



The Field Audio Collection Evaluation Tool

**Format Characteristics
and Preservation Problems
Version 1.0**

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1 INTRODUCTION

This document provides detailed information on the characteristics of, and preservation problems associated with, each audio format that may be assessed using FACET. It is not comprehensive and does not attempt to present everything that is known about the formats themselves or the processes by which they deteriorate. Rather, it succinctly covers the format characteristics and preservation problems identified by FACET as contributing to instability, degradation, and/or increased risk, providing specific information to aid in ranking field collections using the FACET software application. Included are descriptions of each characteristic/problem along with guidance on how to identify it and, if appropriate, rate its severity.

There are few metrics or tests available to document or predict the level of deterioration present in any given recording. In addition to format characteristics and preservation problems, media degradation is also dependent on storage history and the specifics of manufacturing. Differences in these variables may cause two identical recordings to deteriorate at substantially different rates. Nevertheless, for timely preservation work sound archivists must prioritize recordings by condition and risk even if this is as much art as science at this point in time. FACET uses the science that is available, but also draws on the experience of archivists and preservation audio engineers to ground the process of assessing risk in not only what is known from research, but what is understood from daily work with these materials.

The aim of this document is to give archivists the tools needed to increase their understanding of the level of risk carried by the collections they administer as well as to successfully use FACET to assess this risk. This document also provides the FACET score for each problem and, in many cases, a justification for the size of the score. Finally, it presents cross-format comparisons to facilitate an understanding of how FACET prioritizes the different formats and their problems. Users of FACET should refer to a separate procedures manual for assistance with the software itself. This manual also details other areas in which FACET assigns points including storage history, copies, and other factors.

FACET does not assess all audio formats. Rather, it is designed to evaluate many of the audio formats historically used by fieldworkers to make recordings, although these formats were also used in other settings such as radio stations and recording studios. FACET does not address formats developed for commercial recordings, most of which are considered relatively stable by sound archivists. For example, formats that are not part of FACET include LPs, commercial 78rpm and 45rpm discs, and commercially-released CDs. All of these formats were mass-produced, commercially released, and exist in multiple copies. Some of these formats—LPs and shellac 78s—are considered to be highly stable and, therefore, poor candidates for preservation treatment. For example, the selection document published by the International Association of Sound and Audiovisual Archives states that:

- Replicated shellac records (commercial 78s) “have proved to be fairly stable over many decades....and are on the low end of the priority scale”
- Vinyl LPs “have proved stable so far....the great majority can be ranked at the lower end of the priority list”¹

There may be compelling reasons to consider preservation work for rare commercial recordings. For example, early LPs can lose plasticizer which migrates to the surface causing playback problems.² This, however, is not the focus of FACET, which concentrates on collections of one-of-a-kind field recordings.

Finally, it is not necessary to read this entire document before using FACET—use the parts that you need, as you need them.



FIGURE 1: TYPICAL FIELD FORMATS

¹ Majella Breen et al., *Task Force to Establish Selection Criteria of Analogue and Digital Contents for Transfer to Data Formats for Preservation Purpose, October 2003* (International Association of Sound and Audiovisual Archives, 2004): 6, <http://www.iasa-web.org/taskforce/taskforce.pdf>.

² Reported to me by Steve Smolian via email, February 12, 2006; also mentioned in Breen, *Task Force to Establish Selection Criteria*, 6.

2 OPEN REEL TAPE

2.1 Introduction

The process of recording onto open reel tape (sometimes called reel-to-reel) was first developed in a practical application in Germany in the mid-1930s. The technology, in the form of tape machines and the media itself, was brought to the U.S. after World War II by Army Signal Corps Major, Jack Mullin. In 1947, 3M produced its first tape stock and Ampex its first tape machine. Open reel tape consists of four primary components:

- A base film (also called a substrate) that may be cellulose acetate, PVC (polyvinyl chloride), paper or polyester that supports the other components
- Magnetic particles or pigments that store the recorded signal. Until 1983 this was ferric (iron) oxide— Fe_2O_3 —for all open reel tapes³
- A binder that holds the pigments together and binds them to the base
- A back coating that is sometimes used to reduce friction and static electricity

The magnetic particles and binder may together be considered a top coat that can also include lubricants, plasticizers, and other ingredients.⁴ Open reel tape used for field recording is almost always $\frac{1}{4}$ inch in width. $\frac{1}{2}$ inch, 1 inch, and 2 inch tape was used primarily in professional settings, typically by recording studios.

2.2 Format Characteristics

FACET identifies a number of open reel tape format characteristics that may impact the stability of any given tape:

2.2.1 Tape Base

Overview

Historically, four types of base films have been used for open reel tape: cellulose acetate, PVC (polyvinyl chloride), paper, and PET (polyethylene terephthalate which is commonly called polyester and sometimes known by the trade names mylar or tenzar).

(1) Cellulose acetate: Cellulose acetate is a generic term for a variety of acetylated cellulose polymers, including cellulose diacetate and cellulose triacetate. It was widely used as a carrier for a number of formats including film, microfilm, photographic negatives, and audio tape. Acetate was used experimentally in audio tape as early as 1932 by chemists from AEG in Germany with production starting around 1935 by IG Farben. Other manufacturers produced cellulose acetate tape from approximately 1946 until 1964.⁵

³ BASF began using CrO_2 for the pigment layer for some brands in 1983.

⁴ For further information on this format, see John W. C. van Bogart, *Magnetic Tape Storage and Handling: A Guide for Libraries and Archives* (Washington, D.C.: The Commission on Preservation and Access; St. Paul, M.N.: National Media Library, June 1995), made available by CLIR at <http://www.clir.org/pubs/reports/pub54/index.html>.

⁵ Australian Network for Information on Cellulose Acetate (ANICA), *Cellulose Acetate Project: Stage One. Final Report, August 2000* ([Canberra]: National Library of Australia, 2000), <http://www.nla.gov.au/anica/cellulose.pdf>.

In the U.S., 3M's first acetate-based tape—Scotch 111—was probably manufactured starting in 1948. Its last—Scotch 201—was introduced in 1962 and both it and Scotch 111 were manufactured until 1972 or 1973.⁶ It is reasonable to assume that fieldworkers continued to record on acetate-based tape for a few years after 1973, using existing tape stock. At the Archives of Traditional Music (ATM), we can document that fieldworkers recorded on Scotch 111, Scotch 190, and Ampex 611 during the time period 1974-77.

Cellulose acetate degrades in the presence of water, making the acetate base particularly susceptible to hydrolysis, which is a chemical reaction with moisture in the air that is accelerated by higher temperatures. Tapes with severe cases of hydrolysis can suffer from the so-called "Vinegar Syndrome," an auto-catalytic process whereby acetic acid is set free in ever increasing quantities, creating an accelerating effect on the decay process.⁷

(2) PVC (Polyvinyl chloride): Open reel tape on a PVC base was manufactured from 1943 to approximately 1969, particularly by BASF, but was not as common as acetate or polyester-based tape. In the U.S., 3M produced one PVC brand—Scotch 311—starting about 1960. This tape base material is stable, and there are few, if any, reports of PVC tape degradation. PVC tape brands, with approximate manufacturing dates, include:⁸

- IG Farben Typ L: 1943-1947
- IG Farben Typ LG, Typ LGN: 1945-1948
- BASF Typ LG, Typ LGN: 1948-1952
- BASF Typ L-extra: 1949-1954
- BASF LGH: 1950-1954
- BASF LGS 52 and LGS 35: 1953-1969
- Agfa FSP: 1954-1958
- BASF LGR: 1956-1967
- BASF LGS 26: 1958-1969
- BASF LGR 30: 1967-1968
- BASF PES 26 and PES 35: 1958-1969
- BASF LR 56: 1960-1969
- Scotch 311: 1960-?

Some Scotch 311 is labeled PVC while other examples appear to be polyester. The polyester 311 includes the 3M trade name Tenzar.

⁶3M information was obtained from the "3M Audio Open Reel Tapes," table linked to Delos A. Eilers, *Introduction to 3M Audio Open Reel Tape List* (2000), <http://www.aes.org/aeshc/docs/3mtape/aorintr1.html>. The chart may be accessed directly at <http://www.aes.org/aeshc/docs/3mtape/aorprod2.html>. Information on the stop date for manufacturing acetate tape comes from an email from Del Eilers, via Bill Lund and Richard Hess, dated April 27, 2006.

⁷From UNESCO, "Magnetic Carriers," in *Safeguarding Our Documentary Heritage*, edited by George Boston ([Paris]: UNESCO, 2000), available online at http://webworld.unesco.org/safeguarding/en/txt_magn.htm. Also available as a CD-ROM.

⁸BASF dates from Friedrich K Engel, "Agfa, BASF, and IG Farben Audio Open Reel Tapes" (2006), <http://www.aes.org/aeshc/docs/basftape/basftapes.html>; Scotch 311 date from Eilers' "3M Audio Open Reel Tapes" table, available at <http://www.aes.org/aeshc/docs/3mtape/aorprod2.html>.

(3) Paper: Paper-backed tape was manufactured in the U.S. from 1947 until possibly the late 1940's or early 1950's. It appears to be chemically stable, at least in the experience of preservation engineers and sound archivists. Paper tape may experience mechanical problems as the backing is somewhat fragile and subject to tearing or breaking upon playback, although with a well-adjusted playback machine this does not seem to be a big issue. There is speculation that acidic paper could be a degradation factor but this has not been observed.⁹ In 1947 and 1948, 3M introduced Scotch 100 and 101, both of which were paper-backed tapes. Paper tapes at the ATM were recorded from 1948-1950 on Audiotape, Panacoustic, and Scotch-brand tapes.

(4) Polyester: Polyethylene terephthalate, or polyester, is the most widely used base film, utilized in all modern audio, video and computer tape. It was introduced as early as 1953 by 3M with the Scotch 102 brand and by 1972 was the only base material in use. Polyester is the most resistant of all the base materials to both mechanical stress and relative humidity and has proven to be quite stable.¹⁰ However, the binder chemistries used with certain polyester tapes are problematic, as discussed below in the section on preservation problems.

Identification

Acetate and polyester-based tapes are easy to identify: hold the tape pack up to a strong light and look through the pack itself. Acetate-based tapes are translucent, and light may be seen through the layers. Polyester tapes are opaque and no light is visible through the tape pack. This test works for most tapes, but may not be completely accurate for double and triple play tapes (0.5 mil or thinner tape base) or for some long play (1.0 mil base) tapes. Acetate tapes may also be identified by tearing a portion of the tape itself: acetate will break cleanly while polyester will stretch. This is, obviously, a highly invasive test that is not generally recommended.

PVC tape is also opaque when viewed through a strong light and it can be difficult to differentiate PVC from polyester. There is a thrashing test that can be used, but it is extremely invasive.¹¹ The best method of identification is simply to know which brands were manufactured on PVC. A list of PVC tape brands is provided above.

Paper tape is easily identified as the tape backing looks and feels like paper.

⁹ Richard Hess, "Tape Degradation Factors and Predicting Tape Life," (paper presented at the 121st Audio Engineering Society Convention, San Francisco, California, October 5-8, 2006).

¹⁰ Information in this section from Hess, "Tape Degradation," 7 and UNESCO, "Magnetic Carriers."

¹¹ Using scrap tape, and the back end of a screwdriver, we hit the end of the tape samples as they lay on a desk. PVC tape tends to fold up and crimp as you strike it. Polyester tapes stay flat. PVC also seems stiffer and less supple in general. We do not recommend repeating this test. Alan Ward discusses thrashing PVC against a hard surface and states it will split into longitudinal strands like a brush. See Alan Ward, *A Manual of Sound Archive Administration* (Aldershot, England; Brookfield, Vermont: Gower, 1990): 173.



FIGURE 2: TRANSLUCENT ACETATE TAPE



FIGURE 3: OPAQUE POLYESTER TAPE



FIGURE 4: PVC BRANDS SCOTCH 311 AND BASF LGS 26

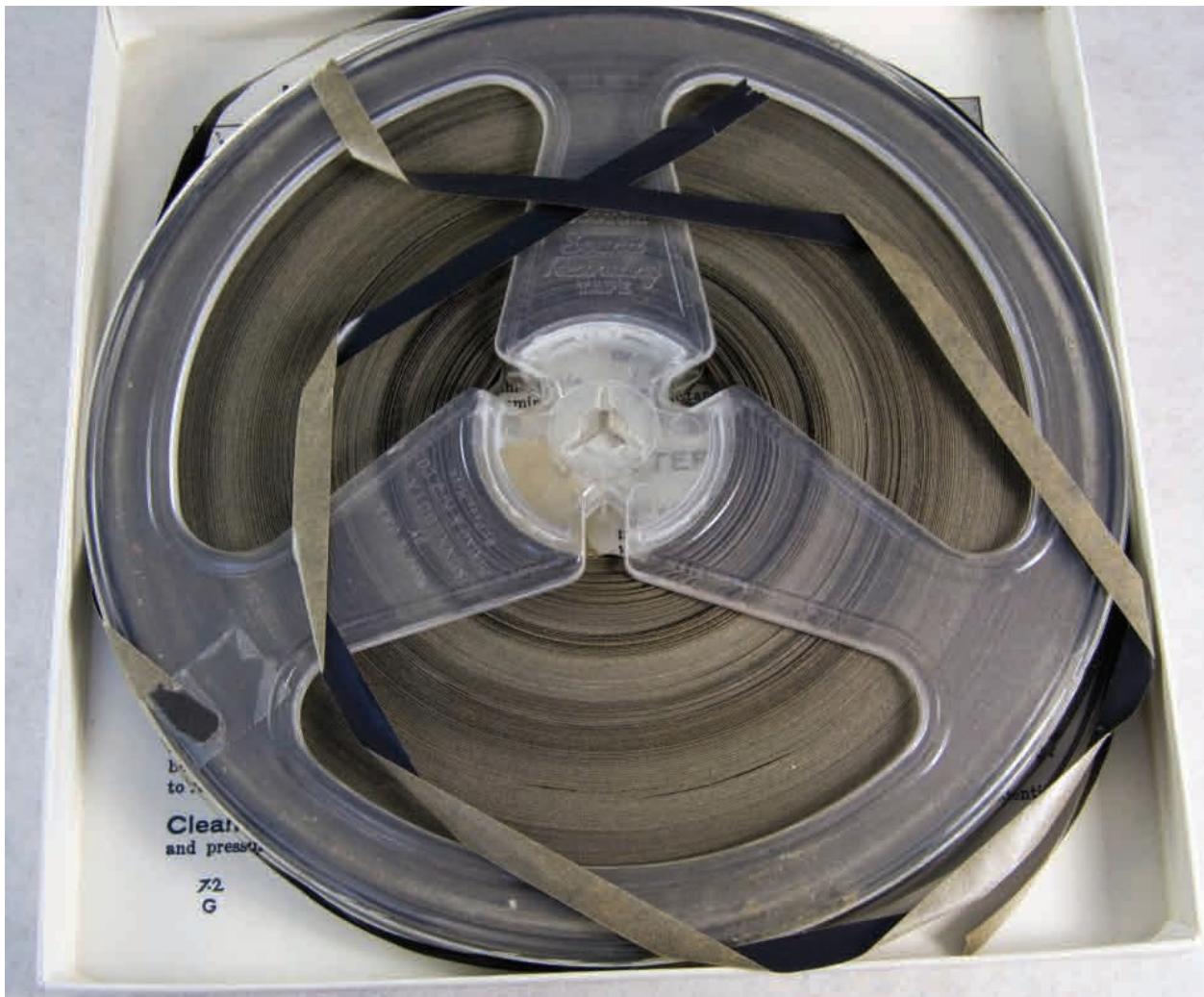


FIGURE 5: PAPER TAPE

Points and Risk

IASA-TC 03 states that acetate tapes should be considered unstable and a high priority for copying.¹² The National Library of Australia's cellulose acetate project concludes that "due to the inherent instability of cellulose acetate, theoretically all information contained on this medium that is to be retained will need to be transferred to another medium."¹³ FACET takes this into account by designating a larger score for acetate-based open reel tape than for other types within the open reel format.

Format base score	Points
Open reel—PVC	2.5
Open reel—polyester	2.5
Open reel—paper	2.75
Open reel—acetate	3.0

¹² Dietrich Schüller, ed., *The Safeguarding of the Audio Heritage: Ethics, Principles and Preservation Strategy*, IASA-TC 03, version 3, December 2005 (International Association of Sound and Audiovisual Archives, IASA Technical Committee, 2005), 10. Available online at http://www.iasa-web.org/IASA_TC03/TC03_English.pdf.

¹³ ANICA, *Cellulose Acetate Project*, 29.

2.2.2 Tape Thickness

Overview

It is commonly understood that thinner tape bases are less stable than thicker ones, although this is more of a handling problem than a degradation issue unless the tape is improperly stored. Thinner tapes are more prone to breaking, stretching and may exhibit other problems, such as twisting and/or folding in half along their width, during playback. Thinner tapes stored under too much tension in a tape pack that also has popped strands or feathering (see tape pack problems, below), may be more prone to curling, edge damage, and other physical problems.

In the U.S., open reel tape thickness is measured in mils (one thousandths of an inch) and is typically expressed as the thickness of the base film by itself. 1.5 mil (often called standard play by manufacturers) is the thickest and most stable, 1.0 mil (often called long play) is next, followed by two types of 0.5 mil base, one of which is known as double play and the other, with either a thinner oxide (magnetic pigment) coating or a thinner base film, that is known as triple play. 3M, for example, manufactured triple play tapes with a 0.5 mil base using a thinner oxide coating while BASF used a thinner base that was about 0.47 mils thick. Note that actual tape base measurements may vary considerably but they cluster around 1.5, 1.0, and 0.5, which we use for convenience. These three tape base film numbers are often placed on the tape box by U.S. manufacturers.



FIGURE 6: TAPE BOX INDICATIONS OF BASE THICKNESS

In the rest of the world tape thickness is measured in micrometers (same unit of measurement as the micron, abbreviated μm) and expressed as *total* tape thickness, which includes the base film and all coatings. Tape boxes from non-U.S. manufacturers identify tape thickness using the terms standard, long, double or triple play and do *not* include the thickness of the base film on the box. Some manufacturers include an indication of total tape thickness as part of their product number. Maxell UD35, for example, is 35 μm thick while BASF LGS 26 is 26 μm , LGS 35 is 35 μm thick, and LGS 52 is 52 μm thick.

Total tape thickness measurements for open reel tape are:

- Standard play tapes (with a 38.1 µm /1.5 mil base film) cluster around 52 µm (2.05mils) total tape thickness
- Long play tapes (25.4 µm /1.0 mil base) measure around 35 µm (1.38 mils)
- Double play tapes (12.7 µm/0.5 mil base) measure around 26 µm (1.02 mils)
- Triple play tapes (12.7 µm/0.5 mil or thinner base) measure around 18 µm (0.71 mils).

Other ways of indicating long play on tape boxes include the words “extra length” and “extra play” (3M) and “plus 50—50% extra playing time” (Soundcraft). Additional ways of designating double and triple play include “double length” and “triple length” (3M), “plus 100—100% extra playing time” (Soundcraft), and “extra long play” (Crescendo).



FIGURE 7: TAPE BOX INDICATIONS OF TOTAL TAPE THICKNESS

Identification

Double and triple play tapes (0.5 mil base thickness) on an acetate substrate are extremely rare. For certainty with any type of tape, it is possible to measure the total thickness of a tape using a thickness gauge, dial caliper or similar instrument calibrated in either micrometers or mils.¹⁴ If assessing risk by tracking the thickness of the base film in mils, as is typically done in the U.S., then the resulting total thickness number must be converted to provide the thickness of the base. For example:

- A tape with a total thickness of approximately 1.77 to 2.13 mils has a nominal base thickness of 1.5 mils
- Total thickness of approximately 1.27 to 1.51 mils has a nominal 1.0 mil base thickness
- Total thickness of approximately 0.67 to 1.03 mils has a 0.5 mil base thickness-- lower numbers (around 0.7 mils) are triple play tapes while higher numbers (around 1 mil) are double play

As discussed above, information on the tape box may provide an indication of total tape thickness using the terms standard, long, double, or triple play, or tape base thickness using 1.5, 1 or $\frac{1}{2}$ mil. It is important to assess the likelihood that the tape is in its original box and to decide whether to use this information based on your confidence level. A measuring device can, of course, help confirm the accuracy of the box.

It is also possible to generate tape thickness information from playback speed and tape length information as these variables interact with thickness. See the tape charts in Appendix 2.

Points and Risk

IASA-TC 03 states that all long, double, and triple play tapes "can be considered to be inherently unstable and should, therefore, be copied."¹⁵ In practice, preservation transfer engineers report that double and triple play tapes (0.5 mil or thinner base thickness) are much more problematic than long play (1 mil base thickness). Fast winding (rewind or fast forward) double and triple play tapes may not be possible without great risk of the tape stretching or breaking. Tape machines that do not handle tape well or are simply out of adjustment can increase this risk. Polyester tapes stretch rather than break, resulting in lost content. Even simple playback can result in problems such as twisting and/or folding along the tape's width, although it is often possible to play from beginning to end without issue. At the ATM, the working procedure is to never fast wind a double or triple play tape.

¹⁴ An example of a thickness gauge is the Mitutoyo dial caliper No. 7326S, which is calibrated in mils. This device, along with others, may be purchased from Precision Graphic Instruments, Inc. 1-800-280-6562. <http://pgiinc.com>

¹⁵ Schüller, *Safeguarding of the Audio Heritage*, 10.

FACET recognizes the greater risk of long, double, and triple play tapes, assigning points for each.

Characteristic: Tape thickness	Points added
Standard play (52 µm total/1.5 mil base)	0.0
Long play (35 µm total/1 mil base)	0.5
Double play (26 µm total/0.5 mil base)	1.0
Triple play (18 µm total/0.5 mil base or thinner)	1.2
Unknown double/triple play	1.1

2.2.3 Age

Overview

Age by itself is not considered a major concern by archivists and preservation engineers—in our experience there are many older recordings with no playback problems. Those that experience problems are usually plagued by issues unrelated to the aging process by itself. The chemical age of a tape cannot be understood exclusively on the basis of calendar time, as two reels from the same batch exposed separately to environments with high and low humidity will show markedly different levels of deterioration.¹⁶

Adding a small point value for each year of tape life provides a way to enable older collections to rank slightly ahead of younger ones with all other things being equal, taking into account the possibility that items will deteriorate further with age in ways that we have yet to experience.

Identification

It is usually not possible to know the actual manufacture date of an individual tape. The best information that can be reliably obtained is the date on which the tape was recorded, and this is the information that FACET uses. This provides a close approximation, certainly within ten years in all but the most unusual cases. Further guidance is available in the FACET procedures manual.

Points and Risk

Each tape format receives 0.005 points for each year of life, giving an added score of 0.3 points for sixty-year-old open reel tapes, for example. Point values in this category are not enough by themselves to move a collection into a serious risk category.

¹⁶ Edward F. Cuddihy, "Aging of Magnetic Recording Tape," *IEE Transactions on Magnetics* 16, no. 4 (July 1980): 567.

2.2.4 Major Manufacturers and Off-Brands

Overview

There is agreement among preservation engineers that tape from major manufacturers is more consistent, reliable, and stable. Off-brand tapes often do not perform consistently, even if they appear to be from the same batch. They may vary wildly in both their physical and magnetic properties and suffer from manufacturing problems such as poor slitting and uneven coating. In some cases, off-brands consist of second grade tape from a major manufacturer that was defined as lower quality, perhaps failed quality control tests, and was sold under a different brand name. Some brands from major manufacturers are also consistently problematic, sometimes exhibiting characteristics similar to off-brands. Any tape in an unmarked white box is suspect, as this is how second grade or off-brand tape was often sold. Off-brand tapes present a number of playback and preservation problems in the experience of sound archivists and preservation engineers.

Identification

Identification strategy is to determine first, when possible, if a tape is produced by a major manufacturer. Everything else, including problem tapes from major manufacturers from the list below, is then considered an off-brand, which is documented by the user in the software. Guidance on how to handle this category is provided in the FACET procedures manual. Here are lists of the various categories:

Major Manufacturers

- Agfa
- Ampex/Quantegy
- AudioTape
- BASF
- EMI
- Maxell
- Orwo
- Reeves Soundcraft
- Scotch
- Sony

Major Manufacturers—problem brands

- Kodak
- Pyral
- Scotch 175 (multiple reports of SBS-UP problems, explained below)
- Scotch 201 (susceptible to base-binder adhesion failure¹⁷)
- Sony PR-150 (multiple reports of SBS-UP problems)
- Melody 169 (3M seconds)

¹⁷This information is from former 3M employee Del Eilers and from the experience of Richard Hess.

Off-brands

Here is a sample of off-brands, many of which reportedly have problems. There are many more off-brand products that were manufactured. See Appendix 3 for a longer list of off-brands in the collections at the ATM.

- Shamrock
- Magna-Reel
- Concertape
- Bel-Cleer
- Sam's
- Wescott
- Sarkes-Tarzian
- Brand Five
- Lafayette
- Knight
- Emerald
- Burgess
- Triton
- Goldcrest
- Meteor
- Golden Tone
- Mallory
- Quality Tone
- Plaza
- Galaxy



FIGURE 8: SAMPLE OFF-BRAND TAPES

Points and Risk

If a tape does *not* fall into the major manufacturer category, or if it is a known problem brand from a major manufacturer, then the user checks the off-brand box in the software and FACET adds 0.75 points to account for the additional, suspected risk.

2.2.5 Track Configuration

Overview

A track is a section or band of an open reel tape running along its length that carries an audio stream. Over the years, field collectors have used a number of open reel tape machines that record with different track configurations. $\frac{1}{4}$ inch tape can be divided several ways for different types of mono and stereo recording, depending on the configuration of the record head on the original recording machine. Figures 9 and 10 below illustrate some common track configurations found in archival collections.

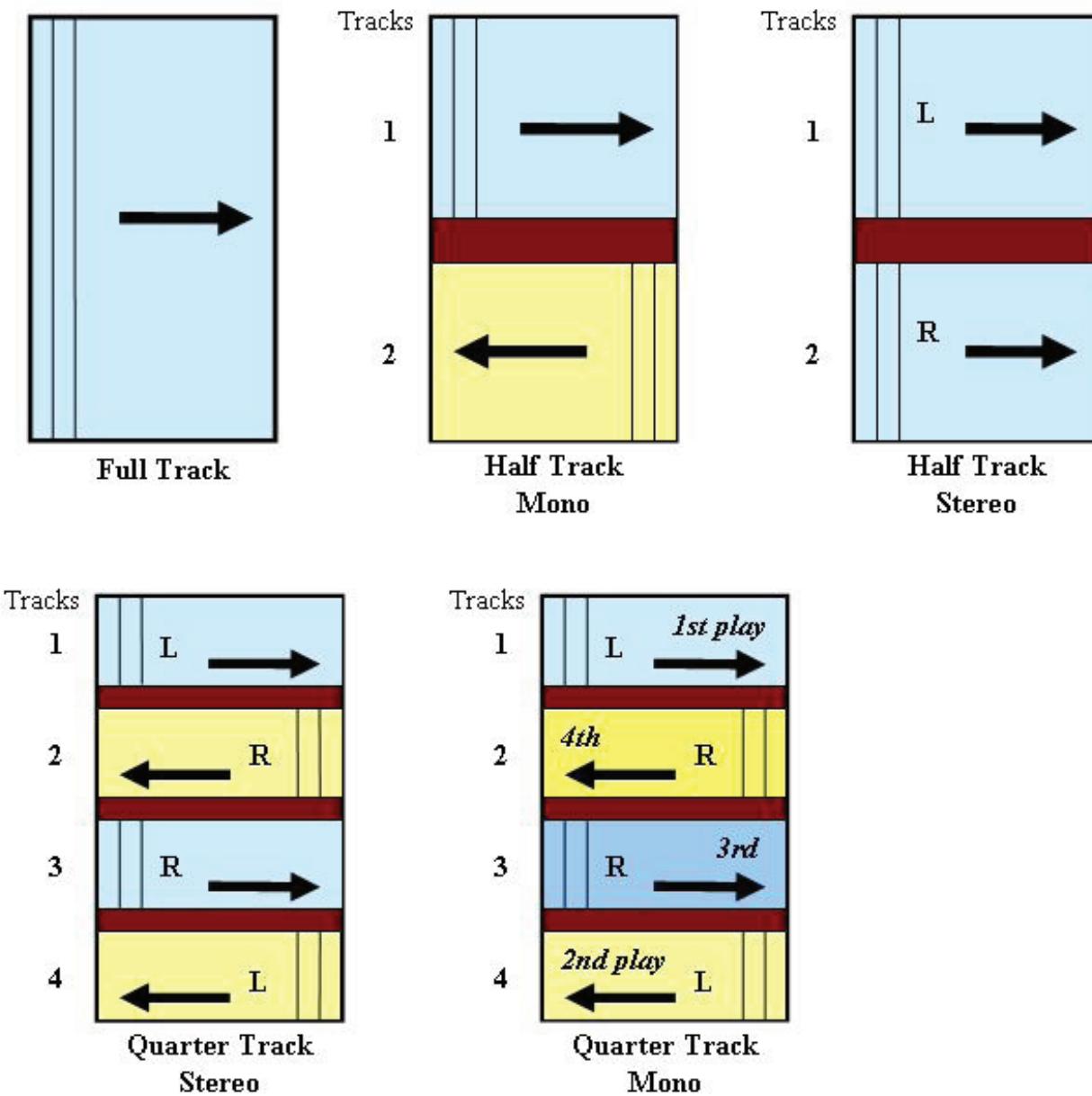


FIGURE 9: OPEN REEL QUARTER INCH TRACK CONFIGURATIONS

A full-track tape machine records one band of recorded signal covering nearly the full width of the tape. By definition, this configuration results in a signal that travels in one direction only, that is, the tape is played from the supply reel (on the left) to the take up reel (on the right) to recover the recorded program. After playback, if you switch the take up reel which is now full to the supply reel position and play, the program will sound backwards.

A $\frac{1}{2}$ track tape machine divides the tape into two tracks with a guard band in between. A $\frac{1}{2}$ track recording may be mono, with a track that runs in one direction and another track in the opposite direction. When listening to a $\frac{1}{2}$ track mono tape that has a recorded program in both directions you will hear a normal-sounding signal on the left channel of the playback machine but a backwards signal on the right channel. When you flip the tape over (start in the other direction) the backwards signal that was on the right channel is now playing normally on the left and vice versa. A $\frac{1}{2}$ track tape may also be stereo with two recorded tracks running in the same direction (flip the tape over and you have the same material playing backwards).

A $\frac{1}{4}$ track tape is divided into four tracks with guard bands between each. $\frac{1}{4}$ track stereo is the most common, with tracks 1 and 3 playing first as the tape is unwound from the supply reel. Track 1 carries the left channel of the stereo signal and track 3 the right. Tracks 2 and 4 carry an entirely different program recorded in the opposite direction, with track 4 carrying the left channel and track 2 the right. Flip the tape over (start in the other direction) to play this content. There are also a few less common $\frac{1}{4}$ track (or four-track) formats. $\frac{1}{4}$ track mono may have a different program recorded on each track, and a tape machine that allows you to select just one track at a time for playback is necessary. Each track may be played after flipping the tape to start in the opposite direction. Track 1 is played first (on the left channel of the playback machine), followed by tracks 4 (left channel), 3 (right channel), and 2 (right channel). It is also possible to have a four-track, multi-track recording in which all four tracks are part of the same program, moving in the same direction, and must be mixed together.

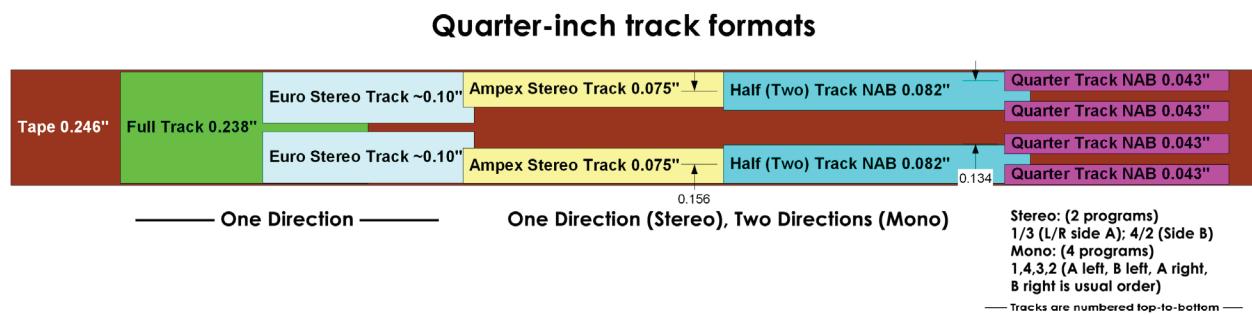


FIGURE 10: OPEN REEL TRACK CONFIGURATIONS BY RICHARD HESS¹⁸

¹⁸This is an edited version of Richard's figure. The full version is available in Richard Hess, "Quarter-inch Track Formats" (March 19, 2006), <http://richardhess.com/notes/formats/magnetic-media/magnetic-tapes/analog-audio/025-reel-tape/>.

Identification

The track configuration of an open reel tape can be identified either by listening or by using a magnetic viewer. Sometimes, both are necessary for positive identification. An open reel tape machine with a playback head that matches the track configuration is necessary for accurate reproduction. A magnetic viewer such as the Arnold B-1022 can be used to examine the tracks on the tape.¹⁹ This viewer has a thin aluminum bottom that touches the tape. On the other side of the aluminum is a slurry of magnetic material that arranges itself analogous to the track on the tape, enabling it to be viewed without putting chemicals directly on the tape itself. The viewer must be placed at a point on the tape where there is recorded signal. If there are bars or ridges that run nearly the full width of the tape, the track configuration is full track. As expected, a $\frac{1}{2}$ track will appear as a track covering nearly half the tape width and a $\frac{1}{4}$ track will cover only a quarter of the tape width. There will be either one or two $\frac{1}{2}$ tracks on a $\frac{1}{2}$ track tape depending on how many were recorded and anywhere from one to four $\frac{1}{4}$ tracks on a $\frac{1}{4}$ track tape.

Open reel machines owned by archives most commonly have $\frac{1}{2}$ track playback heads. Below is a chart to aid in the identification of track configuration using a $\frac{1}{2}$ track machine. This chart provides clues to the track configuration—further investigation by listening and/or using a magnetic viewer is usually necessary.

Using $\frac{1}{2}$ track playback head:

If you hear...	Possible configuration	What to do next...
Left channel program is forwards, separate right channel program is backward	$\frac{1}{2}$ track mono in two directions or $\frac{1}{4}$ track mono in two directions (on tracks 1 and 4)	Use magnetic viewer. If $\frac{1}{4}$ track mono, switching to $\frac{1}{4}$ track head gives forwards program on left and nothing on right
Same program on both channels (both forwards)	$\frac{1}{2}$ track stereo, Full track mono, or $\frac{1}{4}$ track stereo	Listen for stereo vs. mono, use magnetic viewer
Same program on both channels with right channel much softer than left	$\frac{1}{4}$ track stereo in one direction	Use magnetic viewer. Switching from $\frac{1}{2}$ to $\frac{1}{4}$ track playback head will result in significant volume boost
Forwards and backwards program in both channels	$\frac{1}{4}$ track stereo in two directions	Use magnetic viewer. The $\frac{1}{2}$ track playback head is picking up multiple quarter tracks on each channel
Signal on left channel only	$\frac{1}{2}$ track mono in one direction or $\frac{1}{4}$ track mono on only one track	Use magnetic viewer. If $\frac{1}{4}$ track, switching to a $\frac{1}{4}$ track head will result in a significant volume boost
Signal on right channel only going forwards	Probably $\frac{1}{4}$ track mono recorded on track 3	Use magnetic viewer

¹⁹ Arnold B-1022 Magnetic Viewer. Plastiform Division of Arnold. 1000 E. Eisenhower Ave, Norfolk, NE 68702-1567. 402-371-6100 ext. 176. For more discussion of magnetic viewers, see Richard Hess, "Seeing the tracks II—An improved magnetic viewing system" (June 20, 2007), <http://richardhess.com/notes/2007/06/20/seeing-the-tracks-ii-an-improved-magnetic-viewing-system/>

Points and Risk

See the section on recording speed, below.

2.2.6 Recording Speed

Overview

7.5 (7 ½) inches per second—abbreviated in/s or ips—is generally the most common recording/playback speed represented in archival field collections, although 3.75 (3 ¾) in/s is also quite common. Less common are speeds of 15 in/s, 1 7/8 in/s (also the speed for analog audio cassettes) and 15/16 in/s (15/16th of an inch per second). Rare in archival collections are tapes recorded at 30 in/s, which is one of the standard professional studio speeds. In general, higher speeds have better frequency response, a stronger output signal (and less noise) and fewer problems with drop-outs.

Outside of the U.S., recording speed is sometimes designated using centimeters per second (cm/s). Here is the relationship between in/s or ips and cm/s:

15/16 or 0.9375 in/s=	2.38 cm/s
1 7/8 or 1.875 in/s=	4.76 cm/s
3 ¾ or 3.75 in/s=	9.525 cm/s
7 ½ or 7.5 in/s=	19.05 cm/s
15 in/s=	38.1 cm/s
30 in/s=	76.2 cm/s

Identification

The speed at which a tape was recorded—and therefore the speed at which it must be played back—is determined by playing the tape and listening to the content. The backs of tape boxes and other documentation often indicate tape speed—if you have a high level of confidence in your documentation there may be no need to play the tape at the data-gathering stage.

Points and Risk

Areal density—the amount of data contained in a given area—on an open reel tape is a function of recording speed and tracking configuration. If a tape is physically degraded, data residing on a larger swath of tape may have a greater chance of full recovery than the same amount of data occupying a smaller area. For example, some types of tape degradation result in physical problems such as curling that occur commonly at the edges of the tape. If a tape edge is curled, the tape may not make optimal contact with the playback head for recovery of the recorded signal. A full track tape has signal across nearly its entire *width*, making high-quality recovery of the signal on a curled tape relatively easier due to its larger areal density compared to a ¼ track tape with narrow tracks, some of which are located at the edges of the tape. In addition, the recording/playback speed governs the *length* of tape that holds a given amount of information. The same amount of information will be spread over a significantly larger length of tape if it is recorded at 15 in/s rather than 3.75 in/s. Therefore, a full track tape recorded at 15 in/s will have a larger areal density than a ¼ track tape recorded at 3.75 in/s, because on the full track tape the same information is spread over a wider and longer swath of tape due to both the larger track size and faster speed. Combined, larger track widths and higher speeds provide a relatively greater chance of high-quality signal recovery if degradation is present.²⁰

²⁰The idea of analyzing areal density was suggested to me by Richard Hess.

FACET recognizes this risk and assigns points for track configuration by itself, recording speed by itself, or the combination of track configuration and recording speed if both are known. We consider this an optional category and the risk relatively subtle, so point values are small for the most common combinations. Most of the largest areal density values will not move a collection into a high risk category, but they will help differentiate collections that are otherwise similar. The exception is $\frac{1}{4}$ track at $\frac{15}{16}$ in/s—very rare—which receives a full point, also accounting for obsolescence issues related to finding a high-quality tape machine that can handle this speed. Values from there decline to .006 for full track at 30 in/s which has the largest areal density. This is an optional category—do not worry if documentation of track configuration and recording speed is not available and you have no data available in this area.

2.2.7 Sound Field

Overview

Mono means a single source of audio, often referred to as a single channel of audio. A mono tape recording is often made up of one track that contains an entire program which is meant to be played by itself. A mono tape recording may also contain more than one discrete track, each containing an entire program and each meant to be played by itself. For example, a full track recording is mono by definition as only one track will fit on the tape, while a $\frac{1}{2}$ track mono recording has one mono track moving in one direction and, possibly, a separate mono track carrying another program that moves in the other direction. A stereo recording contains one or more pairs of tracks that together contain an entire program and are meant to be played together. One track is the left channel while the other, which is discrete but related, is the right channel. Both must be played together. A $\frac{1}{2}$ track stereo tape contains two tracks while a $\frac{1}{4}$ track stereo tape may contain either one stereo pair (tracks 1 and 3, left and right) or two stereo pairs (tracks 1 and 3 plus tracks 4 and 2, left and right), which carry separate programs.

Identification

Sound field is tied to track configuration. See this section above for information on identifying mono and stereo recordings.

Points and Risk

Sound field does not affect the type or rate of degradation of a recording, but often degradation is more noticeable on a stereo recording because of image shift between the channels, which is disturbing to the listener. All other things being equal, it might make sense to transfer tapes that are stereo before mono to obtain a higher-quality transfer before degradation advances. FACET adds a small value—0.15 points—for a stereo recording. We consider this an optional category and the risk relatively subtle.

2.2.8 Noise Reduction

Overview

Noise reduction is a process used to remove noise from a signal. On open reel tapes, these processes are sometimes applied to reduce the level of background tape hiss. If a tape has been encoded using a noise reduction system it requires an appropriately aligned hardware decoder for accurate playback. Noise reduction is rarely encountered on open reel tapes recorded in the field. Possible noise reduction systems include:

- Dolby A, introduced in 1966 and developed for professional use
- Dolby B, introduced in 1968, developed for consumer use and widely used on audio cassettes but also found on some slow speed (3.75 in/s), consumer, open reel tape machines
- Dolby SR, designed for professional use and found on professional analog recorders only
- dbx, developed in 1971. Type I was used in professional recording while Type II was common in four-track audio cassette home studio recorders

Identification

Documentation provided by the collector or field recorder provides the best identification of the use of noise reduction. An expert ear may be able to identify the presence of certain types of noise reduction.

Points and Risk

It is harder to find working decoder units than tape machines, leaving tapes with noise reduction at a somewhat higher risk due to the obsolescence of analog noise reduction systems. FACET adds 0.5 points for any of the noise reduction systems used on open reel tape.

2.3 Preservation Problems

2.3.1 Tape Pack Problems

Overview

FACET uses the phrase “tape pack problems” to refer to abnormalities visible on or within the tape pack that is typically held between two flanges or reels. Tape is least vulnerable to physical or mechanical damage when wound in a smooth, even pack that has neither too much nor too little tension.²¹ Poor tape winding, which may lead to a poor pack, is “one of the most underrated risks for magnetic tapes....prolonged storage of badly wound tapes causes irreversible deformations, which may lead to severe replay problems, specifically with thin tapes and high density recordings...”²² A tape machine that is out of adjustment may wind tapes poorly. Placing a tape into storage after fast winding—either rewind or fast forward—may also lead to pack problems. Standard procedure is to wind a tape from beginning to end before storing using either play or the library wind setting found on some machines. High temperature or relative humidity levels may also contribute to pack problems. Tape pack problems include such things as edge curling, windowing, popped strands, and other phenomena as discussed below.

Identification

Tape pack problems may be discovered and assessed by visually inspecting the tape. Following is a discussion of each major problem.²³

(1) Cinching: The wrinkling, or folding over, of tape on itself in a loose tape pack. This may occur when a loose tape pack is stopped suddenly, causing outer tape layers to slip past inner layers, which in turn causes a buckling of tape in the region of the slip.

(2) Curling: The transverse warping of magnetic tape, sometimes called cupping, most commonly seen on acetate-based tapes. This can cause poor contact between the tape and playback head resulting in signal loss. It may manifest as edge curling or the entire tape may exhibit cupping.

(3) Flange Pack: A condition where the tape pack is either wound or has fallen against one of the flanges of the tape reel instead of being suspended in the middle. This often leads to damaged edges from the tape scraping across the flange as it winds. If there are also popped strands, they may be severely bent.

²¹ See section entitled “Ampex Guide to the Care and Handling of Magnetic Tape” in van Bogart, *Magnetic Tape Storage and Handling*. Available on the CLIR website at http://www.clir.org/pubs/reports/pub54/care_and_handling.html.

²² Breen, *Task Force to Establish Selection Criteria*, 7. Available online at <http://www.iasa-web.org/taskforce/taskforce.pdf>.

²³ Some of the descriptions of physical problems offered below are adapted from Appendix C of *The IASA Cataloging Rules* (International Association of Sound and Audiovisual Archives, 1999), <http://www.iasa-web.org/icat/icat001.htm>, and from the National Film and Sound Archive, *Technical Glossary of Common Audiovisual Terms* ([Canberra]: National Film and Sound Archive, 2007), http://www.nfsa.afc.gov.au/preservation/audiovisual_terms/. Other descriptions are derived from our own experience.



FIGURE 11: CINCHING



FIGURE 12: CURLING



FIGURE 13: FLANGE PACK

(4) Slotted Hubs: This is not a tape pack problem but a condition that causes pack problems. We define slotted hub as the existence of one or more extra wide slots on the hub of the two flanges that hold the tape pack. The outer, round part of an *unslotted* hub is unbroken—there is a solid surface for the tape to rest against all the way around. Many sets of flanges have at least one small slot used for threading the tape. The extreme is the existence of three wide, open slots. The tape, under pressure within the tape pack, begins to sag into the open space, causing or contributing to problems such as drop-outs, windowing and/or spoking. These flanges are most often found on older, acetate-based tapes. If there are wide slots, you are most likely to see three of them.

(5) Windowing: A gap in the tape pack caused by obvious pack deformation. You can actually see through the pack, like looking through a window, because of the separation of tape layers.



FIGURE 14: WIDE SLOTS IN HUBS - NOTE HOW THE TAPE IS DEFORMED AT THE THREE SLOTS



FIGURE 15: WINDOWING

(6) Popped Strands: The tape pack may have individual layers of tape misaligned with each other so that some layers stick up from the others. These misaligned layers are often called popped strands. Many groups of misaligned layers indicate a condition that is called either a stepped pack or feathering. Sometimes this is the result of winding the tape on fast forward or rewind and can be corrected by playing from beginning to end on play without stopping.



FIGURE 16: POPPED STRANDS

²⁴van Bogart, "Ampex Guide," *Magnetic Tape Storage and Handling*.



FIGURE 17: POPPED STRANDS

(7) Spoking: Usually the tape pack has uniform, circular layers. Sometimes the circle is not uniform and the layers curve non-uniformly, looking a bit like waves. It also may appear as if there are kinks in the circle. There will often be radial lines, or a pattern radiating out from the hub, known as spokes. Excessive tension leads to spoking which results from the outer layers in the pack compressing the inner layers so that the turns develop a small kink instead of a smooth curve. These kinks align radially and look like a spoke when you look through the flange from the edge of the tape.²⁴

(8) Stepped Pack: Many groups of misaligned layers that may look like ridges across the tape pack. This is sometimes called feathering or scatter wind. Individual layers that are misaligned are called popped strands.

Points and Risk

Tape pack problems are divided by FACET into minor, moderate, and severe categories with an increasing number of points assigned to each. Placing tapes into these categories is necessarily somewhat subjective, but here are some guidelines:

- Minor (0.25 points): several popped strands
- Moderate (0.5 points): many popped strands or a stepped pack, edge curl at the head or tail of the tape only
- Severe (0.75 points): cinching, flange pack, windowing, spoking, curling throughout the pack, slotted hubs



FIGURE 18: SPOKING



FIGURE 19: STEPPED PACK

Additional examples of tape pack problems:



FIGURE 20: STEPPED PACK AND SPOKING



FIGURE 21: CURLING AND SPOKING

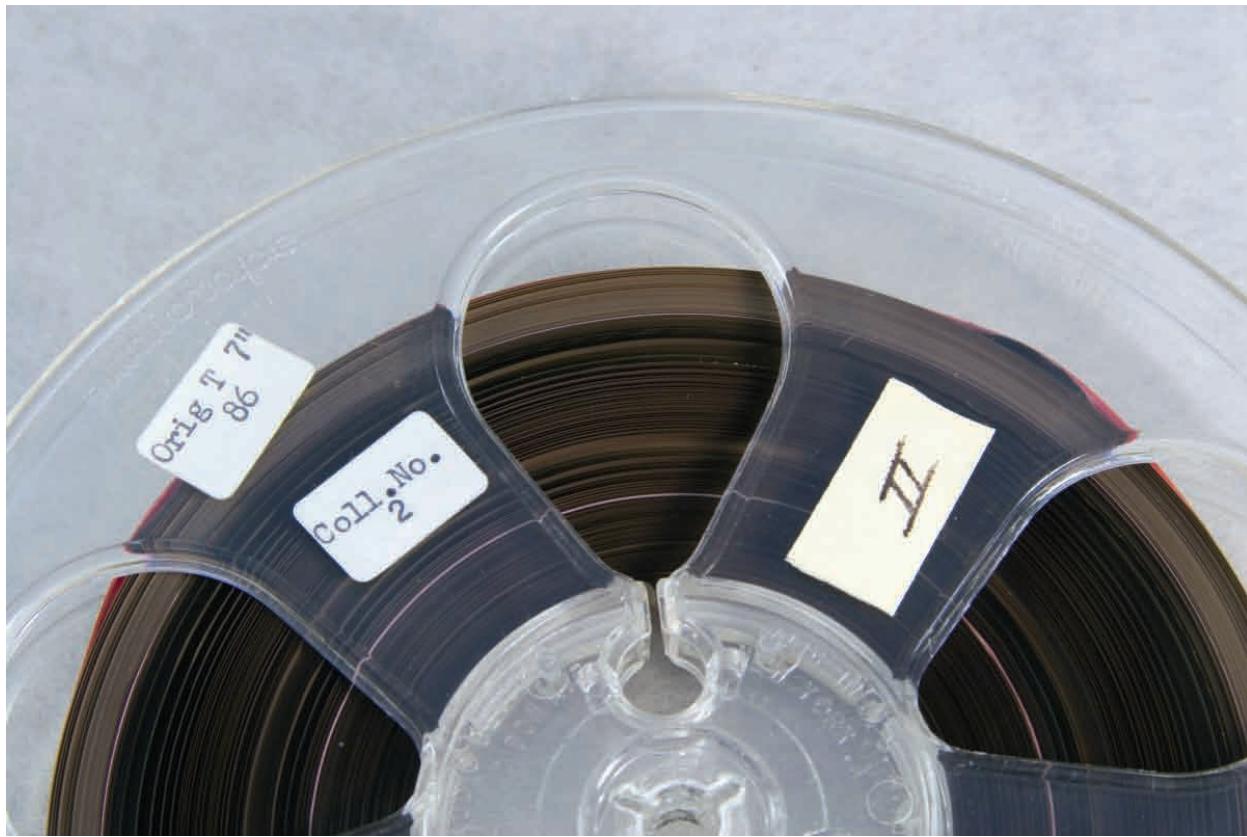


FIGURE 22: STEPPED PACK AND MULTIPLE TAPE BASES SPLICED TOGETHER



FIGURE 23: WIDE SLOTS IN HUB, MULTIPLE TAPE BASES, AND STEPPED PACK



FIGURE 24: FUNGUS ON TAPE

2.3.2 Fungus

Overview

Storage at high temperature and/or relative humidity levels may lead to the growth of fungus or mold on the tape. Fungi can live off the binder materials and may be present on the edges of the tape—easily visible on the tape pack surface—or may have worked their way into the surface of the tape itself. Mold colonies may be either active or dormant. Active mold contains some moisture and may smear while dormant colonies are dry and dusty. Active fungi will continue to damage the tape.²⁵ Most mold will become dormant below 70% RH although some can remain active as low as 50% RH. Fungus will cause dropouts and other permanent damage over time but can be removed. Tape with fungus can present a health hazard and should be handled carefully and minimally, if at all. Gloves and masks should be used during handling. Moldy tape should be isolated from other archival materials to prevent contamination.

²⁵ Much of the information in this section comes from Peter Brothers, "Moldy Audiotape" *Abbey Newsletter* 21, no. 7 (1997): 106 (available online at <http://palimpsest.stanford.edu/byorg/abbey/an/an21/an21-7/an21-709.html>), and Peter Brothers, "Disaster Avoidance and Recovery of Magnetic Tapes: Key Findings from a 20 Year Study" (paper presented at the Joint Technical Symposium, Toronto, Canada, June 24-26, 2004), available online at <http://www.jts2004.org/english/proceedings/Brothers.htm>.

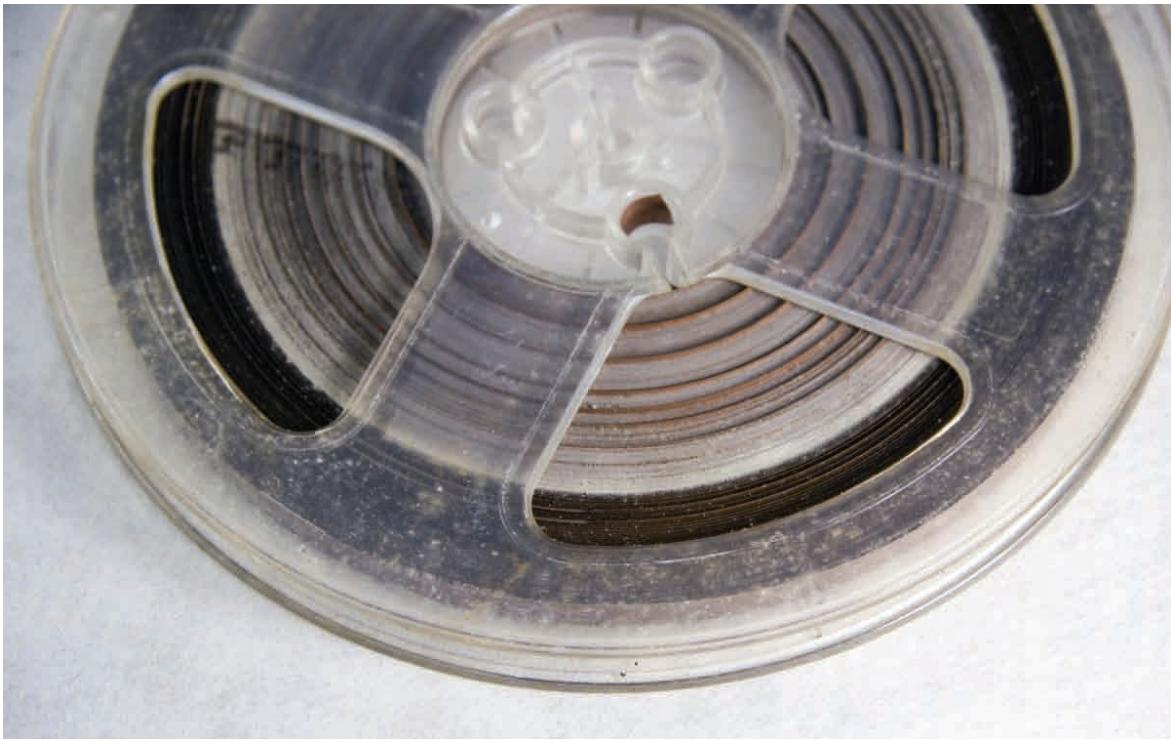


FIGURE 25: FUNGUS ON TAPE

Identification

Look for patterned, fuzzy, thread-like, or hairy-looking growths on the surface of the tape pack. Typically, these growths are white in color on open reel tape although they may also be black, brown, or mustard-colored. Try to distinguish mold from other types of visible contamination such as dirt, which may look similar but usually does not appear as fuzzy or patterned.

Points and Risk

The presence of fungus is considered a serious risk factor by FACET, which adds 1.5 points for this condition. Although active mold is a more serious problem as it continues to damage the tape, FACET does not differentiate between active and dormant. Testing for dormancy is usually best done by an expert and not something that we want to encourage. It is enough to know that mold is present, whether active or dormant.

2.3.3 Soft Binder Syndrome—Sticky Shed Syndrome (SBS-SSS)

Overview

Soft Binder Syndrome (SBS) is a new term coined by Richard Hess for all polyester-backed tapes that exhibit sticking, squealing, and abnormal shedding.²⁶ This includes tapes identified as failing due to the two degradation modes defined until now, Sticky Shed Syndrome (SSS) and Loss of Lubricant (LoL). Hess' work in consultation with a group of scientists, audio engineers, and tape specialists, has demonstrated that what has been termed LoL is not truly loss of lubricant but deterioration caused by a number of factors not yet completely understood. His work also suggests that the mechanism by which baking (also called incubation) renders a SSS tape playable has also been misunderstood.

²⁶Hess, "Tape Degradation," 8.

In the 1970s, most audio tape manufacturers switched from either an acetate or PVC binder to a polyester urethane binder for performance reasons related to changes in the oxide (magnetic pigment) coating. Note that by this time all tape base (the substrate or base film) material was polyester. Back coating—a usually black coating on the back of the tape—was added to many tape brands at the time, resulting in a premium mastering-quality tape. Polyester urethane binders are particularly susceptible to degradation via a process called hydrolysis, a chemical reaction caused by water in the form of humidity in the air that is accelerated at high temperatures. The result—a tape that sticks to the guides and heads of the tape machine, squeals, and often exhibits massive oxide and backing shed—is known as Sticky Shed Syndrome. SSS, as defined, appears to occur only on back-coated tapes. For many years it has been treated through baking, which renders the tape temporarily playable. A small number of tapes with SSS reportedly have deteriorated to the point that they do not respond to baking.²⁷ There are also reports that increasingly longer baking times are needed for SSS tapes to be playable, suggesting that this type of deterioration is continuing and becoming worse.²⁸

Identification

Audio engineers and sound archivists have over twenty years of experience identifying SSS tapes and treating them through baking. There are a small number of tape brands that are known to be afflicted with SSS in almost all cases. It is not only safe, but prudent, to assume that these brands have SSS as playback of sticky shed tapes will usually damage them. Below is a list of known SSS tape brands. All of them are polyester-based, back coated, mastering-quality tape stock. PVC, paper, and acetate-based tape do not experience SSS. This list is probably incomplete.

Ampex 406, 407, 456, 457
Capitol Q15
Scotch 226, 227, 806, 807, 808, 809

Points and Risk

Because some SSS tapes have deteriorated to the point that they do not respond to baking, because baking times are reportedly increasing, and because baking is an invasive procedure that is not fully understood, FACET considers this an extremely serious problem, adding 2.0 points for this condition.

²⁷ Reports from various people on the ARSC listserv. See UNESCO's *Safeguarding Our Documentary Heritage*, edited by George Boston at: http://webworld.unesco.org/safeguarding/en/txt_magn.htm, which states that baking "cannot restore the most severely affected tapes." Also see Otto Hinterhofer et al., "The Chemical Degradation of Magnetic Tape and Its Assessment by Physical and Chemical Testing" (paper presented at the 104th convention, Amsterdam, The Netherlands, May 16-19, 1998. Preprint 4701). On page 1, the authors state that "with further deterioration...the rate of successful re-conditioning may drop significantly in the future."

²⁸ Hess, "Tape Degradation," 11.

2.3.4 Soft Binder Syndrome—Unidentified Problems (SBS-UP)

Overview

In addition to SSS, there is another class of polyester-based tapes that are also severely degraded and exhibit some similar and some different symptoms. Typically, these tapes squeal and stick but show little or no oxide shedding, do not have a back coating, and do not respond to baking. These tapes have generally been diagnosed as losing lubricant although, as discussed above, this is no longer considered accurate. There is much yet to learn about how these tapes deteriorate, so FACET classifies them as SBS—following terminology in Richard Hess' paper—adding the term unidentified problems.²⁹ SBS-UP tapes are often unplayable due to the sticking and un-recordable due to the squealing, which makes its way through the signal chain into the digital file. Restoration strategies include applying lubricant, using rolling tape guides, working with tape tension, and playing in a cold environment, all with either mixed or preliminary results so far.

Identification

SBS-UP is identified through playback by assessing the symptoms that are presented. There are a few tape brands—particularly Sony PR-150 and Scotch 175—that are known to have SBS-UP. Our experience at the ATM with Scotch 175 is that some of it exhibits SBS-UP symptoms while some does not. These tape brands should be considered suspect until proven otherwise. The FACET user must identify these tape brands, which are included in the list of problematic major manufacturer tapes above.

Points and Risk

FACET identifies SBS-UP as a very serious problem, equivalent to SBS-SSS, and adds 2.0 points if diagnosed through playback. Tape brands in which SBS-UP is known to be a problem some of the time, but which have not been diagnosed through playback, receive 0.75 points through the assessment of major manufacturers, problem tapes from major manufacturers, and off-brands.

2.3.5 Vinegar Syndrome (VS)

Overview

Vinegar Syndrome is a major degradation mode for acetate-based tape. According to a UNESCO report, “cellulose acetate has a tendency to become brittle through hydrolysis caused by the moisture contained in the atmosphere. This brittleness generally causes serious problems when playing old audio tapes. Tapes with severe cases of hydrolysis can suffer from the so-called ‘Vinegar Syndrome’, an auto-catalytic process whereby acetic acid is set free in ever increasing quantities and thus creates an accelerating effect on the decay process. This has been particularly experienced in film archives, especially in hot and humid climatic areas. Affected films become soft and limp, ending up as powder or slime. While, in theory, this may also happen to acetate audio tapes, no disastrous losses similar to those in the film world have been reported.”³⁰

²⁹ Hess, “Tape Degradation,” 8.

³⁰ From the section titled “Typology and History” in UNESCO, “Magnetic Carriers,” available online at http://webworld.unesco.org/safeguarding/en/txt_magn.htm.

There is no evidence that Vinegar Syndrome in audio tape will result in an unplayable tape. The few reports of Vinegar Syndrome so far indicate, with one exception, little or no problems with playback and transfer.³¹ It is quite possible that not enough time has elapsed for the serious problems seen with film to manifest in audio tape, but there is also no evidence that this problem will develop in the same way with tape. Richard Hess presents in his paper some factors that support the theory that serious deterioration of audio tape as a result of Vinegar Syndrome is inevitable.³²

Identification

Vinegar Syndrome affects acetate-based tape only—polyester, PVC, and paper tape do not suffer from this problem. The presence of acetic acid as part of the degradation process gives a definite vinegar smell to tapes with this problem, although the ability to differentiate by smell is highly individual and somewhat subjective. In some cases there is no doubt: if you notice a strong vinegar smell immediately after opening a tape box, it is likely that VS is present. When the box has been open for a few seconds the acetic acid dissipates and the smell is no longer as perceivable. Note that VS is infectious, and tapes with this condition must be kept away from the rest of the collection.

The film community uses acid-detection strips such as those manufactured by the Image Permanence Institute to diagnose and assess VS.³³ These strips have been tested on film and there is uncertainty about their accuracy in detecting threshold danger levels for audio tape, which has much less mass than film.³⁴ Still, it may be possible to diagnose the presence of VS and gain insight into the general condition of an acetate tape collection using the strips.

Points and Risk

FACET considers VS a serious problem, although not as serious as SBS-SSS and SBS-UP which nearly always result in unplayable tapes. 1.5 points are added for collections with Vinegar Syndrome.

2.3.6 Other Documented Problems

Overview

Problems may exist that are not part of the conditions described above or are found on tapes that have simply not yet been diagnosed with one of the “syndromes.” The section below presents a few to look out for, most of which are diagnosed through playback. This category, however, can also be used for any other problems that are encountered or observed.

³¹ The exception was reported by the Cutting Corporation in an article that is apparently no longer available online. They reported brittle and buckling open reel tape along with a strong vinegar smell.

³² Hess, “Tape Degradation,” 5.

³³ Information available through Image Permanence Institute, “A-D Strips,” (Rochester, N.Y.: Image Permanence Institute, Rochester Institute of Technology, 2006), http://www.imagepermanenceinstitute.org/shtml_sub/cat_adstrips.asp. A-D strips are dye-coated paper strips that detect and measure the severity of acetate film deterioration.

³⁴ Hess, “Tape Degradation,” 20.

Identification

(1) Binder-base adhesion failure (BBAF) or delamination: BBAF is a failure of the binder/oxide (magnetic pigment) coating to adhere to the substrate film, resulting in the delamination—the peeling away—of one from the other. BBAF is rare, but has been encountered with Scotch 201, a 1.5 mil acetate-based tape. It has also occurred with Type III, Ferric Chrome, cassettes which contain two binder/oxide layers—one ferric oxide and the other chromium dioxide. This format may be particularly susceptible to BBAF.³⁵ Delamination may also be localized to a small part of a tape that has experienced trauma. For example, a splice that was cleaned with a chemical that resulted in localized loss of the binder/oxide coating. This is less serious than general delamination and may not be indicative of a larger problem.

(2) Blocking and Pinning: Blocking is the layer-to-layer adhesion or sticking together of adjacent layers of tape, usually due to long-term storage under conditions of high relative humidity or temperature, deterioration of the binder, or excessive tape pack stresses. The term pinning is also used to describe small, limited areas where there is adhesion.³⁶ Blocking and/or pinning may result in delamination, depending on how the layers are separated. Sometimes layers will appear to adhere because of static electricity which can be discharged, solving the problem. This is not blocking.

(3) Dirt: The presence of dirt or other foreign matter on or in the tape pack. A significant amount of foreign matter may cause drop-outs or lead to spacing loss from poor tape-to-head contact.

(4) Oxide (Magnetic Pigment) Loss: Look for oxide flakes or powder (brown colored if the tape oxide coating is brown) on any of the points along the tape path where the oxide part of the tape makes contact with the guides, heads or rubber parts of the tape machine's transport system.

(5) Stick Slip: A description of various processes of friction between magnetic tape and tape heads. The process may occur when

- the tape sticks to the recording head because of high friction;
- the tape tension builds because the tape is not moving at the head;
- the tape tension reaches a critical level, causing the tape to release from and briefly slip past the read head at high speed;
- the tape slows to normal speed and once again sticks to the recording head;
- this process is repeated indefinitely.

Stick Slip is characterized by jittery movement of the tape in the transport and/or audible squealing of the tape.³⁷

Points and Risk

These problems are all serious, and FACET adds 1.5 points for this category. For other problems that are less serious, a point adjustment may be made in the Other Factors section of the software.

³⁵ Hess, "Tape Degradation," 16. Information on Scotch 201 from an email from Del Eilers, dated April 27, 2006, in which he stated that this stock was prone to layer-to-layer adhesion which accelerated 3M's discontinuing the product.

³⁶ Hess, "Tape Degradation," 15.

³⁷ This definition is from National Film and Sound Archive, "Stick Slip," *Technical Glossary of Common Audiovisual Terms* ([Canberra]: National Film and Sound Archive, 2007), http://www.nfsa.afc.gov.au/preservation/audiovisual_terms/audiovisual_item.php?term=Stick%20Slip.

3 ANALOG AUDIO CASSETTES

3.1 Introduction

The analog, audio cassette format was introduced by Phillips in Europe in 1963 and in the U.S. in 1964. Mass production of audio cassettes began in 1964 in Germany with pre-recorded music cassettes launched in Europe in late 1965 and the US in September, 1966.³⁸ Characteristics of the format include:

- Polyester base
- Playback speed of 1 7/8 or 1.875 in/s which is equivalent to 4.76 cm/s, although both slower ($15/16$ ips/2.38 cm/s) and faster speeds (3.75ips/9.525 cm/s) are known
- Tape width of 0.15 inches (3.81 mm)
- Two mono tracks each in a different direction (on a separate side) or four tracks as two stereo pairs each in a different direction
- Plastic tab on top that may be broken off to prevent further recording on that side

Use of this format has declined sharply in some parts of the world, including the U.S., and its eventual obsolescence is now foreseeable. Professional-quality machines are becoming very scarce. However, in other parts of the world cassettes are still the dominant music format.

3.2 Format Characteristics

Characteristics of the audio cassette format that are identified by FACET as impacting its stability are presented below. The format itself receives a base score of 2.75 points, placing it in-between polyester base open reel tape and acetate base open reel tape in level of risk. IASA-TC 03 lists cassettes as an analog carrier that “can be considered inherently unstable and should, therefore, be copied.”³⁹ However, in the experience of most sound archivists and preservation transfer engineers the format is relatively stable with both younger and older tapes remaining playable. One report states that out of a collection of 1,800 poorly stored cassettes, only 0.5% were unplayable, and some of those could have been restored with heroic efforts.⁴⁰ Problems with cassettes are often mechanical and solved by re-housing into a new shell.

3.2.1 Tape Type

Overview

Over time, cassette tapes were manufactured with a magnetic pigment or oxide layer that had significantly different properties, leading to the classification of cassettes by type. These type classifications were standardized by the IEC (International Electrotechnical Commission). Each type has different bias and equalization requirements with specific settings that are used by the tape machine during playback.

³⁸ “Compact Cassette,” Wikipedia, the Free Encyclopedia, http://en.wikipedia.org/wiki/Compact_Cassette (accessed September 12, 2006).

³⁹ Schüller, *Safeguarding of the Audio Heritage*, 10.

⁴⁰ Reported by Peter Brothers on the ARSC list, January 29, 2004. Many others commented on the stability of the format in their experience in response to my questions in 2006. Problems based on specific format characteristics were reported, but these were relatively unusual.

The magnetic material for Type I cassettes, sometimes called normal bias tapes, is ferric (iron) oxide or Fe_2O_3 , which is the same as nearly all open reel tape. Type I was the original cassette formulation and probably the most common type. Type I uses a playback equalization of 120 μs (microseconds).

Around 1971 a chromium dioxide (CrO_2) formulation was developed that required a playback equalization of 70 μs . Shortly after, a cobalt-doped ferric oxide formulation (sometimes known as chrome equivalent) appeared that also required playback equalization of 70 μs . These formulations, developed to improve high frequency response and gain a higher tape signal output, were commonly called “high bias” tapes and became the IEC Type II classification. Both of these formulations are represented in best selling brands: Maxell XLII is chromium dioxide while TDK SA is a cobalt ferric oxide formulation.⁴¹

Type III is a dual layer tape with both ferric oxide and chromium dioxide that was introduced by Sony in 1973 and is sometimes called ferrichrome. Type III tapes were also manufactured by BASF, Agfa, and Scotch. This formulation probably died out by the early 1980s, although the Sony TC-D5 cassette machine manufactured starting in 1978 had a position for ferrichrome tapes as did the Beocord 9000, which was manufactured from 1982-86. Playback equalization for Type III is 70 μs .

In 1979, 3M introduced metal particle tapes, leading to the establishment of the IEC Type IV tape type. This formulation enabled even higher output and better frequency response than Type II. Type IV tapes require 70 μs playback equalization.

Identification

Each tape type carries its own equalization requirement that must be provided by the playback machine or sound quality will be compromised. Most cassette decks sense the tape type by reading the holes or notches on the top of the cassette housing or shell, adjusting bias and equalization as appropriate. A few decks do not read the notches but have a switch that the operator uses to select the appropriate equalization. Type I, II, and IV tapes may be accurately identified visually by the notches on the top of the cassette shell, located on each end. Type I tapes have one notch at each end, corresponding to a cassette side, while Type II have an additional notch directly adjacent to the first. The notch, or tab, in a Type I tape may either be in place or it may have been punched out. Removing the Type I notch prevents recording on that side of the cassette. If this record tab is out, then a Type II cassette appears to have a double-wide notch.

Type IV cassettes have the same notches as Type II along with two additional ones located in the middle of the top of the cassette. A Type III cassette has a Type I notch, even though it should be reproduced with the same equalization as a Type II tape. A different notch system was not developed for Type III. This is obviously an issue when reproducing a Type III cassette. Playback machines with a Type III setting, now quite rare, can reproduce these accurately, as can machines with adjustable equalization switches that the operator can set. See Appendix 5 for a partial list and photographs of Type III tapes.

⁴¹ From websites selling TDK SA tapes, text probably generated by TDK: TDK SA tape uses an ultrafine Super Avilyn Type II high bias Cobalt formulation with high density packing and uniform orientation.



FIGURE 26: TYPE I, TYPE II, AND TYPE IV CASSETTES

Points and Risk

The Type I formulation—ferric oxide—is not at risk and receives no points from FACET. According to the IASA selection document, "...CrO₂ and [cobalt] doped particles are less stable magnetically. Some MP [metal particle] tapes are threatened by oxidation or corrosion of the particles. The MP coatings at greatest risk are those manufactured in the late 1980s and early 1990s..."⁴² In addition, it appears that chromium dioxide contributes to the instability of the binder in CrO₂ formulations.⁴³ Recognizing this increased risk, FACET adds 0.5 points to the scores of collections consisting of Type II and Type IV cassette tapes. Type III tapes, relatively rare, are a dual layer formulation that could be subject to delamination of the layers. There is, in fact, at least one documented case of delamination caused by binder-base adhesion failure.⁴⁴ It is also difficult to find playback machines that can be set to handle the Type III equalization. Because of these factors, FACET adds 1.15 points for Type III collections.

⁴² Breen, *Task Force to Establish Selection Criteria*, 7.

⁴³ Emails from Benoît Thiébaut, a scientist conducting research sponsored by the Centre de Recherches sur la Conservation des Documents Graphiques in Paris, France and the PrestoSpace consortium, from February, 2006.

⁴⁴ Richard Hess, "Project Notes: Advanced Oxide Delamination of a Cassette" (31 March 2006), <http://www.richardhess.com/notes/2006/03/31/project-notes-advanced-oxide-delamination-of-a-cassette/>.

3.2.2 Tape Thickness

Overview

The discussion of tape thickness for open reel tapes, above, generally holds true for cassettes as well: thinner tape bases are less stable than thicker, although this is more of a handling problem than a degradation issue unless the tape is improperly stored. Thinner tapes are more prone to breaking, stretching and may exhibit other problems, such as twisting and/or folding in half along its width, during playback. Thickness measurements for cassettes reflect total tape thickness—base thicknesses are usually not stated. Because the format features tape mounted within a housing or shell—which means that the size of reel inside the housing can only be so large since the shell cannot expand—thickness is usually understood in terms of the recording/playing time of the tape. For example, a 90 minute tape must be thinner than a 60 minute tape since the reel cannot be significantly larger. Below are total tape thicknesses for the standard cassette lengths. Note that thicknesses vary from manufacturer to manufacturer and even among different brands from the same manufacturer. In general, they tend to cluster around these numbers for manufactured, branded tapes (bulk-loaded, generic cassettes contain whatever thickness of tape was used):

C-10–C-66 or so: 15-16+ μm (approximately 0.59–0.65 mils)

C-74–C-100 (this range is a guess): 10-11+ μm (approximately 0.39–0.45 mils)

C-120: 7-9 μm (approximately 0.28–.35 mils)

C-180: no data

Note that even though the thickest cassette is thinner than the thinnest open reel—the most at-risk triple play tapes—stability issues are not quite equivalent between the two. This may be due to the different playback configuration of the cassette format which contains the tape within a shell that includes a pressure pad and various rollers to assist in feeding the tape to the heads within a more controlled environment. Although there is some thought that degradation problems may have a greater effect on thinner tapes regardless of format, greater instability is generally noticed where the limits of the format's configuration is pushed. For cassettes, the limits are experienced with 120 minute (or 180 minute, which are rare) tapes. C-120s are more prone to tearing away from the hub or stretching, which may result in loss of content. C-60s and C-90s are stable—at least in terms of thickness issues—in the experience of sound archivists and preservation engineers. C-100s appear to have the same total thickness as C-90s according to measurements done at the ATM.

Identification

120 minute cassettes are usually identified as such on the cassette label or box. They may also be identified through playback—each side can hold 60 minutes of content.

Points and Risk

FACET acknowledges the greater risk represented by 120 or 180 minute cassettes by adding 0.75 points. No points are added for C-60s, C-90s, or C-100s which are carried on thicker tape.



FIGURE 27: 120 MINUTE CASSETTES

3.2.3 Age

Overview

The issues here are the same as for open reel tape, discussed above. Age by itself is not considered a major concern by archivists and preservation engineers—in our experience there are many older recordings with no playback problems. Those that experience problems are usually plagued by issues unrelated to the aging process by itself. Adding a small point value for each year of tape life provides a way to enable older collections to rank slightly ahead of younger ones with all other things being equal, taking into account the possibility that items will deteriorate further with age in ways that we have yet to experience.

Identification

It is usually not possible to know the actual manufacture date of an individual tape. The best information that can be reliably obtained is the date on which the tape was recorded, and this is the information that FACET uses. This provides a close approximation, certainly within ten years in all but the most unusual cases. Further guidance is available in the FACET procedures manual.

Points and Risk

0.005 points are added for each year of life, giving an added score of 0.2 points for a forty-year-old cassette, for example. Point values in this category are not enough by themselves to move a collection into a serious risk category.

3.2.4 Major Manufacturers and Off-Brands

Overview

As for open reel tape as discussed above, there is agreement among preservation engineers that tape from major manufacturers is more consistent, reliable, and stable. Off-brand tapes are often not the same, even if they appear to be from the same batch. They may vary wildly in both their physical and magnetic properties and suffer from manufacturing problems such as poor slitting and uneven coating. In some cases, off-brands are apparently second grade tape from major manufacturers that was defined as lower quality, did not pass quality control tests, and was sold under a different brand name. Some brands from major manufacturers are also consistently problematic, exhibiting characteristics similar to off-brands. Off-brand tapes present a number of playback and preservation problems in the experience of sound archivists and preservation engineers. Some engineers have noted that off-brand stability issues appear to be greater for the open reel than cassette format, which tends to be more stable in general.

Identification

Identification strategy is to determine first, when possible, if a tape is produced by a major manufacturer. Everything else is then considered an off-brand, which is documented by the user in the software. Guidance on how to handle this category is detailed in the FACET procedures manual.

Major Manufacturers

- Ampex
- Agfa
- BASF
- Maxell
- Sony
- Scotch
- TDK
- Fuji
- Denon
- Philips
- Quantegy
- Orwo

Points and Risk

If a tape does not fall into the major manufacturer category, or if it is a known problem brand from a major manufacturer (not yet defined for cassettes), then the user checks the off-brand box in the software and FACET adds 0.75 points to account for the additional, suspected risk.



FIGURE 28: OFF-BRAND CASSETTES

3.2.5 Track Configuration and Sound Field

Overview

Analog audio cassettes may contain mono or stereo tracks within several configurations:

- Two pairs of stereo tracks, one on each side. This gives a total of four tracks on the tape. This is the most common configuration. Unlike open reel tape, the left and right channels of each stereo pair are located adjacent to each other on the tape, enabling a stereo tape to be compatible with a mono tape.
- Two half track mono tracks, one on each side. Side A contains one mono track with one program while side B contains another mono track with a different program. Because the stereo configuration places the two channels of the stereo pair next to each other, a mono cassette player can successfully play a stereo tape, although with the loss of stereo information. Conversely, a stereo cassette machine can play a mono tape, although with potential phase problems.
- Four mono tracks covering the entire tape, each with discrete content. This is typically the output of a multi-track cassette recorder such as the home studio machines manufactured by Tascam and Fostex. Side A presents all of the content, which must be mixed together. If the tape is played on side B, the content sounds backwards.

Identification

It may be difficult to distinguish between a mono and stereo cassette recording, depending on the content and how it was recorded. Expert listening may help in identifying by listening either to program content or ambiance within a stereo field. A magnetic track viewer (see the section on open reel tracks, above) may also help, although cassette tracks are small and often difficult to identify accurately.

Points and Risk

Sound field does not affect the type or rate of degradation of a recording, but often degradation is more noticeable on a stereo recording because of image shift between the channels, which is disturbing to the listener. All other things being equal, it might make sense to transfer tapes that are stereo before mono to obtain a higher-quality transfer before degradation advances. FACET adds a small value—0.15 points—for a stereo recording. We consider this an optional category and the risk relatively subtle.

3.2.6 Noise Reduction

Overview

Noise reduction is a process used to remove noise from a signal.⁴⁵ On cassette tapes, these processes are sometimes applied to reduce the level of background tape hiss. If a tape has been encoded using a noise reduction system it requires an appropriately aligned hardware decoder for accurate playback. Noise reduction is not uncommon on cassette tapes recorded in the field. Possible noise reduction systems used with cassettes include Dolby B, Dolby C, Dolby S, and dbx.

Dolby B was developed in 1968 to address the hiss of slow-speed consumer tape recording formats such as cassette (as well as open reel tapes recorded at 3.75 in/s). The first cassette recorders with Dolby B, built by Nakamichi but sold by Advent, Fisher and Harman Kardon, were introduced in the summer of 1970. Dolby B was developed for consumer use and widely used on audio cassettes. It could provide acceptable, although not optimal, playback on machines without a decoder. It is the most commonly encountered noise reduction system.

Dolby C, introduced in 1980 and also developed for consumer use, provides greater noise reduction than Dolby B. It also sounds much worse on playback machines that do not have Dolby C capabilities. This system was found on Sony portable cassette recorders often used by fieldworkers and Fostex cassette multi-track machines, among others.

Dolby S, introduced in 1990, was also designed for the consumer market and included on some consumer tape machines and multi-track units. Tape machines must meet performance standards set by Dolby to include Dolby S. The first cassette machines with Dolby S, sold by Harman Kardon, shipped in December, 1990.

⁴⁵ Information in this section from Dolby, “Dolby B, C, and S Noise Reduction Systems: Making Cassettes Sound Better” ([San Francisco]: Dolby Laboratories, n.d.), available at http://www.dolby.com/assets/pdf/tech_library/212_Dolby_B,_C_and_S_Noise_Reduction_Systems.pdf; Dolby, “Who We Are” ([San Francisco]: Dolby Laboratories, 2007), http://www.dolby.com/about/who_we_are/history_1.html; Paul White, “Taping the Hiss! Tape Noise Reduction Explained,” *Sound on Sound* (January, 1996), http://www.soundonsound.com/sos/1996_articles/jan96/reducingnoise.html; and email correspondence with Roberto Landazuri, Corporate Archivist, Dolby Laboratories, dated September 8, 2006.

dbx, a competing noise reduction system, was developed in 1971. Type I was used with open reel tape in professional recording settings while Type II was common in four-track audio cassette home studio recorders such as the Tascam Portastudio.

Identification

Documentation provided by the collector or field recorder provides the best identification of the use of noise reduction. On many cassette labels there is a box in which the use of Dolby may be indicated. The letters NR stand for noise reduction, after which the type of noise reduction can be indicated, followed by a check in either the on or off box. An expert ear may also be able to identify the presence of certain types of noise reduction.



FIGURE 29: DOLBY C INDICATED ON LABEL

Points and Risk

It is harder to find working decoder units than tape machines, leaving tapes with noise reduction at a somewhat higher risk due to the obsolescence of analog noise reduction systems. These systems have not been modeled in software so there are no digital tools available for decoding. In addition, Dolby B and Dolby C are dependent on the level or amount of signal on the tape for accurate playback. Dolby C particularly requires the same level of high frequency information from the day it was recorded for the Dolby decoder to track correctly. These levels may decrease as the tape ages and deteriorates and the transfer engineer must change the relative level by ear to obtain an accurate transfer. According to one source, a decrease in signal output of two dB may be observed over the lifetime of metal particle and chromium dioxide cassettes.⁴⁶ FACET addresses these issues by adding 0.25 points for a Dolby B-encoded collection and 0.5 points for collections with Dolby C, Dolby S, and dbx noise reduction, which are either more difficult to transfer or for which it is harder to find working decoders.

⁴⁶Van Bogart, *Magnetic Tape Storage and Handling*, section 2.2. Available online at <http://www.clir.org/PUBS/reports/pub54/>. Level problems with Dolby-encoded tapes were also reported by a number of audio engineers on the ARSC listserv.

3.3 Preservation Problems

3.3.1 Fungus

Overview

Storage at high temperature and/or relative humidity levels may lead to the growth of fungus or mold on the tape. Fungi can live off the binder materials and may be present on the edges of the tape—easily visible on the tape pack surface—or may have worked its way onto the surface of the tape itself. Mold colonies may be either active or dormant. Active mold contains some moisture and may smear while dormant colonies are dry and dusty. Active fungi will continue to damage the tape.⁴⁷ Most mold will become dormant below 70% RH although some can remain active as low as 50% RH. Fungus can be removed, but over time will cause dropouts and other permanent damage. Tape with fungus can present a health hazard and should be handled carefully and minimally, if at all. Gloves and masks should be used during handling. Moldy tape should be isolated from other archival materials to prevent contamination.

Identification

Look for patterned, fuzzy, thread-like, or hairy-looking growths on the surface of the tape pack. Typically, these growths are white in color although they may also be black, brown, or mustard-colored. Try to distinguish mold from other types of visible contamination such as dirt, which may look similar but is usually does not appear as fuzzy or patterned.

Points and Risk

The presence of fungus is considered a serious risk factor by FACET, which adds 1.5 points for this condition. Although active mold is a more serious problem as it continues to damage the tape, FACET does not differentiate between active and dormant. Testing for dormancy is usually best done by an expert and not something that we want to encourage. It is enough to know that mold is present, whether active or dormant.

⁴⁷ Much of the information in this section comes from Brothers, "Moldy Audiotape," 106, <http://palimpsest.stanford.edu/byorg/abbey/an/an21/an21-7/an21-709.html> and Brothers, "Disaster Avoidance and Recovery," <http://www.jts2004.org/english/proceedings/Brothers.htm>.

3.3.2 Soft Binder Syndrome—Unidentified Problems (SBS-UP)

Overview

SBS-UP was discussed with open reel tapes, above. This syndrome also affects cassette tapes which exhibit symptoms such as squealing, sticking, along with little or no oxide shed. Cassettes do not have a back coating and have never responded to baking in the experience of most sound archivists and preservation engineers. SBS-UP tapes have generally been diagnosed as losing lubricant, most commonly using the term Loss of Lubricant, although as discussed above this is no longer considered accurate. There is much yet to learn about how these tapes deteriorate, so FACET classifies them as SBS with unidentified problems, following terminology in Richard Hess' paper. SBS-UP tapes are often unplayable due to the sticking and un-recordable due to the squealing, which makes its way through the signal chain into the digital file. Restoration strategies include applying lubricant, using rolling tape guides, working with tape tension, and playing in a cold environment, all with either mixed or preliminary results so far.

Identification

SBS-UP is identified through playback by assessing the symptoms that are presented. We do not recommend assuming that any cassette brands are afflicted with SBS-UP at this time without confirmation through playback.

Points and Risk

FACET identifies SBS-UP as a very serious problem and adds 2.0 points if diagnosed through playback.

3.3.3 Other Documented Problems

Overview

As with open reel tape, problems may exist that are not part of the conditions described above. The section below presents a few to look out for, most of which are diagnosed through playback. This category, however, can also be used for any other problems that are encountered or observed.

Identification

(1) Binder-base adhesion failure (BBAF) or delamination: BBAF is a failure of the binder/oxide coating to adhere to the substrate film, resulting in the delamination—the peeling away—of one from the other. BBAF is rare, but has been encountered with Type III, Ferric Chrome, cassettes which contain two binder/oxide layers—one ferric oxide and the other chromium dioxide. This format may be particularly susceptible to BBAF. Delamination may also be localized to a small part of a tape that has experienced trauma. For example, a splice that was cleaned with a chemical that resulted in localized loss of the binder/oxide coating. This is less serious than general delamination and may not be indicative of a larger problem.

(2) Blocking and Pinning: Blocking is the layer-to-layer adhesion or sticking together of adjacent layers of tape, usually due to long-term storage under conditions of high relative humidity or temperature, deterioration of the binder, or excessive tape pack stresses. The term pinning is also used to describe small, limited areas where there is adhesion.⁴⁸ Blocking and/or pinning may result in delamination, depending on how the layers are separated. Sometimes layers will appear to adhere because of static electricity which can be discharged, solving the problem. This is not blocking.

(3) Dirt: The presence of dirt or other foreign matter on or in the tape pack. A significant amount of foreign matter may cause drop-outs or lead to spacing loss from poor tape-to-head contact.

(4) Oxide Loss: Look for oxide flakes or powder (brown colored if the tape oxide coating is brown) on any of the points along the tape path where the oxide part of the tape makes contact with the guides, heads or rubber parts of the tape machine's transport system.

(5) Stick Slip: A description of various processes of friction between magnetic tape and tape heads. The process may occur when

- the tape sticks to the recording head because of high friction;
- the tape tension builds because the tape is not moving at the head;
- the tape tension reaches a critical level, causing the tape to release from and briefly slip past the read head at high speed;
- the tape slows to normal speed and once again sticks to the recording head;
- this process is repeated indefinitely.

Stick Slip is characterized by jittery movement of the tape in the transport and/or audible squealing of the tape.⁴⁹

Points and Risk

These problems are all serious, and FACET adds 1.5 points for this category. For other problems that are less serious, a point adjustment may be made in the Other Factors section of the software.

⁴⁸ Hess, "Tape Degradation," 15

⁴⁹ National Film and Sound Archive, "Stick Slip,"

http://www.nfsa.afc.gov.au/preservation/audiovisual_terms/audiovisual_item.php?term=Stick%20Slip.

4 DIGITAL AUDIO TAPE (DAT)

4.1 Introduction

Digital Audio Tape (DAT or R-DAT) was introduced in March, 1987 as the first mass market digital audio tape recorder and format.⁵⁰ In appearance the tape is similar to the analog, audio cassette format, using tape that is the same width (3.81 mm) enclosed in a shell that is roughly half the size. The tape is housed inside the cassette. When the tape is loaded into a DAT deck a slider is retracted to reveal tape hubs and the lid is opened to give access to the tape. Tape guides draw the tape from the cassette and wrap it around a rotary drum.

DAT recorders borrow technical solutions, such as a rotary head, from videotape technologies and are more complex in their construction than machines in other formats. DAT machines record a digital signal on polyester-based magnetic tape. The format supports three sampling frequencies: 32, 44.1, and 48 kHz with a fourth, 96-kHz, available on only a few machines. Bit depth is 16 bit although 12 bit recording is possible on some machines. DAT tape is typically 13 µm thick and anywhere from 10-60 meters in length. A typical configuration is a 60 meter tape that can hold 120 minutes of recorded material. There are thinner tapes—particularly 90 meters in length—that are less common.

Although the DAT format was designed for audio use, it was also adopted for general data storage, holding from 1.3 to 72 GB on a 60 to 180 meter tape depending on the standard and compression. A computer- or data-grade tape was developed for this purpose, called DDS which stands for Digital Data Storage. DDS was defined in 1989 by Sony and HP and has currently reached the 6th generation of technological development. However, in November, 2005 Sony announced that the manufacture of DAT machines would discontinue at the end of the year, effectively making the format obsolete for audio use. Transports for DAT machines are either no longer made or soon to be discontinued.



FIGURE 30: DAT TAPES

⁵⁰ Information in this section from chapter 7 of Ken C. Pohlman, *Principles of Digital Audio*, 4th ed. (New York: McGraw-Hill, 2000), 195-217; and "Digital Audio Tape," Wikipedia, the Free Encyclopedia, http://en.wikipedia.org/wiki/Digital_Audio_Tape (accessed September 11, 2006).

4.2 Format Characteristics

Listed below are a number of DAT format characteristics that FACET has identified as impacting stability. The format itself receives a base score of 4.0 points, placing it at the high end of the base scores for the various formats assessed by FACET. This is almost entirely due to issues related to both the obsolescence of the format and machine-tape interchange problems, as the tape itself is relatively stable.⁵¹ DAT was never popular outside of professional or semi-professional circles, and far fewer machines were sold than for other formats such as the analog audio cassette. Therefore, in addition to no new machines reaching the market, there is a smaller pool of used machines available to archives for use in preservation transfer of their holdings. DAT machines used in professional settings were typically worked hard and the heads are likely to be worn from extensive use. As fewer and fewer machines become usable over time, archives must determine whether they have enough head life on their machines to transfer their holdings.

In addition, mechanical misalignment has always been an issue with this format—a tape plays fine on the recording machine but does not play on others. This problem may be more acute for earlier recordings. At a 1995 meeting, a staff member from Sony stated: “There’s always that little moment when you put the thing in the machine. Is it going to play or not?” At the same meeting, another archivist stated that one in twenty DAT tapes malfunction.⁵²

DAT machines are sophisticated and not as easy to service as open reel or cassette tape machines. There are currently few DAT repair technicians and their numbers will continue to decline. As of this writing, it is possible to obtain parts for Tascam and many Panasonic machines, but it is difficult to do so for machines manufactured by Sony and those sold by HHB. One DAT repair technician, who is familiar with the condition of used machines on the market, suggests that archives should migrate holdings on DAT sooner rather than later, as he can clearly see a time in the near to medium term when the format cannot be maintained.⁵³ Archives that own a large number of DAT machines, with more than enough head life to transfer their holdings, may feel that the risk associated with this format is smaller and want to reflect this in their FACET scores. Adjustments can be made using the Other Factors category of the software.

Note that off-brands have not yet been defined for this format. The lists of major manufacturers and off-brands earlier in this document refer to open reel and cassette tape only.

⁵¹The conclusions reached in this section benefited from conversations with preservation engineer Richard Hess, DAT repair technician Dennis Charney, and posts to the ARSC List. These conclusions were reinforced by presentations and conversations at the Unlocking Audio conference at the British Library, October, 2007, in which it was clear that many of the archivists in attendance believe that DATs require preservation transfer in the near-term due to obsolescence issues. Many also report playback problems with the format.

⁵²Frank Beacham, “Archivists Warn: Don’t Depend on Digital Tape,” *The MiniDisc Community Portal* ([1998?]), http://www.minidisc.org/dat_archiving.html. The quote is from Mark Kirkeby, senior director of the American music archives for Sony, from a panel discussion at a 1995 meeting of the Audio Engineering Society.

⁵³Dennis Charney, NXT Generation. Phone conversation on August 3, 2006.

4.2.1 Tape Thickness

Overview

This issue is the same as with open reel and cassette tape: thinner tape bases are less stable than thicker ones, although this is more of a handling problem than a degradation issue unless the tape is improperly stored. Thinner tapes are more prone to breaking, stretching and may exhibit other problems. DAT tapes longer than 60 meters are thinner than the typical 13 µm, and are reported to be problematic. 60 meter tapes are usually labeled in terms of recording time—120 minute, 124 minute, or thereabouts is typical depending on the product. DATs longer than 60 meters—for example, tapes labeled as 180 minute (DT180 is a typical label)—may not be handled well by some machines.

Identification

The tape label usually provides an indication of recording time and may include tape length as well.

Points and Risk

FACET adds 0.75 points to DAT tapes longer than 60 meters.

4.2.2 Age

Overview

DAT collections receive the same points for age as the other magnetic tape formats—0.005 points per year of life. Adding a small point value for each year of tape life provides a way to enable older collections to rank slightly ahead of younger ones with all other things being equal, taking into account the possibility that items will deteriorate further with age in ways that we have yet to experience.

There is an additional issue for DATs, however, as there are multiple reports of increased problems with tapes recorded in the early days of DAT recording, from about 1987-1993. Some tape brands were questionable, earlier tape machines were not as good, and tape-machine compatibility problems were common.⁵⁴

Identification

It is usually not possible to know the actual manufacture date of an individual tape. The best information that can be reliably obtained is the date on which the tape was recorded, and this is the information that FACET uses. This provides a close approximation, certainly within ten years in all but the most unusual cases. Further guidance is available in the FACET procedures manual.

Points and Risk

Each tape format receives 0.005 points for each year of life, giving an added score of 0.1 points for a twenty-year old DAT, for example. Point values in this category are not enough by themselves to move a collection into a serious risk category. An additional 0.5 points are added, however, for tapes recorded in 1993 or earlier.

⁵⁴This information comes from DAT repair technician Dennis Charney and from a post to the ARSC list by Konrad Strauss, Director of the Recording Arts Department, Jacobs School of Music, Indiana University.

4.2.3 Tape Type

Overview

As discussed above, both audio- and computer/data-grade DAT tapes were manufactured. Some fieldworkers used data-grade DDS tapes for audio recording, believing that they were manufactured using a stricter standard and were of higher quality. There is conflicting evidence on the truth of this but, unfortunately, data-grade tape appears to shed extensively and begins scoring the head drum when played on a DAT machine. One DAT repair technician suggests that DDS tape was manufactured for a computer drive which does not have as high of an internal temperature as a DAT machine. He states that he can quickly tell the DAT machines that have seen data-grade tape.⁵⁵ Reportedly, Panasonic stopped selling data-grade tape after the problems for audio work became evident.

Identification

DDS tape can be identified by the use of the following wording on the tape shell:

- DDS
- Digital Data Storage
- Data Cartridge
- Data Tape

Points and Risk

FACET adds 0.5 points for data-grade DAT tapes.



FIGURE 31: DDS TAPES

⁵⁵ Dennis Charney, phone conversation on August 3, 2006. There are various other reports on the web of problems with DDS tape in DAT machines.

4.2.4 Recording/Playback Mode

Overview

Both the 44.1 and 48 kHz sampling rates are considered standard record/playback modes for the DAT format. As discussed above, the format is also capable of recording with a 32 kHz sample rate using either 12 or 16 bit quantization. The 12 bit version is called long-play mode as it is possible to record more content on the same length of tape than recording in 16 bit. Using this mode—which is a non-linear quantization scheme—results in poorer frequency response and greater distortion. These two 32 kHz modes are not interchangeable—you cannot play a tape recorded in the 12 bit long-play mode on a machine that only supports the 32k/16 bit mode. Many machines do not support the 12 bit long-play mode at all. Apparently, Sony machines support this mode but Panasonic and Technics machines do not. Some manufacturers introduced DAT recorders that could use a sampling rate of 96 kHz. Tapes recorded with this sample rate are not compatible with conventional DAT machines.

Identification

Collection documentation may specify the recording mode used by the fieldworker. If not, playback will be necessary to determine this.

Points and Risk

Due to the shrinking pool of working professional DAT machines, and the fact that not all of them support non-standard recording modes, FACET adds 0.5 points for a collection recorded in long-play mode or at a 32k or 96k sampling rate.

4.2.5 Portable DAT Recorders

Overview

Tapes recorded on portable “walkman” machines are more vulnerable than others according to multiple reports.⁵⁶ Portable machines are much more likely to be out of alignment and their tapes may not always play on other DAT machines. The increased likelihood that a portable machine—typically purchased for use in the field—has been dropped may cause or contribute to this problem.

Identification

Documentation from the collector is necessary to determine what kind of a machine was used to record a tape. It is likely that tapes recorded in the field were done on a portable DAT recorder.

Points and Risk

FACET adds 0.25 points for collections recorded on portable DAT machines.

⁵⁶This information comes from conversations with Dennis Charney and with Dietrich Schüller, Director of the Vienna Phonogrammarchiv.

4.3 Preservation Problems

The DAT format does not suffer from any of the “syndromes” that affect open reel and cassette tape. Below are a few problems that may be encountered.

4.3.1 Fungus

Overview

Storage at high temperature and/or relative humidity levels may lead to the growth of fungus or mold on the tape. Fungi can live off the binder materials and may be present on the edges of the tape—easily visible on the tape pack surface—or may have worked its way onto the surface of the tape itself. Mold colonies may be either active or dormant. Active mold contains some moisture and may smear while dormant colonies are dry and dusty. Active fungi will continue to damage the tape.⁵⁷ Most mold will become dormant below 70% RH although some can remain active as low as 50% RH. Fungus can be removed, but over time will cause dropouts and other permanent damage. Tape with fungus can present a health hazard and should be handled carefully and minimally, if at all. Gloves and masks should be used during handling. Moldy tape should be isolated from other archival materials to prevent contamination.

Identification

Look for patterned, fuzzy, thread-like, or hairy-looking growths on the surface of the tape pack. Typically, these growths are white in color although they may also be black, brown, or mustard-colored. Try to distinguish mold from other types of visible contamination such as dirt, which may look similar but is usually does not appear as fuzzy or patterned.

Points and Risk

The presence of fungus is considered a serious risk factor by FACET, which adds 1.5 points for this condition. Although active mold is a more serious problem as it continues to damage the tape, FACET does not differentiate between active and dormant. Testing for dormancy is usually best done by an expert and not something that we want to encourage. It is enough to know that mold is present, whether active or dormant.

4.3.2 Other Documented Problems

Overview

The section below presents a few problems to look out for, most of which are diagnosed through playback. This category, however, can also be used for any other problems that are encountered or observed.

Identification

(1) Binder-base adhesion failure (BBAF) or delamination: BBAF is a failure of the binder/oxide coating to adhere to the substrate film, resulting in the delamination—the peeling away—of one from the other. BBAF is rare, and is unlikely to be encountered on a DAT tape.

⁵⁷ Much of the information in this section comes from Brothers, “Moldy Audiotape,” 106, <http://palimpsest.stanford.edu/byorg/abbey/an/an21/an21-7/an21-709.html>; and Brothers, “Disaster Avoidance and Recovery,” <http://www.jts2004.org/english/proceedings/Brothers.htm>.

2) Blocking and Pinning: Blocking is the layer-to-layer adhesion or sticking together of adjacent layers of tape, usually due to long-term storage under conditions of high relative humidity or temperature, deterioration of the binder, or excessive tape pack stresses. The term pinning is also used to describe small, limited areas where there is adhesion.⁵⁸ Blocking and/or pinning may result in delamination, depending on how the layers are separated. Sometimes layers will appear to adhere because of static electricity which can be discharged, solving the problem. This is not blocking. This is also likely to be rare with DATs.

(3) Dirt: The presence of dirt or other foreign matter on or in the tape pack. A significant amount of foreign matter may cause drop-outs or lead to spacing loss from poor tape-to-head contact.

(4) Oxide (Magnetic Pigment) Loss: Look for oxide flakes or powder (brown colored if the tape oxide coating is brown) on any of the points along the tape path where the oxide part of the tape makes contact with the guides, heads or rubber parts of the tape machine's transport system.

(5) Head Clogs: This is not uncommon on DATs—clumps of coating material become trapped in the head gap or debris adheres to the head leading to drop-outs or worse. It manifests as an error message or high error rates, then progresses to digital glitches, then loss of audio. If one head remains clogged only 50% of the signal is present.

(6) Stick Slip: A description of various processes of friction between magnetic tape and tape heads. The process may occur when:

- the tape sticks to the recording head because of high friction;
- the tape tension builds because the tape is not moving at the head;
- the tape tension reaches a critical level, causing the tape to release from and briefly slip past the read head at high speed;
- the tape slows to normal speed and once again sticks to the recording head;
- this process is repeated indefinitely.

Stick Slip is characterized by jittery movement of the tape in the transport and/or audible squealing of the tape.

Points and Risk

These problems are all serious, and FACET adds 1.5 points for this category. For other problems that are less serious, a point adjustment may be made in the Other Factors section of the software.

⁵⁸ Hess, "Tape Degradation," 15.

5 ALUMINUM DISCS

5.1 Introduction

Discs recorded in the field are unique or one-of-a-kind recordings, often called direct-cut discs or instantaneous recordings because sound is recorded directly onto the disc. In contrast, commercially-issued discs are created from several generations of intermediate forms (including a mother, stamper, and others) that carry the recorded content that exists not only in multiple generations but in the multiple copies that were sold. The earliest field discs were cut onto metal—usually aluminum but more rarely zinc or copper—starting probably in the late 1920's. At least as early as 1929 radio stations, advertising agencies, and performers hired private recording studios to record aluminum discs of broadcasts to assess and improve performances.⁵⁹ Ethnographic field recording on aluminum may have started as early as this although its heyday was the 1930s. In 1931, Victor offered for sale an attachment to a home phonograph with which it was possible to record onto pre-grooved black plastic discs.⁶⁰ Until the introduction of the lacquer disc in late 1934, aluminums (and the novelty black plastic, zinc Echo discs, and others) were the sole available field disc format. At the ATM, we are able to document field recordings on aluminum disc as early as 1932, although there are strong indications that a collection of pre-grooved zinc discs may date to the mid- to late-20s and that another collection of aluminum discs may also date to this time period.⁶¹ The latest aluminum disc field recordings at the ATM date to 1941 although one collection may have been recorded in 1945.

Aluminum discs have a bright, silver, metallic surface. There is no coating and the grooves carrying the recorded content reside in the metal itself. There may or may not be a label and, if not, there may be identifying words or marks engraved into the metal surface. The grooves on an aluminum disc were not actually cut into the metal but were embossed. That is, no material was removed from the disc during recording but the groove was impressed into it, with material from the recording process displaced and shoved upwards, appearing as two small ridges at the edges of the track. The grooves are soft and meant to be played using a thorn, bamboo, cactus, or fiber needle. Instructions from this time period warn against using steel needles for playback as this material will damage the grooves. Today, a modern turntable with a lighter tracking force and diamond stylus is used for reproduction of this format. Both 10" and 12" aluminum field discs are common with the smaller capable of carrying approximately 3 minutes of recorded content on one side while the larger may contain up to 4:22.

Aluminum is a relatively durable material and these discs, in the experience of archivists and preservation engineers, do not deteriorate as rapidly as other types of field discs, particularly lacquers. Aluminum disc deterioration is more subtle than lacquer degradation resulting in a less catastrophic outcome. FACET assigns a base score of 3.0 to this format, balancing both the obsolescence of the format and its relative stability.

⁵⁹ Mike Biel has documented broadcast recordings on aluminum disc from 1929. See Biel's web page "A History of Radio Broadcast Recordings," <http://community.mcckc.edu/crosby/transcrib.htm>.

⁶⁰ Walter L Welch and Leah Brodbeck Stenzel Burt, *From Tinfoil to Stereo: The Acoustic Years of the Recording Industry, 1877-1929* (Gainesville: University Press of Florida, 1994): 290.

⁶¹ The zinc discs are Echo discs in the Lawrence Gellert collection. These are pre-grooved discs that were evidently available in the 1920's for recording in the home using a standard playback-only phonograph.



FIGURE 32: ALUMINUM DISC

5.2 Preservation Problems

5.2.1 Oxidation

Overview and Identification

Aluminum discs are shiny at first but become relatively duller in appearance as they deteriorate. In time, white-colored material may appear on the surface of the metal. Aluminum is a self-oxidizing metal and discs made from this material sometimes exhibit white, crusty, bumpy surface deposits from oxidation. These deposits cannot be completely removed by cleaning and the use of aggressive cleaning techniques and substances may polish or wear down the grooves, affecting the recoverable sound. The products of oxidation may act to seal the surface of the recording, but underneath this seal the grooves may be damaged. It is not clear if oxidation continues to get worse over time, or if this type of deterioration progresses for a certain period of time, after which it basically stops and the condition of the disc remains static.⁶²

⁶² Much of the information on the deterioration of aluminum discs comes from a conversation with Art Shrifin in April 2006.

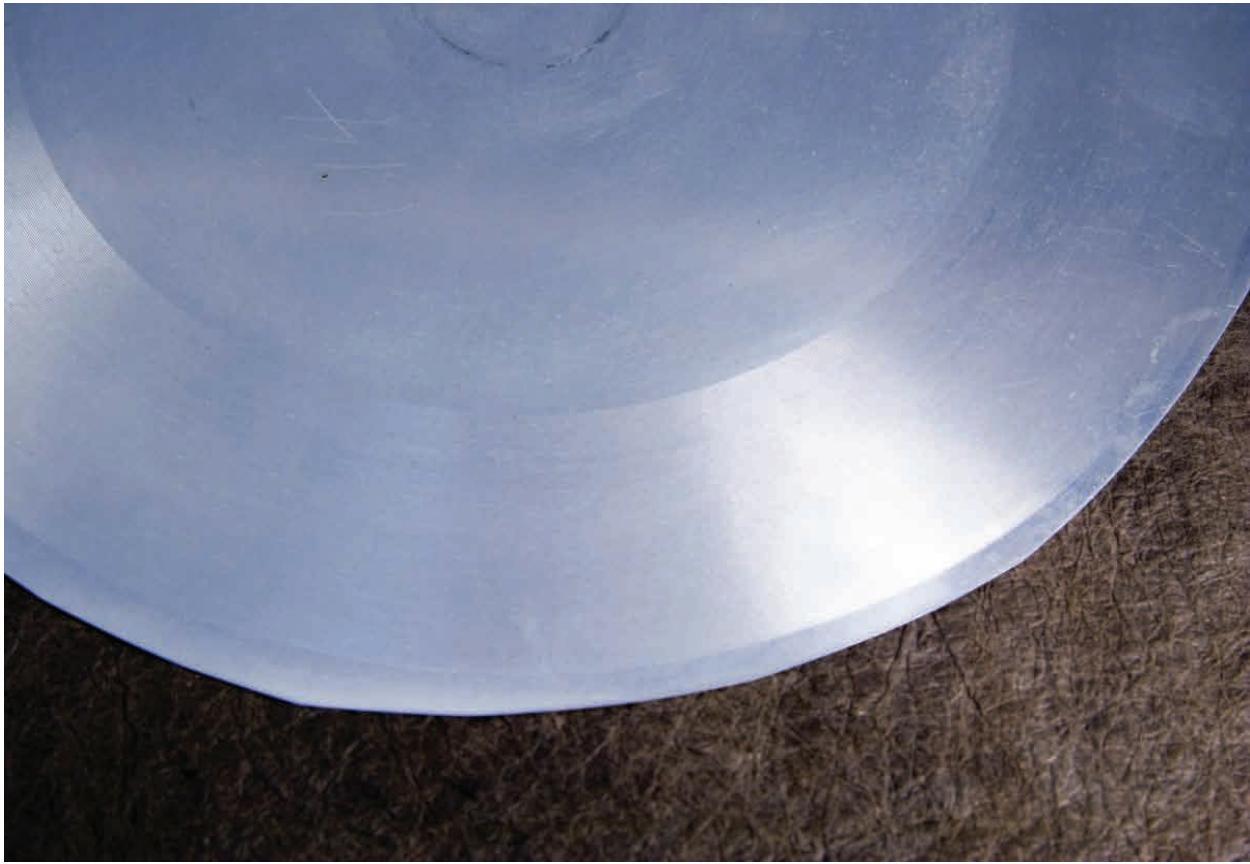


FIGURE 33: ALUMINUM DISC WITH SOME SURFACE DETERIORATION ON THE RIGHT SIDE

Points and Risk

FACET assigns 1.0 point for oxidation or any other similar surface deterioration found on this format. Use this category for any type of surface deterioration on these discs.

6 LACQUER DISCS

6.1 Introduction

The lacquer disc was introduced in the United States in late 1934 by the Presto Recording Corporation and quickly supplanted aluminum discs in the broadcasting industry and, later, for field recording. Companies in France and England developed a similar type of disc at roughly the same time. This format, often mistakenly called acetate, consists of a (usually) black nitrocellulose lacquer coating on an aluminum or glass base. The format also includes non-black colored coatings on a cardboard base. A 12" lacquer may resemble an LP in appearance, particularly if the coating is in good condition, but is heavier, thicker, and less flexible. These discs often have a label that may be pre-printed with the name of the manufacturer of the blank disc (such as Recordio or Audiodisc, for example), although notation of the contents recorded on the disc are almost always hand-written. The exception might be lacquer masters produced in a professional recording studio or manufacturing plant, which may have a pre-printed or typed label with contents. The earliest documented lacquer disc at the ATM was recorded in 1938, although one collection was possibly recorded earlier. Two ATM lacquer field collections date from the 1950s—one spanning the years 1949-53 and the other dating to 1956—even though open reel tape machines were widely available by that time.

IASA-TC 03 states that “instantaneous discs of all types and especially ‘lacquer’ discs” are inherently unstable and should be copied.⁶³ Archivists agree that lacquers represent the highest priority format for preservation transfer because of their instability and the rapid, catastrophic way in which they deteriorate. For this reason, the lacquer disc format receives a base score of 4.25 points, which is the highest base score assigned by FACET, automatically placing it in the moderate to severe risk category, even for discs in comparatively good shape. Lacquer degradation mechanisms are discussed below.

⁶³ Schüller, *Safeguarding of the Audio Heritage*, 11.



FIGURE 34: LACQUER DISC WITH TYPICAL LABEL

6.2 Format Characteristics

6.2.1 Base

Overview

The lacquer coating is carried most commonly on an aluminum base, although glass was used during World War II due to a shortage of aluminum. Discs used for home recording may have a cardboard base. Aluminum is durable and stable while glass is, obviously, fragile and breakable. Cardboard-based discs, made by the Wilcox-Gay Company and others, will deteriorate if wet. The thin lacquer coating on a cardboard disc is also susceptible to crazing, which is a series of thin fracture lines on the surface of the disc.

Identification

The standard way to identify the base material of a lacquer disc is to examine the disc's center hole where silver metal (from an aluminum base), glass, or cardboard will be visible. These bases also have distinctive sounds when the disc is struck gently against its edge using an object such as a ring. An aluminum base yields a sound that has been described as a "pong" while the glass sound is more of a "ping." Cardboard will, of course, have no sound.

Points and Risk

Glass is fragile and carries significant risk of breaking as it is handled over time. For this reason, FACET assigns an additional 0.5 points for a glass-based disc.

6.3 Preservation Problems

6.3.1 Plasticizer Exudation and Delamination

Overview

The lacquer disc coating contains castor oil which was used as a plasticizer or softener. Over time, castor oil leaches out of the coating, usually as a reaction to moisture in the storage environment. This process is sometimes called plasticizer exudation. As plasticizer is lost the coating shrinks; however, the metal or glass base of the disc does not shrink. This leads to delamination—the separation of the coating from the base—which manifests as cracking or peeling of the coating and the consequent loss of recorded content. That is, the gradual loss of plasticizer results in progressive embrittlement and catastrophic failure of the coating. Some have noted that as plasticizer is lost that there is an increase in noise—this is probably from the shrinking of the coating which exposes small nodules of imperfectly dispersed carbon black or other solid material as well as the formation of minute pores due to the exudation of the castor oil. It is estimated that approximately 25% of plasticizer in some discs may be lost without visible serious damage but, presumably, with an increase in noise during playback.⁶⁴

In addition, the cellulose nitrate coating is itself an unstable material with thermal, photo-oxidative, and hydrolytic degradative mechanisms. Both plasticizer loss and general deterioration of the cellulose nitrate coating occur simultaneously, and the products of both decomposition processes react with each other to hasten the failure of the coating. Differences in manufacturing and in storage environment affect when any given individual disc reaches the delamination stage. A disc's age is not a useful predictor and failure is not consistent.

Identification

Plasticizer exudation manifests as a white, oily sheen that is easily spotted on the surface of the disc. Delamination begins as obvious cracks that form in the disc's coating, leading to separation of the coating from the base, leaving only the base material visible. This delamination may be limited to the edge or center of the disc where it does not yet affect the grooves that carry recorded content, or it may occur in the middle of the disc where content resides. The presence of either cracks in the coating or actual separation (or both) are defined as delamination by FACET.

Points and Risk

Plasticizer exudation and delamination are related phenomena as the first leads inexorably to the second. However, either may be present without the other. Delamination, which is one of the most serious preservation problems possible since it is an active process that results in loss of content, does not become worse if plasticizer exudation is present. In effect, a delaminating disc is already as bad as it can get. For this reason, FACET assigns points for both conditions but it is not possible use both categories at the same time. Because of the seriousness of these problems, FACET assigns 1.5 points for plasticizer exudation and 2.0 points for delamination. If plasticizer exudation is present but not delamination, use the score for plasticizer exudation. If delamination is present use its own score, which is large enough to place the disc in the most at-risk category.

⁶⁴The discussion of how lacquer discs deteriorate is from A. G. Pickett and M. M. Lemcoff, *Preservation and Storage of Sound Recordings* (Washington D.C.: Library of Congress, 1959), 15-24.



FIGURE 35: LACQUER DISC WITH PLASTICIZER EXUDATION AND DELAMINATION

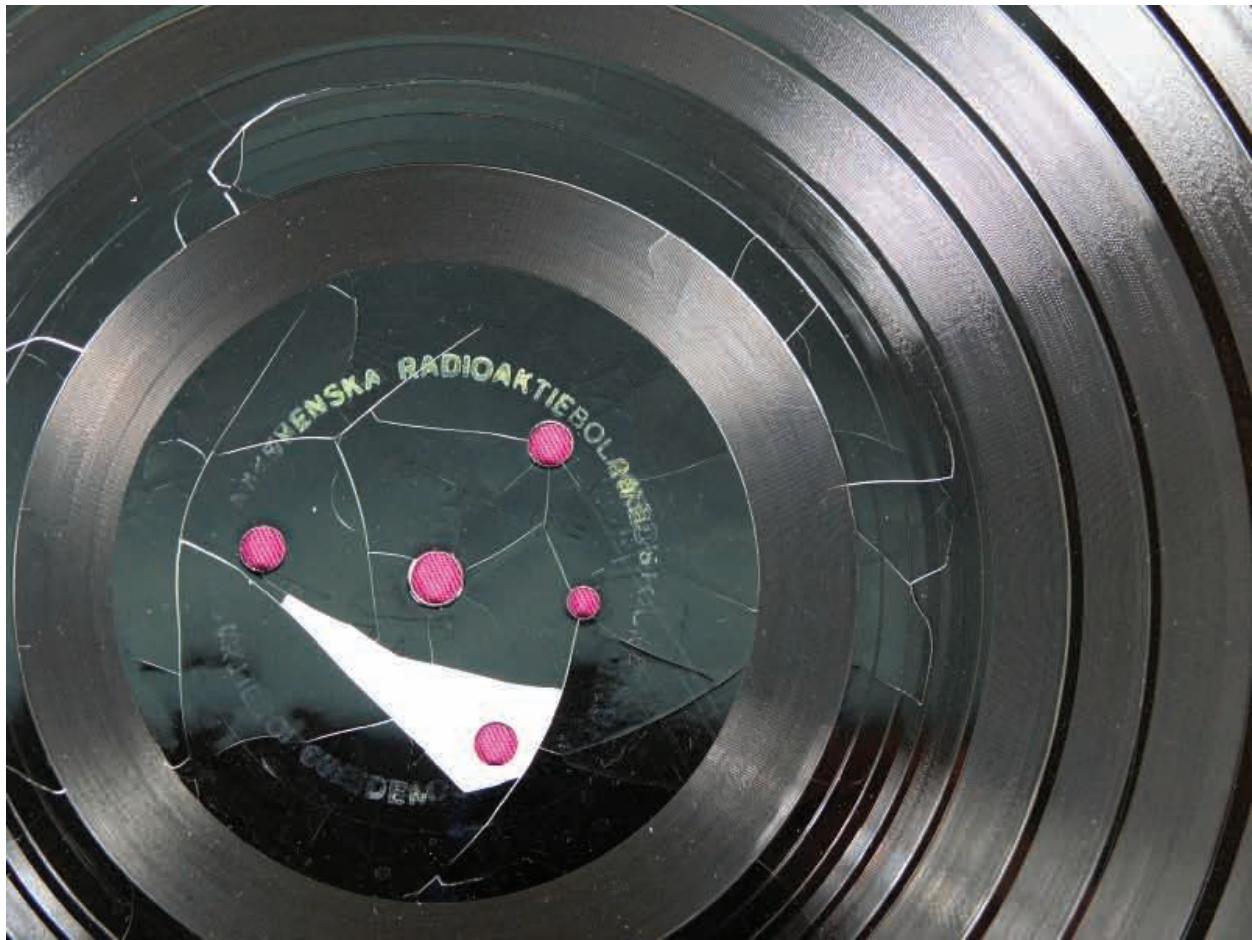


FIGURE 36: LACQUER DISC DELAMINATION

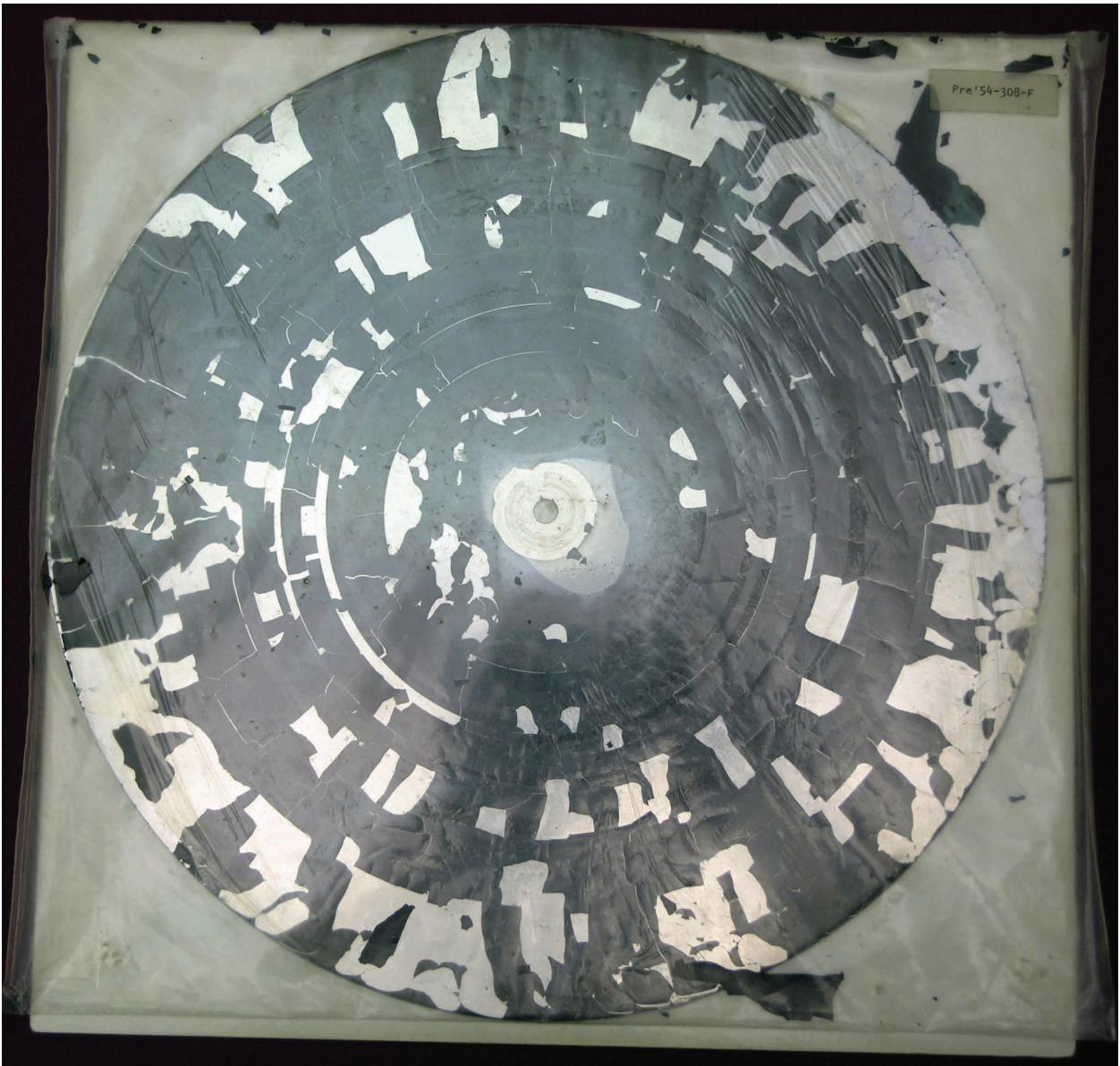


FIGURE 37: SEVERELY DELAMINATED LACQUER DISC THAT IS UNPLAYABLE

7 WIRE RECORDINGS

7.1 Introduction

Around the turn of the 20th century Valdemar Poulsen invented the Telephone, a telephone recording device that used steel wire as a recording medium.⁶⁵ In the 1920s, several European companies attempted to market a wire recorder for dictation and telephone use while several American companies developed magnetic recording devices. None were commercially successful. It was not until Marvin Camras at the Armour Research Foundation developed an improved version around 1939 that the format was put into practical use. Armour received a contract from the U.S. Navy and the wire recorder was primarily used by the military, especially for wartime news reporting by the Armed Forces Radio Service, until the end of World War II. Beginning in 1945, Armour licensed the manufacture of its wire machines to over a dozen U.S. and European companies and by 1947 many Armour-based wire recorders began to appear in the commercial marketplace. They were marketed to businesses for dictation use, as telephone answering machines, and for conference recording. In the home, wire machines were used to record favorite radio shows or disc recordings and to record letters to soldiers stationed overseas. The best selling brands in the U.S. were Webcor, made by Webster-Chicago, and Silvertone, sold by Sears. Sales of wire recorders were promising at first, then quickly declined. By the early 1950's the format had been almost completely superseded by open reel tape and by the mid-1950s there were only a few wire format products on the market. Webcor machines were manufactured from 1945 to 1952, after which the company focused exclusively on open reel tape recorders. At the ATM, the earliest field collection on wire that can be definitively dated is from 1948. Several wire collections were recorded in 1951 and 1952. At least one collection contains wires with recording dates in the late 1950s as well as several wires recorded in the early 1960s. One of these was apparently recorded in 1964.

The wire format provided a recording medium with several advantages over earlier field disc formats. Potential recording time was much longer (up to 60 minutes), background disc noise (scratches and clicks) were absent, and the wire could be erased and re-used. The wire used for recording purposes is very thin—approximately 4 mils in diameter—which is slightly larger than the diameter of a human hair.⁶⁶ Until World War II this wire was typically made of steel and susceptible to rust. Later, wire was made of a type of stainless steel—which is a stable and durable material—that was manufactured specifically for recording. The wire is passed over a recording head and becomes magnetized, carrying the recorded signal. It is carried on a spool, the size of which was not standardized at 2.75 inches (6.99 cm) in diameter and about 0.65 inches (1.65 cm) thick (measured from the outer edge of each flange or reel) until around 1946. Armour, early Pierce, and General Electric machines used larger spools that were often 3.75 inches (9.53 cm) in diameter and 1.25 inches (3.18 cm) thick. Each of the standard-size reels could hold up to 7200 feet of wire. Recording speed was 24 in/s (60.96 cm/s), which yielded up to an hour of recorded content. The older, larger reels—which are relatively rare—are not compatible with the later standard and do not fit on later machines. Also, many early wire recordings were recorded at speeds faster than the later 24 in/s standard.⁶⁷

⁶⁵ Information on wire recorders in this section comes from David Morton, "Armour Research Foundation and the Wire Recorder: How Academic Entrepreneurs Fail," *Technology and Culture* 39, no. 2 (April 1998): 213-244, and Gretchen King, "Magnetic Wire Recordings: A Manual Including Historical Background, Approaches to Transfer and Storage, and Solutions to Common Problems," <http://depts.washington.edu/ethmusic/wire1.html>.

⁶⁶ Much of the information in this section is from the Video Interchange website, <http://www.videointerchange.com>

⁶⁷ For example, early Pierce wires were recorded at 36 in/s, Armour wires at 30 or 60 in/s, and the Brush Navy Wire Recorder operated at 54 to 60 in/s. This information is from Semi J. Begun, *Magnetic Recording* (New York: Rinehart, 1949), 137-140.



FIGURE 38: WIRE RECORDINGS

Stainless steel wires are stable and are not subject to the types of degradation that affect open reel tape.⁶⁸ They are not actively deteriorating in most cases. In fact, one preservation engineer with wide experience transferring wire recordings reports that every example he has seen has been playable. The format is, however, long obsolete and prone to damage through tangling during playback. If the wire becomes tangled it can be nearly impossible to untangle. Playback machines are not common but are available in archives and from preservation engineers and private collectors. Wire recorder electronics are relatively simple and these machines are, for the most part, not difficult for a technician to repair, although familiarity with vacuum tubes may be required. FACET assigns a base score of 2.75 points to wire recordings, which balances the format's stability with its obsolescence.

⁶⁸ Some of the information in this section and below comes from an April 2006 conversation with Art Shrifin, who has much experience with high-quality transfer of wire recordings.

7.2 Format Characteristics

7.2.1 Pre World War II and Armour Brand

Overview

Wires recorded before World War II may be steel, but not stainless steel, and subject to corrosion. These early wires are also likely a non-standard size and/or speed. The primary manufacturer of pre-World War II wire recorders was Armour, which also licensed its technology to General Electric. Note that this category is for Armour brand wires, not wires from other manufacturers labeled as conforming to the Armour standard.

Identification

The standard size wire spool or reel is 2.75 inches (6.99 cm) in diameter and about 0.65 inches (1.65 cm) or 5/8 inch thick, measured to the edge of the flange or reel. Anything larger falls into this greater risk category. Any wire labeled as manufactured by Armour, and possibly by General Electric, also belongs to this category.

Points and Risk

Because non-stainless steel wires are susceptible to rust or corrosion, and because non-standard size and playback speed wires are not compatible with standard machines, these items are at greater risk. FACET assigns 1.0 points for this characteristic of the format.

7.3 Preservation Problems

7.3.1 Rust/Corrosion/Oxidation

Overview

Non-stainless steel wires are rare but, if found, may exhibit corrosion that makes playback more difficult. Even stainless steel wires may be subject to some oxidation.

Identification

Although this problem is reported, we have not been able to find anyone with actual experience with rusty or corroded wires.

Points and Risk

FACET assigns 2.0 points for any evidence of rust, corrosion, or oxidation.

8 FORMAT POINTS AND COMPARISONS

[Review the preservation ranking scale in Appendix 1 before examining the scores below]

8.1 Summary of Format Base Scores

Note that the format scores below are misleading if taken out of context. They must be understood within the context of format characteristics and preservation problems. For example, polyester open reel tape appears to be very stable given its low base score. However, certain types of polyester tape that typically exhibit problems such as Sticky Shed Syndrome, will score near the top of the scale.

Format	Base Score
PVC open reel tape	2.5
Polyester open reel tape	2.5
Paper open reel tape	2.75
Wire recordings	2.75
Audio cassette	2.75
Aluminum disc	3.0
Acetate open reel tape	3.0
DAT	4.0
Lacquer disc	4.25

Summary of rationale—selected points from the discussions of each format above

- DAT receives a high base score because of the near obsolescence of the format and reported widespread playback problems
- Paper based open reel tape appears to be relatively stable in our experience and according to an article by Dr. John W.C. Van Bogart, National Media Laboratory
- Audio cassette receives a relatively lower base score despite its inclusion on the IASA priority list because the format appears to be relatively more stable than others in the practical experience of most archivists and engineers
- Aluminum discs appear relatively stable, except for oxidation. There are mixed reports as to the seriousness of this problem, particularly whether it becomes worse over time
- Wire recordings, most of which are made of stainless steel, are very stable chemically. They are not actively deteriorating. The format is obsolete which places it at some risk, however, there are still machines and expertise available to transfer them, for the next decade at least
- Lacquer discs are the format most at risk due to their relative instability and the process by which they rapidly deteriorate chemically (plasticizer exudation leading to delamination)

8.2 Summary of Points by Format

8.2.1 Acetate Open Reel Tape

Characteristic/Problem	Points added
Format base score	3.0
Age—add 0.005 points for each year of life	0.17–0.31
Long play (1 mil base)	0.5
Double play (0.5 mil base)	1.0
Triple play (0.5 mil base or thinner)	1.2
Unknown if double or triple play (0.5 mil base or thinner)	1.1
Off-brand	0.75
Tracks	0.006–1.0
Sound field—stereo	0.15
Noise reduction	0.5
Vinegar Syndrome	1.5
Fungus	1.5
Visible tape pack problems—minor	0.25
Visible tape pack problems—moderate	0.5
Visible tape pack problems—severe	0.75
Other serious documented problems (not any of above)	1.5

8.2.2 Polyester Open Reel Tape

Characteristic/Problem	Points added
Format base score	2.5
Age—add 0.005 points for each year of life	0.005–0.27
Long play (1 mil base)	0.5
Double play (0.5 mil base)	1.0
Triple play (0.5 mil base or thinner)	1.2
Unknown if double or triple play (0.5 mil base or thinner)	1.1
Off-brand	0.75
Tracks	0.006–1.0
Sound field—stereo	0.15
Noise reduction	0.5
SBS—SSS	2.0
SBS—UP	2.0
Fungus	1.5
Visible tape pack problems—minor	0.25
Visible tape pack problems—moderate	0.5
Visible tape pack problems—severe	0.75
Other serious documented problems (not any of above)	1.5

8.2.3 PVC Open Reel Tape

Characteristic/Problem	Points added
Format base score	2.5
Age—add 0.005 points for each year of life	0.005–0.27
Long play (1 mil base)	0.5
Double play (0.5 mil base)	1.0
Triple play (0.5 mil base or thinner)	1.2
Unknown if double or triple play (0.5 mil base or thinner)	1.1
Off-brand	0.75
Tracks	0.006–1.0
Sound field—stereo	0.15
Noise reduction	0.5
Fungus	1.5
Visible tape pack problems—minor	0.25
Visible tape pack problems—moderate	0.5
Visible tape pack problems—severe	0.75
Other serious documented problems (not any of above)	1.5

8.2.4 Paper Open Reel Tape

Characteristic/Problem	Points added
Format base score	2.75
Age—add 0.005 points for each year of life	0.005–0.27
Long play (1 mil base)	0.5
Off-brand	0.75
Tracks	0.006–1.0
Sound field—stereo	0.15
Fungus	1.5
Visible tape pack problems—minor	0.25
Visible tape pack problems—moderate	0.5
Visible tape pack problems—severe	0.75
Other serious documented problems (not any of above)	1.5

8.2.5 Analog Audio Cassette Tape

Characteristic/Problem	Points added
Format base score	2.75
Age—add 0.005 points for each year of life	0.005–0.22
120/180 minute	0.75
Off-brand	0.75
Type II or Type IV	0.5
Type III	1.15
Dolby B	0.25
Dolby C, Dolby S, or dbx	0.5
Sound field—stereo	0.15
SBS—UP	2.0
Fungus	1.5
Other serious documented problems (not any of above)	1.5

8.2.6 Digital Audio Tape (DAT)

Characteristic/Problem	Points added
Format base score	4.0
Age—add 0.005 points for each year of life	0.005–0.1
Age—1993 or earlier	0.5
Thin tape-over 60 meters	0.75
Long play format or other 32K sampling rate	0.5
Data-grade tape	0.5
Recorded on portable	0.25
Fungus	1.5
Other serious documented problems	1.5

8.2.7 Aluminum Discs

Characteristic/Problem	Points added
Format base score	3.0
Oxidation or other surface deterioration	1.0

8.2.8 Lacquer Discs

Characteristic/Problem	Points added
Format base score	4.25
Glass base	0.5
Plasticizer exudation (no delamination)	1.5
Delamination—with or without plasticizer exudation	2.0

8.2.9 Wire Recordings

Characteristic/Problem	Points added
Format base score	2.75
Pre-WWII and/or Armour brand	1.0
Rust, oxidation or corrosion	2.0

8.3 Score Comparisons Across Formats

For this or any prioritization tool to work, various preservation problem scenarios for the formats must “feel” right and must make sense when compared one against the other. That is, if you have a collection of tapes with one set of problems and another collection with a different set of problems, the total scores for each must match both the research and archival experience in terms of which is most at-risk and should be a higher priority. Constructing various scenarios helps to test the validity of the instrument. In FACET, major preservation problems put collections in the 4+ range—moderate to severe risk. Additional risk factors are then needed to bring them to the top of the scale—5—or over, in extreme cases. Lacquer disc deterioration, for example, is considered an extreme case. Note that the scores below reflect an age score that was calculated in 2006. They are slightly higher using FACET today.

8.3.1 Major Preservation Problems

Description	Points
1990 DAT (format obsolescence, early DAT)	4.580
1975 Open reel, polyester, with SBS—UP	4.655
1975 Open reel, polyester with sticky shed	4.655
1965 Open reel, acetate with Vinegar Syndrome	4.705
1965 Open reel, acetate with fungus	4.705
1975 Cassette, analog, audio with SBS—UP	4.905
Lacquer with plasticizer exudation, no delamination	5.750
Lacquer with delamination (with or w/out plasticizer exudation)	6.250

8.3.2 Other Problems

Description	Points
1976 Cassette	2.900
1976 Polyester open reel, 1 mil	3.150
1976 Cassette, off-brand	3.650
1976 Cassette, 120 minute	3.650
1976 Polyester, double play (0.5 mil base)	3.650
1965 Acetate open reel, 1 mil	3.705
1976 Polyester, triple play (0.5 mil base)	3.850
1976 Polyester, 1 mil, off-brand	3.900
1965 Acetate with severe tape pack problems	3.955
1965 Polyester with fungus	4.205
1965 Acetate, 1 mil, off-brand	4.455
1965 Acetate with fungus	4.705

8.3.3 Scores over 5

Scores above 5 are reserved for the most serious of problems and the collections that are in extreme danger. 5 is the top of the scale—anything over 5 gives added weight to preservation condition/level of risk if you are combining FACET with a ranking of research value that also has a 5 point scale. This may be appropriate for the most endangered collections where postponing transfer, even if research value is not as high, may result in loss of content.

Description	Points
1985 Sticky shed tape, 1 mil	5.105
1995 DAT with serious documented problems	5.555
1985 Cassette with SBS—UP, 120 minute	5.605
Lacquer disc with plasticizer exudation	5.750
1951 Open reel, acetate, 1 mil, off-brand, Vinegar Syndrome	6.025
Lacquer disc with delamination	6.250
Lacquer disc, delamination, on a glass base	6.750

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10 FACET FORMATS APPENDICES

Appendix 1: Preservation Ranking Scale

0.0—1.9 = Collection is in very good shape and there is little or no risk to its content at the present time.

This collection is relatively stable and safe and is considered to be at little risk. The recordings in this collection are carried on formats that are considered relatively stable at the current time. None of them exhibit problems with deterioration and copies of collection originals have been made. There is at least one copy for every original.

There are no compelling reasons relating to preservation condition to take preservation action with this collection.

2.0—2.9 = Collection is in good shape but there is a small risk to its content at the present time.

This collection is relatively stable and safe but has some minor to moderate risk factors present. Collections in this category may also be in somewhat poorer condition but have multiple, high-quality copies.

There are few compelling reasons to take preservation action with this collection. The collection must have multiple important outside factors present (such as potential or actual use or very high research value) to justify preservation action.

3.0—3.9 = Collection is in decent shape but its content is at some risk.

This collection is carried on formats that are known to be somewhat unstable. The recordings in this collection are *not* exhibiting signs of severe deterioration but may have some minor to moderate problems. They may also have the potential for severe problems that may or may not develop but are currently not manifest.

This collection is at some risk and could be a candidate for preservation action depending on other priorities as well as outside factors such as potential use or research value.

4.0—4.9 = Collection is in deteriorating or poor shape and/or is carried on a format that is nearly or completely obsolete. Its content is at moderate to severe risk.

This collection is carried on formats known to be unstable and/or its recordings are known to be actively deteriorating. Collections may also be placed in this category if carried on a format with serious obsolescence issues. The recordings in this collection are exhibiting signs of moderate to severe deterioration or have other serious problems.

This collection is at moderate to severe risk and is a solid candidate for preservation action.

5+ = Collection is in very poor shape or is rapidly deteriorating, has extensive damage and/or significant deteriorative forces at work. Its content is at serious risk and requires attention soon.

This collection is carried on formats known to be highly unstable and obsolete and/or its recordings are known to be in very poor shape or rapidly deteriorating.

This collection is in serious trouble and is a prime candidate for preservation action. If the content of the collection is to survive with the highest quality possible, preservation action must be taken soon.

Here is another set of categories that might be used to interpret collection scores:

Safe Zone = 0—2.4

Caution Zone = 2.5—3.99

Danger Zone = 4 and up

Appendix 2: Open Reel Tape Charts

Table 1: Open reel tape thickness, length, speed, and reel size for US tape stocks

Time (minutes) recorded one direction at:

Reel Size	Length (feet)	Tape Base Thickness	Playback Speed (ips)					
			0.9375	1.875	3.75	7.5	15	30
5"	600'	1.5 mil	128 minutes	64	32	16	8	4
5"	900'	1.0 mil	192	96	48	24	12	12
5"	1200'	0.5 mil double	256	128	64	32	16	8
5"	1800'	0.5 mil triple	384	192	96	48	24	12
<hr/>								
7"	1200'	1.5 mil	256	128	64	32	16	8
7"	1800'	1.0 mil	384	192	96	48	24	12
7"	2400'	0.5 mil double	512	256	128	64	32	16
7"	3600'	0.5 mil triple	768	384	192	96	48	24
<hr/>								
10.5"	2500'	1.5 mil	532	266	133	66	33	16.5
10.5"	3600'	1.0 mil	768	384	192	96	48	24
10.5"	4800'	0.5 mil double	1024	512	256	128	66	33
10.5"	7200'	0.5 mil triple	1536	768	384	192	96	48

Table 2: Open reel tape thickness, length, speed, and reel size for non-US tape stocks

Time (minutes) recorded one direction at:

Reel Size	Length (meters)	Tape Base Thickness	Playback Speed (cm/s)					
			2.38	4.76	9.525	19.05	38.1	76.2
13 cm	180 m	52 µm	128 minutes	64	32	16	8	4
13 cm	270 m	35 µm	192	96	48	24	12	6
13 cm	360 m	26 µm double	256	128	64	32	16	8
13 cm	540 m	18 µm triple	384	192	96	48	24	12
18 cm	360 m	52 µm	256	128	64	32	16	8
18 cm	540 m	35 µm	384	192	96	48	24	12
18 cm	720 m	26 µm double	512	256	128	64	32	16
18 cm	1080 m	18 µm triple	768	384	192	96	48	24
27 cm	750 m	52 µm	532	266	133	66	33	16.5
27 cm	1080 m	35 µm	768	384	192	96	48	24
27 cm	1440 m	26 µm double	1024	512	256	128	66	33
27 cm	2160 m	18 µm triple	1536	768	384	192	96	48

Appendix 3: Off-Brand Open Reel Tapes in the Collections at the Archives of Traditional Music

A/V Educator	Meteor
Akai	National New Yorker Ozafon
American	(Hungarian)
Audio Magnetics	Norelco
Brand five	Omron
Burgess	Pageant
Command	Panacoustic Permo-
Crescendo	Magnetic/Fidelito
DeJur	Pentron
Emerald	Philips
Europa	Plaza
Ferrodynamics	Primus
Full-Range	Quality Tone
Galaxy	Radio Shack
Gevasonor	Realistic
Goldcrest	Ross
Golden Tone	Sam Goody
Hideli-tape	Sarkes Tarzian
Hi-fi sound tape	Schneider
Hitachi	Shamrock
Hi-tone	Sharp
Irish	Silvertone
Knight	Soni-Tape (Tokyo Tsuchin
Lafayette	Kogyo)
Magictape	Soundmirror
Magnribbon	Soundtape
Magnetband	Spiral Hi-Fi
Magneton band	Stenorette
Mallory	Sunset
Mastertape	Synchrotape
Melody	Timpani
Memorex	Tonemaster
Mercury	Toshiba
Meritape	Web-Cor

Appendix 4: Off-Brand Cassettes in the Collections at the Archives of Traditional Music

AC	Hi-Fi	Profi Sound
AIWA	Hitachi	Radio Shack
Akai	IMA	Realistic
ALME	IMT	Rezound
Arista	International Recotape Corporation (IRC)	Ross
ATNT	Jaf	Sanyo
Audio Magnetics Corporation	JVC	Seiko
Audiomaster	KDK	Sentry
Audiopak	Lafayette	Shanghai
Audiovox	Lebotone	Sharp
Audition	Loewe	SKC
Baba	Lucky	Smat
Bell & Howell	Magnet	Sonotech
Bestron	Mallory	Soundcraft
Boots Audio	Mark	Superscope
Capitol	Maxwell (NOT Maxell)	Superphonic (Zayre Corporation)
Capitol 1 (Same as Capitol?)	Mei-Ya	Super-sound von Focitron
Century	Melodie 2000	Supertape
Century Sound (Same as Century?)	Melody	TapeMaster
Certron	Meltrack	TEAC
Combo	Metro	TEAM
Concertape (Radio Shack)	MS 600	Tips
Contek	Music 2000	Tony
Crystal	National Panasonic	Toshiba
Dak Enterprises	Nivico	T-Series
Denon	Norelco	TSIC
Dindy Super	Nulec	Union 3000
EDU-Cassette (BASF)	Okhai	Unitape
Emitape	Passport (Manufactured by 3M)	Universal
Fujisan	Pfatone	Webcor
GE	Pilipe (NOT Philips)	
General	Pioneer	
Gold	Planet	
Golden	POP	
Goldstar	Prinzsound	

Appendix 5: Type III Cassette Brands

Below are typical Type III cassette brands with photographs to aid identification.⁶⁹ This list is probably not complete. As discussed in section 3.2.1, a Type III cassette has a Type I notch, even though it should be reproduced with the same equalization as a Type II tape. Therefore, most modern cassette players will reproduce Type III cassettes with incorrect equalization.



FIGURE 39: AGFA CARAT

⁶⁹ Some of these photographs are from http://www.melofanas.lt/1left/kol/kolekcija_sarasas.htm



FIGURE 40: BASF FERROCHROM SM



FIGURE 41: BASF FERROCHROM SM



FIGURE 42: BASF FERROCHROM III HIFI STEREO SM



FIGURE 43: SCOTCH CLASSIC FERRICHROME



FIGURE 44: SCOTCH MASTER III

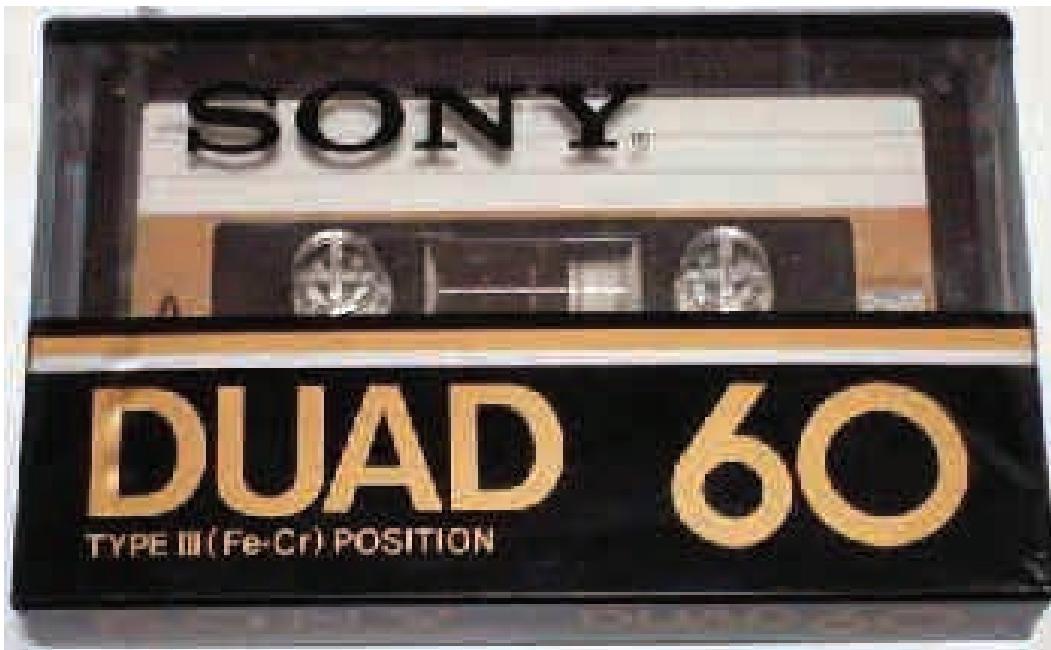


FIGURE 45: SONY DUAD 60



FIGURE 46: SONY FeCr 90



FIGURE 47: SONY FERRICHROME 90

Appendix 6: Relative Stability of Magnetic Tape Components

The table below is a general summary of the relative stability of magnetic tape components. Question marks in the table itself indicate information that is either unknown to us or that we are not sure about.

Format	Base	Stable?	Pigments	Stable?	Binder	Stable?
Open reel	Polyester	Yes	Fe_2O_3	Yes	Acetate? (until early 1970s?)	Yes
Open reel	Polyester	Yes	Fe_2O_3	Yes	Polyester urethane (starting in early 1970s for many)	No
Open reel	Acetate	No	Fe_2O_3	Yes	Acetate	Yes
Open reel	Paper	Chemically stable. Mechanically fragile	Fe_2O_3	Yes	?	Yes
Open reel	PVC	Yes	Fe_2O_3	Yes	PVC	Yes
Cassette	Polyester	Yes	Type I: Fe_2O_3	Yes	Unknown	Sometimes
Cassette	Polyester	Yes	Type II: CrO_2	Somewhat less	Unknown	Sometimes
Cassette	Polyester	Yes	Type III: Fe_2O_3 and CrO_2	No	Unknown	Unknown
Cassette	Polyester	Yes	Type IV: Metal	Somewhat less	Unknown	Sometimes
DAT	Polyester	Yes	?	Yes	Unknown	Yes