Preserving Montreux Jazz Festival Recordings: A New Approach for Restoring Pyral CJ87 Master Tapes

Overview

Degraded magnetic tapes present several challenges for those working in audio preservation. While established techniques like heat treatment (commonly known as 'tape baking') have proven effective in preconditioning various tape types affected by binder hydrolysis (the so-called "Sticky Shed Syndrome"), some tape formulations, like the Pyral CJ87, remain unresponsive to conventional remediation methods. The absence of effective solutions to restore this problematic tape type to a playable condition eventually led the author to develop a new process involving the synergy of tape cleaning and extended tape baking — traditionally considered as separate procedures — to mitigate persistent tape shedding. This article outlines the in-depth restoration workflow that enabled the successful preservation of a collection of Pyral CJ87 tapes containing UNESCO Memory of the World-inscribed concert recordings from the Montreux Jazz Festival, as part of the Montreux Jazz Digital Project — a collaboration between the EPFL in Lausanne, the Claude Nobs Foundation, and the Montreux Jazz Festival.

Over the course of about 24 months, a tape restoration project was conducted by the author, Project Manager at the United Music Foundation, a nonprofit organization established in 2013 in Geneva, Switzerland. The foundation's mission is to preserve, enhance, and transmit recorded musical heritage and its history.[1]

The inception of this project dates back to November 2020, when the Cultural Heritage & Innovation Center at EPFL (École Polytechnique Fédérale de Lausanne)[2] reached out to the author for assistance in preserving a collection of master tapes with historically valuable recordings. Since 2010, EPFL has overseen the Montreux Jazz Digital Project[3] to digitize the *UNESCO Memory of the World*-inscribed collection of Montreux Jazz Festival recordings.

EPFL's inquiry related to recordings originating from the personal collection of the late Franco-Swiss sound engineer Philippe Zumbrunn (1931–2020). Zumbrunn had recorded festival performances on Nagra IV-S tape recorders from 1978 to 1980. His recordings are notable for their excellent sound quality and uniqueness. To ensure their preservation, financial support from the Swiss institution Memoriav[4] was granted to the Claude Nobs Foundation.[5]

The primary challenge in preserving this collection stemmed from most of these concerts being recorded on Pyral CJ87 tapes (Figure 1), which had significantly deteriorated and exhibited persistent shedding.

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With no available procedures for restoring them to a playable condition, the author engaged in discussions with other audio engineers and, through a systematic trial-and-error approach, ended up developing a process that ultimately enabled the preservation of these tapes.

Figure 1. *Pyral CJ87 tape and tape boxes. Source: the author.*

Sticky Shed and Soft Binder Syndromes

"Sticky Shed Syndrome" (SSS) is a condition caused by the deterioration of the binder of magnetic tape, known to affect various polyester tape brands manufactured from the first half of the 1970s onward. Commonly grouped under the broader "Soft Binder Syndrome" (SBS) category, Sticky Shed causes tape layers to stick together (sometimes destructively), produces disruptive squeaking sounds during playback, and causes shedding of pigment on fixed parts of tape machines.[6]

As early as 1982[7], tape binder degradation was enough of an issue for Neal Bertram and Edward Cuddihy to publish a paper on the phenomenon[8]: "for virtually all applications, tapes perform exceptionally well, without user complaint, but occasional problems are encountered. Chief amongst the problems are manifestations related to the tapes becoming sticky, and in some cases, to the tapes shedding gummy and tacky materials which can spread undesirably over various mechanical components of tape drive and recording equipment." Their article argues that maintenance of proper environmental storage can prevent, or even reverse, binder hydrolysis.

At the time they authored this paper, Bertram was a member of the research department at the Ampex Corporation, and Edward Cuddihy was working at the research section of NASA's Jet Propulsion Laboratory (JPL). Ampex manufactured many types of tape, including audio, video, and instrumentation[9], and JPL used mostly instrumentation tape to record scientific data during space missions.

In 1989, Ampex filed for US Patent 5,236,790 for a baking process for tapes, which was issued in 1993.[10] This patent states in part: "The breakdown compounds of this weakened binder migrate, can exude from the coating thus causing the tape to be sticky and to shed." This chemical breakdown has become known as "Sticky Shed Syndrome," often referred to as SSS, and the temporary remediation of heat treatment outlined in the patent is today generally referred to as "baking." The patent states that temperatures of 50–54 °C are preferable, with a range of baking times from 3 up to 24 hours, with a comparatively low RH of 15%.

To this day, both the Ampex patent[10] and the IASA-TC 04[11] have agreed on the following standard approach: "The treatment of hydrolyzed tapes is heating the tape in a chamber at a stable temperature approaching 50 °C and 0% RH for a period of around 8–12 hours. The temperature of 50 °C probably equals or exceeds the glass transition temperature of the tape binder, however, whether that has a long-term effect on the physical characteristics of the tape when returned to room temperature is unclear. It does, however, have a positive short-term electro-acoustic effect by returning the replay characteristics to original condition."

Five years after this patent was issued, audio engineer Eddie Ciletti introduced his own tape baking method in a webpage entitled "If I Knew You Were Coming I'd Have Baked a Tape![12]" This method utilized an American Harvest Snackmaster Pro FD-50 food dehydrator with different temperatures and baking times compared to the Ampex patent: "Provided the wind is smooth, I am not afraid to bake a quarter-inch tape at 135 °F — for two hours — flipping every half-hour. You will find that cooking time varies with tape width, type, brand, condition, and the number of reels being baked. Ampex tape from the seventies might require twice as much time as 3M tape from the eighties."

However, in some cases, baking times increased to an unprecedented degree. This observation was supported by reports from the field, as noted by Richard L. Hess on his "Degrading Tapes" website[13]: "In various conversations, we are finding that the necessary baking times continue to increase, but we have the model of Stuart Rohre's 30-day baking of 1" instrumentation tapes on solid flange Corning 14-inch reels to show us that the current baking times can be significantly extended. These tapes had test signals on them and they reproduced fine."

While "baking" has had a long track record of successful temporary remediation, Richard L. Hess realized in his 2008 *ARSC Journal* article[6] that SSS may be only one type of binder degradation. He and many people he spoke with were finding tapes that would not play even after extended baking. In some cases, it seemed that extended baking would even exacerbate the issue. These tapes still stuck and/or squealed (an audible indicator of rapid stick-slip of the tape and fixed tape-path components, the head being one of those, even if all the other guides are roller guides), while some of them left residue.

The tape that first alerted Hess to this view of the problem was a Sony PR-150 tape that squealed. He found that both over-lubricating the tape-to-head interface (to decrease friction between the tape and the playback head) and playing the tape on a tape recorder in a refrigerator could render the tapes playable for the purposes of a successful transfer. This phenomenon was also observed with 3M 175 and a reel of Melody (a 3M secondary brand) tape.

In email exchanges with the author[14], Richard L. Hess noted that while many people discuss "loss of lubricant" (LOL) as a failure mode (i.e., a putative cause for the squealing or stick-slip that renders the tapes effectively unplayable), he had a squealing PR-150 reel tested and the mass spectrometer showed a normal lubricant load. Enough lubricant was present to allow for playback if the binder had not become softer and stickier.

Therefore, Hess proposed an over-arching term under which to collect all failure modes and their respective remediation techniques relating to binder degradation impeding playback: "Soft Binder Syndrome" (SBS). In his view, SBS is the entire problem, and SSS is a large, but not the only, subset of SBS. For example, cold playback worked with the squealing Sony PR-150 tape because one of the symptoms of some types of SBS is that the glass transition temperature (Tg) of the binder polymer has fallen below room temperature, so lowering the playback temperature below the current Tg of the binder allowed the tape to be played.

To summarize, each failure mode requires a distinct remediation technique. In Hess's understanding, SSS strictly applies to tapes that exhibit stickiness *and* shedding, which can be remedied through baking, as outlined in the Ampex Patent, with adjustments in baking times as necessary.

In the case of the Pyral CJ87 tapes, the author's experience demonstrated that baking does not remedy shedding, even for an extended period, and that they cannot be played without a specialized remediation technique. Therefore, the author believes it is justifiable to categorize Pyral CJ87 tapes within the broader SBS category.

Pyral's Historical Overview

The Société des Vernis Pyrolac was founded in 1926[15] by engineers Albert Barbier Saint-Hilaire, Pierre Chadapaux, and Lucien Ravel. Originally a supplier of paints and varnishes for the automobile industry in Créteil (in the suburbs of Paris), the company initially developed a solid coating layer on a fibrous substrate.[16]

Their connection with the recording industry began in 1929 when a customer requested that they apply a lacquer coating to a flat disc to create a recording blank. This led to the development of precision-machine coating methods and special lacquer formulas.[17]

In 1932, a subsidiary called Pyral (*Pyr*, the Greek word for fire, *al* for aluminum) was created to manufacture coated aluminum lacquer discs, which were sold under the trade name Pyral.[16] Between 1933 and 1946, Pyrolac registered no fewer than eight patents, establishing itself as a leader in instantaneous discs (also called 'transcription discs' or 'acetates') and lacquer discs for cutting and creating stampers for vinyl records, a process that has evolved and is still in use today.

Subsequently, Audio Devices[17] and EMI[16] licensed the rights to manufacture recording discs. In 1946, Pyral became an independent company[18] and expanded into magnetic tape manufacturing[19] and, in the following years, further diversified into perforated magnetic film and compact audiocassettes.

In 1973, Pyral was acquired by Rhône-Poulenc[18], becoming a subsidiary of its plastic film division, Rhône-Poulenc Films. Pyral established distribution partnerships in various countries and subsidiaries in Germany and the UK.[20] Despite international marketing efforts, Pyral tapes remained less popular compared to major brands, and their distribution was primarily confined to Europe and, to a lesser extent, Canada.

While lacquer discs and perforated tapes for the film industry remained Pyral's most successful audiovisual products, the company broadened its range to include various industrial applications, such as magnetic stripes for credit cards and subway tickets. However, in 1980, financial difficulties[21] led to the nationalization of Rhône-Poulenc in December 1981, resulting in the closure of its German and UK subsidiaries.[20] By 1985, Pyral had relocated to Avranches, France[18], focusing on industrial and film applications.

In 1990, Pyral was acquired by Bayer group[18], which already owned the BASF tape brand. Bayer then acquired Agfa tapes in 1992, merging them with BASF and Pyral to form BASF Magnetics France.[22] In 1997, the company was renamed EMTEC Magnetics after BASF Magnetics was sold to the South Korean group KOHAP.[23] Following the Asian financial crisis, EMTEC Holdings was acquired by the British investment group Legal & General Ventures Ltd. (LGV).[24] In 2001, EMTEC Magnetics France became Pyral SAS, expanding its product range to include perforated tapes, transfer foils, lamination foils, magnetic slurries, and magnetic inks.[25]

In 2004, Pyral was taken over by the Swiss group Panachem SA and operated as an independent company.[26] In 2012, Pyral acquired Recording Media Group International (RMGI) and, in an effort to revive the production of magnetic tapes, relocated manufacturing equipment from the Netherlands to Avranches[27], but had to file for bankruptcy in 2013 due to manufacturing delays.[26] In email exchanges with the author, Frédéric Ménétrier commented[28]: "These delays were due in part to the cost of constructing the dedicated building and the significant complexity of relocating and commissioning the coater, partly caused by the lack of knowledge transfer between the RMGI and Pyral teams."

In 2015, Pyral was acquired by the French company Mulann Industries[29], which was part of a group originally specializing in quality control equipment for the card industry.[28] Mulann Industries revived audio tape production under the RecordingTheMasters (RTM) brand. In 2021, Mulann Industries was taken over by RTM Industries, a French company owned by the British investment group Bridford Group.[30]

Frédéric Ménétrier added[28]: "The Pyral brand produced a more extensive range of tape models over the decades than commonly acknowledged. Unfortunately, the company's archive containing their tape formulations had vanished due to changes in ownership. Pyral's most common tape, the CJ87 HR, might have encountered manufacturing issues. However, this is just one of many models among a diverse range including Type 912 E, CJ47, CJ50 SR, CJ89 DH, SD82, DD84, AAT151, all offered in ¼" and some in wider formats for professional audio multitrack applications. These tapes, designed primarily for semi-professionals and professionals, played a crucial role in numerous radio, music, and film productions, and it is essential to improve our knowledge about them to ensure their preservation."

The Pyral CJ87 Tape

The Pyral CJ87 Studio Master tape type (also known as CJ87 HR) was first introduced in 1975[31], while Pyral was still part of Rhône-Poulenc Films.

This matte-backed polyester tape model, with an overall thickness of 57 µm[32], was available in various formats including ¼, ½, 1-, and 2-inch widths.[33] In 1979, Pyral relaunched the CJ87 to reach a broader audience, promoting its release through advertisements and trade shows.[34]

The 1975 version is characterized by a light grey back coating with printing of the tape type and batch (top of Figure 2). The 1979 relaunched version features a much darker grey back coating with printing of the tape type and batch (bottom of Figure 2). It is slightly more rigid than its predecessor.

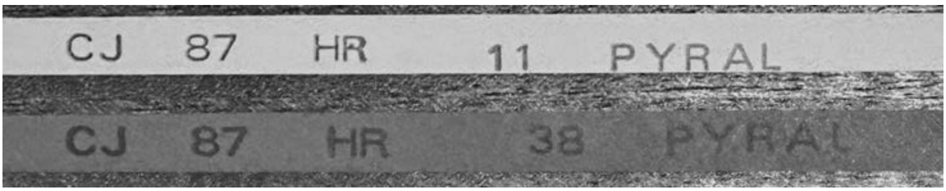

Figure 2. *1975 (top) and 1979 (bottom) versions of the Pyral CJ87 tape. Source: the author.*

Both box designs for their standard 750-meter tape are shown in Figure 3. The smaller box design on the left also exists with red borders.

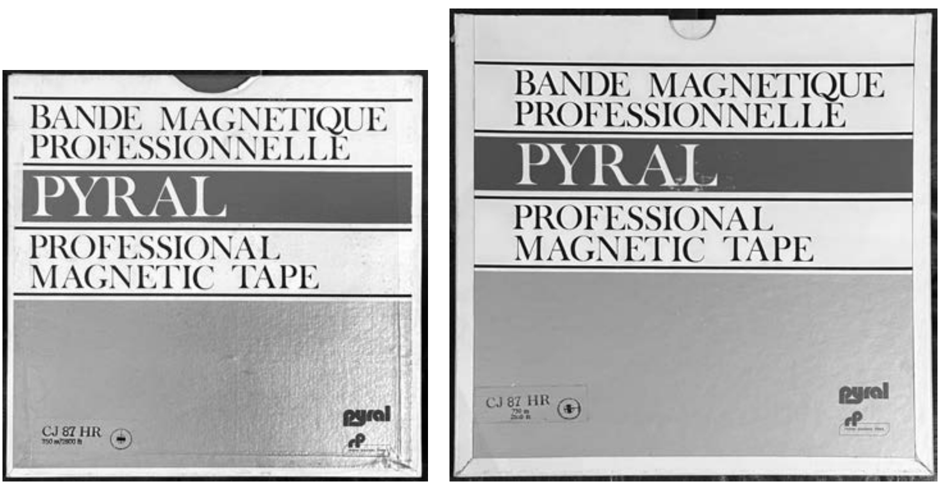

Figure 3. *1975 and larger 1979 Pyral CJ87 tape box designs. Source: the author.*

The main concern associated with both versions of the Pyral CJ87 tape is persistent shedding, which can occur to a significant extent and render the tape unplayable. This major issue is due to back coating degradation, causing particles to migrate to the tape's recorded side.

This shedding problem can lead to squeaking sounds and contamination of the tape path, resulting in the rapid accumulation of a dark, greasy compound — which also suggests that it contains tape lubricant — that significantly muffles the sound in less than 30 seconds due to the increased spacing loss. However, unlike more common tapes affected by "Sticky Shed Syndrome," such as the Ampex 406 and 456, Pyral CJ87 tapes do not exhibit destructive layer adhesion.

Chemical and Physical Inspection

In November 2023, the author provided a sample of Pyral CJ87 blank tape for analysis to Dr. Sebastian Gliga, a scientist at the Paul Scherrer Institute (PSI) in Villigen, Switzerland. The chemical and physical analyses were performed by research fellow Dr. Jack Harrison in the Photon Science Division.[35]

The results confirmed the tape's unresponsiveness to tape baking as well as the migration of back coating particles to the tape's recorded side. The Pyral tape exhibited clear signatures of unplayable tape with "Sticky Shed Syndrome" compared to a non-SSS test (EMTEC) tape (Figure 4).

Moreover, after undergoing an 8-hour baking process at 50 °C (122 °F), its spectrum displayed no significant difference with its untreated state, particularly at the positions characteristic of tapes with SSS marked with vertical lines, indicating that baking does not alter its chemical state, and confirming that it remains unplayable (Figure 5).

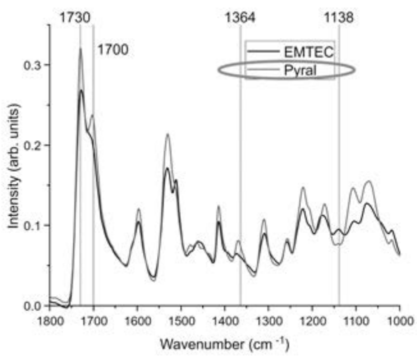

Figure 4. *Fourier-transform infrared spectroscopy of the Pyral CJ87 tape and of a playable EMTEC SM911 tape. The lines indicate characteristic peaks of degraded polyester urethane tapes that are non-playable, along with their wavenumbers as found in references [1[36], 2[37]].*
Source: courtesy of the Paul Scherrer Institute.

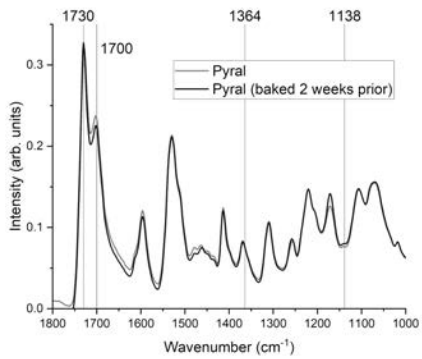

Figure 5. *Fourier-transform infrared spectroscopy of the baked Pyral tape. The spectrum shows no significant difference with respect to the untreated state.*
Source: courtesy of the Paul Scherrer Institute.

When examined under a high-resolution electron microscope, magnetic grains appear as bright micrometer-sized "needles" and large black "blobs" were evident on the surface. This observation is consistent with back coating shedding onto the tape's recorded surface (Figure 6).

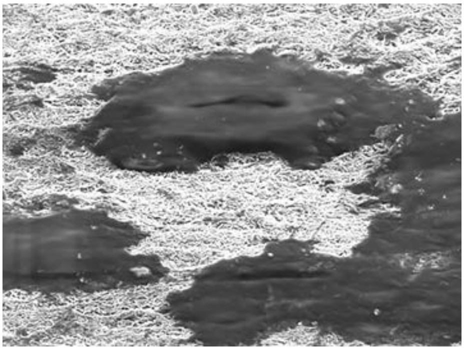

Figure 6. *Scanning electron microscopy image of the Pyral tape surface at 1 µm.*
The large dark 'chunks' are likely pieces of back coating stuck to the magnetic coating.
The visible bright 'needles' are surface magnetic grains.
Source: courtesy of the Paul Scherrer Institute.

Project background and early preservation efforts

In 2014, during early efforts to preserve a Pyral CJ87 ¼" production master for the United Music Foundation containing studio recordings by legendary French singer Nicole Croisille, all of the author's attempts at tape baking failed to mitigate severe tape shedding. To address this challenge, he eventually implemented a workaround by digitizing 20-second segments of each album track while carefully monitoring the audio quality. The digitization process had to be halted at the first sign of clarity loss in the high frequencies, as the tape heads and guides needed cleaning with isopropyl-imbibed swabs before proceeding with the next segment.

This initial process demanded great focus and concentrated listening to accurately identify the critical points for a preservation-grade transfer. After capturing all the segments, these were digitally reassembled to the closest frame and consolidated into a series of audio files corresponding to each album track. While the result proved to be sonically satisfactory, this complex and time-consuming process emphasized the need to find a more efficient method for preserving a larger number of Pyral CJ87 tapes.

This challenge began in 2020, when the EPFL's Cultural Heritage and Innovation Center reached out to the author, Project Manager at the United Music Foundation, to preserve several tapes containing historic Montreux Jazz Festival concert recordings (1978-1980) as part of its broader Montreux Jazz Digital Project. These concerts, recorded by the late Franco-Swiss sound engineer Philippe Zumbrunn, were all on ¼" 38.1 cm/s (15 ips) stereo tapes, with varying head widths depending on the original recording equipment.

Most of these tapes were on Pyral CJ87 tape with Nagramaster tape equalization, a standard introduced in 1971 by the Swiss company Nagra (Kudelski Group) for use at 15 ips (38.1 cm/s) on their professional audio tape recorders. According to their Nagra T service manual[38] and to the MRL calibration tape description[39], the Nagramaster tape equalization has 3180 µs in the low end and 13,5 µs on the high end, i.e., the same low end as NAB with a completely different emphasis/de-emphasis on the high end.

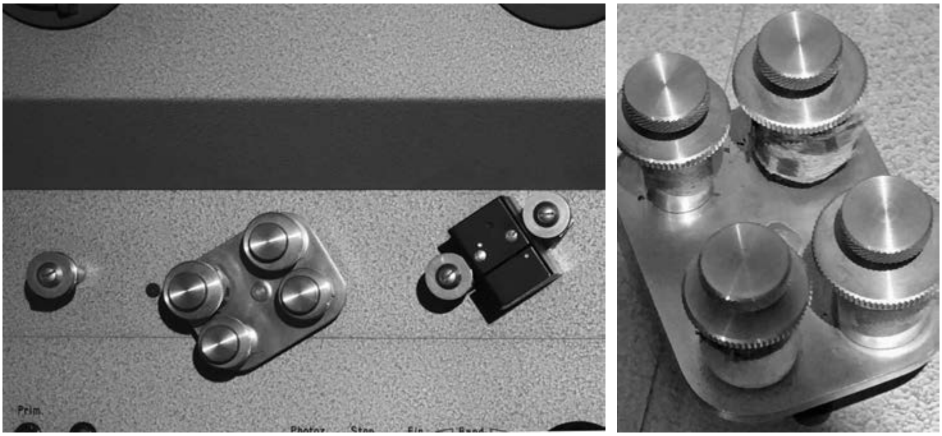

Figure 7. *Closeups of Philippe Zumbrunn's PTT tape cleaning machine. Left: overview of the tape path. Right: closeup of the main cleaning station. Source: the author.*

To determine the most effective approach for this project, the author extensively researched available sources but was unable to find any pre-existing solutions. This prompted him to consult with seasoned fellow audio engineers and engage in discussions.

These exchanges revealed that others had encountered similar challenges with Pyral CJ87 tapes. Jean-Baptiste Meunier, Frédéric Ménétrier, and Gaétan Chaignon (Audio Gecko, Montreuil, France) shared their experiments, which included minimizing tape shedding by adjusting tape tension, attempting longer baking times, and cleaning the tape using Pec-Pad non-abrasive, lint-free camera lens cleaning tissues that would be folded around the tape and either fixed to the headblock or even, sometimes, between the engineer's fingers.

However, they noted that the success of these techniques varied depending on the condition of each tape, and that in some cases shedding remained unmitigated. The author had attempted freezing Pyral CJ87 tapes in 2014 without success. More invasive techniques, such as wet playing or cleaning the tape with a blade, were deemed inappropriate due to the higher risk of damaging the tapes.

Then, the author reached out to Richard L. Hess (Audio Tape Restoration, Repair, and Mastering, Aurora, Ontario), who subsequently created a private group chat on Messenger dedicated to solving the issues encountered with Pyral CJ87 tapes.

In this group, members shared their experiences and, at times, reported mixed results. One of the group's members, Rob Cristarella, Audio Preservation Specialist at the Library of Congress National Audio-Visual Conservation Center in Culpeper, Virginia, reported success with baking four tapes at 130 °F (54.4 °C) in a Fisher Scientific Isotemp gravity flow incubator. Three of the tapes played fine after three overnight cycles, while the fourth required an extra week of baking before it could play. Although the author's experience demonstrated that baking would not remedy a single CJ87 tape, this particular report revealed that exceptions are possible.

Another solution had been found by Philippe Zumbrunn himself after experiencing significant frustration with the unplayability of tapes in his personal collection. He had acquired an early tape cleaning machine built by the PTT (Postal Telegraph and Telephone agency, the former Swiss telecommunications company) (Figure 7). On the footnote of his master tape inventory, which he emailed to the author in December 2015, Zumbrunn had documented his process as follows: “4 passes (2 forward and 2 rewind) on the special cleaning machine to be able to play them afterward without any more issues ... Additionally, I had to redo/change all the tape splices.”[40]

In conversation with the author while lending him his tape cleaning machine[41], Philippe Zumbrunn described the cleaning process as lengthy and challenging, with several unsuccessful attempts before finally being able to play a tape on his Nagra IV-S tape reproducer. However, due to the lack of instructions and the significant accumulation of tape compound on the machine’s fixed guides, the author ultimately decided not to put any tape at risk and to return the machine. Unfortunately, by that time, Philippe Zumbrunn had passed away, and there was no further opportunity to seek clarification regarding the cleaning process.

Nevertheless, Philippe Zumbrunn’s reportedly successful experience prompted the author to search for a tape cleaning machine, ultimately leading to the discovery of the BOW Industries Model 532 Magnetic Tape Conditioner. This model offered several advantages over Zumbrunn’s PTT machine. Notably, it featured four automatically advancing tissue stations specifically designed to prevent the shedding compound from reattaching to the tape while cleaning both sides simultaneously (Figure 8, lower right-hand corner of the image).

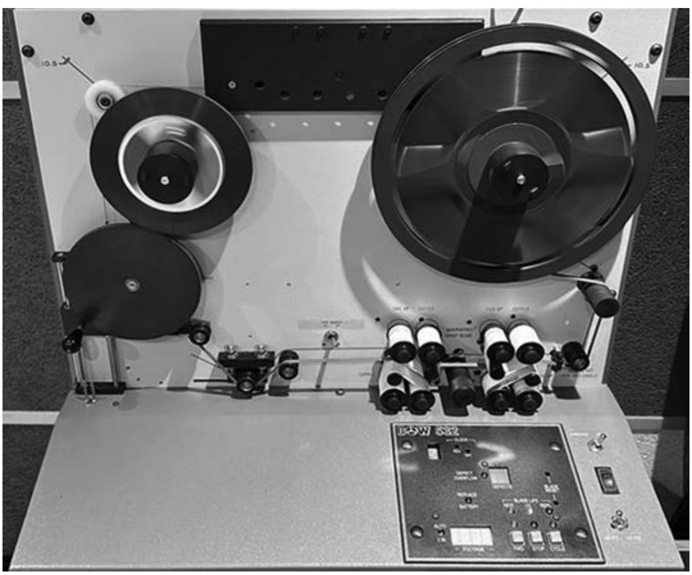

Figure 8. *BOW Industries Model 532 cleaning an open reel tape. Source: the author.*

Thanks to the support of a Geneva-based private foundation, the United Music Foundation was able to acquire a BOW Model 532. The author initially conducted tests using three small blank Pyral CJ87 tapes purchased on eBay, all of which exhibited similar shedding issues. After testing the tape cleaning machine with the three individual tapes, he spliced them together to create a larger tape reel wound onto an AEG spool, and then prepared a clean tape pack using the "Library Wind" function on the Studer A812 tape machine.

Even after subjecting the larger reel to approximately 80 cleaning passes in the BOW Model 532, all three spliced sections continued to shed a significant amount of greasy black/dark grey compound onto the tissues, sometimes accompanied by small grey rubber fluffs. The absence of brown or hazel traces on the cleaning tissues and the intact condition of the tape's magnetic side, showing no signs of scratches or oxide loss, demonstrated that the friction involved in the cleaning process had not caused any damage. Additionally, none of the tape sections exhibited destructive stickiness between layers. Instead, the compound suggested that the tapes were over-lubricated.

Dan Johnson (Audio Archiving Services, Inc., Burbank, California, USA) also introduced the author to an alternative tape cleaning tissue, the 3M 1" 610-1-150 Tape Cleaning Fabric, which he uses for cleaning tapes experiencing lubricant leaching over time. This fabric was compared with the tissue provided with the BOW Model 532 Magnetic Tape Conditioner, and both demonstrated similar efficacy. However, the 3M tissue, being thinner, tends to have a longer lifespan than the BOW Model 532 tissue.

After further efforts to stop persistent tape shedding through cleaning, the author decided to explore tape baking as an alternative approach. He conducted baking tests for extended periods of 5, 10, and even 15 days. After 15 days of baking, he observed a promising development on the tape cleaning fabrics of the BOW Model 532: the greasy dark grey compound from the tape's back coating began to dry, resulting in fewer cleaning passes being necessary in the tape cleaning machine.

Thanks to the combination of tape baking and cleaning, the tape's playback time was extended from a mere 20 seconds to up to 10 minutes. Shedding was significantly reduced and, as the author later discovered, eliminated entirely in some cases.

The author then applied this method to three unplayable tapes containing a 1982 classical concert recorded by Philippe Zumbrunn at the Académie de Musique de Genève. As a result, all three tapes became playable, revealing surprisingly pristine sound quality with only a few minor dropouts due to pre-existing splices. The author preserved this concert recording by transferring it in sections, pausing whenever shedding began to affect the sound quality, and repeatedly cleaning the heads and tape path with isopropyl-imbibed swabs to ensure optimal playback conditions.

Subsequently, all the 24-bit/192 kHz audio segments were reassembled and consolidated to create coherent audio files corresponding to each tape's contents. Finally, the author delivered the resulting digital audio files to the EPFL Cultural Heritage & Innovation Center, along with a Tape Preservation Report.

This positive outcome prompted the EPFL to deliver the Montreux Jazz Festival master tapes to the author, who then initiated the preservation process.

The first batch, preserved in 2023, consisted of 97 tapes, 56 of which were Pyral CJ87. Since 10 of these tapes contained recordings unrelated to the Montreux Jazz Digital Project, the author preserved them for the United Music Foundation with the support of a grant from the City of Geneva. The second batch, preserved in 2024, consisted of 51 tapes, 50 of which were Pyral CJ87. The last reel was a combination of Ampex 456 and Pyral CJ87 tape types spliced together.

These Pyral CJ87 tapes contained concert recordings by legendary artists from various musical genres, countries, and cultures, including Jorge Ben, Willie Bobo, Dennis Brown, Betty Carter, Count Basie, Stanley Clarke, Jimmy Cliff, Albert Collins, Dollar Brand (Abdullah Ibrahim), Fats Domino, Diane Dufresne, Champion Jack Dupree, Rory Gallagher, Marvin Gaye, Stéphane Grappelli, Steve Hackett, Herbie Hancock & Chick Corea, Steve Howe, Irrwisch, Hank Jones & John Lewis, L.A. 4, Miriam Makeba, Jay McShann, Bingo Miki, Mingus Dynasty, Ryoko Moriyama, Oscar Peterson & Niels-Henning Ørsted Pedersen, Ondeko-Za, Bernard Purdie, Toots Thielemans & Dizzy Gillespie, Tito Puente & the Latin Percussion Jazz Ensemble, Steel Pulse, Lee Ritenour, Taj Mahal, Toots Thielemans, Peter Tosh, Gabor Szabo & Joe Beck, Doc & Merle Watson, Xanadu All Stars, and Tsuyoshi Yamamoto.

All of the Pyral CJ87 tapes provided by the EPFL were successfully preserved without exception, using the detailed processes presented in the following sections.

Tape Restoration Workflow

Here is a comprehensive, step-by-step workflow outlining the restoration process for ¼" open reel Pyral CJ87 master tapes.

Step 1: Preparation

1. The Studer A812 tape machine was chosen for its gentle handling, as it is equipped with rotating guides in the tape path.
2. The entire tape path, including the back of the headblock, was demagnetized using a Han-D-Mag Tape Head Demagnetizer. All nearby tapes were cautiously removed beforehand to prevent potential damage during the process.

Step 2: Tape Handling

1. “Pancake” tapes required extra attention when taking them out the box, as Pyral CJ87 tapes are prone to loosening and falling through. (“Pancakes” are tape packs with no flanges, common in Europe where these tapes are placed on a “DIN Plate” and run without a top flange).
2. To prevent a potentially significant amount of tape shedding, each tape was kept from touching fixed components such as heads and non-rotating tape guides. It was routed behind the headblock (see Figure 9). Other tape machines may require the complete removal of the headblock to achieve this routing.

3. Each tape was smoothly and carefully wound, using a reduced speed setting, with a starting point of about 1.3 m/s[42] (51.1 ips) in the Studer's "Library Wind" mode. If there were any signs of the tape sticking, the wind speed was further decreased to prevent any unnecessary stress on the tape.
4. Once this was done, each tape was rewound to achieve a clean and well-packed spool using Studer's "Library Wind" mode at its default speed of 5.0 m/s[42] (196.8 ips).
5. At the end of this process, all rotating guides were cleaned using isopropyl-imbibed swabs.

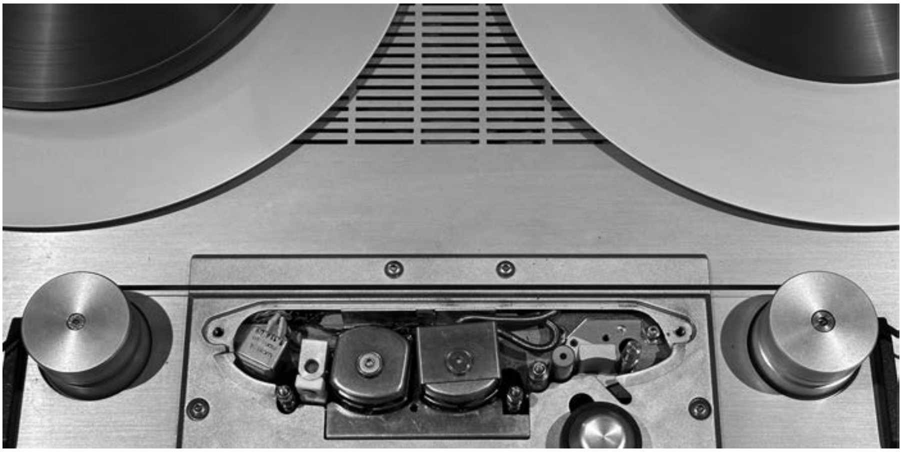

Figure 9. *Winding a Pyral CJ87 tape on a Studer A812 with the tape routed behind the head block. The head block cover was removed for more visibility. Source: the author.*

Step 3: Tape Cleaning and Assessment

1. The BOW Model 532 was used to clean each tape on both sides with non-abrasive, lint-free tissue. Two passes back and forth were performed: one at 60 ips (152.4 cm/s) and another at 120 ips (304,8 cm/s).
2. The cleaning process left traces on the tissues, which varied depending on the shedding intensity:
   - When light gray shedding occurred (indicating light back coating degradation), extra cleaning passes were performed until the grey traces became as clear as possible or disappeared, effectively removing the shedding compound and enabling the tape to become playable with reduced shedding on the heads and tape path
   - When dark grey or black shedding occurred (indicating advanced back coating degradation) (Figure 10), tape baking was performed to dry and facilitate the removal of the degraded back coating compound during the subsequent cleaning process.

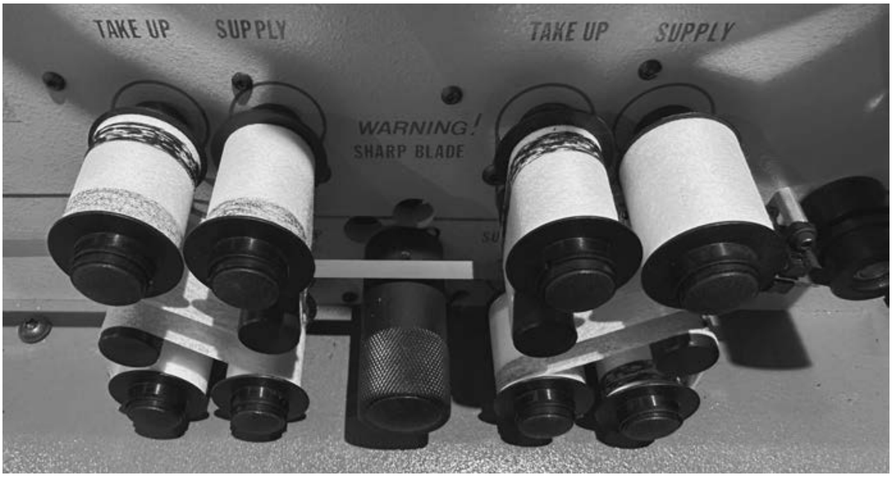

Figure 10. *Cleaning tissues from BOW Industries Model 532 showing black traces left by tape shedding on the tape's recorded side. Source: the author.*

The author initially found that the default tape tension on the BOW Model 532 was fairly 'loose,' resulting in unstable tension during operation. To address this issue, the tension was increased to a maximum of 8 oz. (227 g), which provided better stability and optimized cleaning efficiency. Higher tension values typically produce more shedding, resulting in greater cleaning on the tissues.

To achieve this setting, additional springs provided by BOW Industries were incorporated into the 'dancer' (tension regulator) of the BOW 532 machine (bottom left of Figure 8). Tension settings were then adjusted at both 60 and 120 ips speeds using a blank Pyral CJ87 test tape, monitored with a Tentelometer tape tension gauge. Subsequent tests were also conducted using blank BASF and Agfa tapes to compare the results with the settings established for the Pyral CJ87 tape.

Step 4: Tape Baking

1. When grey or black shedding traces persisted despite cleaning efforts, each tape was heated for 15 days at 135 °F (57.2 °C).
2. After completing the tape baking process, the oven was turned off, and the tapes were left inside to cool gently for 12 to 24 hours.

   Alternatively, the workflow also proved effective when initiated with tape baking, followed by the subsequent steps in their original order, starting with **Step 1**.

While achieving precise and uniform heating typically necessitates the use of a laboratory incubator, domestic food dehydrators are often employed in the industry due to their cost-effectiveness. For many years, the author relied on the American Harvest FD-50, the very model recommended by Eddie Ciletti on his webpage, "If I Knew You Were Coming I'd Have Baked a Tape!"[12]

Further experiments were made by the author with the Stöckli Dörrex, the same food dehydrator model used by the Österreichische Mediathek, as documented in Stefan Kaltseis and Anton Hubauer's article published in the January 2012 edition of the *IASA Journal*[43] (Figure 11).

Although no detrimental effects were observed when using these food dehydrators, the following safety precautions were implemented:

a) The bottom tray always remained empty to prevent any close contact between the tape and the fan motor.

b) The temperature was set within a range of 130 to 140 °F (54.4 to 60 °C).

c) A thermometer was used, with low/high temperature alarms set at 130 and 140 °F (54.4 and 60 °C), to carefully monitor the temperature throughout the procedure and prevent any fluctuations that might compromise the integrity of the tapes.

d) When baking multiple tapes simultaneously, the trays needed to be swapped to improve more uniform heating. Hot air from the lower part was not always evenly distributed, leading to temperature differences between the lower and upper trays. This was particularly noticeable with the Stöckli food dehydrator due to its taller trays compared to the American Harvest one. By swapping them regularly, a more controlled environment was maintained for the tapes.

Figure 11. *American Harvest FD-50 (left) and Stöckli Dörrex (right) domestic food dehydrators. Source: the author.*

In January 2024, thanks to the generous support from a Geneva-based private foundation and the Ernst Göhner Foundation, the United Music Foundation acquired a couple of Binder BF-115 lab incubators (Figure 12).

Through thorough calibration using a Testo 175/T2 reference thermometer, the author observed a temperature variation. Although the incubator was calibrated to 54.4 °C (130 °F) at its center spot, the top and bottom regions were consistently about 2 °C (3.56 °F) colder.

To compensate for this variation during tape baking, the author increased the temperature to 57.2 °C (135 °F). This adjustment proved to be optimal, representing a 'sweet spot' for the baking process, regardless of where tapes were placed within the incubators. After extensive testing with other tapes, the author successfully utilized the incubators for the second batch of Pyral CJ87 tapes containing Montreux Jazz Festival concert recordings.

Figure 12. *Some Pyral CJ87 tapes in one of the Binder BF115 lab incubators. Source: the author.*

Comparing both baking methods highlighted the lab incubator's superior temperature stability, eliminating the need for tray swapping and regular temperature checks. Ultimately, it demonstrated a more effective mitigation of shedding on Pyral CJ87 tapes, marking a significant advancement in the Foundation's preservation efforts.

Thanks to better air circulation and careful temperature maintenance in the incubators, the author observed that some tapes with lighter shedding traces, which had not improved with multiple cleaning passes in the BOW 532, required a shorter baking period of 10 days instead of 15. Furthermore, some of the tapes that had initially exhibited more intense shedding required fewer cleaning passes after baking.

Overall, both baking methods proved to be efficient, and the author observed no undesirable effects that would compromise the integrity of the tapes.

Step 5: Final Tape Cleaning and Assessment

Once the tapes were baked, they underwent another round of winding and cleaning by repeating winding and cleaning (**Steps 2 and 3**) as described above, until shedding had sufficiently reduced to enable playback.

- If shedding traces did not lighten during the cleaning process (**Step 3**), then baking (**Step 4**), followed by winding and cleaning (**Steps 2 and 3**), would be repeated until a successful outcome was achieved.
- For particularly "stubborn" tapes where shedding persisted despite initial efforts, the author found that performing additional cleaning passes (**Step 3**) before baking (**Step 4**) further mitigated the shedding.

The cleaning fabric shown in Figure 13 was used with two different Pyral CJ87 tapes at two different stages of the restoration process.

- On the left, the presence of black traces indicates the shedding intensity of an unbaked tape observed at the initial phase of the workflow, confirming that the tape is in an unplayable condition.
- Conversely, on the right, the light grey traces, which come from a tape that has undergone the entire restoration workflow, exhibit a significant mitigation of shedding and confirm that the tape is now playable.

***Figure 13**. Shedding traces on the same cleaning fabric from two different Pyral CJ87 tapes. Left: Black shedding traces observed at the beginning of the tape restoration workflow. Right: Light grey traces seen at the end of the workflow. Source: the author.*

Digitization process

1. A magnetic viewer was used to select the appropriate headblock, based on the width of the recorded track (Figure 14).

   In most cases, the following was observed for ¼" (6.35 mm) stereo tapes[44]:

   - Stereo tracks with a 2 mm (0.08 in) guard band, requiring an IEC 94-6 1985 2-track stereo head, or
   - Larger stereo tracks with a 0.75 mm (0.03 in) guard band, requiring an IEC 94-6 1985 Stereo head often referred to as "butterfly head," especially in the Studer ecosystem.

   Using mismatched head types may result in unwanted effects. For example:

   - Playing recordings produced with an IEC 94-6 1985 2-track head, or similar, on an IEC 94-6 1985 stereo head may increase hiss or introduce artifacts due to the 2 mm (0.08 in) gap of the stereo recording.
   - Conversely, playing recordings produced with an IEC 94-6 1985 stereo head on an IEC 94-6 1985 2-track head, or similar, will result in reduced playback level and may introduce a "fringing" effect (i.e., irregularities or anomalies in the lower frequencies) due to the narrower tracks on the head.

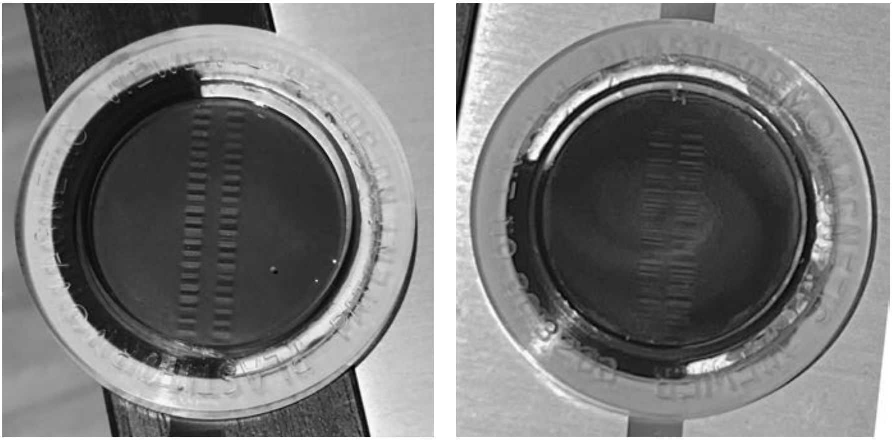

Figure 14. *Magnetic viewer displaying track widths of stereo recordings. Left: narrow tracks with a 2 mm gap, and right: wide tracks with a 0.75 mm gap. Source: the author.*

2. Before playback, the tape reproducer was freshly calibrated, and the head block was demagnetized and cleaned with isopropyl-imbibed swabs. The appropriate speed and EQ curve settings were then selected for each tape.

Original recording EQ curves present in Philippe Zumbrunn's tape collection included CCIR/IEC, NAB, AES, and Nagramaster. However, a Studer tape machine does not normally allow for Nagramaster calibration, but a hidden menu in the A820 (and some other Studer models) provides a workaround.

By accessing the treble setting screen [TRB] of the playback calibration menu and pressing the right arrow button [→] 4 or 5 times (depending on the model and software version), a hidden equalization menu [EQU] is revealed. This menu, which was shown to the author by Studer's former technical manager Roland Baggenstos[45], allows for further adjustments to the playback equalization curve.

Since Nagramaster equalization is actually based on NAB with a different emphasis/de-emphasis in the high end, NAB 15 ips (38 cm/s) was chosen as a default setting for this modification. In the NAB [EQU] menu of the Studer A820, the default value of 68 was then decreased to 20 for the Studer IEC 94-6 1985 stereo "butterfly" head, and to 28 for the IEC 94-6 1985 2-track head (these hexadecimal values are specific to a particular Studer tape machine but provide a general guidance).

This modification enabled Nagramaster calibration using an MRL tape, and the obtained frequency response was validated by Matthieu Latour, audio division manager and Francis Guerra, technical manager at Nagra Audio/Audio Technology Switzerland.[46]

The frequency response measurements, performed using an Audio Precision APx525 analyzer with a IEC 94-6 1985 stereo "butterfly" head, indicated a flat response within ±0.2 to 0.6 dB from 20 Hz to 20 kHz[47], confirming the accuracy and effectiveness of this calibration method.

3. The azimuth of the playback head was adjusted for optimal frequency response while a portion of the tape was being played.[48]

4. Whenever there were important discrepancies between the left and the right channels, the stereo image was corrected by increasing or decreasing the output of one channel on the Studer A820 tape reproducer (Figure 15).

5. The recording level was set on the Prism Sound ADA-8XR A/D converter, and the output of the Studer A820 tape reproducer was then recorded in ProTools Ultimate HDX Digital Audio Workstation (DAW) at a sample rate of 192kHz / 24-bit. To ensure greater stability, an Antelope Audio 10MX Rubidium Atomic Master Clock was utilized.

6. Each tape was digitized in manageable portions, pausing at any sign of shedding affecting sound quality.

   Although the playback time of the Pyral CJ87 tape was extended from a mere 20 seconds to up to about 10 minutes without the need to clean the tape path, shedding was still likely to occur, albeit at a much lower intensity. Therefore, simultaneous listening of each recording was carried out during the entire digitization process, which had to be paused at the first sign of clarity loss in the high frequencies. Before resuming, both the heads and the tape path were cleaned using isopropyl-imbibed swabs.

7. After completing the digitization process, each tape was rewound at a reduced speed, using Studer's default "Library Wind" mode at its default speed of 5.0 m/s[42] (196.8 ips), to create a clean and well-packed spool before returning each tape to its box.

8. All recorded portions were reassembled and aligned to the closest frame in ProTools, and final edits were consolidated into a single audio file containing the entire recording.

9. Each concert was preserved within a separate ProTools session, and a different track was used for each tape within each session.

   Multiple sections per title were systematically managed and archived within the ProTools projects, ensuring that all original files were preserved alongside the edited master recordings. This approach guarantees the availability of both the edited versions and the original recordings for any future reference.

10. For each tape, a comprehensive Tape Preservation Report was prepared in Excel and saved in both database and printable formats. This report, customized to EPFL's specifications, contains the following fields:
    - Concert Title
    - Event Name
    - Location
    - Recording Date
    - Tape Details (e.g., tape number, studio name, etc.)
    - Recording Notes (e.g. musicians, producers, etc.)
    - Concert Reference Number (from Montreux Jazz Festival's database)

- Track Information:
  - Artist
  - Track Number
  - Track Title (verified against original records or label copy information)
  - Track Remarks (e.g. tape degradations, recording quality, etc.)
- Technical Specifications:
  - Tape brand and model
  - Width, Speed, Number of Channels, Track Width, EQ Curve
- Digital Audio Details:
  - File Format (type and resolution)
  - File Name (with extension)
- Processes Carried Out:
  - Tape Restoration (e.g., baking, cleaning, replacement of splices or leader tape, etc.)
  - Tape Transfer Operations (e.g., azimuth setting, etc.)
- Equipment Used (e.g., tape machine, converter, external clock, DAW name and version, tape cleaning machine, with specific models listed)
- Tape Origin (name of the collection)
- Preservation Date

A printed copy of this report was inserted in each tape box.

11. Finally, each edited master and its corresponding Tape Preservation Report, along with an MD5 checksum to verify data integrity, were provided to EPFL.

Figure 15. *Studer A820 tape reproducer with special azimuth adjustment knobs on the top of the headblock cover. Source: the author.*

Further Analysis

The tape restoration workflow described in this article has been specifically designed for Pyral CJ87 tapes exhibiting persistent shedding issues resistant to conventional methods.

The preliminary cleaning passes in **Step 2** of this workflow are primarily designed to assess the condition of all potential generations and batches of Pyral CJ87 tapes, including edited tape masters where shedding may occur on only some portions of the tape. This step can be performed using a tape cleaning machine or a soft, non-abrasive, lint-free cleaning tissue. The observed amount of shedding serves as an indicator of the tape's degradation state. If minimal shedding occurs, the tape is probably still playable and may not need to go through the entire workflow.

While Philippe Zumbrunn documented the success of his own tape cleaning method in 2014,[41] offering a ray of hope for preserving these tapes, the potential harm that extensive baking and cleaning could cause to the tapes remained a major concern throughout the project.

Therefore, from the very beginning, all potential risks, including wow and flutter, loss of high frequencies, and dropouts, were addressed through extensive precautionary testing. In addition, regular maintenance and calibration of the playback, cleaning, and baking equipment, along with further testing, were carried out until the project's completion. All tests confirmed no signs of physical or audio damage, as evidenced by the pristine sound quality of the recordings, which highlighted the resilience of Pyral CJ87 tapes.

Furthermore, the Studer A820 tape machine, known for its sensitivity and tendency to automatically stop when detecting unstable tape tension, showed no signs of stress during playback, and none of the tapes exhibited significant stickiness after the described workflow. The only recurring issue was residual shedding, which, although significantly reduced, still necessitated regular cleaning of the heads and tape path.

Regular cleaning emerged as a critical factor for post-editing. Overlooking this process resulted in signal degradation over time, making it impossible to accurately locate an edit point. The difference in sound quality at edit points was evident in both audible aspects, discernible through listening, and visible characteristics, observed through waveform analysis in ProTools and spectral analysis in iZotope RX. Consequently, the only viable solution was to revert and recapture the degraded segment with clean playback heads.

While indefinite storage in a climate-controlled environment to halt or reverse the degradation process was never considered by any parties involved in this preservation project, the author had the opportunity to compare Pyral CJ87 tapes from various sources, batches, and storage conditions. For example:

- The aforementioned Nicole Croisille production master tape, preserved in 2014 by capturing 20-second segments, originated from the climate-controlled tape archive facility of EMI France (now Warner Music France), where it had been stored for over 25 years.

- Philippe Zumbrunn's tapes had all been kept on the shelves of his living room for many years before their recent transfer to EPFL's premises.
- All the test reels purchased by the author on eBay had been stored in unknown conditions, though they appeared to be new.

Yet, despite their different sources, manufacturing batches and storage environments, all these tapes exhibited similarly persistent shedding.

Although isolated, this example, based on the examination of over 100 Pyral CJ87 tapes, casts doubt on the efficacy of stable conditions in slowing down or halting their deterioration. Moreover, the absence of specific research makes it difficult to determine whether stable environmental conditions, including low temperature and relative humidity, could effectively halt further decomposition of this specific tape type.

In the broader context, the fact that the entire tape medium is considered obsolescent poses a significant risk. It is not just about the potential for further decomposition and the emergence of new degradation symptoms (such as the more recent adhesion syndrome[49]), but also the limited amount of research being conducted or shared, particularly on lower-market-share and problematic tape types.

During email exchanges with the author[14], Richard L. Hess noted that "the lack of funding for this type of research and the limited availability of control samples do not always allow for further experimental evidence that would be conducive to rigorous laboratory analysis.

"Yet, dismissing it as 'anecdotal' is equivalent to ignoring the issue and does not facilitate the recovery of the content entrusted to these degrading carriers. On the other hand, scholarly work publications (like the 'water drop test'[50] paper and other investigations of this kind) are interesting for a better understanding of failure modes, but so far have only had limited influence in advancing the craft of recovering degrading tapes.

"With the apparent unknowable batch-to-batch variations in tape manufacture, coupled with the varied and generally unknowable storage history of each tape, the most useful current information typically is provided from people in the trenches trying to get work done and sharing as much information as possible so that trends may become more visible.

"Increasing the sample size and combining the expertise of multiple practitioners increases all our confidence as we strive to do no harm while recovering content from increasingly degraded tapes. This is the philosophy behind the "Degrading Tapes" website.[13]

"Some of this has been discussed in the ARSCList[51], which is archived in two parts (the early part at Conservation OnLine website (CoOL) maintained by Stanford University[52], and the later part at the Library of Congress[53]). Substantial further discussions have continued on several other mailing lists and their descendants, including the Ampex List at recordist.com[54] and the Studer-Sony-MCI-Pro List at groups.io."[55]

Conclusion

Preserving Pyral CJ87 tapes has proven to be a challenging endeavor, primarily due to their resistance to conventional remediation methods. To address this challenge, the author engaged in discussions with other audio engineers and, through a systematic trial-and-error approach, ended up developing a new process involving the synergy of tape cleaning and extended tape baking — traditionally considered as separate procedures — to mitigate persistent tape shedding.

The application of this process, outlined in this article as an in-depth restoration workflow, resulted in extended playback durations which ultimately enabled the author to preserve a collection of historic Montreux Jazz Festival concert recordings made on Pyral CJ87 tape by the late Philippe Zumbrunn between 1978 and 1980.

The findings presented in this paper aim to inspire further research into preserving legacy recording media, especially challenging tape formulations that are unresponsive to conventional remediation methods. Sharing expertise among audio engineers and preservation specialists is crucial to maintaining cultural heritage stored on problematic media for future generations. This article stands as a testament to this commitment.

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David Hadzis *started out in the music industry in 1985, when audio tape was still the standard format. For more than three decades, he has collaborated with several major artists, musicians, and producers in various capacities, including songwriter, producer, sound engineer, and executive producer. He has also worked on a multitude of recordings, reissues, and compilations through his own audio services and project management company. Since 2013, he has been the Project Manager of the United Music Foundation, an award-winning nonprofit subsidized by the City of Geneva, where he is responsible for preserving, restoring, and enhancing recorded musical heritage.*

Endnotes

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45 Baggenstos, Roland (2022). Personal communication with the author in September 2022.

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32 Hz: -3.8/-3.7; 63 Hz: -4.0/-4.0; 125 Hz: -3.9/-3.9; 250 Hz: -3.9/-3.9; 500 Hz: -4.0/-4.1; 1 kHz: -4.0/-4.0; 2 kHz: -4.0/-4.1; 4 kHz: -4.1/-4.2; 8 kHz: -4.1/-4.2; 10 kHz: -4.0/-4.1; 12.5 kHz: -4.0/-4.0; 16 kHz: -4.2/-4.1; 20 kHz: -4.6/-4.4.

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