# THE REVOLUTION OF DUPLICATED MUSIC: SONIC MARKERS TO IDENTIFY EARLY PHONOGRAPH CYLINDER COPIES IN ARCHIVE COLLECTIONS

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## Abstract
This article explores the evolution of early commercial music production and the shift from selling original recordings to duplicated copies. It focuses on the introduction of the pantographic duplication technique, which allowed for successful mass production of phonograph cylinders. The pantograph copied cylinders mechanically, using the same blank cylinders as original recordings. This made the two products difficult to distinguish. The music industry kept this process of duplication a secret, selling duplicated copies labelled "original" and "master" quality. Recent research reveals that mechanical duplication through the pantographic method was more extensive than previously acknowledged, with millions of copies produced in a short timeframe. The author commissioned the production of a contemporary pantograph copy of a cylinder recording. Its analysis uncovered characteristic sounds and defects, such as additional mechanical noise, deteriorated signal-to-noise ratio, errors in the time axis, and excess harmonic distortion. These signatures can help differentiate between original recordings and pantographic copies in archive collections. Understanding the implications of early duplication techniques also contributes to a better understanding of the development of the music industry and its recording practices.

**Keywords:** phonograph cylinders; music production history; audio analysis; pantographic duplication

## Introduction
The first product offered for sale of prerecorded music was the engraved phonographic cylinder (UC Santa Barbara Library, 2024). The evolution toward the commercial sale of prerecorded music could seem uncomplicated, given the introduction of Edison's commercial phonograph in 1888 (Edison, 1888). However, the steps taken to establish a music industry around the invention were complex and interesting. One important step in the development process of music production was the shift from the sale of original recordings to the sale of duplicated copies (Chamoux, 2015, p. 173). This development was a pivotal step to establishing the music record as the entity it is today. The earliest commercial recordings, in addition to being unique versions, had the disadvantage of having a limited number of playbacks before deterioration of the recorded audio. Thus, the sale of original recordings did not hold the same notion of timelessness as that of duplicate recordings. The single original cylinder could only be played back a set number of times and always depended on the location of the single original cylinder. Edison compared the first recordings to audible telegrams, using the descriptive term "phonogram" (Edison, 1888, p. 647). Copies, on the other hand, could be played back simultaneously at different locations and for an increased number of times. For the first time, a geographically dispersed audience for recorded music could connect to a common reference point by buying and listening to the same recording. In 1916, the process

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of music production for mass duplication was even described as one in which the artist would “sing their way into eternity” (Aftenposten, 1916, p. 4).

Large-scale commercial music production is often attributed to the introduction of duplication through molding and casting (Martland, 2012, p. 12). Early techniques were described as slow, clumsy and limited (Martland, 2012, p. 11), and more focused on the production of cylinders for coin-slot machines (Gronow, 1983, p. 54). As early as the 1940s, people expressed a pejorative attitude toward early engraved cylinders compared to later cast copies. The early cylinders were described as low-quality and produced for personal use (Hegerman-Lindencrone, 1943, p. 92). This attitude may have led scholars to focus on the later molded cylinders and duplicated discs rather than on these earlier brown engraved cylinders.

### One of the best-kept secrets of the music industry

Contemporary research reveals a more nuanced picture of the cylinder industry. Using existing corporate records from Pathé Frères, Henry Chamoux (2015) found that the company’s volume of production developed earlier than previously acknowledged (Chamoux, 2015, p. 410). Around the turn of the century, it was estimated that only a handful of copies could be made from each recording and that the production of prerecorded discs, cylinders and cylinder blanks was 2.8 million in total (Brooks, 2002, p. 23). Original documents state that Pathé alone produced more than two million prerecorded cylinder copies via mechanical duplication between January 1900 and August 1902 (Chamoux, 2015, p. 220). The escalation in production at Pathé was quite rapid. The mass duplication started with the October 1899 signing of a deal with Luis Casarès, a Spanish designer of cylinder duplication systems (Chamoux, 2015, p. 218). Casarès moved to France to oversee the building of a factory and was to be paid 100,000 francs for the production of two million cylinder copies. The installation of 120 duplication machines started in January 1900. Production was estimated at roughly 50 cylinders a day for each machine, with a 10-15% rate of bad copies. In August 1902, Casarès received a final payment for the production of the cylinders, who then returned home to Spain (Chamoux, 2015, p. 220).

In Norway, a similar escalation in the availability of recorded cylinders was observed during the same period. In 1900, the first advertisement campaigns for locally recorded music appeared in local and national newspapers. Two dominant local producers, Anders Skog and Adolf Østby, began their advertisement campaigns in June 1900 (Skog, 1900; Østby, 1900), offering affordable machines and a list of titles available by mail order throughout the country. The ads frequently mention that their cylinders are original. However, this does not exclude them from the possibility of being copies.

In the United States, court documents from 1898 reveal the record industry knowingly sold duplicates marked as “original” and “master” quality (Wile, 1985, p. 24). By falsely labeling duplicates as originals, the record industry gave the public the impression that most brown commercial cylinders were original recordings. Read and Welch (1976, p. 80) discuss how this secrecy led writers reporting on the period to wrongfully assume that mechanical duplication methods were seldom used. Hegermann-Lindencrone described the duplication technique as one of the best-kept secrets in record production history (Hegermann-Lindencrone, 1945, p. 35). As an example, he mentions Numa Peterson in Sweden, who used a copying technique even before 1900, in which the sound was transferred mechanically by a lever. Numa Peterson kept the originals in sealed boxes and sold copies (Hegermann-Lindencrone, 1943, p. 94). However, Peterson’s ads stated that all cylinders for sale were originals as late as 1903 (Numa Petersons Handels & Fabriks

AB, 1903). It seems both Pathé Frères and other manufacturers went to great lengths to ensure their production of copies remained hidden. The duplication seems to be kept secret even from the recording artists (Cummings, 2013, p.18). When Casarès was building his duplication factory for Pathé, the administrative board emphasized a goal of secrecy. The factory was to be built in Casarès' personal garden, isolated from the rest of the plant and kept secret (Chamoux, 2015, p. 218). Similarly, patents and duplication factories were kept hidden in America, where pantographic mass production started as early as 1891 (Wile, 1985, p. 23). Initially, Edison openly offered duplicated cylinders, but after a brief time, he and his contemporaries actively hid their duplication efforts. In Chicago, a company-run duplication facility even marked the facility entrance door with skull and crossbones (Wile, 1985, p. 19).

One possible reason for this secrecy was to protect the music business from unauthorized copying. If the public learned of the existence copying techniques good enough to be used by the major companies, it could lead to an increase in the production of unauthorized copies. In the early days of the phonograph, unauthorized copying was a substantial problem (Cummings, 2013, p. 13). To restrict the activity, larger companies bought duplication patents (Wile, 1983, p. 22) and made announcements in the beginning of the cylinders as evidence of origin (Wile, 1983, p.21). Another explanation is that the illusion of selling originals provided economic benefits to music production companies (Read & Welch, 1976, p. 81). To the public, duplicates were considered inferior (Brooks, 1978, p. 12; Cummings, 2013, p. 15).

By the turn of the century duplication technology was also widely available in Europe. In the first few issues of the German publication *Phonografische Zeitschrift*, duplication machines are repeatedly advertised for commercial sale (Phonografische Zeitschrift, 1900a). The ads boldly state that the machines can produce copies indistinguishable from the original. The same publication also describes the new mass-produced products in a separate article, claiming these new products are of inferior quality and should be priced and treated as such compared to original cylinders (Phonografische Zeitschrift, 1900b). However, mechanical mass production is described as no worse than production using multiple recorders and multiple takes, which affects the placement of recording horns and puts stress on the performer. To duplicate the best take from a perfectly placed recording horn could result in a product quality just as good as that of an original cylinder from an improperly placed machine recording an exhausted artist, the article argues. The relationship between technical quality and performance during this time could seem odd for the contemporary reader (Cummings, 2013, p. 17). At the time most advertisements focused less on the artistic performance but more on the cylinder's ability to be loud and clear (Cummings, 2013, p. 16).

A revolutionary mechanical copying technique, known as the pantograph duplication method, was described early on in a patent held by Gianni Bettini (1892); however, several similar machines were built around the world at the same time as Bettini's (Read & Welch, 1976, p. 81). Bettini describes two cylinders that are placed on connected mandrels so the original and copy rotate at the same speed (Figure 1). The engraving process resembles that of a pantograph, in which the reading stylus is connected to a writing stylus through a hinged lever. Once the reading stylus is forced in a direction, the writing stylus follows.

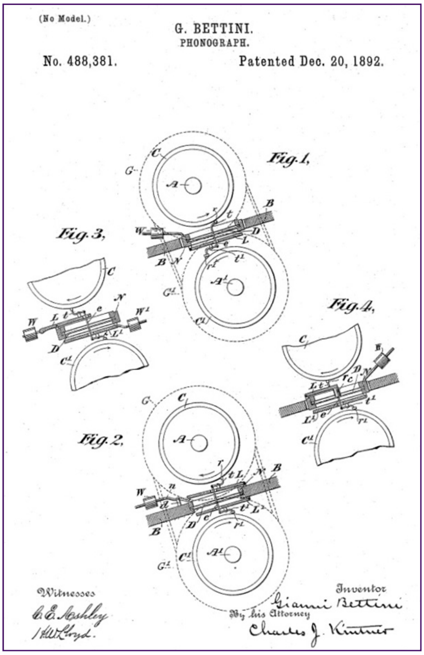


Figure 1. Drawings from patent 488 381 (Bettini, 1892).

**Audio quality in commercial mechanical copies**

The quality of the early mechanical copying technique is unclear. Early attempts at mechanical copy techniques used locked horns, with the reproducer facing the recorder's horn. Another technique was to insert rubber tubes between the diaphragm of the reproducer and recorder (Wile, 1985, p. 22). In comparison with these techniques, the pantograph reflects a clear technological advancement. Given the commercial success of the pantograph method and its important role in the early days of mass-produced music recordings, it is worthwhile to examine the characteristics of the technique and how the technique affected the sound quality of recordings. Duplication through pantograph was widespread in the early 20th century; however, the fragility of the cylinders and their subjection to rough treatment has left just a small number of such recordings available for study today. The pantograph copies were made using the same soft material as the originals, whereas cast copies used a harder and more enduring material. Today, a cylinder with a seemingly unique content could possibly be either an original, unique recording or the last remaining copy of a duplicated recording. To scholars of music production history, the difference is significant. The commercial use of duplication technology represents an important step in the development of the record industry. The durability of master recordings was low. A master cylinder could only produce 25-100 copies (Read & Welch, 1976, p.82). To use a variety of settings and placements and produce multiple master recordings of the same performance, artists would often perform before multiple recorders. This way the audio engineer could select the best cylinder for duplication (Morton, 2004, p. 27).

The largest collection of recordings created using the pantograph duplication method is that of Pathé Frères. Pathé Frères used this method for both cylinders and discs on all their acoustic production into the 1920s. Henri Chamoux, an expert on Pathé Frères recordings, noted several sonic markers that can be used to identify pantograph copies, along with examples that can be verified through the Phonobase database[2] (Chamoux, 2019). Chamoux identifies three broad categories of signature sounds in the Pathé recordings. One category is "machine noise," one subtype of which is described as sounding "like a galloping horse". Examples of this type of machine noise can be heard in Pathé catalog numbers 1007[3] and 3384[4]. Another subtype of machine noise is a low-pitched thump resembling a heartbeat, which can be heard in Pathé catalog number 1589[5]. A third subcategory is periodic colored noise, as in Pathé catalog numbers P3113-2[6] and 3387[7]. The most striking variety of machine noise is described as "entry noise," which consists of extra background noise introduced shortly before the content. The first moments of the recording have a slightly lower level of background noise that is altered just before the content. An example of entry noise can be heard in Pathé catalog P3117[8]. The second group of audible defects Chamoux identifies consists of distortions of the original signal, as can be heard in Pathé catalog number 969[9]. The third group are artifacts caused by misalignment between the grooves of the original and the copy, resulting in missed or locked grooves, as heard in Pathé catalog number 569(22)[10].

Notably, an original recording may also be prone to these same flaws if, for instance, the original recorder had defects or if it was poorly engineered. For single private recordings, this may be the case; however, it is important to avoid underestimating the craftmanship of music production in commercial recordings from the acoustic period. Acoustic recording engineers learned from experience how instruments and performers should be best placed and selected the best recording horn and adjustments to fit the production (Morton, 2004, p. 26). Acoustic audio engineers, even at small domestic labels, took great pride in their sonic output. In a 1916 newspaper article describing a recording session for the Scandinavian Pathé agent William Farre, the quality control stage for the master cylinder is described in detail. Immediately after recording, the master cylinder was replayed and analyzed by the producer, engineer, and artists. Small flaws were found in the recording, prompting adjustments and subsequent re-recording and listening cycles until all parties approved of the result (Aftenposten 1916, p. 4). Modern experiments re-enacting acoustic recordings point to the technical skill and finesse of engineers displayed in historic acoustic recordings (Kolkowski, Miller & Blier-Carruthers, 2015). However, not all recordings were done with such care for detail. The alternative mass production technique described by the *Phonografische Zeitschrift* (1900b), in which multiple machines and multiple takes were used, increased the likelihood of large or small defects in the finished product.

## Experimental copy of a test cylinder

To study the distinctions between original recordings and copies of cylinders in more detail, an investigation was undertaken to find a working pantograph and to create pantographic copies to examine. Berlin Phonograph Works and Norman Bruderhofer briefly

2 www.phonobase.org
3 www.phonobase.org/8964.html
4 www.phonobase.org/9062.html
5 www.phonobase.org/2649.html
6 www.phonobase.org/7832.html
7 www.phonobase.org/9067.html
8 www.phonobase.org/7842.html
9 www.phonobase.org/9225.html
10 www.phonobase.org/1609.html

had a working Edison Studio pantograph from the late 1890s available[11]. In 2017, the author of this article ordered pantographic duplication of two cylinders for testing purposes (Bårdsen, 2019, p. 130). For original cylinders, two newly produced test cylinders from Poppy Records were selected (Poppy Records, 2024). The test cylinder content consisted of a frequency sweep shifting from 5 kHz to 20 Hz, followed by single frequencies at 400 Hz, 800 Hz, 1,000 Hz, 1,600 Hz, and 3,200 Hz. The test cylinder was a special combination of their model CXPn001 and CXPn003 (Poppy Records, 2024). Unfortunately, higher frequencies were not chosen for the test due to the limitation imposed by the available test cylinders. In future studies, expanding the frequency range to include higher frequencies would undoubtedly provide valuable insights into the characteristics of the recordings in the higher frequency regions. Poppy Records produced the originals using an electric cutter head recording onto high quality wax blanks supplied by Paul Morris Music (Poppy Records, 2024). The same brand of wax blanks was acquired and used for the duplicates. The goal of the experiment was to closely examine the copying process. However, there are some limitations to this study that should be considered. First, the experience, skill, and knowledge available when this technique was in full use no longer exist today. In the early 1900s, dedicated professionals made original recordings with the pantographic process in mind and could fine-tune their duplication machines and handling techniques to produce a better result than is possible today. The age of the machinery is another factor to consider. The machine used for the study was built in Edison's facility in West Orange, New Jersey in 1898 (Bruderhofer, 2020). At this time, Edison had mastered the molding process through the "press" method and used this in tandem with the pantograph (Wile, 1985, p. 20). The molded first-generation copies were cast in a harder material and then used to create pantographic copies on demand. Thus, the machine in use for this study may have been made with the intention of using harder originals than the soft brown direct-cut original used for this study.

Bruderhofer used the machinery to produce the two copies as requested. There were two primary findings from the copying process itself. First, Bruderhofer reported some difficulty synchronizing the two cylinders. If the copy started recording before the cylinders were perfectly in sync, the pitch of the content in the copy would vary until the two were synchronized. Often this is heard as a short sweep from an unnatural high pitch in the first second of the content. To achieve the best copy of the content from the original, Bruderhofer started the recording slightly before the start of the master cylinder to leave a few extra seconds of silence at the beginning of the recording. Bruderhofer reported that doing so made it challenging to copy the content from a full master cylinder onto a copied cylinder. If the content was delayed too much, the ending would be cut short. The duration of the test cylinder was a bit long at 2 minutes and 15 seconds in total. On the first attempt, the content was cut short by a few seconds, but on the second attempt, the complete content was copied over.

## Analysis

In the laboratory at the National Library in Norway, the two cylinders were played back using an Archeophone contemporary cylinder reproducer and analyzed using a Cedar Cambridge digital audio workstation[12]. The special design of the Cedar Cambridge

11 Norman Bruderhofer is a German technician and specialist on phonograph cylinders and their reproduction. He runs the project Berlin Phonograph Works where he reproduces rare cylinders and provides modern cylinder copies for sale. For more information, visit www.phonoworks.com.

12 Cedar Cambridge 64 bit v1 1.0.0.9487, https://www.cedaraudio.com/products/cambridge/cambridge.shtml.

Spectrum Analyser can display the average amplitude at each frequency over a given time span with a resolution of 0.02 Hz (Cedar Audio, 2024). This gives a clear and simple graph which also makes it possible to visualise both the copy and the original in the same window. In addition, the Cedar Cambridge workstation can display a spectrogram where the vertical axis displays frequency, the horizonal axis represents time, and the amplitude is represented by color. The colors with the lowest wavelengths, like purple and blue, represents the lowest amplitude of the audio signal while the colors with the highest wavelengths, like orange and red, represents the highest. The two methods complement each other. The average amplitude analysis offers a detailed examination of frequency amplitude performance, while the spectogram provides a broader overview including time.

First, the noise floor[13] was examined. On the copy, the initial run-in groove received a boost when the signal from the reproducer started. The sample in Figure 2 was taken just after the introduction of the reproducer signal and before the program material started, representing the noise floor. The Cedar analysis (Figure 2) indicates a clear increase in the noise floor.

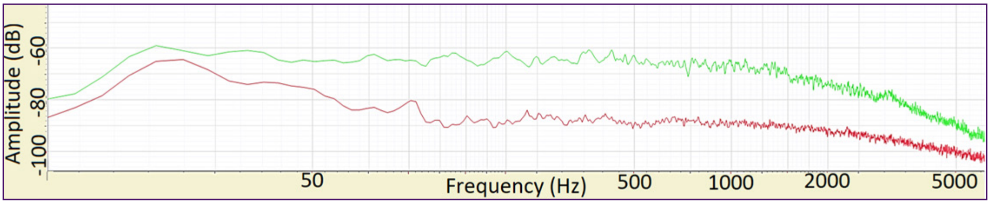


Figure 2. Noise floor original (red) versus copy (green).

The extra noise introduced at the beginning of the cylinder prior to the content material is a telling indication of a pantograph copy. Another finding from the audio analysis is a small but distinct mechanical noise introduced in the copy. In the copy, there is a lead-in groove with a few cycles of noise before the introduction of the reproducer signal. As soon as the reproducer signal starts, there is additional background noise caused by the copy technique. The shift in the noise floor representing the addition of the replay system starts at about 2 seconds into the recording. In examining the noise floor at the start of the recording and shortly past the 2-second mark, the added noise was found to be strongest between 100 and 800 Hz (Figure 3).

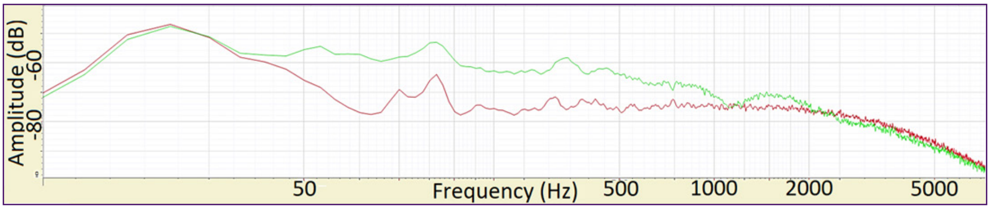


Figure 3. Red noise floor: before introduction of reproducer. Green noise floor: shortly after introduction of reproducer.

13 The term noise floor refers to the level of noise produced by a system itself with no external signal.

The first section of the cylinders contains a frequency sweep shifting from 5 kHz to 20 Hz. A close analysis of this sweep reveals that the copy is imperfect in certain areas of the frequency spectrum. Figure 4 shows the average amplitude of the whole sweep. At 65 seconds this is the longest content analysed in this study by the average amplitude method. Above 4000 Hz and below 200 Hz the copy fails to reproduce the signal adequately. Between these points the copy more closely replicates the original.

Overall, the signal strength is not greatly reduced, but the copy is not linear compared to the original. Signal loss can be noted with certain frequency bands, such as the region around 1500 Hz, while other areas, like the region around 2700 Hz appeared to be amplified.

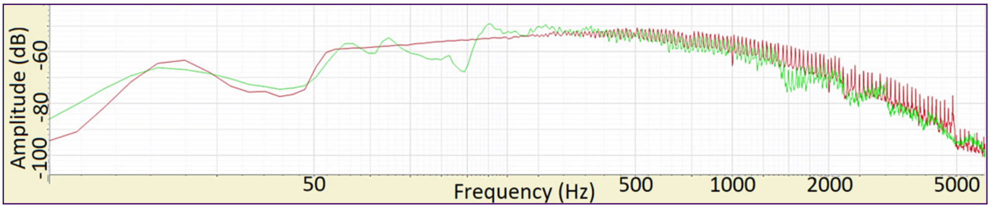

Figure 4. Sweep. Original in red and pantograph copy in green.

This observation is strengthened by examining the next section of the cylinders containing single frequencies. The overall volume of the copy is close to that of the original, but the content's linearity is distorted. The single frequency analysis reveals that the pantographic method has a severe effect on the amount of harmonic distortion present in the copy (Figure 5). Examining spectrograms of both the original cylinder (Figure 6) and the copy (Figure 7), the increase in harmonic distortion caused by the pantograph process is seen throughout the copy. This increase in distortion is a clue that can help determine whether a commercial brown cylinder is an original or a pantograph copy. Conversely, the overall volume or frequency spectrum is less useful as a clue because the copy is as loud as the original and has a similar frequency spectrum.

The unwanted additional noise is directly caused by the pantograph method; thus, the noise could vary in character depending on the success of the pantograph mechanism design but will likely remain consistent in copies made on the same machine. Future researchers could consider using this additional noise as a clue to determine the fabrication history of copies.

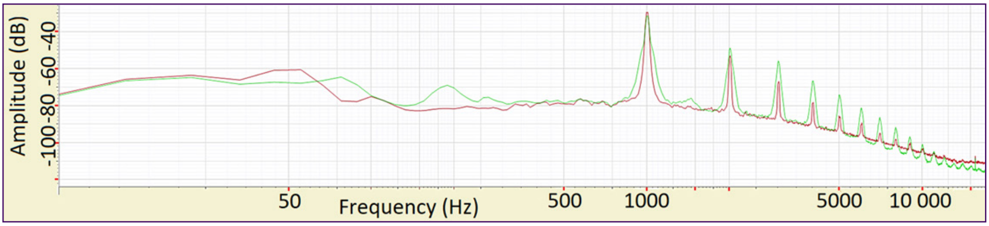

Figure 5. 1,000 Hz single frequency. Original in red and pantograph copy in green.

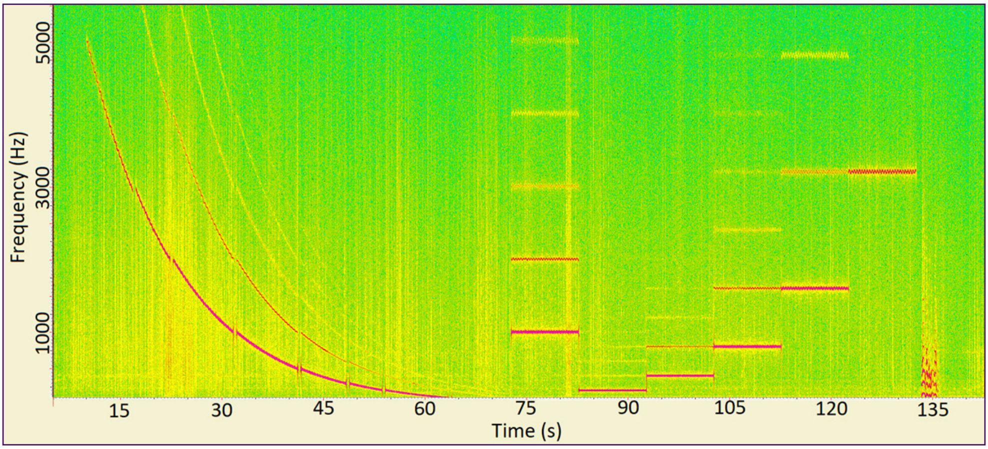


Figure 6. Spectogram of the original cylinder.

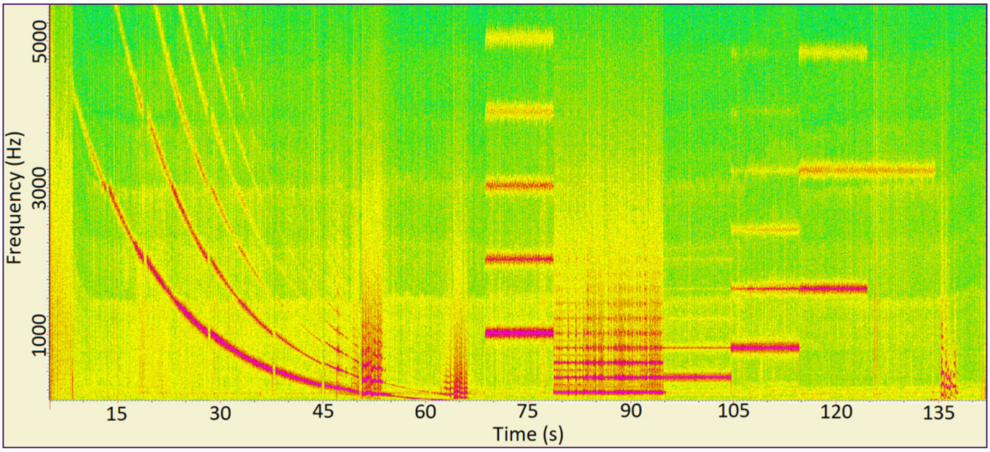


Figure 7. Spectogram of the pantograph copy.

A close listen to the frequency sweep shifting from 5 kHz to 20 Hz on the copy and original reveals additional distortions occurring in periods of a few seconds. This periodic distortion is also described by Chamoux (2019). The strength of the sweep is constant; thus, it may be that the periodic distortion is either randomly triggered by mechanical flaws or is triggered by specific frequencies.

Evidence of Chamoux's third category, locked or missing grooves, was also found in the experiment. Both copies have several locked grooves, which makes the content of the copy a few seconds longer than the original. It is worth noting that these locked grooves are not large skips but small repetitions of as little as a single groove cycle. However, the locked grooves are exacerbated by worsened tracking. On the original, the lowest frequencies track perfectly, but on both copies, the lowest frequencies in the sweep become hard to track. The arm requires guidance to complete the playback of the cylinder.

## Cross-reference to commercial engraved cylinders

Focusing on commercial brown phonograph cylinders from the labels Anders Skogs Fonografrullar and Østby Record, several examples contain the sonic markers that indicate a pantograph copy. The characteristic entry noise is found on many recordings, but it varies greatly in distinction. On some recordings, the entry noise is barely noticeable, whereas it is more evident on others. Analysis of Anders Skogs Fonografrullar catalog number 1080[14] reveals that the entry noise has similar characteristics to those found in the experimental cylinder copy (Figure 8).

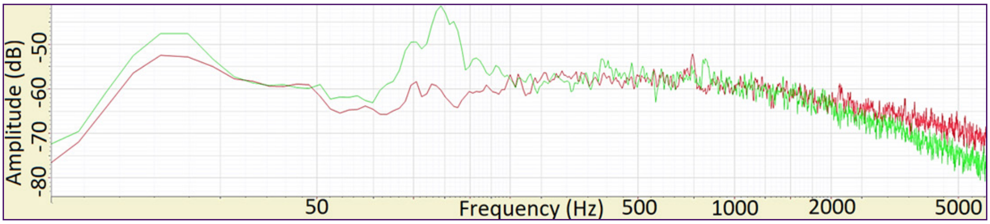

Figure 8. Green: post-introduction of the reproducer, red: pre-introduction of the reproducer. Skogs Fonografrullar 1080.

Examples of locked grooves are also evident. To ensure that the locked groove was present in the copy at hand and not a flaw caused by poor tracking during playback, the stylus was closely monitored during playback. The stylus tracked perfectly on the copy, but the content was clearly skipping, which indicates that the flaw originated with a locked groove during the pantograph copy process. Many of the recordings examined also exhibit the delayed start and cut endings extremely close to the cylinder edge found in the experiment.

Many examples of harmonic distortion are also found in the collection, but these may not be a clear sign of pantograph copying technique. The effect of wear from playback over time is another factor that could contribute to harmonic distortion.

One of the most distinct examples of a potential pantograph copy found in the collection of the National Library of Norway, is Østby Record number 9 . Two brown cylinders with the same title were located in a private collection, and one of them could be confirmed to contain identical content to the cylinder at the National Library of Norway.

## Conclusion

This article establishes a formal method for distinguishing original recordings from mechanical copies. In analyzing a known pantographic copy, several sonic signatures were identified:

1. Additional mechanical noise in the copy.
2. A deterioration of the signal-to-noise ratio.
3. Errors in the time axis represented through locked or skipped grooves and a delayed start, contributing to the risk of abrupt endings in the audio content.
4. Excess harmonic distortion introduced through the copy process.

These signs can be used to determine whether a cylinder is an original recording or a mechanical copy made through the pantograph method. It is worth noting that the copy

14 www.nb.no/items/URN:NBN:no-nb_digilyd_2021010517008

process alone does not weaken the copied cylinders or introduce significant flaws in the audio spectrum; rather, the copied cylinders appear much like the originals. An analysis of a collection of commercial brown cylinders from 1900-1903 from the local labels Anders Skogs Fonografrullar and Østby Records revealed the same sonic markers and led to the finding of two identical copies of one early title. Thus, it is safe to conclude that the pantograph copy process was in use in the region at the time.

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