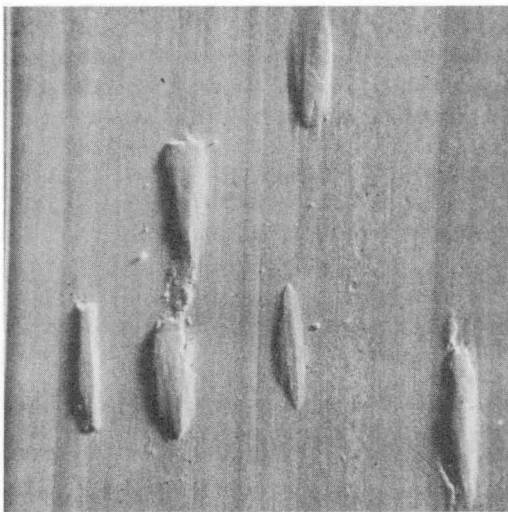


Figure 1. Surface of a well worn tape showing lumps of redeposited debris under 50x magnification. These lumps are the major cause of performance degradation as a tape wears.

tape drive operating at 800 bits per inch, a 50% signal reduction will result from a lump protruding 150 microinches from the tape surface.

In analog recording redeposition will produce an increase in the dropout count, an increase in modulation noise and non-uniformity of recorded and reproduced signals, and a decrease in short-wavelength response. A single protrusion less than ten microinches high will cause a 50% signal reduction at a recorded wavelength of 100 microinches. Present-day broadband instrumentation recorders operate at wavelengths as short as 60 microinches, so that a very slight amount of redeposition can severely impair their performance.

In most types of recording, separation between tape and heads interferes with both the recording and reproducing processes. Therefore, performance degradation will appear more rapidly when a tape is re-recorded than when a previous recording is replayed. This normal wear process is a cumulative one. Once wear products have started to collect on the tape surface, the rate of production of wear products increases rapidly. Thus, once the first permanent dropout is formed, additional dropouts in increasing numbers will follow rapidly. Similarly, any substantial increase in short-wavelength non-uniformity is a sign of incipient tape failure. Once this point of incipient failure has been reached it is extremely difficult to renew or rehabilitate the tape, because the offending lumps are affixed so firmly to the tape surface as to defy normal cleaning methods.

Factors that determine the length of time a given tape can operate before failure include the strength of the magnetic coating, its adhesion to the base material, the tape surface roughness and coefficient of friction, the softening or melting temperature of the binder resin, the degree of straightness or smoothness of the edge of the tape and the operating conditions such as the tape speed, tension, temperature, humidity and the smoothness of the fixed surfaces. It is not always possible to predict the specific effect of any of these factors. For instance, it has been observed that some tapes with lower-temperature binder resins will, under some conditions, outlast tapes containing higher-temperature resins. One might expect the reverse to be true, but studies on friction and lubrication have shown that a low-melting material can often outwear a higher-melting material. In fact, lubrication between two surfaces is sometimes produced by a molten layer of the lower-melting material which may be only a few molecules thick.

Since performance deterioration is normally a function of the amount of redeposition rather than of the percentage of the coating worn away, tapes with thin coatings can wear equally as long as those with thicker coatings.

A ragged edge, resulting from improper slitting, can cause even the toughest tape to fail prematurely. See Fig. 2. The rough edge will tend to wear very rapidly, thus producing debris at a much higher rate than that from surface wear and accelerating the normal redeposition process. Of course, if all other conditions are equal, the tougher binder will outlast the weaker one. Neither is hardness or softness of the binder an indication of its durability. Both very hard and very soft binders tend to wear poorly, and the optimum hardness

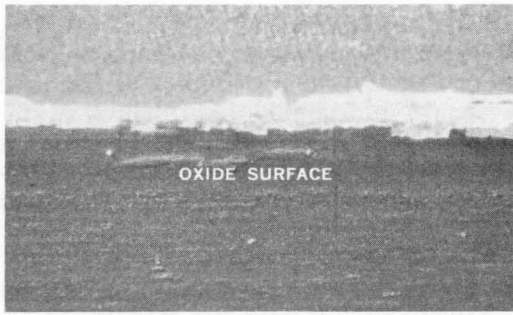


Figure 2. Severe edge wear under 50x magnification. This resulted from prolonged use in a tape handler with hard spring-loaded edge guides of a tape which was poorly slit and had poor adhesion between binder and base film. The bright ridged strip is the damaged base film from which the coating has actually been chipped away.

varies with the type of application. Indeed, the factors which may cause one tape to outwear another in a given application are so complex in their interrelation that it is very difficult to determine probable tape life by means other than an actual use test.

### Accidental Damage

Accidental failure may be defined as that which would not occur under ideal operating and handling conditions. It may be produced through handling either by human operators or the tape machine itself or through a combination of improper handling and storage conditions. Operator handling errors which can cause tape failure range from such violent things as dropping a reel of tape to improper threading of the tape on the machine which can cause creases or folds in the tape. Somewhat less obvious is the damage caused by squeezing the flanges or grasping the tape directly through the flange holes. This can quite readily cause severe damage if the tape has been wound on the reel with some individual layers protruding from the rest of the pack. These protruding layers can very easily be nicked, torn or permanently deformed.

A poorly designed or improperly adjusted tape handler may lead to premature failure of the tape in a multitude of ways. When winding or rewinding tape, the recorder may produce a "pack" or "wind" with protruding layers which are subject to damage as mentioned above. It may also wind the tape under insufficient tension so that later handling will cause the pack to shift from side to side against the flanges, leading to later edge damage. A loose pack is also subject to tangential slippage between layers, called cinching. Cinching is likely to occur when a reel of tape with one or more regions of too-low tension is subjected to rapid angular acceleration or deceleration such as may occur during starting or stopping of a tape handler, or improper handling during shipment. The acceleration which is applied to the hub acts against the moment of inertia of the pack, so that where tension is too low, the acceleration forces will overcome the friction between layers and slippage will occur. During slippage, the tape may fold over on itself so that permanent creases will form, either immediately or later when tension is applied and the tape attempts to return to its original position (see Fig. 3). These creases will cause dropouts through separation between tape and heads.

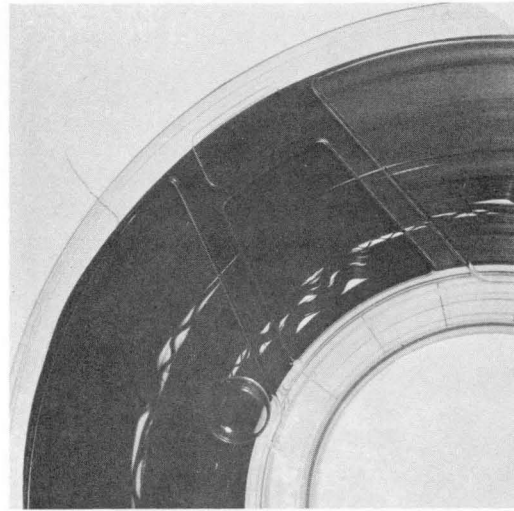


Figure 3. Cinched reel. Cinching was caused by winding at too low a tension and subsequent fast braking of the reel. Layers of the tape have been folded over and creased, which produces errors.

If there is a small burr or sharp protrusion on any of the recorder's fixed surfaces, the tape surface may be scratched. The scratch will produce wear products, which will add to those produced by normal abrasion. It may also produce a continuous scratch in the tape surface or backing throughout an entire reel. The slight ridge thus produced can multiply through the layers of tape wound on the reel to produce a much larger ridge in the outer layers of the tape — often large enough to cause permanent deformation in the outer layers. For instance, a ridge only 10 millionths of an inch in height will, if continuous throughout the tape, wound on a standard 14" reel, appear as a 30 mil high ridge at the outside layer. See Figs. 4 & 5. Even under normal storage this can cause sufficient deformation so that contact between tape and head will be lost. When the deformation is along an edge and the tape is held loosely, the stretched edge will exhibit waviness as

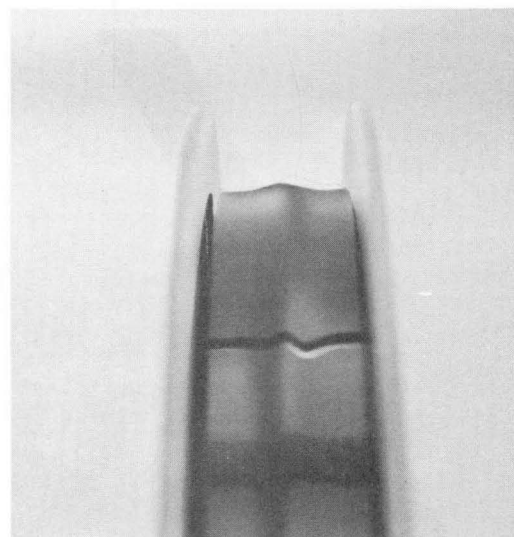


Figure 4. Ridged tape. This ridge can be produced by a tiny scratch on either side of the tape which continues throughout a major portion of the reel. After prolonged storage the deformation will be semi-permanent and may cause loss of contact between tape and heads.



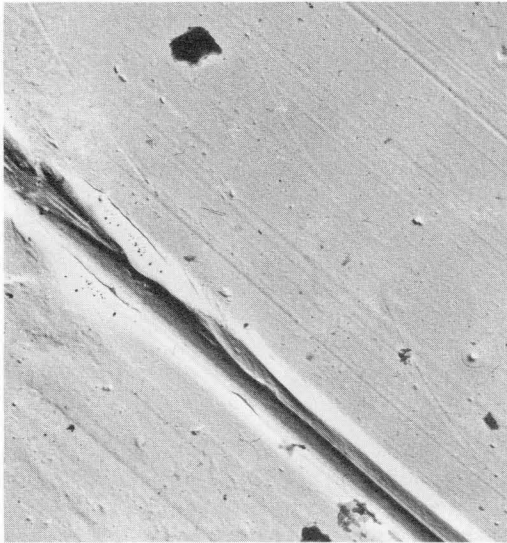


Figure 5. Electron photomicrograph (6000x) of a scratch in the polyester base film. The ridge to one side of the trough is about 10 microinches high.

shown in Fig. 6. This is particularly undesirable because, in most tape handlers, the edge tracks tend to lose contact rather more readily than those in the center of the tape.

In similar fashion to ridge formation small bits of loose dirt, which would ordinarily fall off the surface when the tape is played, can, when wound up in the tape pack and stored for a period of time, cause permanent deformations. These "pimples" can readily lift the tape away from the heads, producing dropouts.

### Storage and Shipping

Of course mechanical agitation during shipping will tend to shift the tape pack, especially if wound under improper tension. But serious damage can occur even while tape is being stored. Elevated temperatures and high humidity can lead to blocking and to mechanical

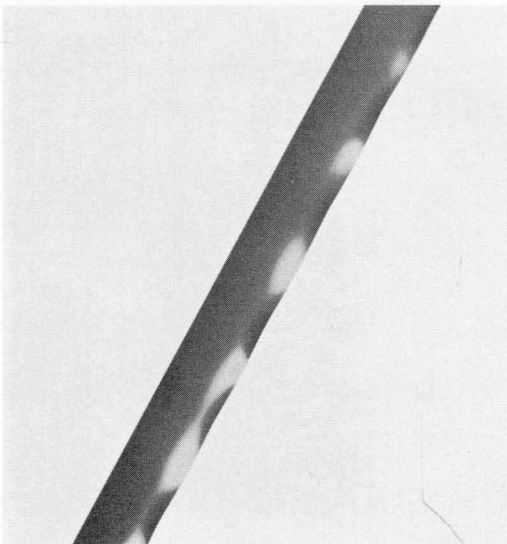


Figure 6. Wavy edged tape. This defect occurs when one edge of the tape has been elongated. It most usually occurs after storage of a reel which has a ridge or scratch along one edge of the tape.

deformation of the pack such as cinching, spoking, cupping and skew. When blocking is mild the tape will tend to stick slightly when it is unwound from the reel. This may cause undesirable disturbances in the tape handler tension control but will not produce permanent damage to the tape. On the other hand severe blocking can cause complete delamination between coating and base film, making the tape unusable. Environmentally induced mechanical deformations are accentuated when the tape has been wound under insufficient tension or when the pack is poor and contains protruding layers. Tape with such defects may be reconditioned by rewinding under proper tension and with a smooth even pack and storing under moderate environmental conditions for about 48 hours. The combination of high temperature and humidity can also lead to fungus growth if no fungus inhibitors are included in the coating.

Low temperatures may cause the reel hub to shrink away from the tape leaving the pack free to shift sideways and tangentially. This is especially likely to occur when the thermal coefficient of expansion at the reel hub is larger than that of the tape. Most plastic reels have a thermal coefficient about twice that of the polyester base film, while the thermal coefficient of aluminum is very nearly equal that of polyester. Tape stored on plastic reels is therefore particularly susceptible to damage when it is handled while still cold.

The possibility of damage during storage or shipment can be minimized by using the following procedures:

- 1) Proper winding of the tape. The pack should be even and tension should be carefully controlled throughout the reel. A compromise between constant torque and constant tension is usually preferable.
- 2) Tape should be stored under controlled environmental conditions. It is desirable to maintain the temperature between 40° and 90°F and the relative humidity between 20% and 80%. Further, large or rapid changes in environment should be avoided.
- 3) Tape which has been stored under less than ideal environmental conditions should be conditioned by allowing it to remain in a suitable environment for at least 24 hours prior to use.
- 4) When large changes in temperature cannot be avoided, the probability of damage can be minimized if the reel hub has a thermal coefficient of expansion similar to that of the base film.
- 5) To reduce the probability of spoking or buckling caused by hub compression, tape may be stored on reels with very rigid hubs, such as those in precision reels. Keeping the ratio of outside pack diameter to reel hub diameter small will reduce compression forces on the hub. This ratio should not exceed 3.
- 6) Tape should always be stored with the reel on edge rather than lying flat. This will tend to eliminate sideways shifting of the pack against the flanges.
- 7) Finally, tape should always be handled as gently as possible.

