Media Stability and Life Expectancies of Magnetic Tape for Use with IBM 3590 and Digital Linear Tape Systems

J. S. Judge, R. G. Schmidt and R. D. Weiss
Arkival Technology Corp.
Email: mailto:nhinc@aol.com

G. Miller
University Of New Hampshire
Email: gpm@cisunix.unh.edu

Abstract

The purpose of this study was to determine the environmental stability and life expectancies of magnetic media used with certain high density, digital recording tape systems, specifically the IBM 3590 and both Quantum's Digital Linear Tape (DLT) and Super DLT products. The goal of the study was to compare the tape stabilities and life expectancies of the corresponding tape media and tape storage products and to determine the most suitable magnetic medium for the archival preservation of electronic records.

1. Introduction

This study determines the relative environmental stabilities of ten different tapes for use with IBM 3590 and Quantum SDLT tape drives with a view of archival storage.

2. Experimental

The magnetic storage media were conditioned in accelerated temperature/humidity environments. Environmentally conditioned tape cassettes and tape samples were periodically tested for changes in bulk magnetic properties, physical and chemical properties and recording/playback performance -- factors relating to their functionality, life-expectancy (LE) and their overall impact on long-term preservation requirements.

The specified tasks of the study embodied six (6) technical areas significant to a magnetic storage system undergoing change. They are

- Magnetic and microstructure analysis of the recording media
- Intrinsic magnetic characteristics,
- Physical characteristics,
- Binder chemistry,
- Recording characteristics,
- Error/drive performance

3. Results

The media binder degradation was of great concern in earlier generation tapes. In this study, the binder hydrolysis extracts from the evaluated tape media subjected to GC-MS analyses revealed minimal degradation and only minor changes in the compositions of their extracts over time. Samples subjected to an extreme condition of 100 ^{o}C and 100% RH revealed the same set of molecules seen at time zero**.** Tapes subjected to these most severe aging conditions however did show significant signs of physical breakdown becoming stiff and brittle, strongly suggesting that oxidation of the MP particles (and perhaps the substrate) were the predominant failure mechanisms.

The changing values of resistivity with environmental exposure were substantial but within specification limits. It is preferable for no resistivity change to occur. Tapes C and D were the most stabile on both sides (magnetic and conductive).

Changes in tape friction could also be detrimental to performance. Tape B and I exhibited the most change. The frequency response of each tape media was compared to its original after each interval of temperature/RH exposure. Throughout all test environments, tape C and D was the most stabile among the subject tapes of this evaluation.

The error study reported tape/drive error results during both the first write and all subsequent reads. The error evaluation was also based upon noting tape errors at receipt and error changes resulting from environmental exposure. Parameters of importance during write/read were correctable(s) errors, retries, non-correctable(s) errors and the bit-error-rate (B*ER). The results of this error analysis will be discussed.

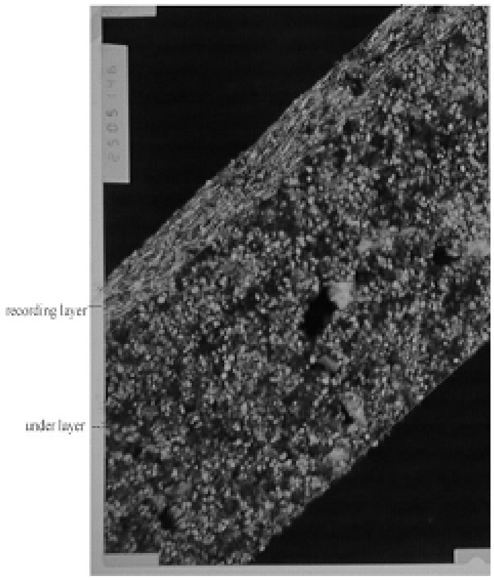

Figure 1. Tape E - 25X

Error rates were also reported as a function of environmental exposure time. The resulting data was consistent with the above findings and supported the most favorable performance of the storage system using dual layer tapes. The life expectancy (LE) of these storage systems was projected with actual data collected for this study, a selected end-of life (EOL) criteria and mathematical trend-forecasting models. LE's were forecasted on the basis of the media performance in the three Storage Systems studied at three different environmental conditions of media storage.

Initially, in order to identify, compare and understand the microstructure facets of the recording media TEM studies were done on each. As an example, Figure 1 is a TEM of tape E (a double layer (DL) tape) at 25 kx magnification illustrating the double layer magnetic coating; the magnetic layer consists of a thin layer of oriented acicular metal particles and it's non-magnetic under layer of spherical TiO_2-type particles. The initial magnetic properties of each tape are shown in Table 2.

3.1 Effects of Temperature and Humidity Exposure on the Magnetic Properties.

Samples of each tape studied were environmentally conditioned for periods of time from 100 hours to 3500+hours. The change in Is is proportional to the amount of oxidation of the metal particles (MP) when they are converted from ferromagnetic iron to non-ferromagnetic iron oxide. (2) It will be shown that the rate is parabolic (see Figure 2) and also that the rate constants, k, obey the following relationships:

$$k = Z * 10^{-\Delta E/kT}$$

Here ΔE is the activation energy and Z is the pre-exponential term.

$$\text{Log } k = A [RH]^2 + B$$

where A and B represent the slope and intercept for the lines, for example, as shown in Figure 3 for tape B. The

Table 1 Media Layer Thickness-obtained from TEM micrographs*

Study #	Type	Usage	Top layer (um)	Substrate (um)	Back layer (um)	Total (um)	Magnetic layer (um)
A	DL	DLT IV	2.08	7.87	0.45	10.40	0.264
B	SL	3590	2.51	18.24	0.50	21.25	-
C	DL	S DLT I	2.06	8.86	0.47	11.41	0.197
D	DL	S DLT I	2.18	7.45	0.49	10.12	0.327
E	DL	DLT IV	2.08	8.62	0.47	11.17	0.321
F	DL	DLT IV	2.49	9.54	0.43	12.46	0.245
G	DL	DLT IV	2.03	8.11	0.51	10.65	0.265
H	DL	DLT IV	2.32	8.75	0.51	11.58	0.333
I	SL	DLT III	2.40	14.67	0.63	17.70	-

SL = single layer; DL = dual layer

Table 2 Summary of VSM Data*

Study #	Type	Usage	Is (memu)	Ir (memu)	SQ (Ir/Is)	Hc (Oe)	SFD	SQt	OR (Sql/Sqt)
A	DL	DLT IV	1.96	1.56	0.79	1915	0.35	0.40	1.98
B	SL	3590	18.64	15.21	0.82	1622	0.34	0.37	2.19
C	DL	S DLT I	1.74	1.44	0.83	1934	0.35	0.35	2.36
D	DL	S DLT I	1.96	1.64	0.84	1930	0.35	0.37	2.26
E	DL	DLT IV	2.29	1.91	0.83	1811	0.34	0.37	2.25
F	DL	DLT IV	1.77	1.41	0.80	1920	0.35	0.36	2.20
G	DL	DLT IV	2.40	1.99	0.83	1819	0.33	0.37	2.24
H	DL	DLT IV	2.50	2.03	0.80	1801	0.33	0.40	2.00
I	SL	DLT III	9.57	7.05	0.74	1405	0.33	0.38	1.92
J	SL	DLT III	19.34	15.24	0.79	1479	0.35	0.38	2.07

long-term stability of magnetic tape is dependent upon many factors including the integrity of the polymer binder in the magnetic recording layer. Most polymer binders are composed of polyester polyurethanes and are prone to (hydrolytic) degradation over long times and/or over shorter times under severe conditions. Early studies indicated that controlling humidity is essential for the long-term stability of polymer binder, much more so than controlling exposure to air (3). The hydrolysis of the polyester polyurethane binder was implicated as a major cause of binder degradation and because polyester hydrolyzes faster than polyurethane (4) most binder hydrolysis studies have first and foremost considered polyester hydrolysis.

Prior to this work, tape binder hydrolysis was studied in detail by NML (1) and Fuji(5) . In this study, under the most severe conditions tested (100 °C, 100% RH), the

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tapes showed signs of physical breakdown, but even then the degradation was not accompanied by exhaustive binder hydrolysis.

4. Conclusions

Thusly the major mechanism for degradation and lifetime limits for MP tapes is oxidation of the metal particles. Lifetimes vary significantly for different conditions for each tape. The lifetimes of double layer tapes are longer than for single layer tapes. The most stable tape under most conditions was tape E. However, at moderately controlled temperature and humidities the projected lifetimes for these tapes is sufficient for archival storage and lifetimes of 50 to 100 years can be anticipated for the more stable ones.

FIGURE 2
CORROSION VS TIME
(TAPE B AT 80 C/85 %RH)

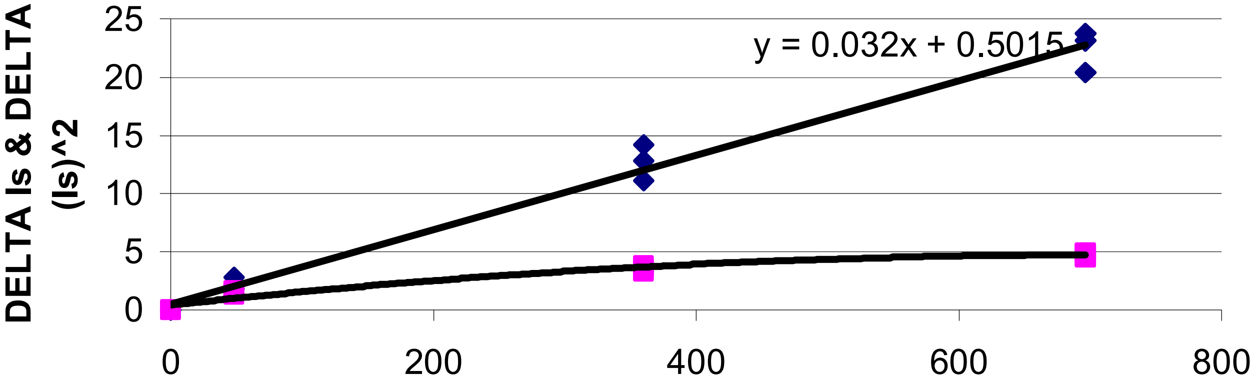
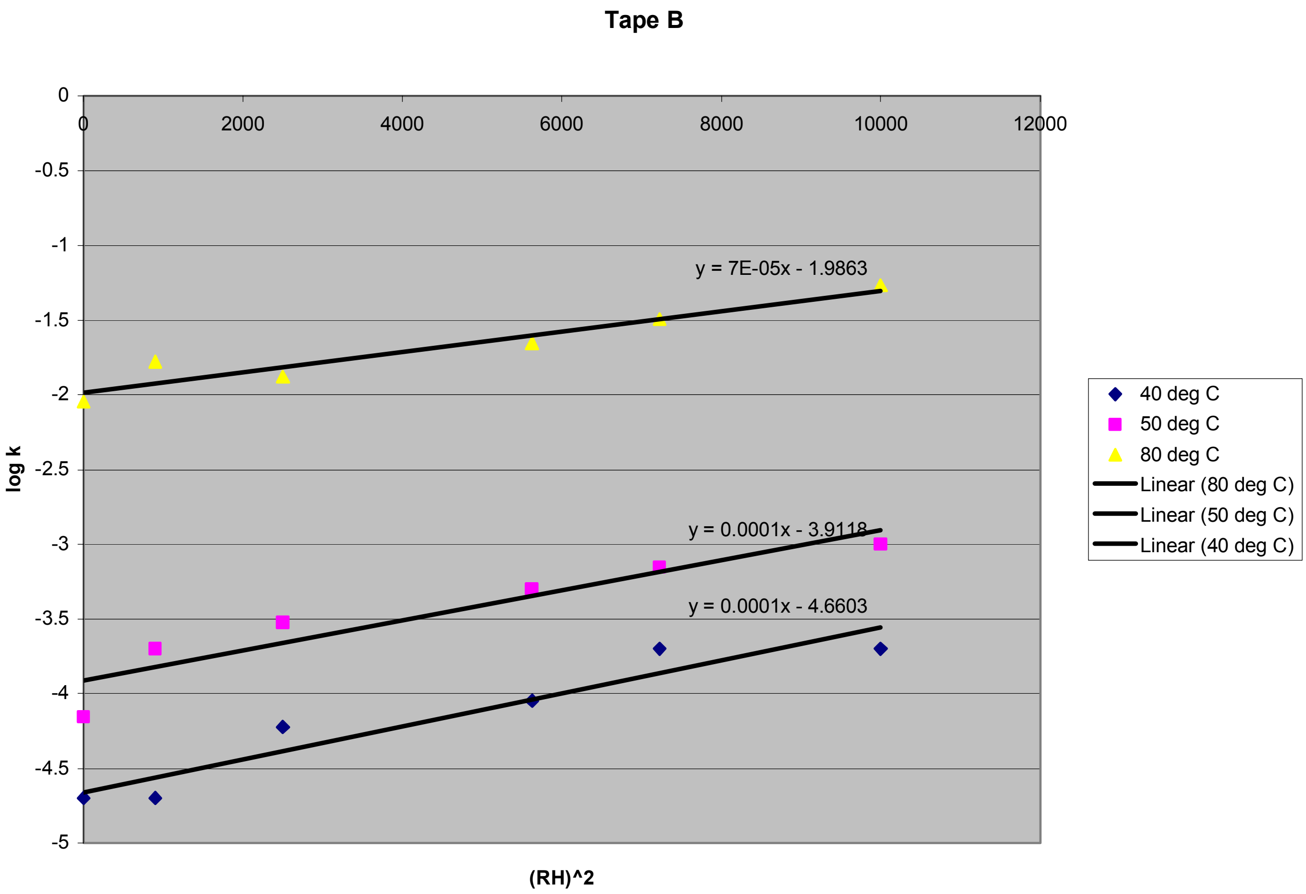


Figure 3 Dependence of log k on Relative Humidity for Tape B



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