Piano Rolls and Contemporary Player Pianos:

The Catalogues, Technologies, Archiving and Accessibility

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Declaration

I declare that the research presented in this thesis is my own original work and that it contains no material previously published or written by another person. This thesis contains no material that has been submitted to any other institution for the award of a higher degree. All illustrations, graphs, drawings and photographs are by the author, unless otherwise cited.

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Abstract

Reproducing piano rolls have been of great interest to me for nearly 40 years, yet despite their significant potential in a number of research areas, they remain largely untapped. In my thesis I seek to discover why this vast historical library of music and interpretations is not more widely acknowledged and utilised. Reproducing piano rolls provide a valuable evidence of nineteenth-century performing practices, as well as offering unique pathways to other forms of research. The substantive catalogues of art music alone prove the musical worth of these rolls.

Numerous commentators have chosen either to ignore or to consciously dismiss reproducing piano roll recordings as a valid representation of the art of the pianist. Clearly, in the majority of cases, their opinions have been formed through hearing rolls replayed on poorly adjusted instruments; the piano rolls themselves are not the problem. To dispel the myths that have taken hold as a result, I examine how three major piano roll companies made their recordings, and test the common criticism that these recordings were subjected to invasive editorial change.

Accessing faithful piano roll recordings is an acknowledged problem. My viewpoint is that if piano roll recordings are made as accessible as early sound recordings, many rich research opportunities will present themselves. Archiving piano rolls remains an area desperately in need of further research. In this thesis I present the philosophy underpinning my methodology for developing the means to record piano rolls as raw MIDI files. Making the raw files compatible with contemporary MIDI instruments provides the sought-after accessibility, a topic that has so far attracted minimal academic interest.

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Introduction

> There can be no question that the Welte-Mignon library is an indispensable adjunct to the study of the history of musical performance. In short, the Welte-Mignon opens a window on the past. It is a documentation that no historian can afford to neglect.
>
> Albert Goldberg, Critic Emeritus,
> *Los Angeles Times*, 1970[1]

In early September 1904, the German company Popper and Co., GmbH exhibited "an 80-ton mechanical player called the *Artist*" at the Leipzig Autumn Trade Fair.[2] The instrument was most likely a prototype of the world's first reproducing piano, the Welte-Mignon. This invention heralded a new era, and led to the creation of an industry lasting over 25 years that was dedicated to producing piano roll recordings of live artists for playing on the various brands of reproducing pianos being manufactured at the time. The significance of the reproducing piano roll is that the recording on the roll is, in all respects, of a pianist's actual playing.

At this time, the sound recording technology was in its infancy. Early disc recordings include those made by the fledgling Gramophone and Typewriter Company (G & T), such as several recordings made in 1901 by Cécile Chaminade (1857–1944), and a number of recordings made in Paris in 1903 by artists that included Raoul Pugno (1852–1914) and Louis Diémer (1843–1919). In general, the majority of sound recordings of art music at this time were of operatic singers, as the technology was not able to fully capture the sound of a piano.

Albert Goldberg,[3] music critic for the *Los Angeles Times*, referred only to the Welte-Mignon library of reproducing piano rolls, and may have been unfamiliar with other similar libraries. Nevertheless, Goldberg realised that "in some cases [the Welte-Mignon library] provides the only clue as to what the playing of certain pianists of the past was like, and it permits evaluations and comparisons that would otherwise be impossible."[4]

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[1] Quoted in Charles Davis Smith and Richard James Howe, *The Welte-Mignon: Its Music and Musicians* (New York: Vestal Press, 1994), Preface [unpaginated].
[2] Hans W. Schmitz, "Music Roll Production at Ludwig Hupfeld AG, Leipzig," in *Famous Pianists at the Hupfeld Recording Salon*, ed. Eszter Fontana (Germany: Verlag Stekovics, Halle / Saale, 2000). English translation, 2000, 19.
[3] Albert Goldberg (1899-1990) was a pianist and conductor who worked as a music critic from 1943 for the *Chicago Tribune*, then from 1947 to 1965 as chief music critic for the *Los Angeles Times*.
[4] Smith and Howe, *The Welte-Mignon*, Preface [unpaginated].

From 1905 to 1930 the major companies that competed in the reproducing piano market were the German companies M. Welte und Söhne, Ludwig Hupfeld AG, Popper and Co., GmbH, and J.D. Philipps und Söhne. In the US, the market was dominated by the Aeolian Company and the American Piano Company, along with a number of smaller companies that manufactured reproducing pianos such as the Artrio, Artecho and Apollo. Rolls for the latter instruments were often adaptations of rolls made by the major companies.

Researchers such as Larry Sitsky, Charles Davis Smith, Richard Howe and Elaine Obenchain have compiled piano roll catalogues that cover the output of the major companies.[5] The Sitsky catalogue lists rolls of art music produced by all piano roll companies, other catalogues list all categories of rolls produced by a particular company. Each catalogue lists thousands of piano rolls recorded by hundreds of pianists playing works by hundreds of composers—a treasure trove of historic recordings.

Aims of my research

My long exposure to piano rolls convinces me of their many values, and also of the need to examine a number of areas associated with piano rolls. My research seeks to:

1. Establish quantitative and qualitative data concerning the catalogues of piano roll recordings of art music made for Welte, Ampico and Duo-Art reproducing pianos. This research is presented in Chapter 1.
2. Identify the limitations inherent in piano roll recordings though an examination of the technologies and principles associated with producing a piano roll recording. This topic occupies Chapter 2.
3. Examine methodologies for archiving piano rolls, and establish criteria applicable to analogue roll reading equipment intended to record a raw MIDI file of a piano roll performance. See Chapter 3.
4. Develop methodologies for converting raw MIDI files of piano rolls into a form suitable for use with modern MIDI instruments.[6] See Chapter 4.

[5] Larry Sitsky, *The Art music Reproducing Piano Roll: A Catalogue-index* (New York: Greenwood Press, 1990); Smith and Howe, *The Welte-Mignon*; Charles Davis Smith, *Duo-Art Piano Music: A Complete Classified Catalog of Music Recorded for the Duo-Art Reproducing Piano* (Monrovia, California: The Player Shop, 1987); Elaine Obenchain, *The Complete Catalog of Ampico Reproducing Piano Rolls* (New York: William H. Edgerton, 1977, PDF version 2009).
[6] MIDI is an acronym for Musical Instrument Digital Interface.

Background

Denis Condon (1933–2012) introduced me to reproducing piano rolls in 1976. Condon was a Sydney-based music teacher, lecturer and writer who had collected thousands of reproducing piano rolls. Over the intervening years I have become aware of a number of issues with piano rolls that have since guided my research. Issues include the difficulties of accessing the music recorded on piano rolls, the importance of a quality player piano, and an apparent mistrust of piano rolls as a form of recording.

Accessing piano roll recordings

Early acoustic recordings on wax cylinder or disc, once limited to collectors and institutions, are now widely available on commercially released CDs and on the internet. What were once extremely rare recordings can now be obtained for the cost of a download. This unprecedented access to historical recordings has provided researchers with numerous avenues of exploration, albeit with one limitation: few of the recordings were made by contemporaneous pianists playing solo piano works. The gap in our recorded history is covered by recordings made on reproducing piano rolls.

However, anyone wishing to use piano roll recordings in their research will face the issue of accessing the performances. Options presently include variable-quality recordings on CD and YouTube of piano rolls played on original instruments, or having access to a collector or institution with the necessary play-back instruments and rolls.

A problem inherent in reproducing piano rolls is incompatibility between brands, and even between types of rolls from the same brand. Each type of roll plays only on its particular reproducing piano, which in the case of Welte-branded rolls, encompasses three different types of reproducing pianos. Another problem lies in finding fully working instruments, in particular for Hupfeld and Duca piano rolls. Both companies produced significant libraries of reproducing piano rolls, but well-adjusted and properly operational instruments are now difficult to locate. In many cases, having the roll is only half the solution; there remains the issue of how to hear it.

MIDI technology

My experience with reproducing pianos and associated rolls began earnestly in 1977, when I acquired and restored an Ampico reproducing piano. I realised then that piano rolls were expensive, hard to find, and that they were fragile, especially those dating back to the early 1900s. I was keen to establish a library of music from piano rolls and during 1978-79 I developed a means of recording piano roll perforations as digital data stored on magnetic tape. Over the next ten years I recorded some 1500 Ampico rolls, initially onto magnetic tape, later into an Apple II computer, thereby providing a library of music for playing on the Ampico reproducing piano.

In 1987 Yamaha began marketing its MIDI mechanical piano called the Disklavier.[7] Competitor PianoDisc soon appeared, a US company that produced a retrofit MIDI player system that could be installed in any piano. After acquiring one of these systems in 1995, I began investigating ways of converting the raw MIDI files of Ampico rolls I had previously recorded to MIDI files that I could play on the PianoDisc. A colleague introduced me to a new computer program that would do this, and by the late 1990s I had two means of hearing MIDI versions of Ampico piano rolls—on an Ampico, or on the PianoDisc—allowing direct comparisons.

Importance of the playback piano

Condon and I both believed that piano rolls should be played on the best available instrument, which Condon achieved with pneumatic push-up players operating a Yamaha Disklavier in a C7 grand piano.[8] He could record the rolls as they played on the Disklavier, thereby creating a library of MIDI files for later playback.

My approach to using a quality instrument was through the MIDI files of the rolls I had adapted to play on modern player pianos. The difference between our separate approaches was the technology being used; Condon relied on original pneumatic technology, I used computer-based technology.

[7] A MIDI mechanical piano plays from computer files called MIDI files. It has electrically powered key actuators called solenoids, and the force applied by a solenoid is determined by 'velocity' values in the MIDI file. A Disklavier usually allows pianists to record themselves by making a MIDI file of their playing, which can then be replayed on the instrument.
[8] Separate vorsetzers are needed for each brand of roll.

In 2007, my MIDI files of Ampico piano rolls were the subject of two weeks of recording sessions in Vienna, sponsored by Bösendorfer. A series of recordings were made by playing the MIDI files on an Imperial piano fitted with Bösendorfer's newly developed CEUS MIDI player system. Developed at Vienna University, the system incorporated advanced technology to ensure the highest playback accuracy. In comparison to the PianoDisc system, the superior playback of these MIDI files convinced me that a high-end MIDI playback system in a quality piano is to be preferred when reproducing a MIDI file of a piano roll. The implication is that pneumatic reproducing pianos and standard MIDI pianos are themselves a potential limitation in the reproduction of an artist recorded on piano roll.

Mistrust of piano rolls

Neal Peres Da Costa was among the first to use piano rolls as a means of researching the performance practices of late nineteenth-century pianists. He concludes that "the information that I feel can safely be extrapolated from them at this stage concerns practices that are not directly influenced by dynamics, tone, touch, and pedalling."[9] To gain access to the piano rolls he sought, Peres Da Costa listened to recordings, and also rolls played on reproducing pianos owned by enthusiasts such as Denis Hall in London.

Anatole Leikin examined sound recordings made from reproducing piano rolls in his research into the performance practices of Enrique Granados (1867–1916) and Alexander Scriabin (1872–1915). In the case of the Duo-Art rolls of Granados' playing, he refers to "the far-from-sensational renditions heard on the modern compact discs."[10] Consistent with Peres Da Costa he concludes that "elements such as dynamic nuances, pedaling, phrase shadings, chord voicings and tone colors are far less detailed."[11] Jocelyn Ho, when researching Debussy's performance practice via his piano rolls concluded that "the information on the pitch, duration and the placing of notes in the piano rolls is preserved completely accurately," while accepting that "differing opinions and speculations exist on whether dynamics and pedalling can be reproduced exactly to the original performance."[12]

[9] Neal Peres Da Costa, *Off the Record: Performing Practices in Romantic Piano Playing* (New York: Oxford University Press, 2012), 40.
[10] "Piano Roll Recordings of Enrique Granados: A Study of a Transcription of the Composer's Performance." *Journal of Musicological Research*, vol. 21 nos. 1-2 (2002), 3.
[11] Anatole Leikin, *The Performing Style of Alexander Scriabin* (UK: Ashgate Publishing, 2011), 16.
[12] Jocelyn Ho, "Debussy and Late-Romantic Performing Practices: An Investigation of Debussy's Piano Rolls of 1912." (Ph.D diss., University of Sydney, 2015), 4.

The limitations of a piano roll recording are generally agreed on, and for Leikin, Peres Da Costa and Ho, these were not an impediment to their research. However, acceptance of the virtues of piano roll recordings is by no means universal. For example, when introducing Vladimir de Pachmann's discography, Allen Evans writes:

> Although Pachmann recorded a number of piano rolls, I have chosen not to include a list of them here. The roll is an inferior, essentially non-musical medium and contributes nothing substantive to our understanding of how Pachmann—or any other pianist who made them—played the piano.[13]

An explanation as to why reviewers have a mistrust of piano rolls is that they are often heard through recordings made on poorly-adjusted instruments. An example is a damning review by Donald Manildi of three Naxos CDs of sound recordings made of Welte-Mignon piano rolls: "In the present instance, 'travesty' is not too strong a word. It would be odious to provide still further examples of the crudity of the Naxos versions." He explains that "not all compact disc recordings based on piano-roll playbacks use perfectly reconditioned reproducing pianos. […] This is why direct transcriptions of piano-roll perforations may be more reliable."[14]

Harold Schonberg says of piano rolls: "Almost as much could be done to doctor a piano roll as can be done these days to magnetic tape. In addition, tempo, dynamics and pedalings are highly suspect."[15] Despite this, Schonberg's review of a set of five LPs issued by L'Oiseau-Lyre in 1985 of recordings of Ampico piano rolls concludes with: "Results like this might make one a believer in piano rolls."[16]

Schonberg's change of heart was due to hearing recordings of piano rolls played on a new concert grand piano fitted with a restored Ampico mechanism.[17] His assumption that because piano rolls *could* be edited therefore proves that they *were* edited is therefore questionable. Negative opinions, when expressed by established writers such

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[13] Mark Mitchell. *Vladimir de Pachmann: A Piano Virtuoso's Life and Art* (Bloomington: Indiana University Press, 2001), 199. Allan Evans is the discography compiler for this book.
[14] Donald Manildi, "Sound Recording Reviews: "Welte-Mignon Piano Rolls, Volumes 1, 2, and 3"." *ARSC Journal* 36, no. 2 (2005), 290-93.
[15] Harold C Schonberg, *The Great Pianists* (New York: Simon and Schuster, 1963, paper back, 2006), 16.
[16] Schonberg, "Romantic Pianists Display Mastery on Piano Roll Disks," *The New York Times*, July 28, 1985, http://www.nytimes.com/1985/07/28/arts/romantic-pianists-display-mastery-on-piano-roll-disks.html (accessed 15 November 2016).
[17] L'Oiseau-Lyre issued five discs of recordings of piano rolls: two by Rachmaninoff (414-096-1 and 414-099-1), two by Josef Lhévinne (414-097-1 and 414-121-1), and one by Moriz Rosenthal (414-098-1).

as Schonberg and Evans have undoubtedly lead to a general mistrust of the integrity of piano rolls as a form of recording.

It is clear that some of the issues reported by researchers and reviewers are associated with the reproducing instrument, not necessarily the piano roll recording. I argue it is important to separate the two when discussing the limitations of piano rolls, and that their inherent limitations are not as significant as is often portrayed in written literature.

The research project

In 2006, armed with my prior experience, I began developing a new suite of equipment to record piano rolls into computer as MIDI files. A key factor was accuracy, which meant paying detailed attention to many aspects of the equipment, and devising ways of testing for accuracy. My aim was to continue recording piano rolls from different brands of rolls. By now, I was not the only person producing MIDI files of piano rolls, but I was to find that many of these attempts were fraught with inaccuracies and errors.

With the completion of much of the new roll reading equipment by the end of 2011, I resumed making recordings, this time of Duo-Art rolls. By the end of 2012, I had built up a good library of MIDI file recordings of Duo-Art rolls, all to satisfy a personal goal.

Becoming involved

After reading Peres Da Costa's *Off the Record*, I was inspired to look at piano rolls in a different way, not just for their musical qualities, but what they offer in terms of avenues of research. I wondered then if MIDI files of piano rolls, such as those I was producing, might have application in research projects involving not just performance practice, but also other avenues which might become apparent.

Undertaking a PhD has provided the opportunity to test my belief that piano rolls offer many applications in academic research. An important question is how piano roll recordings can be made more accessible. I argue that the raw MIDI file equivalent of a piano roll performance is a suitable substitute that can provide a pathway to adapting the file for playing on a contemporary MIDI player piano, such as a Disklavier. It can be argued that authenticity of reproduction is only achieved by playing reproducing piano rolls on an original reproducing piano. Unfortunately, the practicalities imposed are often impediments to using piano rolls at all.

Research into piano roll catalogues

While the various companies produced large numbers of rolls of popular music, I have limited my research to the art music piano roll catalogues for the Ampico, Duo-Art and Welte instruments. My analysis of each catalogue seeks to throw light on the pianists, the composers and the type of music recorded by these companies.

Examination of any piano roll catalogue of art music shows an extensive selection of light classical music, salon 'lollipops', works that remain in the repertoire, operatic selections and many unfamiliar works by composers of the times. By analysing the catalogues in terms of the composers and the number of recordings made of their works, a clearer idea can be obtained about the musical make-up of each of the three catalogues. An important aspect is the extent to which the catalogues cover works by major composers, as the presence of such works provide a comparison of the performing practices of piano roll artists and contemporary pianists. The extent to which the catalogues contain works by forgotten composers is of interest, as it identifies once-famous composers who now lie forgotten.

The makeup of the piano roll catalogues gives an insight into musical tastes of the time. In terms of solo piano works, the only other source of information is sales of published music. Because the three companies being examined had recording studios in America, England and Germany, the catalogues are a potentially useful source for sociological research into the musical tastes in these three parts of the world.

Other questions to resolve are the number of recordings in each of the catalogues under discussion, and in particular, the number of recordings in these catalogues that were made by notable pianists. That is, I seek to establish the significance of piano roll recordings in terms of quantity and also the quality of musical content by analysing the catalogues in terms of the composers, the extent of their representation in each catalogue, and the stature of the recording artists.

The number of hours of disc and wax cylinder recordings made up to 1930 of solo piano works played by historical pianists can be estimated from existing catalogues and reissued CDs. The total playing time of all rolls of art music in a piano roll catalogue is more difficult to determine. Even so, I am able to establish close estimates for the catalogues under examination, thereby providing a meaningful comparison with the library of early sound recordings.

Research into piano roll technology

It is accepted that piano roll recordings do not include every aspect and nuance of the original performance. Peres Da Costa, Leikin and Ho identify similar shortcomings of piano rolls, and I agree in principle with their conclusions. However, my experience with piano rolls has shown that, when played on a well-adjusted instrument, some rolls give a performance that is almost indistinguishable from live playing. Therefore, my research into piano roll technologies seeks to establish how the three companies I am researching recorded their artists, with the aim of determining the degree of accuracy that the technologies provided.

A common criticism of piano rolls concerns the potential for editing a performance. Michael Broyles and Denise Von Glahn, in their biography of Ampico artist Leo Ornstein (1892–2002), explain that when it came to producing the final roll recording, "the role of the performer diminished and the role of the editor loomed even larger than in modern recordings."[18] How do these authors know what happened in the production process? Admittedly, there is scant evidence about the role of the editors and the extent to which a performance was modified post recording. Nonetheless, the existing evidence can be used to make informed assumptions, rather than assumptions based on the editing practices used in recording studios today.

Research into piano rolls as MIDI files

In Chapter 3, I examine the question of what constitutes an archive of a piano roll; perhaps a paper duplicate of the roll, a photographic image of the entire roll, a MIDI file or a combination of these. My research into this topic has shown there is little published information, especially of an academic nature. Instead, it remains the province of enthusiasts, and then primarily to produce MIDI files for use in making duplicate rolls. Stanford University is currently developing roll scanning equipment that will capture piano rolls using video technology, with an aim of producing MIDI and audio files.[19] Because of the limited amount of research material on this topic, I have needed to establish base-line data found through my own research.

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[18] Michael Broyles and Denise Von Glahn, *Leo Ornstein, Modernist Dilemmas, Personal Choices* (Bloomington: Indiana University Press, 2007), 200.
[19] Stanford University Libraries, *About the [Player Piano] Project*, https://library.stanford.edu/projects/player-piano-project/about-project (accessed 30 October 2016).

My concern has been to achieve a paper-to-MIDI transfer process that offered the highest accuracy. As previously mentioned, Manildi's opinion, and a view that I share, is that "direct transcriptions of piano-roll perforations may be more reliable."[20] Therefore, the philosophy behind the technology I have developed is presented with only brief reference to its implementation. My aim is to establish and present information that amplifies the published knowledge that presently exists.

Research into piano roll MIDI files and contemporary instruments

The process of adapting raw MIDI files of piano rolls to make them compatible with contemporary instruments remains captive to a few enthusiasts, none of whom have published their findings. As there is no documented academic or general information, I present my own research and philosophy behind the process which I followed to achieve the objective of producing piano roll MIDI files that are compatible with contemporary MIDI instruments. My aim is to provide a base-line reference for future research.

Research into correcting piano roll recordings

The prospect of editing MIDI files of piano rolls to remove inaccuracies associated with the original technology is an important area to examine. For example, I have encountered numerous instances involving incorrect dynamics caused by the way pneumatic reproducing pianos function, such as single notes in a long trill being accented if they are aligned with accented thematic notes playing in the same part of the keyboard.[21] Because the dynamic of each key is controlled separately in a MIDI piano, these wrongly accented notes can be corrected.

There are other limitations with piano roll recordings that can be overcome, including adding notes that could not be played due to the limited compass of the instrument. Making corrections to achieve greater accuracy to the original performance is only possible with a MIDI file recording of a piano roll performance.

[20] Manildi, *Sound Recording Reviews*, 293.
[21] A number of examples are given in Chapter 4.

Applications in research

When piano roll recordings are converted to MIDI files, it becomes possible to apply research techniques that are not easily applied to paper rolls. I am aware of a number of research projects that involve piano roll recordings as MIDI files, although discussion of these is outside the scope of this thesis. Software presently exists that analyses performances recorded as audio files, such as *Sonic Visualiser* written by Nicholas Cook and Daniel Leech-Wilkinson, a freely available program.[22] Unfortunately, software to analyse a performance recorded as a MIDI file does not appear to exist, and yet the structure of MIDI files means analytical software would be less complex to develop. This topic is not in the scope of my thesis, but is surely a way forward when piano rolls are converted to MIDI files.

Conclusion

Reproducing piano rolls remain a largely untapped resource, although signs are emerging that indicate a growing interest in this form of recording. The recent acquisition by Stanford University of the Condon collection of piano rolls is one example. Researchers at Bern University are using piano rolls and MIDI files of piano rolls in their research into performance practice. Academic staff at the Biblioteca de Catalunya in Barcelona are examining ways of digitising the institution's collection of Hupfeld rolls.

This thesis therefore comes at an opportune time to add to the research that has so far been conducted into reproducing piano rolls. There is a growing awareness that piano roll recordings, despite the limitations, can bridge the large gap that currently exists between contemporary and nineteenth-century performances of works from the Romantic piano repertoire. My research shows that piano rolls also open up other avenues of research, and the key to involving piano rolls in research is accessibility to the recordings, the primary subject of this thesis.

[22] Nicholas Cook and Daniel Leech-Wilkinson, *A Musicologist's Guide to Sonic Visualiser,* http://www.charm.rhul.ac.uk/analysing/p9_1.html (accessed 15 October 2016).

Glossary of terms

The following terms are used when discussing piano rolls, pneumatic player pianos and catalogues. Terms specific to a particular chapter are defined in that chapter.

- *Work*. Defined as any complete composition or items within an opus number. A sonata or symphony is one work, as is a prelude or a study.
- *Recording*. A piano roll recording of a work. Some works were recorded by several different artists, giving a number of recordings of the same work.
- *Piano roll*. Paper medium containing a recording, in which a roll is a single entity. Some works occupy several rolls. Piano roll is sometimes used in this thesis in lieu of the term 'reproducing piano roll.'
- *Reproducing piano roll*. A type of piano roll that incorporates additional perforations to control the dynamics of playing notes.
- *Reproducing piano*. A pneumatic player piano with an electrically-powered vacuum pump in which the dynamics of playing notes are determined by pneumatic regulators that are in turn controlled by piano roll perforations.
- *Player piano roll*. A type of piano roll with perforations to operate only notes and pedals. Also called an 88-note standard roll.
- *Player piano*. A pneumatic player piano with a foot-operated vacuum pump.
- *Playerist*. Also called a Pianolist, a person operating a player piano.
- *Sound recordings*. Recordings made on disc or cylinder. Prior to 1925, recordings were made by capturing the sound with acoustic horns which were coupled to a moving stylus that inscribed sound 'tracks' in the revolving media.
- *Tracker bar*. A metal (sometimes wooden) bar containing square holes that align with each perforation track. When a hole is uncovered by a perforation, a function within the pneumatic player piano will operate, such as a note or pedal.
- *Vorsetzer*. German term for 'sitter before' and which refers to a piano roll player that is placed externally to the piano. A vorsetzer has wooden fingers controlled by the piano roll to operate the piano keys and pedal actuators to operate the soft and damper pedals. Also called a push-up player.

Chapter 1 – Art music catalogues

Introduction

The catalogues of roll recordings of art music produced for the Ampico, Duo-Art and Welte reproducing pianos are examined and analysed in this chapter. Collectively, the piano rolls that were produced for these three types of instruments are the most widely available, as they were sold worldwide, not just in their country of manufacture. There are also many examples of working instruments that play these brands of rolls, plus numerous references to the instruments, the companies and the rolls in trade magazines that date to the start of the reproducing piano industry.

These three companies produced piano roll recordings covering a period from 1904 to 1930, in which Welte was the first to enter the market, making it the most historic of all the companies. As pointed out in the Introduction (page 2), there are other piano roll companies with historically interesting catalogues that remain more difficult to research due to the lack of information, rolls and working instruments. It is important to at least mention these companies, as some are referred to later in this thesis.

The earliest is the German company Ludwig Hupfeld AG, a company that began making hand-recorded rolls in 1905 for its manually operated, foot-powered Phonola player piano. A hand-recorded roll was made by a live pianist playing on a recording piano that was connected to apparatus that recorded each key stroke, typically by scribing lines on a moving sheet of paper. The lines were later punched to form perforations.

The DEA, Hupfeld's first reproducing piano, was introduced in 1907, other models following, culminating in the Triphonola in 1920.[23] Although Hupfeld established a large library of art music made by many prominent pianists, there is sometimes doubt as to the provenance of rolls for the Triphonola. In some instances these are from the early Phonola or DEA recordings, not from a recording specially made for the Triphonola.

J.D. Philipps und Söhne manufactured its Duca reproducing piano, making recordings from late 1908. The company established a worthy but smaller roll catalogue compared to Hupfeld and Welte.[24]

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[23] Martin Elste, "You Had to be Able to Play the Piano," in *Famous Pianists at the Hupfeld Recording Salon*, edited by Eszter Fontana. (Germany: Verlag Stekovics, Halle/Saale, 2000. English translation), 11.
[24] *The Reproducing Piano - Philipps Duca*, http://www.pianola.org/reproducing/reproducing_duca.cfm (accessed 25 March 2016).

The US company Wilcox and White was founded in 1877, and initially produced a player piano called the Angelus. In 1915, the company announced its Artrio-Angelus reproducing piano, which is referred to here as the Artrio. A number of acclaimed pianists recorded for the company, although none that were exclusive to the Artrio.[25]

Other companies such as Artecho and Apollo produced rolls from masters made by Welte, Ampico or Aeolian, under a business arrangement. These recordings and those made by the companies were not separately identified in the catalogues.

Source data for piano roll databases

In the course of this research I have recorded as MIDI files over 6,500 reproducing piano rolls produced for the Ampico, Duo-Art, Welte-Mignon and Welte Licensee instruments.[26] Part of the recording process meant cataloguing each roll, in which details were taken from its label and entered into a database, along with data obtained during recording, such as the playing time of the roll and category of music. Information, if available, was also collected about each pianist and composer, such as nationality, sex, birth and death dates, teachers and career highlights.

By referring to the published catalogues, the rolls not in my databases were identified and their details added, thereby giving complete detailed databases of all Ampico, Duo-Art, Welte-Mignon and Welte Licensee roll recordings that qualify as art music.

Applying the data

To analyse the catalogues, the data is used to develop a profile of each catalogue, in terms of the contributions by the composers and pianists within that catalogue. The results are presented as a series of bar graphs and tables, along with explanatory text to give a visual and quantitative outline of the contents and make-up of each catalogue.

The pianists who made roll recordings are especially important, not just who they are, but how much music they recorded on roll, and what sort of music. Notable pianists are listed in tables and are singled out on the basis of criteria that are later explained. Space limitations made it impossible to include detailed information about the pianists, many of whom will need no introduction to researchers of historical pianists.

[25] *The Reproducing Piano - Artrio-Angelus*, http://www.pianola.org/reproducing/reproducing_artrio.cfm (accessed 25 March 2016).

Typical content of piano roll art music catalogues

Welte, Aeolian and Ampico each produced piano roll catalogues at regular intervals. Typically, popular titles would appear in monthly fliers or magazines, whereas art music was listed in permanently bound books issued every few years. These catalogues show that among their range of offerings, the three companies produced roll recordings of stand-alone works; recordings of accompaniments for singers or other instruments; and rolls that contain excerpts of art music.

Accompaniment rolls are listed separately in the 1925 Ampico, 1927 Duo-Art and 1924 Welte De Luxe catalogues and are generally recordings of art music. These companies also produced a range of 'instructional' rolls aimed at educational and general markets. Examples include rolls explaining the principles of conducting, those that offer ear training or a study of musical forms. Therefore art music appears on various categories of rolls where the intent is instructional or secondary to the enjoyment of listening to the recording. Clearly defining the categories of roll recordings to be included in the databases, along with categories to be excluded was therefore essential.

[26] These four instruments are described in Chapter 2. Types of Welte instruments are outlined further in this chapter.

Criteria defining art music categories

Each database is limited to roll recordings of art music for piano for which listening was the intended focus. Table A lists all categories of art music that have been included.

Table A *Categories of art music included in the databases*

Category	Details
Works within an opus number	▪ All numbered items within an opus number are counted as individual works. ▪ Includes art music on rolls recut from discovered masters that were not issued during the lifetime of the company.
Works without an opus number	▪ Includes works of a light classical nature. ▪ Includes works referred to as 'salon' music.
Large works counted as a single work	▪ Includes symphonies, sonatas, piano concertos, overtures and any work on a number of rolls that are labelled as being part of the work. ▪ Where a work is incomplete, parts of the work, such as one or two movements from a sonata, are counted as one work.
Arrangements or transcriptions	▪ These are entered separately to the original work and are counted as a work by the original composer, noted as an arrangement or transcription. The exception is the group known as Liszt's Paganini studies, which are attributed to Liszt. ▪ Transcriptions are therefore counted once, where compiled roll catalogues list these twice, under composer and transcriber. ▪ Arrangements of traditional songs with a 'classical flavour' are included.
Comic operas and operettas	▪ Excerpts from comic operas and some operettas are included, such as those by Gilbert and Sullivan, Oscar Straus, and Offenbach. ▪ Songs from Friml's *Rose Marie* are not included, where songs from his operetta *Firefly* are included. ▪ Personal judgement has been required in some cases regarding songs from operettas, especially those that have entered the popular arena. German operettas recorded on Welte-Mignon roll are generally assumed to be of popular music unless contrary evidence is established.
Medleys	▪ A roll recording of an art music medley (operatic arias, works by different composers) is counted as one work.

Table B lists the categories of piano rolls and music that are excluded from the databases. Although accompaniment rolls are not included, they remain an important resource, as many of the pianists who recorded accompaniment rolls were renowned accompanists of the day. Artists include Richard Hageman (1882–1966), André Benoist (1879–1953) and Carl Lamson (1879–1966).

Table B *Categories of rolls and music not included in the databases*

Roll category	Details
Art music on accompaniment rolls	▪ Defined as rolls for accompanying voices or other instruments. ▪ Category includes roll recordings of the solo piano part of piano concertos, and first or second part of a four-hand piano work.
Art music on instructional rolls	▪ Defined as roll recordings of an instructional nature for schools, conservatoriums, piano students and the like. ▪ This category is excluded as the music is secondary to the main purpose of the roll. There are not many of these rolls.
Art music excerpts	▪ Defined as extracts of recordings available on other rolls. ▪ Found on demonstration rolls to show off an instrument's capabilities, on some test rolls and some Duo-Art Audiographic 'biographical' rolls. ▪ De Luxe issued a number of 'comparison' rolls with excerpts of the same work played by different pianists.
Popular songs	▪ Defined as tunes or songs written by popular composers of the day and played by pianists specialising in popular music. ▪ Lack of information about a work may mean its incorrect inclusion in the database. For example, a ballad might be mistaken as a salon work and vice versa.
Dance music	▪ Defined as music for social dancing, includes foxtrots, waltzes, tangos, one-steps, barn dances. The type of dance is usually given on roll labels.
Jazz	▪ Some roll titles include the term 'jass' to identify the piece as having a 'jazz' character. ▪ Gershwin's *Rhapsody in Blue* and *An American in Paris* are examples of the jazz style on piano roll, and are not included, although it could be argued these are a form of art music.
Novelties	▪ Includes rags, one-steps and novelty solo piano pieces such as *Nola* by Felix Arndt (written 1915), which spawned similar pieces.
Songs from shows and musicals	▪ Identified by their title, composer, pianist or description in original and compiled piano roll catalogues. ▪ Roll labels typically state from which show or musical the song is taken. ▪ Songs and tunes from most operettas are excluded, such as those that have entered the popular arena.
Folk and traditional songs	▪ Includes roll titles such as *Irish Songs*, *Plantation Songs* and the like. ▪ Traditional tunes such as *Annie Laurie* that are arranged and played by classically-trained pianists are included in the database.
Religious music	▪ Includes hymns and song rolls of a devotional nature. ▪ Rolls of religious music were usually found to have words, helping identify them. ▪ There may be instances where lack of information about a roll has caused a contestable inclusion in the database.
New issues not from original masters	▪ Defined as rolls produced by enthusiasts after 1941, the year when the last factory-made rolls were issued. ▪ Includes transfers made by enthusiasts from one roll type to another, such as Duo-Art rolls recoded for Ampico and vice versa, also 88-note standard rolls with added expression for playing on a reproducing piano.
Transfers from one roll type to another made by Aeolian-Ampico	▪ Identified as rolls of art music converted from one format to another during the 1930s when Aeolian and Ampico were operating as one company. ▪ These are excluded as they are not original recordings made by the company being discussed. However, the original recording is included under the company that produced the recording.

The categories described in Table B cover most situations encountered with piano roll recordings. However, there are issues that cannot be avoided that will affect the accuracy of the figures in the tables that are presented in this chapter. The same rules and judgements are applied to each catalogue, but errors and omissions, plus incorrect judgements mean the figures given cannot be regarded as absolute. Rather, they are likely to be within a few percent of figures other researchers might obtain.

Presenting data about composers

Because there are hundreds of composers whose works are recorded on piano roll, composers are grouped according to the number of their works in a catalogue. For example, all composers with more than twenty works are identified and presented graphically to show the extent of their representation. Composers with few works are not identified, but are grouped to show how many composers fall into this category. The aim is to give a visual indication of the musical content of each catalogue in terms of its composer complement and to identify the major contributors to a catalogue.

Identifying notable pianists

Notable piano roll recording artists are singled out on the basis of:

- *Date of birth.* Pianists born before 1870 and who appear in biographies or published literature about historical pianists.
- *History.* Position within musical circles, teachers, pupils, reviews of recitals, presence in relevant literature, discography.
- *Type of works recorded on piano roll.* Pianists who generally recorded light classical music or salon works are not highlighted, but in a few cases are pointed out.
- *Composers playing their own works*. Famous composers are highlighted, even if they are not generally known as a pianist.

Pianists sometimes used pseudonyms and where these are known, recordings are attributed to the real pianist.

Welte—the company

Overview

The Welte-Mignon reproducing piano was first demonstrated in 1904 by the German mechanical musical instrument manufacturer known as M. Welte und Söhne. At this time, the company was based in Freiburg im Breisgau in Germany; in 1913 the company established a manufacturing plant in Poughkeepsie, New York. The original Welte-Mignon pre-dated the roll size standards that had been established in the US in 1908,[27] which led to the development in the US of what is generally referred to as the Welte Licensee, an instrument that could play standard size rolls. A similar instrument, known today as the Green Welte, was later produced for the European market.

As a result, after 1920, there were two independent companies in the US dealing with Welte-branded instruments and making recordings for the instruments. Subsequently, two distinct catalogues of music, one for the Welte-Mignon, the other for the Welte Licensee were developed. The German-based company was always known as M. Welte und Söhne and is referred to here by that name. The American company had various names, depending on the era, including M. Welte and Sons, which is the name used here.[28] Smith and Howe detail the story of Welte and its operations in the US, and is the main source used to outline the background to the company.[29]

Brief history

The firm M. Welte und Söhne was established in 1832 by Michael Welte (1807–1880), located at Vöhrenbach. In 1865, Michael's son Emil Welte (1841–1923) set up a branch of the company in the US to market the company's mechanical organs. Michael moved the manufacturing plant to Freiburg in 1872, where it remained. In 1883, the company patented the use of perforated paper rolls to play a mechanical player organ.

Over the period 1900 to 1904, Michael Welte's grandson Edwin Welte (1876–1958) and Edwin's brother-in-law Karl Bockisch (1874–1952), developed the Welte-Mignon recording and reproducing systems.[30] The instrument, known as the Welte-Mignon was marketed in Europe and the US from early 1905. To make rolls for the

[27] "Player Convention Aftermath," *Music Trade Review*, vol. 47 no. 25 (December 19, 1908), 10.
[28] Company names in the US included The Welte Artistic Player Piano Company, while Emil Welte held the name M. Welte and Sons Incorporated, with both companies being part of M. Welte und Söhne.
[29] Smith and Howe, *The Welte-Mignon*, 3-101.
[30] Smith and Howe, *The Welte-Mignon*, 13.

instrument, a recording studio was established in Leipzig in premises owned by Popper and Co., GmbH, distributors and manufacturers of mechanical musical instruments. Proprietor Hugo Popper (1859–1910) was very supportive of the Welte-Mignon, and his position in musical circles allowed him to convince many of the most important pianists of the time to make recordings for the instrument. Popper had sole distribution rights of the Welte-Mignon for the German empire until 1909.[31] The first recordings at the Leipzig studio were made in January 1905, the last during April 1906. These early recordings are examined separately because of their historical significance.

In May 1906 Edwin Welte began travelling to the US to establish a manufacturing plant in Poughkeepsie. From this time on, recordings made in Germany for the Welte-Mignon appear to have been made only at Freiburg. In 1909, the recording equipment was taken to London, in 1910 to Russia and in 1912 to Paris. In 1913, the Poughkeepsie factory began manufacturing Welte-Mignon instruments, producing Welte-Mignon rolls from existing masters, and making new recordings. Roll numbers from 3601 to 3962 were duplicated between the American and German factories, giving two different roll titles for the same roll number for 362 Welte-Mignon rolls.

When war broke out in 1914, Edwin Welte returned to Germany where he was enlisted in the German army. During 1916, the management of the Poughkeepsie factory granted the Auto Pneumatic Action Company rights to the Welte-Mignon patents to develop the so-called Welte Licensee instrument. Rolls for the new instrument were produced at Poughkeepsie from existing Welte-Mignon masters.

In June 1918, the US government's Alien Property Custodian took control of the Poughkeepsie factory, selling it, the patents, equipment and stock in 1919. The *Music Trade Review* stated that the take-over "would not in any way interfere with existing contracts […] it merely means the Americanization of the company."[32] Thus began the unusual situation where M. Welte and Sons traded as a company in the US without any connection with the parent company M. Welte und Söhne in Germany. The new owners moved the plant and recording equipment to other locations and the Poughkeepsie factory was sold. Roll recordings continued to be made by the new owners in small numbers up to around 1920.

[31] Gerhard Dangel, "A History of M. Welte & Sons: The Family and the Company," *The Pianola Journal*, no. 18 (2007), 310.
[32] "Takes Over Welte Business," *Music Trade Review*, vol. 66 no. 26 (June 29, 1918), 31.

Welte instruments and piano rolls

By 1914, the Welte-Mignon had evolved into two types, those produced in Germany and those made in the US. A major difference between them was that the US version played standard size rolls, as also found in the Welte Licensee instrument. In the early 1920s, M. Welte und Söhne began marketing the Green Welte in Europe, an instrument that could also play standard size rolls.[33] Therefore, rolls for the various Welte-branded instruments were made in two sizes (original size and standard size) to suit three different types of Welte-branded reproducing pianos.

1. Rolls of unique size (12.875 inches or 327.025 millimetres) produced by M. Welte und Söhne (Germany) for use with the Welte-Mignon. Rolls were generally punched on red paper so the Mignon is often referred to as the Red Welte, and the rolls as 'Red' rolls.
2. Standard size rolls (11.25 inches or 285.75 millimetres) produced by M. Welte and Sons for the US version of the Welte-Mignon, and produced by De Luxe for the Welte Licensee instrument. The De Luxe recording company is discussed later in this chapter, and had no affiliation with M. Welte and Sons.
3. Standard size rolls punched on green paper for the Green Welte reproducing piano.

Welte and the 1920s

In 1920, the De Luxe Roll Corporation established its own recording system to produce rolls for the Welte Licensee instrument that was manufactured by the parent company.[34] Thus began a new set of recordings, which are discussed separately to those produced for the Welte-Mignon. As a result of prior agreements with Wurlitzer, some Welte-Mignon recordings were adapted for the Apollo and Artecho reproducing pianos, and therefore appear in the catalogues for these two instruments.

Gerhard Dangel, writing for the *Pianola Journal* explains that in Germany a limited number of roll recordings were made during World War 1.[35] After the war, the company recovered sufficiently to resume production of instruments and roll recordings, and by 1919 had begun a new programme of recordings. During the 1920s recordings of art

[33] The term "Green Welte" is used today by collectors, and is unlikely to have been used by Welte.
[34] The De Luxe Reproducing Roll Corporation and Auto Pneumatic Action Company, makers of the Welte Licensee reproducing mechanism, were divisions of Köhler Industries.
[35] Dangel, "A History of M. Welte & Sons," 40-41.

music began again at the Freiburg recording studio. While the output was nothing like the 1905-06 sessions, various recordings of notable pianists were made along with many recordings of popular music, and also a number of mechanically arranged works for the Welte-Mignon, which as Dangel points out were "not in the least commercially successful."[36] These eleven rolls are not included in my database, as they are a separate category.

The last recordings of art music made for the Welte-Mignon took place in 1928, with subsequent recordings being of popular music. By 1930 M. Welte und Söhne was in financial difficulty, although the company remained a registered entity until 1954.[37] In the US, Aeolian took over both the Ampico and De Luxe companies in 1932. As a result, during the 1930s a number of popular rolls made for the Ampico or Duo-Art were re-coded for the Welte Licensee.

Summary

Rolls for the Welte-Mignon were made over the period 1904 to 1930, the majority recorded in Germany. Smith and Howe estimate some 560 recordings for the Welte-Mignon were made in the US, although most were of popular music.[38] Rolls for the Green Welte instrument were produced during the 1920s from Welte-Mignon masters only at Freiburg. Rolls for the Welte Licensee, except those made from Welte-Mignon masters, were made in the US during the 1920s by two companies no longer connected with the German company. Collectively, the Welte-Mignon and Welte Licensee catalogues list all rolls for the Welte range of reproducing pianos, but no single instrument can play the entire library.

Roll numbering

Welte-Mignon rolls were numbered sequentially, starting with roll number 1. Of the first 164 roll numbers, which were presumably recorded at the Freiburg factory, only 40 were to remain in the catalogue, with all but two recorded by pianist Eugenie Adam-Bernard (1861–1925). Two of Adam-Bernard's recordings that remained in the

[36] Dangel, "A History of M. Welte & Sons," 42.
[37] Dangel, "A History of M. Welte & Sons," 46.
[38] Smith and Howe, *The Welte-Mignon*, 38.

catalogue were recorded in June 1904,[39] so it is likely the 107 rolls that were issued then withdrawn were also made in 1904, suggesting the factory was still perfecting the art of recording and producing Welte-Mignon rolls.

Because of the simple numbering system, roll numbers can sometimes approximately identify where and when a particular roll was recorded. Smith and Howe give a breakdown of Welte-Mignon and Welte Licensee roll numbers in terms of recording location and date.[40] A variation occurs with popular rolls produced in Freiburg. After 1922 and roll number 3785, popular recordings were allocated a new number series starting at 5500.[41] All rolls of art music continued to be numbered sequentially, ending in number 4196, which was issued in October 1928. Seven more titles in the 4000 series were issued in 1929, numbered 4199 to 4205.[42] They are not included in my database as the category of music cannot be identified.

Green Welte rolls were given the same number as the Welte-Mignon roll of the same title. Welte Licensee rolls cut from a Welte-Mignon master were assigned the same roll number as the master, but preceded by a letter that indicated the price of the roll. The letter P identifies rolls belonging to the so-called 'Purple Series' which were produced by M. Welte and Sons at Poughkeepsie.

[39] Gerhard Dangel and Hans W. Schmitz, *Welte-mignon klavierrollen: Gesamkatalog der europäischen aufnahmen 1904-1932 für das welte-mignon reproduktionspiano*, 2 parts (Stuttgart: Rombach Druck, 2006), 511.
[40] Smith and Howe, *The Welte-Mignon*, 168.
[41] Smith and Howe, *The Welte-Mignon*, 241.
[42] Dangel and Schmitz, *Welte-mignon klavierrollen*, Part B, 217.

Welte-Mignon recordings to April 1906

The 1904 recordings for the Welte-Mignon were made at the Freiburg factory. From January 1905 to April 1906, recordings were generally made at Leipzig, although some could have been made also at Freiburg.

Statistics to April 1906

Table 1.1 gives the statistics of the Welte-Mignon library up to roll number 1277, the last roll to be recorded at the Leipzig studio in April 1906.[43] The recordings of art music made up to April 1906 constitute a third of the entire library of Welte-Mignon art music.

Table 1.1 *Statistics of Welte-Mignon library of art music as at April 1906*

Aspect	Quantity	Comments
Recordings	778	Up to April 1906, less than 40 rolls of popular music and no accompaniment recordings were made
Works	666	Some works have a playing time of over twelve minutes, showing that from the start, Welte was recording large works
Rolls	790	The larger number of rolls compared to recordings shows that large works (such as sonatas) requiring more than one roll were being recorded
Composers	144	See Figure 1.1 for the major contributors
Pianists	94	50 pianists were born before 1870, number takes into account one pseudonym
Playing time	at least 60 hrs	Conservative value, based on known playing times of nearly half of all Welte-Mignon rolls of art music produced up to 1906

Not included in the table are the 295 rolls that were issued then later withdrawn. Because of their rarity and potentially imperfect quality, the withdrawn rolls fall into a separate category. Several of the withdrawn recordings were made by significant pianists and are therefore an historically important resource, albeit a difficult one to access.

[43] Smith and Howe, *The Welte-Mignon*, 71.

Composers to April 1906

Figure 1.1 lists the composers with ten or more works in the Welte-Mignon catalogue as at April 1906. The bar graphs show the number of works and number of recordings made of the works.

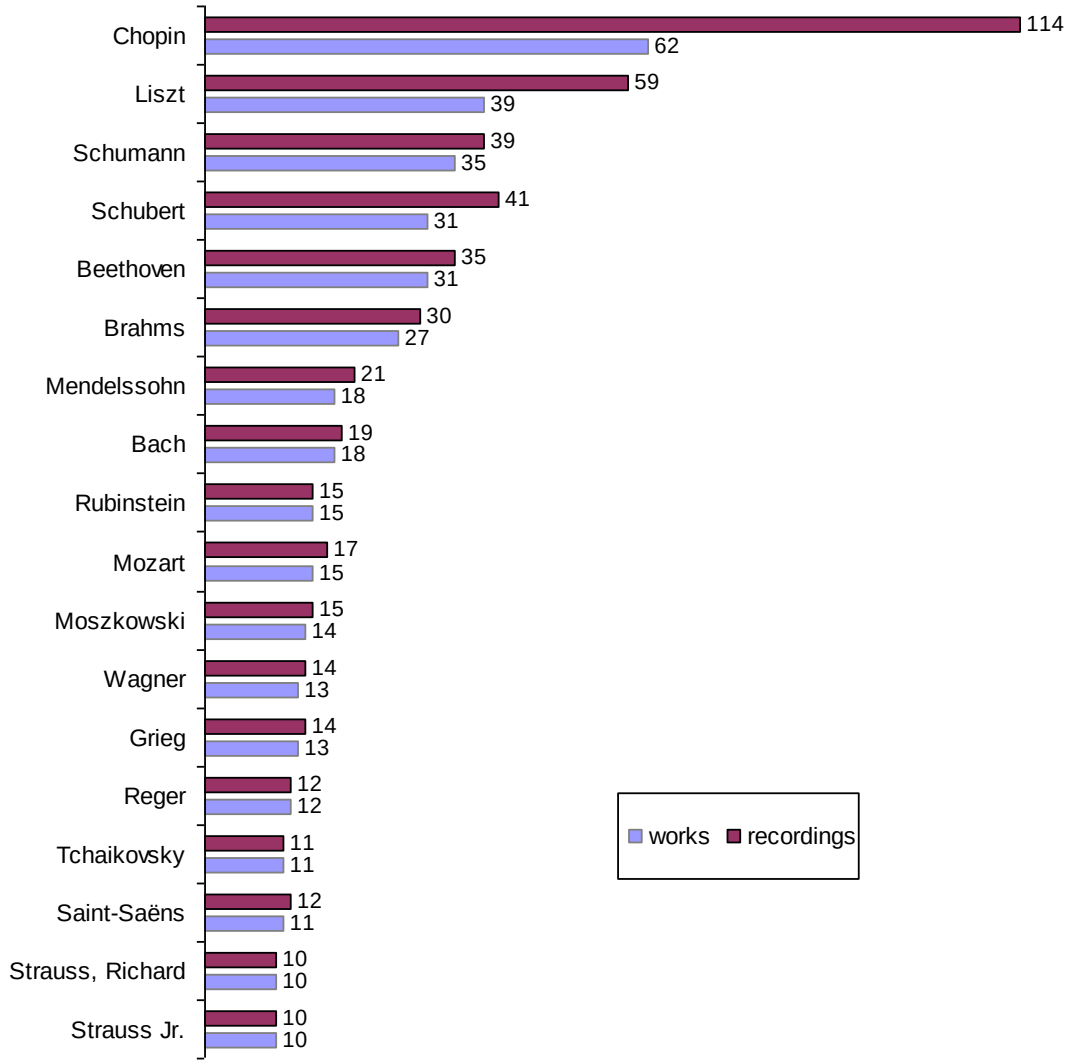

Figure 1.1 *Recordings of works by these eighteen composers comprise nearly two thirds of the Welte-Mignon recordings of art music made by April 1906*

The list of composers in Figure 1.1 shows that from the start, the Welte-Mignon catalogue was aimed at the serious music lover. Many of the major composers are well represented, offset with lighter works by Moritz Moszkowski (1854–1925) and Johann Strauss Jr (1825–1899). Major works include eighteen sonatas by Ludwig van Beethoven (1770–1827), although in many cases only one or two movements were recorded. Other large works include the B minor Sonata S.178 by Franz Liszt (1811–1886), recorded by Germaine Schnitzer (1888–1982).

Composers who had eight or nine works in the catalogue are Carl Maria von Weber (1786–1826), Theodor Leschetizky (1830–1915) and Erik Meyer-Helmund (1861–1932). Around 70 percent of the remaining composers have three or less works; some of these composers recorded their own works. Many of the composers are unknown today.

Pianists to April 1906

Most of the historically notable pianists on Welte-Mignon roll made their recordings at the Leipzig studio. Birthdates could be found for 87 of the 94 pianists who recorded during this period, of which at least 50 were born before 1870. Table 1.2 lists all Welte-Mignon recording artists who were born in 1850 or earlier and who recorded at Leipzig, in chronological order. Where relevant, each listing shows the number of Ampico or Duo-Art recordings made by these pianists, and the related table(s) that give more information. The pianists in Tables 1.2 and 1.3 appear on Ampico roll only from their Hupfeld recordings. See Table 1.15 on page 70.

Table 1.2 *1905-06 Welte-Mignon pianists born 1850 or before*

Pianist	No. of works	Playing time (*approx*)[44]	Nationality	[Recording date(s)] composers represented, other roll companies
Carl Reinecke (1824–1910)	7	25 mins	German	[January 20-21, 1905] Mozart (3), Reinecke (2), Beethoven & Schumann (1); Ampico (1)
Theodor Leschetizky (1830–1915)	13	40 mins	Polish	[February 18 & 27, 1906] Leschetizky (8), Chopin & Heller (2), Mozart (1)
Camille Saint-Saëns (1835–1921)	13	55 mins	French	[July 13, 1905] Saint-Saëns (9), Chopin (2), Beethoven & Schumann (1); also Ampico (2), Duo-Art (6) see Table 1.25 (a)
Friedrich Gernsheim (1839–1916)	3	n/a	German	[November 25, 1905] rolls issued October 1909, own works
Edvard Grieg (1843–1907)	3	6 mins 37 secs	Norwegian	[March 15 & April 17, 1906] own works; Ampico (3)
Vladimir de Pachmann (1848–1933)	20	74 mins	Russian	[February 19, 1906] Chopin (9), Pachmann (3), Mendelssohn & Schumann (2), Mozart, Liszt, Raff & Schubert (1); also De Luxe (17) see Table 1.13, and Duo Art (12) see Table 1.25 (a)
Xaver Scharwenka (1850–1924)	14	87 mins	Polish	[March 7, 1905] Chopin (4), Schumann (3), Beethoven & own works (2), Liszt, Schubert & Schumann (1); also Ampico (1), Duo-Art (6) see Table 1.25 (a)

[44] Taken from actual playing times, sometimes conservatively approximated from limited data; in some cases a figure could not be determined, indicated by n/a.

- **Pianists born 1851-59**

Table 1.3 lists in chronological order nine of the fourteen pianists born in the period 1851 to 1859. Few of these pianists recorded exclusively for the Welte-Mignon, as many also recorded later for Hupfeld and other piano roll companies. Exceptions are Essipoff, Leoncavallo and Wendling, who were exclusive to the Welte-Mignon.

Values in parenthesis are the number of recordings made at other dates, values in square brackets are the total number of Welte-Mignon recordings made by a pianist. The recording sessions could have been held many years apart.

Table 1.3 *Notable 1905-06 Welte-Mignon pianists born 1851-59*

Pianist	**No. of works**	**Playing time** (*approx*)	**Nationality**	**[Recording date(s)] composers represented, other roll companies**
Annetta Essipoff (1851–1914)	10	40 mins (at least)	Russian	[February 7, 1906] Chopin (4), d'Albert, Arensky, Bellini-Thalberg, Schubert-Liszt, Schumann & Verdi-Liszt (1)
Alfred Grünfeld (1852–1924)	16	75 mins	Austrian	[January 19-20, February 1, 1905] Grünfeld (4), Chopin & Schumann (3), Schubert (2), Beethoven, Strauss Jr-Grünfeld, Volkmann-Fischhof & Wagner-Liszt (1); also Ampico (1)
Otto Neitzel (1852–1920)	10	75 mins	German	[October 23-24, 1905] Beethoven, Neitzel & Schumann (2), Bach, Brassin, Debussy & Saint-Saëns (1)
Raoul Pugno (1852–1914)	11 (10) [21]	45 mins (to 1906)	French	[September 25-27, 1905 & 1907] Chopin (3), Bach, Beethoven, Chabrier, Fauré, Handel, Liszt, Paradies & Scarlatti (1); see Table 1.7 for 1907 recordings (10)
Teresa Carreño (1853–1917)	11	1 hour 40 mins	Venezuelan	[April 2 and 10, 1905] Chopin (4), Liszt (3), Beethoven, Carreño, Smetana & Schumann (1); also Ampico (4), Duo-Art (7) see Table 1.25 (a)
Engelbert Humperdinck (1854–1921)	3	n/a	German	[October 19, 1905] one work each from three of his operas
Ruggero Leoncavallo (1857–1919)	6	n/a	Italian	[December 8 & 27, 1905] own works only including extracts from three of his operas
Karl Wendling (1857–1918)	10	30 mins	German	[April 3, 10, May 16, 20, 1905] Grieg (2), Bizet, Jadassohn, Jensen, Raff, Scholtz Schuett, Sinding, Wagner-Liszt & (1)
Arthur Friedheim (1859–1932)	5	36 mins 49 secs	German	[January 23-24, 1905] Liszt (4), Mendelssohn (1); also Ampico (1), Duo-Art (15) see Table 1.25 (a)

Artists not included in Table 1.3 are Wilhelm Kienzl (1857–1941)—known as a composer associated with Wagner—and conductor Arthur Nikisch (1855–1922). Others are Liszt's pupil and Sarasate's accompanist Berthe Marx-Goldschmidt (1859–1925)—who made four recordings only, and, perhaps surprisingly, Hugo Popper (of Popper and Co)—who recorded three salon works and a number of songs and popular waltzes.

- **Pianists born 1860-69**

At least 29 pianists who made recordings in this period were born between 1860 and 1869. Table 1.4 lists seventeen of these artists, in chronological order. Busoni and d'Albert made a number of later recordings, shown in parenthesis. Their total Welte-Mignon recordings are shown in square brackets. Artists with four or less roll recordings (except Mahler) are not included in the table. Others not included are composer Erik Meyer-Helmund (1861–1932) and composer-violinist Georg Alfred Schumann (1866–1950), both of whom recorded eight works, and pianist-composer Felix Dreyschock (1860–1906) who recorded ten works.

Another pianist not included in Table 1.4 is Eugenie Adam-Bernard (1861–1925), about whom little is known except that she was the first pianist to record for the Welte-Mignon. Her husband Alexander Adam (1853–1915) was a orchestral conductor.[45] The name Eugenie Adam appears later in the catalogue, playing accompaniments and also art music. The similarity of the names suggests the same person, which is not assumed here.

[45] Dangel and Schmitz, *Welte-mignon klavierrollen,* Part A, 45.

Table 1.4 *Notable 1905-06 Welte-Mignon pianists born 1860-69*

Pianist	**No. of works**	**Playing time** (*approx*)	**Nationality**	**[Recording date(s)] composers represented, other roll companies**
Gustav Mahler (1860–1911)	4	27 mins	Austrian	[June 9, 1905] own works, two songs and extracts from symphonies
Ignace Jan Paderewski (1860–1941)	14	1 hour 27 mins	Polish	[February 27, 1906] Chopin (7), Schubert-Liszt & own works (2), Beethoven, Liszt & Schubert (1); also Duo-Art (33) see Table 1.25 (a)
Konrad Ansorge (1862–1930)	6	n/a	German	[April 6, May 10, 1905] Schubert-Liszt & own works (2), Bach & Schubert (1)
Arthur de Greef (1862–1940)	10	n/a	Belgian	[February 15, 1906] own works (4), Grieg (3), Wagner-Brassin (2), Schumann (1)
Emile von Sauer (1862–1942)	10	40 mins	German	[November 25, 1905] own works (4), Chopin (3), Liszt transcriptions (2), Liszt (1); also Ampico (1), Duo-Art (6) see Table 1.25 (a)
Bernhard Stavenhagen (1862–1914)	8	35 mins	German	[December 9, 1905] Chopin & Liszt (4)
Alfred Reisenauer (1863–1907)	7	1 hour	German	[April 9-10, 1905] Beethoven (3), Chopin, Liszt, Schumann's *Carnaval* Op. 9, & Chopin-Liszt (1)
Eugen d'Albert (1864–1932)	11 (34) [45]	45 mins (n/a)	Scottish-German	[May 19 & 24, 1905 & 1913] own works (3) Chopin, Liszt & Schubert (2), Beethoven & Schubert-Liszt (1); 1913 recordings (34) see Table 1.7, also Ampico (1), Duo-Art (8) see Table 1.25 (a)
Richard Strauss (1864–1949)	10	35 mins	German	[February 15-16, 1906] own works only, also Ampico (2)
Josef Weiss (1864–1945)	5	n/a	German	[May 8, 1905] own works (2), Bach, Brahms & Dohnányi (1)
Fritz von Bose (1865–1930)	8	n/a	German	[October 17, 1905] Moszkowski & Schubert (2), Liszt, Mozart, Reinecke & Schumann (1)
Josef von Slivinski (1865–1945)	8	n/a	Polish	[September 12, 1905] Chopin & Liszt transcriptions (3), Liszt & Tchaikovsky (1); pupil of Leschetizky and Rubinstein
Ferruccio Busoni (1866–1924)	8 (5) [13]	43 mins (53 mins) [96 mins]	Italian	[Five dates in 1905, & March 16, 1907] Liszt transcriptions (5), Chopin (2), Bach-Busoni (1); see Table 1.7 for 1907 recordings (5), also Ampico (4), Duo-Art (30) see Table 1.25 (a)
Clotilde Kleeberg (1866–1909)	10	n/a	French	[November 9 and 11, 1905] Beethoven & Chopin (2), Dubois, Fauré, Mendelssohn, Moszkowski, Rameau & Saint-Saëns (1)
Max Pauer (1866–1945)	10	n/a	German	[November 21, 1905] Liszt & Heller (3), Beethoven, Mendelssohn, Pauer & Schumann (1); also Ampico (1), pupils include d'Albert
Wassily Sapellnikoff (1867–1941)	12	n/a	Russian	[December 1, 1905] own works (6), Chopin & Liszt (2), Schubert & Strauss Jr-Tausig (1); also Ampico (1), pupil of Tchaikovsky
Frederic Lamond (1868–1948)	8	55 mins	Scottish	[September 25, 27 & November 27, 1905] Beethoven, Chopin & Liszt (2); own work & Rubinstein (1); also Ampico (1), Duo-Art (15) see Table 1.25 (a)

- **Pianists born after 1869**

The pianists listed in Tables 1.2 to 1.4 collectively made 300 recordings, which when added to the recordings made by Adam-Bernard comprise nearly half the art music recorded up to April 1906. Table 1.5 (a) lists, in chronological order, the notable pianists with birth dates of 1870 to 1879 and who recorded at least seven works at Leipzig. Table 1.5 (b) lists pianists born 1880 or later.

Table 1.5 (a) *Notable 1905-06 Welte-Mignon pianists born 1870–1879*

Pianist	**No. of works**	**Playing time** (*approx*)	**Nationality**	**[Recording date(s)] composers represented, comments, other roll companies**
Carl Friedberg (1872–1955)	11	30 mins	German	[February 9, 1906] Schubert (3), Brahms & Friedberg (2), Beethoven, Chopin, Scarlatti-Tausig & Schuett (1); also Duo-Art (9) see Table 1.25 (b)
Max Reger (1873–1916)	10	n/a	German	[December 8, 1905] own works only
Paul de Conne (1874–1959)	16	40 mins	Russian	[November 29, 1905] Rubinstein (4), Schubert & Strauss Jr (2), Chopin, Daquin, Haydn, Lwoff, Sauer, Schuett, Schumann & Wagner (1); pupil of Rubinstein, exclusive to Welte-Mignon
Josef Hofmann (1876–1957)	10 (11) [21]	56 mins (80 mins) [2hr 16m]	Polish-American	[12 & 20 October 1905; 1913] Chopin, Moszkowski, Rubinstein & Wagner (2), Schubert-Liszt & Schumann-Tausig (1); for 1913 recordings (11) see Table 1.7, also Ampico (2), Duo-Art (52) see Table 1.25 (b)
Ernő Dohnányi (1877–1960)	12	1 hour	Hungarian-American	[September 13, 1905, January 31, 1906] Liszt & Schubert (3), Dohnányi (2), Bach, Brahms, Chopin & Schumann (1); also Ampico (18) see Table 1.17 (a)
Ossip Gabrilowitsch (1878–1936)	9	n/a	Russian-American	[March 10, April 7 & 10, 1905] Chopin, Brahms & own works (2), Raff, Schumann & Tchaikovsky (1); also Ampico (6) & Duo-Art (15) see Tables 1.17 (b) & 1.25 (b)
Gottfried Galston (1879–1950)	14	30 mins	Austrian	[October 15, 1905] Chopin, Liszt, Rubinstein (1), Brahms Waltzes Op. 39 (11); pupil of Leschetizky and Reinecke
Mark Hambourg (1879–1960)	7	40 mins	Russian-English	[November 30, 1905] Chopin & Rubinstein (2), Bach, Beethoven & Liszt (1); also Ampico (2) & Duo-Art (6) see Tables 1.17 (a) & 1.25 (b)
Wanda Landowska (1879–1959)	12	n/a	Polish-French	[December 4, 1905] Bach (3), Chopin (2), Berlioz-Liszt, Dandrieu, Daquin, Durante, Scarlatti-Tausig, Schubert & Schumann (1); also Ampico (2), Duo-Art (4) see Table 1.25 (b)

Table 1.5 (b) *Notable 1905-06 Welte-Mignon pianists born 1880 or after*

Pianist	**No. of works**	**Playing time** *(approx)*	**Nationality**	**[Recording date(s)] composers represented, comments, other roll companies**
Egon Petri (1881–1962)	12	n/a	Dutch-German	[September 22, 1905] Liszt (5), Alkan & Schumann (2), Beethoven, Gluck-Sgambati & Mozart (1)
Elly Ney (1882–1968)	13	n/a	German	[February 9, 1906] Brahms & Seiss (2), Beethoven, Chopin, Delibes, Haeuser, Handel, Kaun, Koehler, Liszt & Rubinstein (1); also Ampico (6) & Duo-Art (3), see Tables 1.17 (b) & 1.25 (c)
Artur Schnabel (1882–1951)	13	n/a	Polish	[May 8-9, 1905] Chopin (4), Schubert (3), Bach (2), Brahms, Lanner, Joseph Strauss & Weber (1); also Ampico (6) see Table 1.17 (b)
Michael von Zadora (1882–1946)	16 (21) [37]	n/a	American	[September 12, 23, 29, 1905 & 1921] Chopin (5), Bach-Busoni (3), Schumann (2), Beethoven, Busoni, MacDowell, Schubert, Strauss Jr-Tausig & Zadora (1); for 1921 recordings (21) see Table 1.10, also Ampico (4) & Duo-Art (11), see Tables 1.17 (b) & 1.25 (c)
José Vianna da Motta (1886–1948)	10	n/a	Portuguese	[October 10, 25, 27, 1905] own works (3), Chopin & Schubert-Liszt (2), Liszt, Scarlatti & Weber (1)
Yolanda Mérő (1887–1963)	10 (17) [27]	n/a	Hungarian-American	[October 30, Nov 11, 1905, also 1909 & 1911] Liszt (3), Saxlehner (2), Bach, Handel, Haydn. Mozart & Vogrich (1); for 1907-11 recordings (17) see Table 1.7, also Ampico (3) & Duo-Art (4) see Tables 1.17 (b) & 1.25 (c)
Germaine Schnitzer (1888–1982)	9	n/a	French	[November 28, 1905] Chopin (3), Liszt (2), Chabrier, Moszkowski, Saint-Saëns & Schubert-Tausig (1); also Ampico (11) see Table 1.17 (b)
Alice Ripper (1889–1961)	7	n/a	Hungarian	[September 16, 1905] Backer-Grondahl, Glinka-Balakirev, Gounod-Liszt, Liszt, Moszkowski, Schubert-Liszt & Stradal (1)

The pianists listed in the tables or mentioned in the text account for 58 of the 94 pianists who recorded at Leipzig during the period 1905-06. They were responsible for nearly three quarters of all works recorded during this period.

Summary

The 1905-06 Leipzig recordings are the most historically important of all reproducing piano roll recordings. Although sound recordings of famous pianists were made at the time, the Leipzig Welte-Mignon recordings far outnumber them. The Welte-Mignon recordings include some of the most legendary figures from the nineteenth century, as well as recordings made by high-profile pianists who had their careers in the twentieth century such as Dohnányi, Hofmann, Landowska and Schnabel.

Welte-Mignon recordings April 1906 to end 1913

After Edwin Welte left for America in 1906, the recording equipment was probably moved back to Freiburg, as no more recordings appear to have been made at the Popper studio. During the remainder of the year only two recording sessions involving art music were held. During the first session in July, recordings were made by Bella (Arabella) Fichter (1861–1930), who recorded operetta selections and light classical works. The second session on October 6, 1906, involved Josef Lhévinne (1874–1944) who recorded 21 works. He later made further recordings for M. Welte and Sons in the US, and also for Ampico.

During this period, Karl Bockisch was seemingly in charge of the recording process as according to Richard Simonton: "It was always Karl Bockisch's job to handle the talent, many of whom were very temperamental."[46] Previously, Popper would most likely have been involved in procuring and managing the artists. During 1907 the art music library grow by a further 74 recordings, involving pianists such as Pugno and Busoni who had previously recorded at Leipzig, and several other high-ranking artists such as Vera Timanoff (1855–1942) and Felix Mottl (1856–1911).

Three recording sessions were held during 1908. On August 6, Fannie Bloomfield Zeisler (1863–1927) recorded twelve works, followed by more recordings in 1912. (She also made recordings for De Luxe in 1924.) On August 24, Olga Samaroff (1880–1948) recorded nine works. The third session involved pianist Count Carl von Pückler (1857–1943) who made two recordings, giving a total of 23 more recordings of art music.

In 1909, the recording equipment was taken to England for a period of six months, where over 100 recordings of art music were made involving artists based in England.[47] Pianists who were recorded include Clara Schumann's pupil Fannie Davies (1861–1934) and composer Cyril Scott (1879–1970). It is possible that during this time recordings were also made at Freiburg, in which pianists Paula Utz (dates unknown) and Edwin Fischer (1886–1960) recorded thirteen works between them, although Fischer's recordings did not appear until the mid-1920s.[48]

[46] David Q. Bowers, *Encyclopedia of Automatic Musical Instruments* (New York: Vestal Press, 1972), 324.
[47] Time spent in England taken from roll recording dates.
[48] Smith and Howe, *The Welte-Mignon*, 367.

During early 1910 the recording equipment was taken to Russia where over 140 works were recorded by some 35 local pianists or composers, many of whom were likely to have been students or teachers from conservatories in St Petersburg or Moscow.[49] Among the composers were Alexander Glazounov (1865–1936) who recorded ten of his own works, Alexander Scriabin (1872–1915) who recorded nine of his own works, and Sergei Liapounov (1859–1924) with four recordings of his own works. Noted teacher and pianist Konstantin Igumnoff (1873–1948) recorded six works, three by Sergei Rachmaninoff (1873–1943). Thirteen year old prodigy Irene Eneri-Gorainoff (1897–1980) recorded seven works. The Russian recordings are possibly unique as no other piano roll company visited Russia to make such recordings.

A further sixteen recordings of art music were made at Freiburg during 1910, with noted accompanist Richard Epstein (1869–1919) making fifteen of them, and Hungarian violinist and prodigy Arpad Kun (1894–1925) making one. During 1911, a further 65 recordings were made at Freiburg. Pianists included Lhévinne and Yolanda Mérő (1887–1963), both of whom had made previous Welte-Mignon recordings. Austrian pianist Emil Paur (1855–1932) made twenty recordings in December of 1911.

During 1912 the recording equipment was taken to Paris. The Paris recordings were made by artists that included Claude Debussy (1862–1918), Gabriel Fauré (1845–1924), Manuel de Falla (1876–1946) and Auguste Delacroix (1871–1936). It is also possible that Diémer and Maurice Ravel (1875–1937) were recorded at this time.[50] Lesser known pianists, such as Paul Gayraud are believed to have also made recordings in Paris.

The Freiburg recordings made during 1912 included thirteen works recorded by Fanny Bloomfield Zeisler, and numerous recordings by pianists about whom little is written. Arts include Tosta di Benici (1867–1961), Russian concert pianist Fanny Weiland (1898–1931), R. Goodall (a pseudonym) and the young Johanna Löhr (1897–1980), a pupil of Pauer. Between them, the lesser-known pianists made half of all roll recordings produced in 1912.[51]

[49] Dangel and Schmitz, *Welte-mignon klavierrollen*, Part A, 69.
[50] In *The Welte-Mignon*, Smith and Howe state that Diémer recorded at Freiburg. Roll numbers either side of those assigned to Diémer are of works recorded in Paris, 358.
[51] Dangel and Schmitz, *Welte-mignon klavierrollen*, Part A, 51, 73 and 74.

Important artists who were recorded in 1913 include Enrique Granados (1867–1916) who recorded nine works, and d'Albert who recorded an astonishing 34 works during a one-day session on June 2, 1913. Rudolph Ganz (1877–1972) made 28 recordings and Josef Hofmann made eleven recordings, adding to the ten recordings he had made at Leipzig. Other lesser known artists include Charles Steinway (1857–1919), grandson of Henry E. Steinway (1797–1871) who founded the piano company Steinway & Sons, and Cornelius Rybner (1853–1929) who also recorded for Ampico.

Statistics (April 1906–1913)

Table 1.6 gives the statistics of the roll recordings of art music made for the Welte-Mignon over the period April 1906 to December 1913.[52]

Table 1.6 *Statistics of Welte-Mignon library of art music recorded April 1906–13*

Aspect	Number	Comments
Recordings	758	During this period, there was an increased emphasis on recordings of dance music and popular songs
Works	730	Works by major composers were still being recorded, but alongside a greater number of in-house transcriptions of songs from operettas and operas
Rolls	783	The larger number of rolls compared to recordings is partly due to many of the 'Operatic Fantasie' recordings occupying two rolls
Composers	184	See Figure 1.2 for the major contributors (page 35)
Pianists	108	At least 25 pianists were born before 1870; number takes into account two pseudonyms and includes three pseudonyms not accounted for
Playing time	60 hrs	Conservative estimate, based on known playing times of 35 percent of all art music Welte-Mignon recordings made during this period

[52] Includes Welte-Mignon roll numbers from 1287 to 3064.

Composers (April 1906–1913)

From April 1906 to 1913, a large number of popular songs and dance music recordings were made at Freiburg. The amount of art music recorded over this period is slightly less than that recorded at Leipzig, despite the much longer time frame of nearly eight years. Figure 1.2 lists the composers who had ten or more of their works recorded over this period.

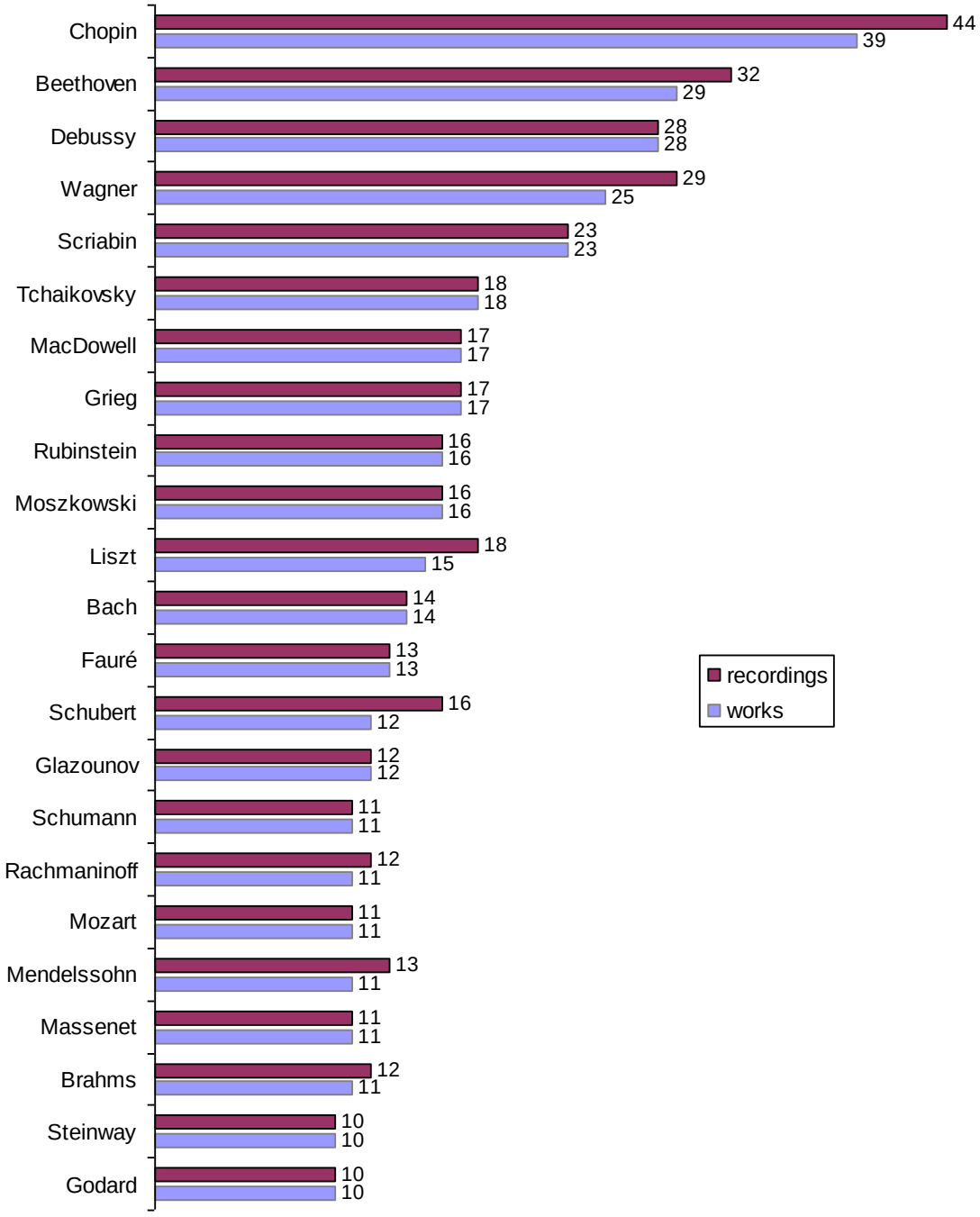

Figure 1.2 *Recordings of works by these 23 composers comprise over half the Welte-Mignon recordings of art music made during 1906-13*

When compared to the recordings made at Leipzig, the 1906-13 recordings covered works by a greater number of composers. There is also a greater representation of composers of salon and light classical music, such as Steinway and Benjamin Godard (1849–1895), both of whom previously had little or no presence in the catalogue. A substantial number of recordings were made of works from operas by Richard Wagner (1813–1883), adding to the fourteen works by Wagner that were recorded at Leipzig. Jules Massenet (1842–1912) is well represented, mainly through his operas, having previously had no presence in the catalogue. Edward MacDowell (1860–1908) previously had only one work in the catalogue.

The recordings made in Russia are reflected by the presence of works by Rachmaninoff, Glazounov and Scriabin, all of whom previously had few or no works in the catalogue. Similarly, the Paris recordings captured more works by French composers, in particular Debussy and Fauré, who previously had only two works each in the catalogue.

Pianists (April 1906–1913)

Of the over 100 pianists who recorded for the Welte-Mignon over this period, birth dates could be established for nearly 80 of them. As mentioned, there was now an increasing use of in-house pianists with fictitious names, and a greater number of artists who are unknown today.

Notable artists who made at least five recordings during this period are listed in Table 1.7. The recording location is assumed to be Freiburg unless otherwise stated. As noted in the table (where relevant), some of these artists made Welte-Mignon recordings at an earlier or later date, and some artists made recordings for the Ampico or Duo-Art reproducing pianos. The total number of Welte-Mignon recordings for each artist is shown in square brackets, numbers in parenthesis show the Welte-Mignon recordings made at another date.

Table 1.7 *Notable 1906-13 Welte-Mignon pianists born before 1870*

Pianist	**No. of works**	**Playing time** (*approx*)	**Nationality**	**[Recording date(s)] composers represented, other roll companies**
Louis Diémer (1843–1919)	10	n/a	French	[1912] own works (5), Massenet (2), Daquin, Godard & Rameau (1)
Gabriel Fauré (1845–1924)	5	n/a	French	[Paris 1912] own works (5), also Ampico (1)
Raoul Pugno (1852–1914)	10 (11) [21]	n/a	French	[March 6, 1907] Mendelssohn & Schumann (2), Bach, Couperin, Grieg, d'Indy, Mozart & Weber (1); for 1905 recordings (11) see Table 1.3, also Ampico (1)
Vera Timanoff (1855–1942)	14	n/a	Russian	[1907] Rubinstein (3), Cui, Glazounov, Glinka-Balakirev, Karpov, Liapounov, Liszt, Moszkowski, Napravnik, Paderewski, Sapellnikoff & Schlözer (1); exclusive to Welte-Mignon
Felix Mottl (1856–1911)	10	over 1 hour	Austrian	[Freiburg June 2, 1906] extracts from Wagner operas only; exclusive to Welte-Mignon
Fanny Davies (1861–1934)	12	n/a	British	[England, March 22 & 28, 1909] Brahms, Mendelssohn & Schumann (2), Bach, Gheyn, Leo, Mozart, Sgambati & Zipoli (1); exclusive to Welte-Mignon
Claude Debussy (1862–1918)	9	38 mins	French	[Paris 1912] own works, including entire *Children's Corner*; exclusive to Welte-Mignon
Fannie Bloomfield Zeisler (1863–1927)	25	2 hours	Austrian-American	[August 6, 1908 & 1912] Chopin (10), Schuett (4), Beethoven & Moszkowski (3), Bach-d'Albert (2), Brahms, Chaminade, d'Albert, Liszt & Poldini (1); also De Luxe (8) see Table 1.13, and Ampico (5) see Table 1.17 (a)
Eugen d'Albert (1864–1932)	34 (11)	n/a	Scottish-German	[June 2, 1913] Beethoven (7), Chopin (5), d'Albert (4), Tchaikovsky (3), Bach, Liszt & Sinding (2), Couperin, Grieg, Handel, Korngold, Rubinstein & Sgambati (1); see Table 1.4 for 1905-06 recordings (11), also Ampico (1), Duo-Art (8) see Table 1.25 (a)
Alexander Glazounov (1865–1936)	10	n/a	Russian	[Russia, January 1910] own works only, including 2nd movement from his Sonata No. 1 Op. 74; exclusive to Welte-Mignon
Ferruccio Busoni (1866–1924)	5 (8) [13]	43 mins (53 mins) [96 mins]	Italian	[March 16, 1907] Liszt transcriptions (3), Chopin & Liszt (1); see Table 1.4 for 1905 recordings (8), also Ampico (4), Duo-Art (30) see Table 1.25 (a)
Enrique Granados (1867–1916)	9	56 mins	Spanish	[September 1913] own works only; also Duo-Art (10) see Table 1.25 (a)

Table 1.8 lists, in chronological order, ten notable pianists born after 1870 who recorded for the Welte-Mignon during the period April 1906 to 1913.

Table 1.8 *Notable 1906-13 Welte-Mignon pianists born after 1870*

Pianist	**No. of works**	**Playing time** (*approx*)	**Nationality**	**Recording date(s), composers represented, other roll companies**
Alexander Scriabin (1872–1915)	9	15 mins	Russian	[Russia, February 1910] own smaller works only
Konstantin Igumnoff (1873–1948)	6	n/a	Russian	[Russia, February 1910] Rachmaninoff (3), Arensky, Brahms & Scriabin (1), exclusive to Welte-Mignon
Josef Lhévinne (1874–1944)	21 (6) [27]	n/a	Russian-American	[October 6, 1906 & 1911, also New York (6)] Rubinstein (4), Chopin (3), Beethoven, Czerny, Gluck-Brahms, Godard, Liszt, Mendelssohn, Meyerbeer- Liszt, Moszkowski, Schlözer, Schumann, Scriabin, Sgambati, Strauss Jr-Schulz-Evler & Weber (1); also Ampico (21) see Table 1.17 (a)
Josef Hofmann (1876–1957)	11 (10) [21]	80 mins (56 mins)	Polish-American	[1913] Beethoven & Rachmaninoff (2), Chopin, Handel, Hofmann, Mendelssohn, Paderewski, Rubinstein & Sgambati (1); see Table 1.5 for 1905 recordings (10); also Duo-Art (52) see Table 1.25 (b)
Ernest Schelling (1876–1939)	12	52 mins	American	[October 23, 1907] Chopin (6), Debussy & own works (2), Beethoven & Mendelssohn (1); also Duo-Art (6) see Table 1.25 (b)
Herbert Fryer (1877–1957)	23	n/a	English	[England, March 19, 1909] MacDowell (13), Beethoven (3), Brahms, Chopin, d'Albert, Debussy, Dvořák, Mozart & Rameau-Godowsky (1); also Duo-Art (10) see Table 1.25 (b)
Rudolph Ganz (1877–1972)	28 (27) [55]	n/a	Swiss-American	[August 1913, and New York 1914-25] Debussy & Ganz (4), Liszt & Godard (3), Barblan, Boccherini, Brahms, Cady, Chaminade, Chopin, Glazounov, Grieg, Korngold, Massenet, Moszkowski, Saint-Saëns, Schumann-Raff & Wagner (1); also Duo-Art (66) see Table 1.25 (b), see also Table 1.10
Olga Samaroff (1882–1948)	9	70 mins	American	[August 24, 1908] Grieg (3), Wagner (2), Chopin, Brahms, Fauré & Rubinstein (1); also Ampico (4) see Table 1.17 (b)
Yolanda Mérő (1887–1963)	17 (10) [27]	n/a	Hungarian-American	[England, July 1909 & Freiburg 1911] Chaminade & Nevin (5), Bortkiewicz, Debussy, Dohnányi, Heymann, Merkler, Schubert-Liszt & Strauss Jr-Tausig (1); also Ampico (3) & Duo-Art (4), see Tables 1.17 (b) & 1.25 (c)
Leff Pouishnoff (1891–1958)	5	n/a	Russian-English	[Russia 1910] Debussy (2), Arensky, Grieg & Rachmaninoff, (1); also De Luxe (16) see Table 1.13

Summary

By the end of 1913, the German companies Hupfeld and Philipps had established substantial reproducing piano roll libraries and were marketing their instruments in Europe in particular, and in the case of Hupfeld, in other parts of the world. By now, the American Piano Company had begun marketing a reproducing piano (Ampico) and developing its catalogue of rolls. Aeolian was about to announce its Duo-Art, with first roll recordings appearing in 1914.

Therefore, the Welte-Mignon rolls produced up to the end of 1913 cover a period when competitors in the US were just starting out. By now the company had made over 1500 recordings of art music. Unlike other piano roll companies, M. Welte und Söhne had taken the recording equipment to various countries capturing the playing of artists that in many cases recorded on no other medium, or for no other piano roll company.

Welte-Mignon recordings 1914 to 1930

When World War 1 broke out in 1914, Edwin Welte was enlisted in the army, while Karl Bockisch continued to run the business. During the war, few roll recordings were made in Germany, but recordings were now being made in the US. A limited number of the American issues were marketed in Germany.[53] Although the majority of recordings made in the US were of popular music, over 140 recordings were made of art music during the period 1914 to 1920, involving artists such as Lhévinne and Ganz.

Recording for the Welte-Mignon resumed at Freiburg from about 1919, initially concentrating on popular music. By now Edwin Welte had resumed his position at the Freiburg factory and presumably took on a leading role. Dangel explains that the aim was to add to the repertoire already recorded and to include younger artists.[54] Increasing the repertoire was partly achieved through in-house artist Hans Haass (1897–1955) who joined the company around 1922. According to Smith and Howe, when taking his pseudonyms into account, he would have been responsible for well over 500 recordings, much of it of popular music.[55]

Younger pianists who were recorded include Wilhelm Backhaus (1884–1969), Walter Gieseking (1895–1956), Rudolf Serkin (1903–1991) and Vladimir Horowitz (1904–1989), who in January 1927, made his roll recordings after his "spectacular debut

[53] Dangel, "A History of M. Welte & Sons," 39.
[54] Dangel, "A History of M. Welte & Sons," 40-41.
[55] Smith and Howe, *The Welte-Mignon*, 380.

in Hamburg."[56] Younger composers include Nicolai Medtner (1880–1951) and Erich Korngold (1897–1957).

Statistics (1914–1930)

Table 1.9 summarises the Welte-Mignon recordings made at Freiburg and in the US from the beginning of 1914 to 1930.[57]

Table 1.9 *Statistics of Welte-Mignon library of art music recorded 1914–1930*

Aspect	Quantity	Comments
Recordings	684	At least 130 recordings were made by in-house pianist Hans Haass, numerous recordings were made by unknown artists
Works	667	Large works such as symphonies and piano concertos were produced in this period, also a greater number of in-house transcriptions of songs from operettas and operas
Rolls	722	The larger number of rolls compared to recordings is due to large works such as symphonies requiring three or four rolls
Composers	223	See Figure 1.3 for the major contributors (next page)
Pianists	57	Over a quarter of the recordings were made by in-house or local pianists; number accounts for four pseudonyms used by Haass, and one used by Starke
Playing time	60 hrs	Highly conservative estimate, based on known playing times of twenty percent of all art music recorded by Welte during this period

The total output in terms of art music recordings from 1914 to 1930 is less than either of the two periods previously discussed. Of the 57 pianists, there were 37 about whom some information could be found. From the available data, the most senior pianist to record in this period was Alonso Cor de Las (1856–1933), who made fourteen recordings, mainly selections from operas or operettas.

Lesser known pianists include Georges Kiek (1882–1972), who recorded twenty works including three of Beethoven's Piano Concertos, and Alexander Laszlo (1895–1970) who recorded five symphonies and Liszt's Piano Concerto No. 1 S.124. Paul Strecker (unknown artist, possibly a pseudonym), recorded 23 works, including Sonatas by Joseph Haydn (1732–1809), Liapounov, Wolfgang Mozart (1756–1791), Sergei Prokofiev (1891–1953) and Rachmaninoff.

[56] Dangel, "A History of M. Welte & Sons," 42.
[57] Includes Welte-Mignon roll numbers from 3113 to 4196, inclusive of duplicate numbers.

Composers (1914–1930)

Figure 1.3 shows the composers who had ten or more of their works recorded over the 1914-30 period.

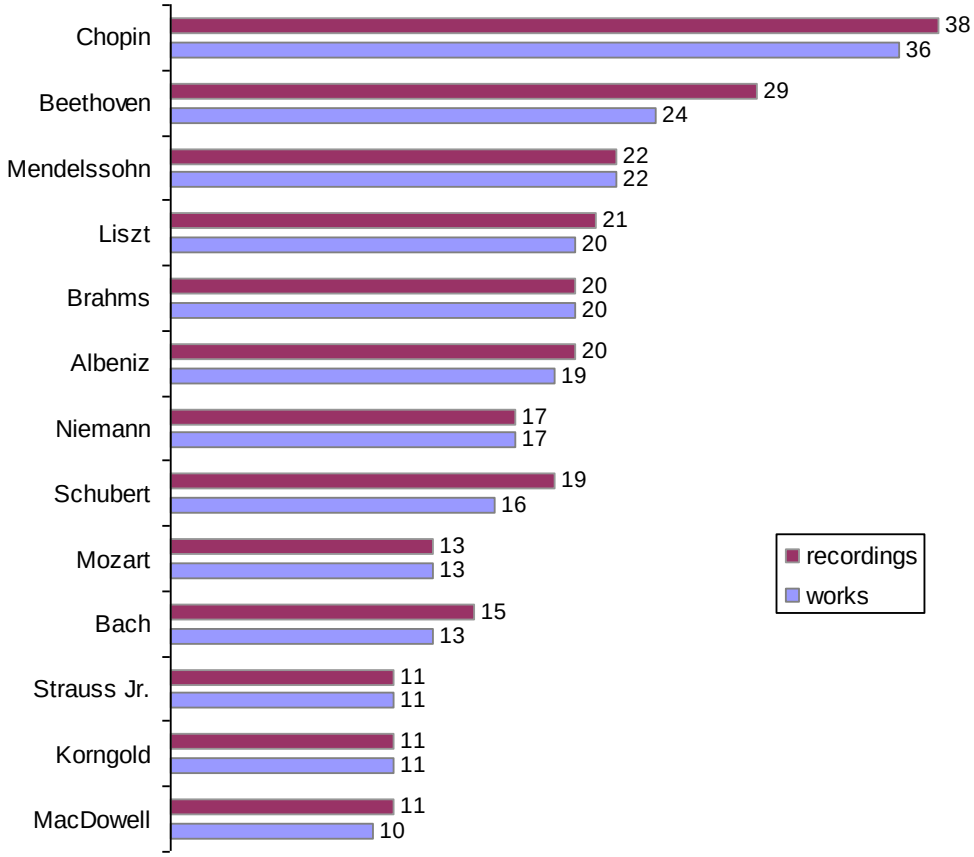

Figure 1.3 *Recordings of works by these thirteen composers comprise over a third of the Welte-Mignon recordings of art music made during 1914-30*

New entrants to the catalogue are Walter Niemann (1876–1953) who recorded only his own works, and Isaac Albéniz (1860-1909) whose works were recorded by Spanish pianist Ignacio Telleria (1880–1944) and Granados pupil Frank Marshall (1883–1959). Of the three recording periods, the 1914-30 period captured works by the greatest number of composers, which is surprising considering the fewer number of recordings that were made. Around 120 composers (nearly half the composers) had one work recorded and only 33 had five or more works recorded.

Pianists (1914–1930)

Table 1.10 lists fourteen notable artists in chronological order who recorded at least five works for the Welte-Mignon during this period. Backhaus is included as his three recordings are of substantial works.

Table 1.10 *Notable 1914–1930 Welte-Mignon pianists*

Pianist	No. of works	Nationality	Composers represented; brief information
Antoinette Szumowska (1868–1938)	10	Polish	Chopin (2), Beethoven, Daquin, Mendelssohn, Mozart, Paderewski, Schumann, Stojowski & Whiting (1); also Ampico (6) see Table 1.17 (a)
Maria Carreras (1872–1966)	14	Italian-American	Liszt (5), Beethoven, Chopin & Sgambati (2), Flagny, Palmgren & Rossi (1); also De Luxe (10) see Table 1.13, and Duo-Art (8) see Table 1.25 (b)
Walter Niemann (1876–1953)	13	German	Own works only, known mainly as a composer
Josef Lhévinne (1874–1944)	6 (21) [27]	Russian-American	[New York] Schumann's Symphonic Etudes Op. 13, Beethoven-Busoni, Dohnányi, Poldini, Rachmaninoff & Schubert-Liszt (1); also Table 1.8, Ampico (21) see Table 1.17 (a)
Rudolph Ganz (1877–1972)	27 (28) [55]	Swiss-American	Chopin (4), Korngold, Liszt and Scott (2), Amani, Bartok, Beethoven, Ganz, Gounod, Grainger, Granados, Haydn, Heller, Mendelssohn, Moszkowski, Palmgren, Ravel, Rubinstein, Sinding, Sodermann & Stojowski (1); see also Table 1.8, Duo-Art (66) see Table 1.25 (b)
Frank LaForge (1879–1953)	9	American	Chaminade, Godard & own works (2), German, Puccini & Schuett (1); also Duo-Art (2) and Ampico (2), pupil of Leschetizky
Nicolai Medtner (1880–1951)	10	Russian	Own works (9), Beethoven's Piano Sonata Op. 53, last two movements; also Duo-Art (4) of own works
Michael von Zadora (1882–1946)	21 (16) [37]	American	Liszt transcriptions (6), Amadis, Liszt & Rubinstein (3), Felton (2), Alkan, Busoni, Handel & Stojowski (1); for 1905 recordings (16) see Table 1.5, also Ampico (4) & Duo-Art (11), see Tables 1.17 (b) & 1.25 (c)
Frank Marshall (1883–1959)	18	Spanish	Albéniz & Granados (8), Chavarri & Mompou (1); exclusive to Welte-Mignon
Wilhelm Backhaus (1884–1969)	3	German	*Romance* from Chopin's Piano Concerto, *Wanderer Fantasie* Op.15 by Schubert-Liszt, and Schubert's *Marche Militaire*; 33 mins playing time, also Ampico (3) & Duo-Art (15), see Tables Table 1.15 & 1.25 (c)
Walter Gieseking (1895–1956)	13	French-German	Bach (4), Debussy (3), Beethoven, Brahms, Liszt, Neimann, Ravel & Schonberg (1); also Ampico (4) see Table 1.15
Rudolf Serkin (1903–1991)	9	Austrian-American	Bach's Goldberg Variations BWV 988, Schubert's Sonata D 958, Beethoven's Sonata Op. 10 No. 2, and five Etudes by Chopin; exclusive to Welte-Mignon
Carlo Zecchi (1903–1984)	11	Italian	Stravinsky & D. Scarlatti (2), Casella, Alaleona, Bajardi, Castelnuovo-Tedesco, D'Avico, Gasco & Pizzetti (1); exclusive to Welte-Mignon, pupil of Busoni and Schnabel
Vladimir Horowitz (1904–1989)	15	Russian-American	Chopin (5), Liszt & Rachmaninoff (3), Bach-Busoni, own works (2); also Duo-Art (7) see Table 1.25 (c)

Summary

The 1914 to 1930 Welte-Mignon recordings were made during the same period as those produced for the Ampico and Duo-Art instruments, with some of the artists appearing on all three brands of rolls. Several Welte-Mignon artists also recorded for De Luxe during the 1920s, when the reproducing piano was at the height of its popularity.

During this sixteen year period a number of acclaimed artists made Welte-Mignon roll recordings, including those returning to make further recordings and several young artists who went on to have distinguished careers in the twentieth century. Overall, the majority of the recordings made between 1914 and 1930 are by Haass and various unknown pianists, in which perhaps less than twenty of the names are likely to be known today. The recorded repertoire contains numerous examples of a single work played by its composer, many of whom are unknown today.

Complete Welte-Mignon art music catalogue

Statistics

Table 1.11 gives the statistics of the entire Welte-Mignon catalogue of art music recorded from January 1905 to 1930.

Table 1.11 *Statistics of complete Welte-Mignon library of art music*

Aspect	Quantity	Comments
Recordings	2220	▪ 35 percent of the catalogue was recorded during 1905-06 ▪ 220 recordings are transcriptions of operatic tunes or overtures, and 55 are operetta selections. Welte produced over 250 recordings of music from operettas, those included here are based on the composer, such as Offenbach. Around 72 operettas are listed in Welte's popular series, showing this type of music was generally of a popular nature.
Works	1936	Recordings of the same work by different pianists constitute around 12.5 percent of the catalogue
Rolls	2295	Compared with Ampico or Duo-Art, the Welte-Mignon art music catalogue has more recordings occupying two or more rolls, despite the company also issuing rolls with a playing time of up to fifteen minutes
Composers	388	See Figure 1.5 for the major contributors
Pianists	243	Birth dates were found for 185 pianists, at least 76 were born before 1870, seven were born in 1900 or later
Playing time	180 hrs	A conservative estimate only, could be 200 hours or more due to high number of lengthy roll recordings

Figure 1.4 shows the number of composers related to the number of their works in the final Welte-Mignon art music catalogue. For example, of the 388 composers, 180 have only one work in the catalogue. Over 80 composers have five or more works in the catalogue, which constitute three quarters of all works in the catalogue.

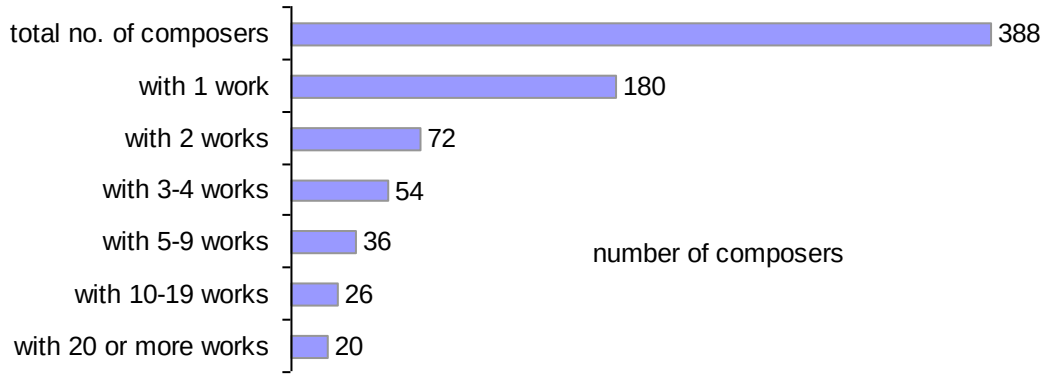

Figure 1.4 *Number of composers by number of their works (Welte-Mignon art music catalogue)*

Figure 1.5 lists the composers who have at least twenty works in the catalogue. All the major composers are well represented, in particular Mozart and J. S. Bach (1685–1750), also Russian composers such as Anton Rubinstein (1829–1894), Scriabin and Rachmaninoff.

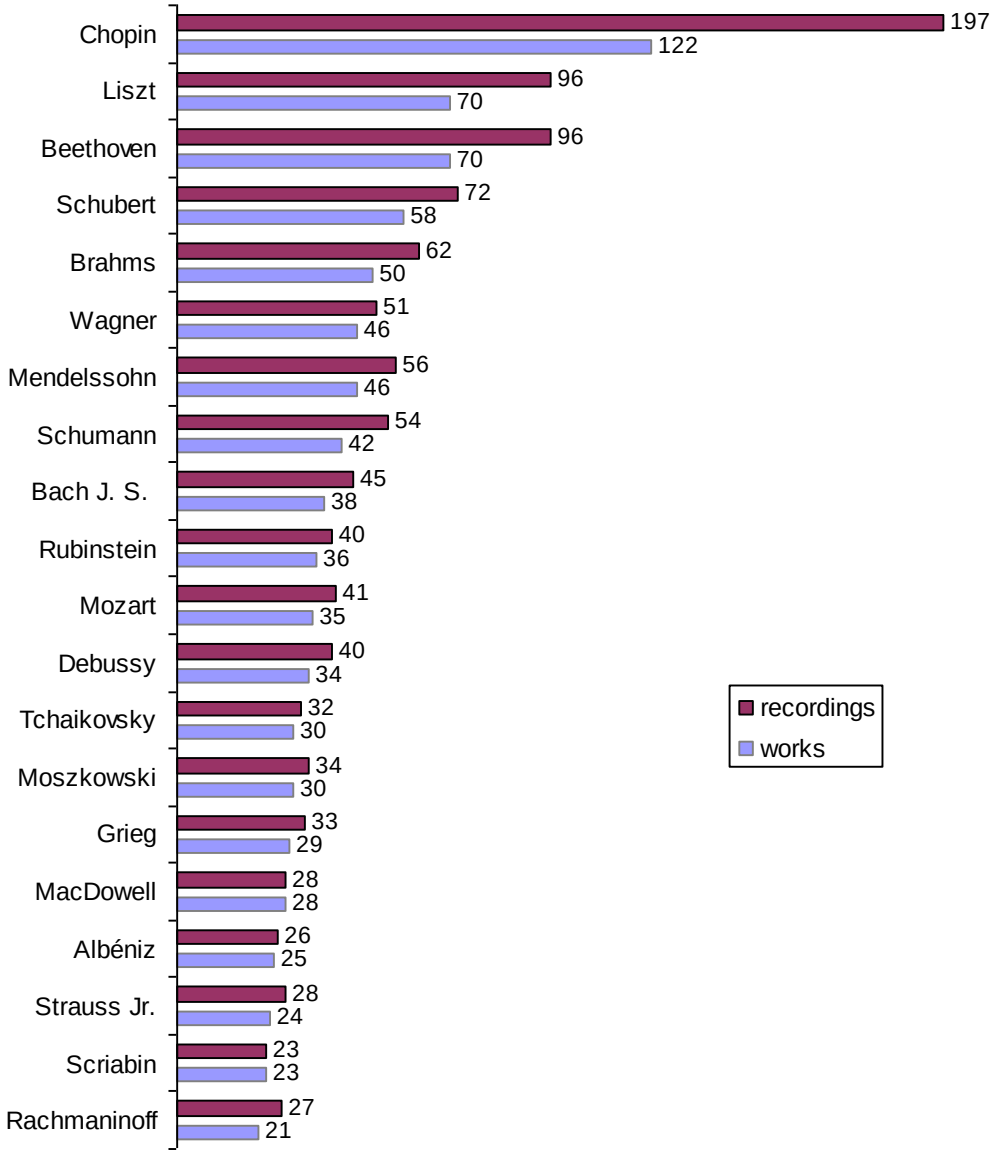

Figure 1.5 *Recordings of works by these twenty composers comprise nearly half the Welte-Mignon art music catalogue*

The bar graphs show that Liszt and Beethoven were equally popular. However, the popularity figures for Liszt would be greater if his transcriptions were included, instead they are credited to the composer of the original work (except for the Paganini Etudes). Also, not all of Beethoven's Piano Sonatas were recorded in their entirety, but are

nonetheless counted as a single work, even if only one movement was recorded.[58] There is a lesser number of salon and light classical works in the Welte-Mignon catalogue compared to the Ampico and Duo-Art catalogues, although this is offset by a greater number of waltzes by Strauss Jr and transcriptions of tunes from operas and operettas.

Figure 1.6 lists the composers who have fifteen to nineteen works in the catalogue. Five of these composers recorded their own compositions and include Glazounov, Reger and Niemann, all of whom have a minor presence in the Ampico and Duo-Art catalogues. Granados made nine of the recordings of his works, and Saint-Saëns recorded thirteen of his works.

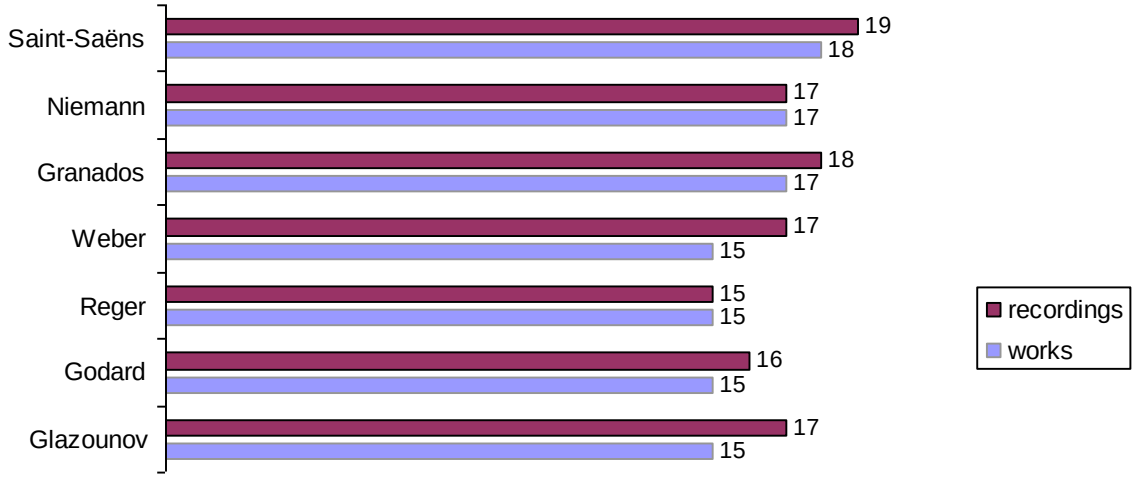

Figure 1.6 *Recordings of works by these seven composers comprise five percent of the Welte-Mignon art music catalogue*

[58] The same approach is taken with the graphs and tables for the Ampico and Duo-Art catalogues.

Composers with ten to fourteen works in the catalogue are listed in Figure 1.7. Opera composers such as Giacomo Meyerbeer (1791–1864), Massenet, Giuseppe Verdi (1813–1901), Gioachino Rossini (1792–1868), Georges Bizet (1838–1875) and Charles Gounod (1818–1893) are well represented through the transcriptions of their operas. Light classical music is provided by Émile Waldteufel (1837–1915) and Chaminade, also operettas by Jacques Offenbach (1819–1880). Christian Sinding (1856–1941) is well represented with thirteen works; Scott recorded four of his own works. All works by Steinway are salon pieces and are played by the composer. Ganz, Heinemann and d'Albert recorded music by Korngold; d'Albert also recorded seven of his own works.

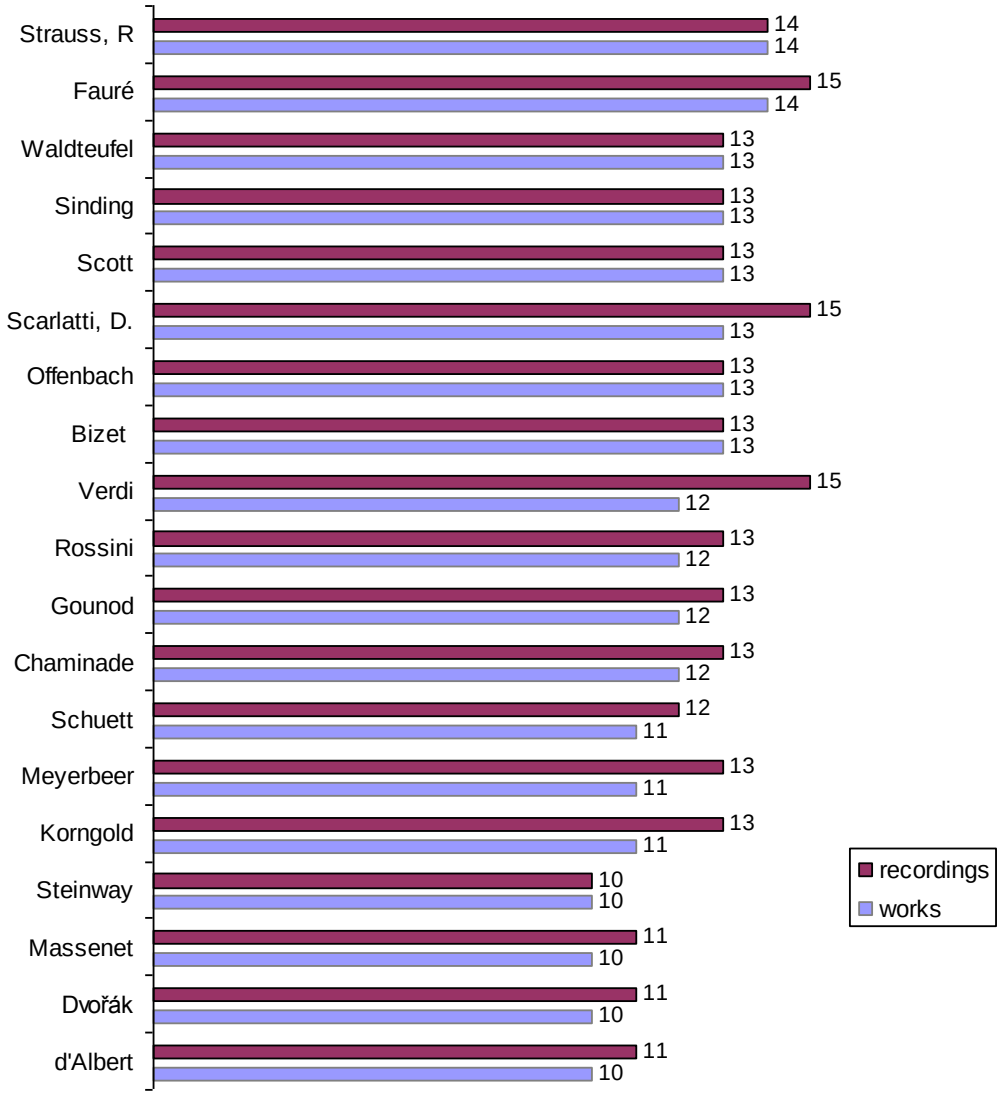

Figure 1.7 *Recordings of works by these nineteen composers comprise eleven percent of the Welte-Mignon art music catalogue*

The composers with seven, eight or nine works in the catalogue are listed in Figure 1.8. Meyer-Helmund, Medtner, Kienzl and Diémer are the only Welte-Mignon artists who made roll recordings of their compositions. Ruggero Leoncavallo (1857–1919) recorded six of his works, including extracts from his *Pagliacci*. Piano Concerto Op. 15 by Giovanni Sgambati (1841–1914) was recorded by pupil Maria Carreras (1872–1966), Leschetizky recorded eight of his works, Paderewski recorded two of his works and composer-pianist Max Vogrich (1852–1961) recorded six of his seven works in the catalogue, but not his otherwise much-recorded *Staccato Caprice* in F sharp.

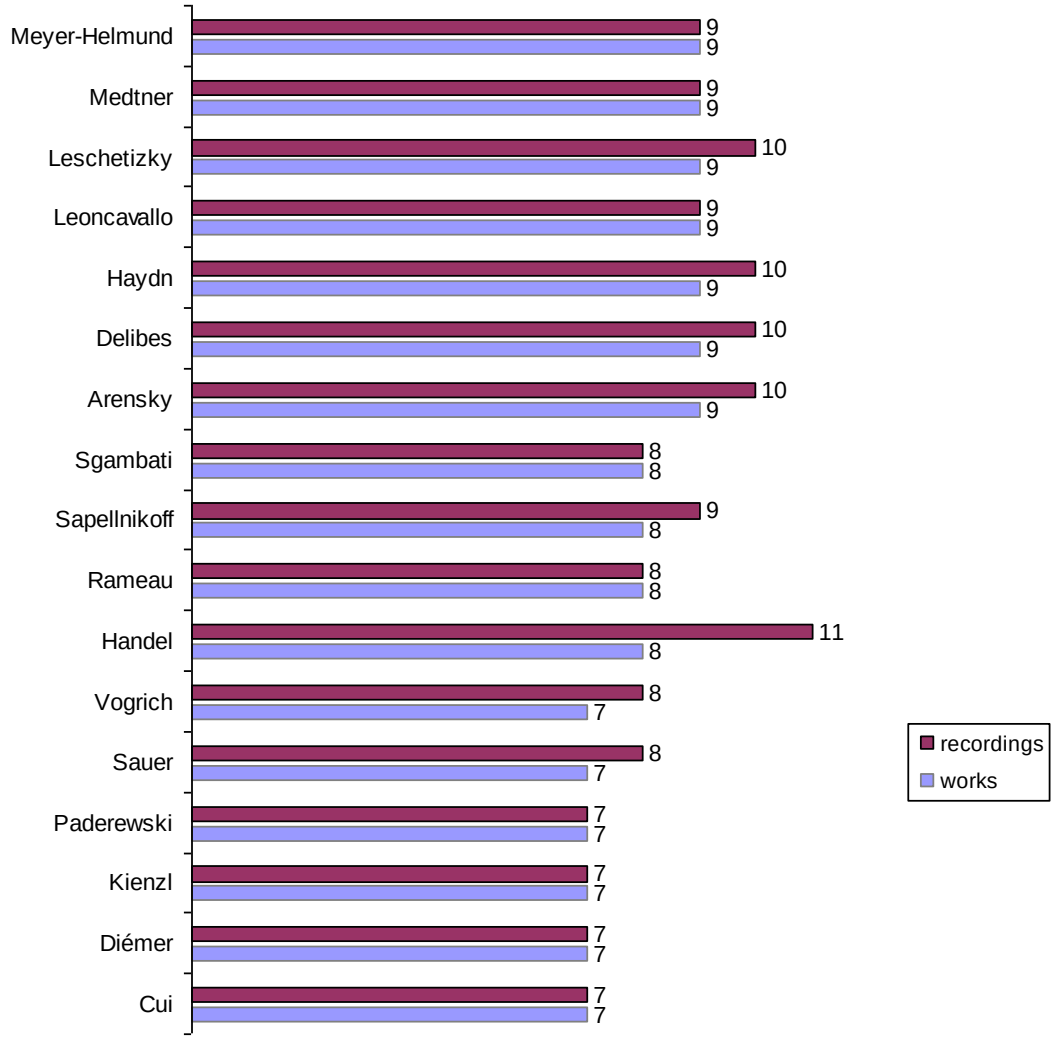

Figure 1.8 *Recordings of works by these seventeen composers comprise nearly seven percent of the Welte-Mignon art music catalogue*

Composers with five or six works in the catalogue are listed in Figure 1.9. Liapounov recorded four of his own works, those by Mily Balakirev (1837–1910) were recorded by Russian pianist Leocadie Kaschperov (1872–1940). Dohnányi recorded only two of his compositions for the Welte-Mignon, although he recorded fourteen of them for Ampico. Julius Weismann (1879–1950) is described in Welte-Mignon literature as a German pianist-composer who was a student of Josef Rheinberger (1839–1901) and Ludwig Thuille (1861–1907), and who wrote in a range of genres.[59]

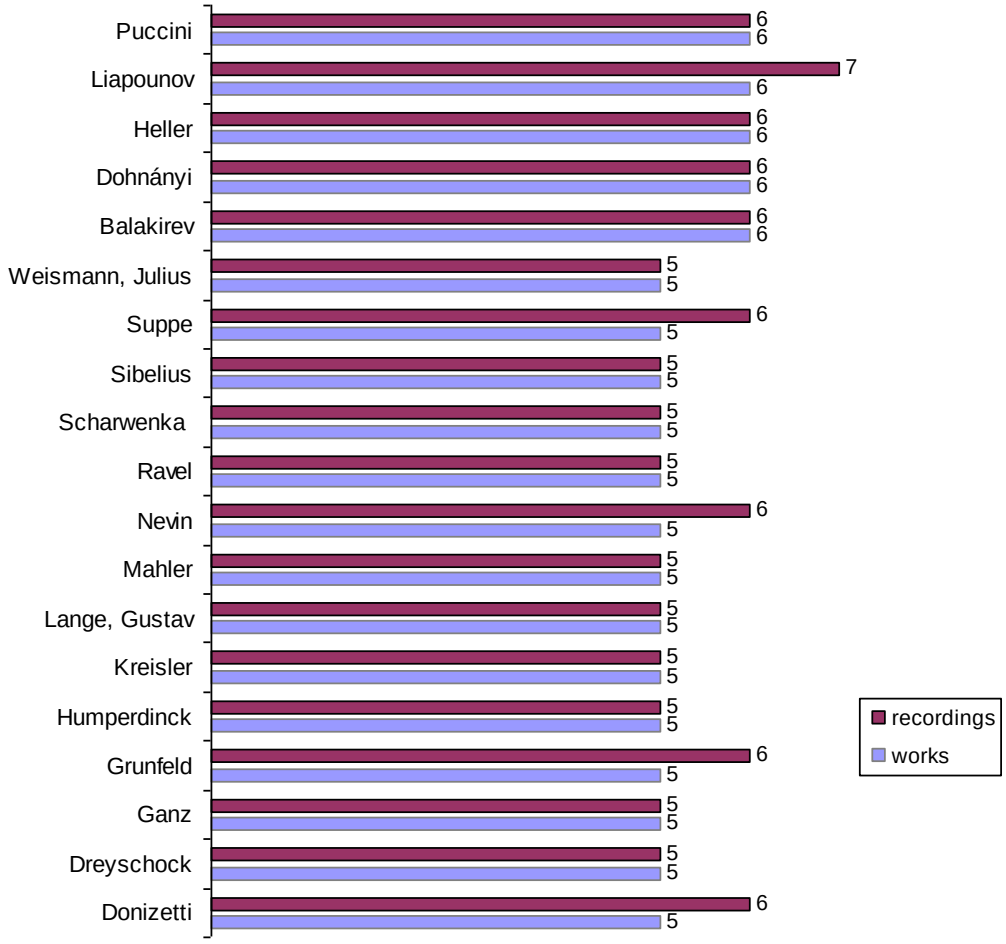

Figure 1.9 *Recordings of works by these nineteen composers comprise nearly five percent of the Welte-Mignon art music catalogue*

Fourteen composers in Figure 1.19 have five works in the catalogue, including Mahler and Ravel who recorded four and two of their own works respectively. Humperdinck recorded three of his own works. Pianist-composers with five works each in the catalogue include Scharwenka, Dreyschock, Ganz and Grünfeld.

[59] Smith and Howe, *The Welte-Mignon*, 483.

Summary – composers

Figure 1.10 summarises Welte-Mignon recordings of art music and the composers in terms of composer representation in the catalogue. It shows, for example that twenty composers are represented on nearly half of all recordings in the catalogue. These composers are listed in Figure 1.5 (page 45). Composers with ten to nineteen works are listed in Figures 1.6 and 1.7 (pages 46 and 47), and collectively cover only sixteen percent of Welte-Mignon recordings. Those with five to nine works are listed in Figures 1.8 and 1.9.

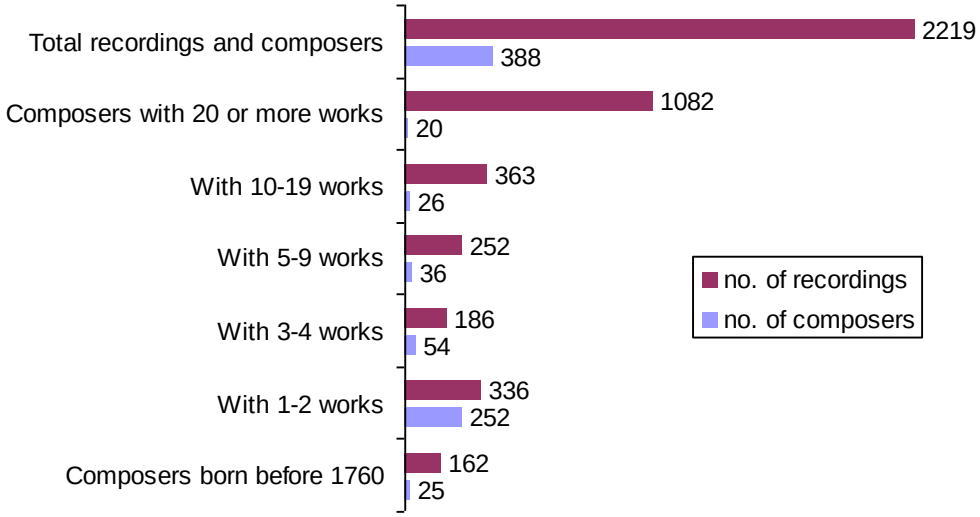

Figure 1.10 *Summary of composer content (Welte-Mignon art music catalogue)*

The number of recordings of works written by composers from the eighteenth century is shown in Figure 1.10 to give a comparison to other piano roll catalogues. In the case of the Welte-Mignon, about seven percent of the catalogue comprises music written by composers born before 1760, compared with four percent for the Duo-Art and Ampico catalogues. The birth date of all but 50 of the 388 composers could be established, in which 90 percent of them were born before 1880. Only two were born in the twentieth century, indicating that the majority of the music recorded for the Welte-Mignon was written by nineteenth-century composers.

Of the 375 composers whose gender could be established, only eleven were identified as female. The female composers have 30 recordings in the catalogue, the majority of them composed by Chaminade. Several female pianists, such as Carreño recorded their own compositions.

Summary – pianists

Of the nearly 250 pianists who made Welte-Mignon roll recordings, at least 80 are regarded as notable and are listed in tables 1.2 to 1.5, 1.7, 1.8 and 1.10. These 80 pianists made nearly half of all the Welte-Mignon recordings in the art music catalogue. Figure 1.11 shows the Welte-Mignon artists who made twenty or more recordings, giving in total nearly 730 recordings. An asterisk beside a name indicates the pianist is listed in the previously mentioned tables.

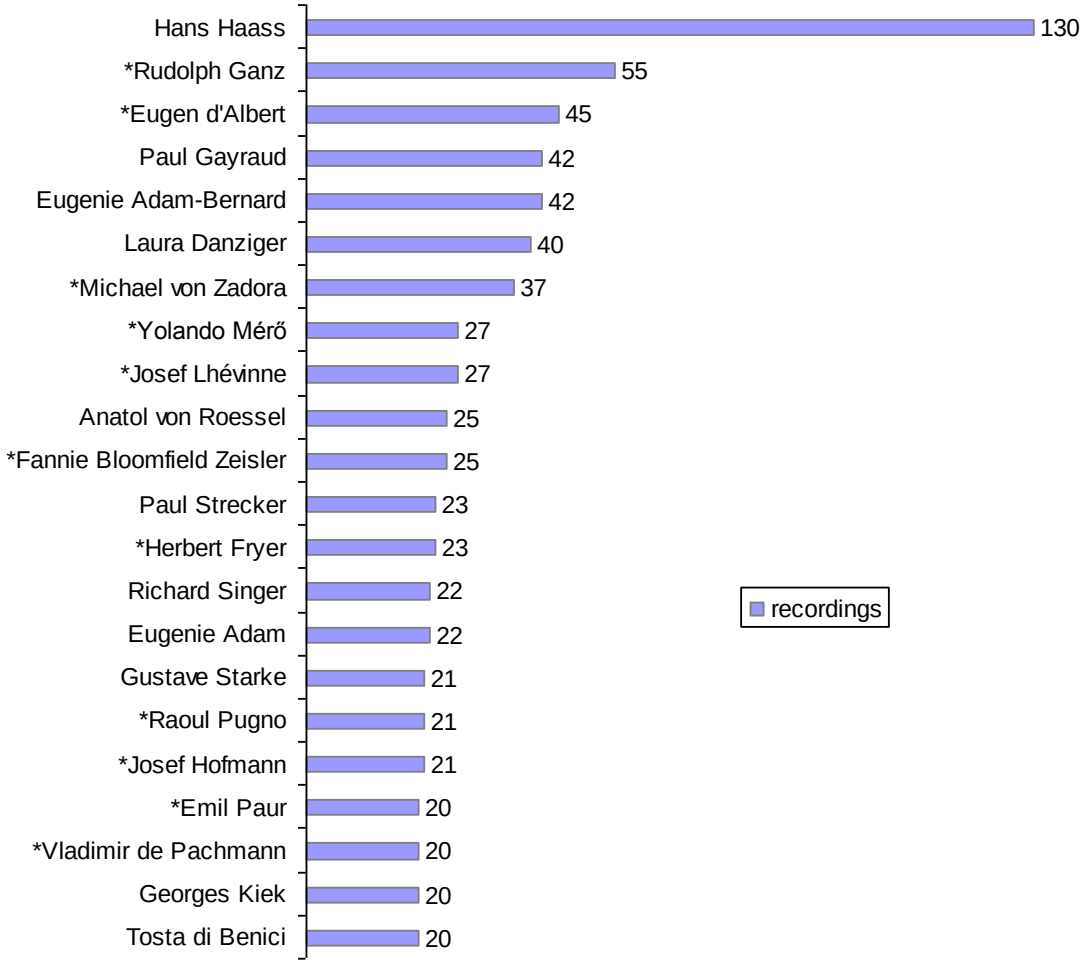

Figure 1.11 *Recordings by these 21 pianists comprise a third of the Welte-Mignon art music catalogue*

The 55 pianists who made ten to nineteen Welte-Mignon roll recordings make up another third of the catalogue. The remaining third of the catalogue (780 recordings) comprises works played by 165 pianists of which only eighteen pianists made a single recording.

Summary – catalogue content

Recordings for the Welte-Mignon were made over a period of around 25 years. The initial support provided by Popper meant that many of the most historically important artists made recordings for the instrument. The Leipzig studio, where over a third of the catalogue was recorded in sixteen months, was also convenient to many of the artists.

Among those pianists whose backgrounds could be traced are at least eleven pupils of Leschetizky, numerous pupils of Liszt, and around 80 artists whose careers took place largely during the nineteenth century. At the other end of the spectrum are several notable twentieth-century pianists who recorded for the Welte-Mignon in the late 1920s.

Many of the composers whose works make up the catalogue are today still well known, or at least remembered, and over half the Welte-Mignon recordings are of their works. There are numerous composers with one work in the catalogue, but of fewer number compared to such composers in the Duo-Art and Ampico catalogues, which is reflected by the lesser number of salon and light classical music works in the Welte-Mignon catalogue.

There are many works by unknown composers recorded on Welte-Mignon rolls, as there are on Ampico and Duo-Art rolls. However, compared to the latter two catalogues, there are many more Russian and European composers in the Welte-Mignon catalogue. This reflects musical tastes in Germany and other European countries where the Welte-Mignon was sold. It is also due to the company making recordings in Russia.

Conclusion

Edwin Welte and Karl Bockisch, both young men in their twenties, developed a technology that, considering the times, was extraordinary. Hugo Popper's support of the invention is important in terms of the outcomes: a significant body of recordings that captured so many historically important artists. Because roll recordings for the Welte-Mignon were made from 1905, they cover a period when the acoustic recording industry was in its infancy, and when no other reproducing piano rolls were being made. The recorded repertoire, the number of historically important pianists and the number of well-known composers who recorded their own works make Welte-Mignon rolls a very significant collection of roll recordings.

De Luxe rolls for the Welte Licensee

The De Luxe Player Roll Corporation began producing rolls for the Welte Licensee instrument in 1920, starting with popular music.[60] Previously, the De Luxe catalogue only listed roll recordings derived from Welte-Mignon masters. An advertisement in a 1923 issue of *Presto* describes the De Luxe catalogue released July 6, 1923 as containing 912 titles, or 1019 titles "when the latest issues were considered."[61] Of these, around 900 titles are likely to be from Welte-Mignon recordings.

The foreword in the 1924 De Luxe Music Roll catalogue explains that: "These recordings of world famous pianists […] also includes the recordings of a number of newer artists who are rapidly rising to the heights of musical fame." The foreword concludes with: "Many new records of world known artists will be released monthly with new recordings by new pianists."[62] The task was to add to an already strong catalogue of art music recorded by world-famous artists, but which had been developed to suit European tastes. Because the De Luxe catalogue also contains roll recordings from Welte-Mignon masters, I differentiate between these and De Luxe recordings by referring to De Luxe recordings only, not the De Luxe catalogue.

Statistics

Table 1.12 gives the statistics of the roll recordings of art music made by the De Luxe Player Roll Corporation over the period 1920 to 1930.

Table 1.12 *Statistics of De Luxe recordings of art music*

Aspect	Quantity	Comments
Recordings	1011	Number achieved over ten years, which is consistent with the output of other roll companies over the same period
Works	980	Most works (97 percent) were recorded once
Rolls	1035	Ten symphonies on 44 rolls and other multiple roll recordings are offset by rolls containing more than one work
Composers	294	See Figure 1.13 for the major contributors (next page)
Pianists	116	Birth dates of 48 artists were found; five were born before 1870, eight were born 1900 or later
Playing time	70 hrs	Estimate, based on known playing times of a third of the De Luxe recordings of art music

[60] "New De Luxe Reproducing Rolls Well Received," *Presto*, no. 1780 (September 4, 1920), 8.
[61] "New De Luxe Roll Catalog," *Presto*, no. 1932 (August 4, 1923), 17.
[62] De Luxe Roll Corporation, *Library of De Luxe Welte-Mignon (Licensee) Music Records* (USA, 1924).

Composers

Figure 1.12 shows the number of composers related to the number of their works that were recorded by De Luxe. For example, 150 composers have only one work.

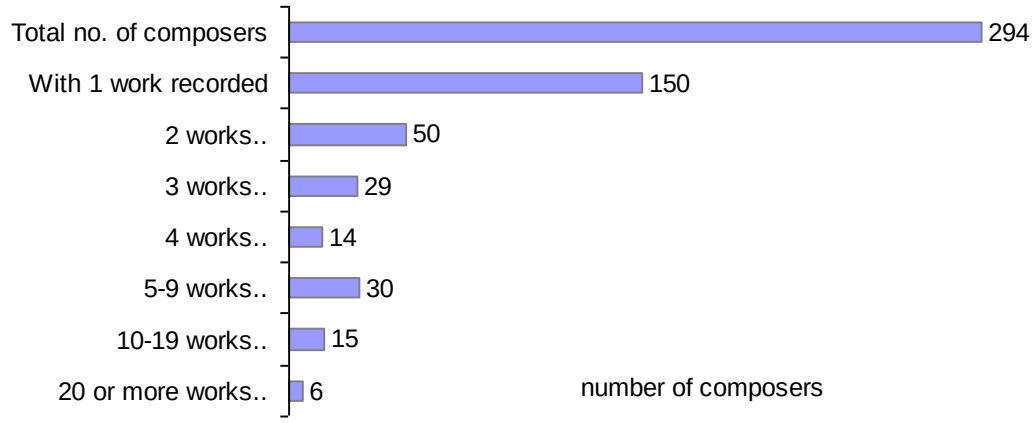

Figure 1.12 *Number of composers by number of their works (De Luxe recordings)*

Figure 1.13 lists the composers with fifteen or more works recorded by De Luxe, and the number of recordings of their works.

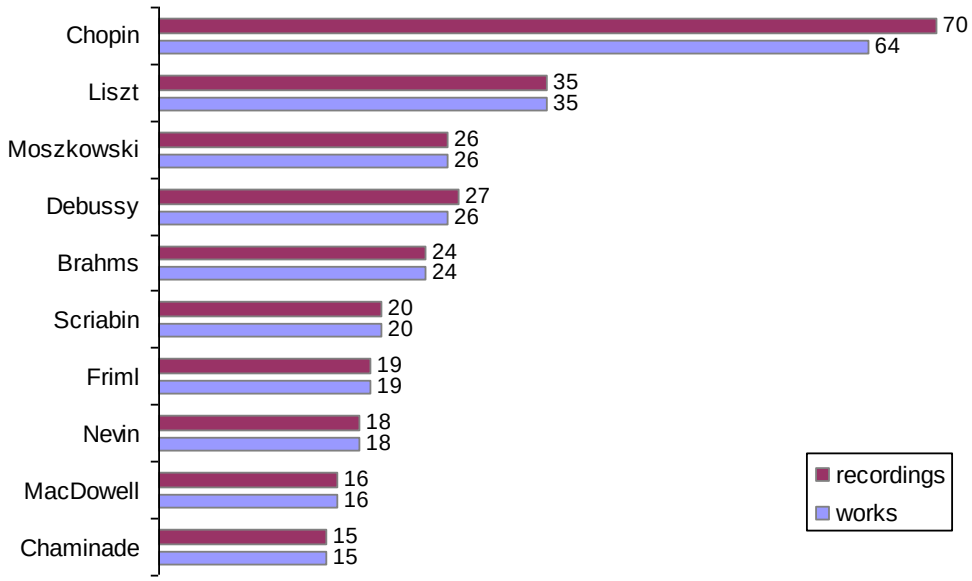

Figure 1.13 *Recordings of works by these ten composers comprise over a quarter of all De Luxe recordings of art music*

Composers of salon and light classical music include Rudolf Friml (1879–1972), who has no works in the Welte-Mignon catalogue and Ethelbert Nevin (1862–1901), who has five. Chaminade's popularity is shown with twelve works recorded for the Welte-Mignon and fifteen by De Luxe. Music by Scriabin is well covered by both companies, with a total of 43 recordings, showing his popularity in Europe and America.

Figure 1.14 lists the composers with ten to fourteen works in the catalogue. Dutch-American composer Louis Victor Saar (1868–1937) is the only pianist to record his compositions and does not appear in the Ampico or Duo-Art catalogues. Pianist-composer Georg Liebling recorded three of his own works for the Welte-Mignon, and ten of his own compositions among his 35 recordings for De Luxe. He has no presence in either the Ampico or Duo-Art catalogues.

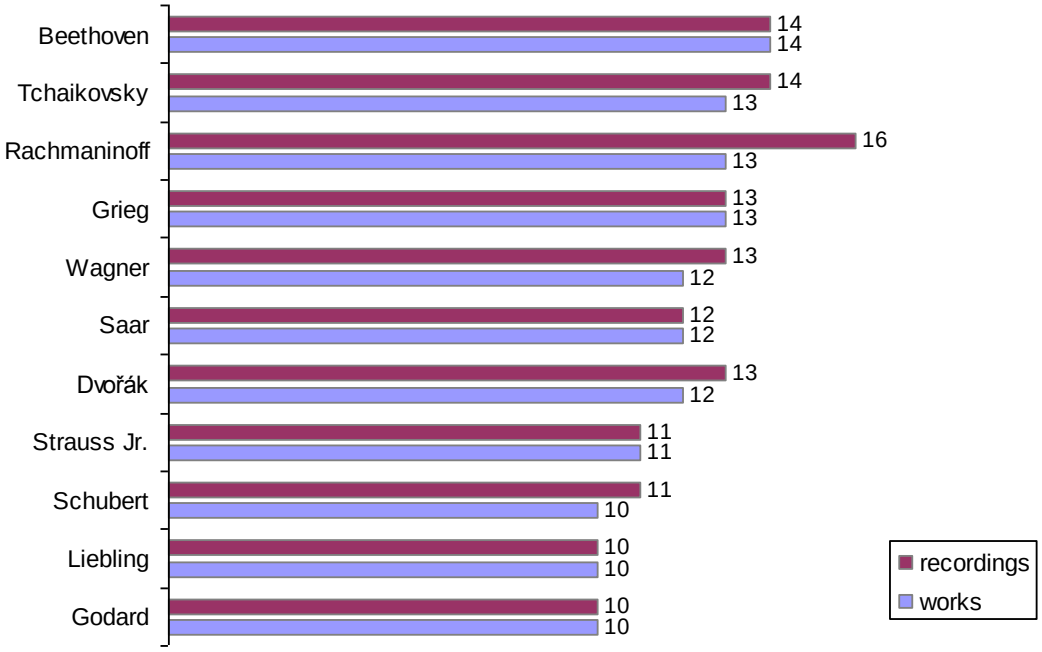

Figure 1.14 *Recordings of works by these eleven composers comprise nearly thirteen percent of all De Luxe recordings of art music*

The 73 composers who had three or more works recorded by De Luxe include Australian pianist George Boyle (1886–1948), who recorded eight of his own works, and Heitor Villa-Lobos (1887–1959), with four compositions recorded by unknown pianist Alfredo Oswald. The two works by Béla Bartók (1881–1945) in the Welte-Mignon catalogue are complemented by four works recorded for De Luxe by the composer. Ottorino Respighi (1879–1936) joins Alfredo Casella (1883–1947) on De Luxe roll recordings of three movements from Respighi's tone poem *Fountains of Rome*. French composer Darius Milhaud (1892–1974) recorded three of his own works for De Luxe.[63] The remaining 200 composers had one or two works recorded by De Luxe.

[63] Milhaud also recorded one work for the Pleyel company's reproducing piano called the Auto Pleyela.

Summary – composers

Figure 1.15 summarises De Luxe recordings of art music and the composers in terms of composer representation in the catalogue. The ten composers with fifteen or more works are represented on nearly a third of all De Luxe recordings, as are the 200 composers with one or two works.

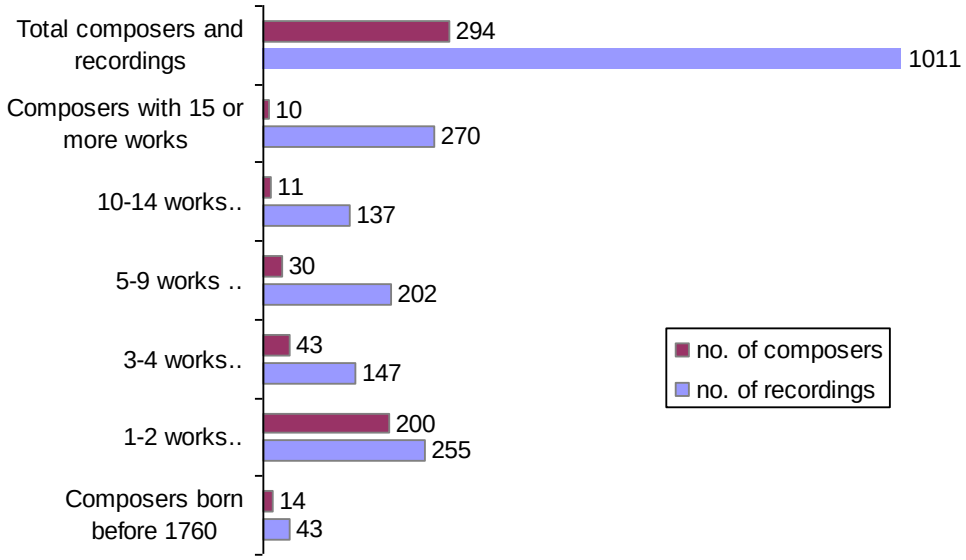

Figure 1.15 *Summary of composer content (De Luxe recordings)*

Figure 1.15 shows that works by composers of early music had limited popularity in the US, with fourteen composers represented and 43 recordings of their works. The birth dates of 254 of the 294 composers were found, in which all but 82 of them were born before 1880, indicating that the majority were trained or composing in the nineteenth century. The gender of 286 composers could be identified, showing that seventeen are female, a figure that is consistent with other piano roll catalogues. There is little doubt that in the nineteenth century composing was generally a male-dominated activity.

Pianists recorded by De Luxe

De Luxe did not need to seek high-profile artists, because so many were already in the catalogue via their Welte-Mignon recordings. Nine notable pianists who recorded for De Luxe are listed in Table 1.13. Pachmann, Bloomfield Zeisler and Gieseking in particular are mentioned in published literature. Boyle and Bacon were exclusive to De Luxe, all others in the table made recordings for other piano roll companies.

Table 1.13 *Notable pianists who recorded for De Luxe*

Pianist	**No. of works**	**Playing time** (approx)	**Nationality**	**Composers represented, brief information**
Vladimir de Pachmann (1848–1933)	17	62 mins	Russian	Chopin (13), Bach, Godowsky, Henselt-Pachmann & Verdi-Liszt (1); also Welte-Mignon 1906 (20) see Table 1.2, and Duo-Art (12) see Table 1.25 (a)
Fannie Bloomfield Zeisler (1863–1927)	8	40 mins	Austrian-American	Chopin (3), Moszkowski (2), Liszt, Rubinstein & Schuett (1); also Welte-Mignon (25) see Table 1.7, and Ampico (5) see Table 1.17 (a)
Maria Carreras (1872–1966)	10	n/a	Italian-American	Chopin, Kreisler & Liszt (2), Godard, Herbert, Hummel-Friedman & Schubert-Liszt (1); also Welte-Mignon (14) see Table 1.10 and Duo-Art (9) see Table 1.25 (b)
Alfredo Casella (1883–1947)	14	< 40[64] mins	Italian	Debussy (4), own works (3), D. Scarlatti (2), Albéniz & Granados (1), plus duo piano with Respighi, three parts from Respighi's *Fountains of Rome*; also Duo-Art (3)
Augusta Tollefsen (1885–1955)	16	n/a	American	Schumann, Liszt & Strauss Jr (2), Bendel, Goldmark, Klein, MacDowell, Moszkowski, Olsen, Rice, Saint-Saëns, Schlözer, & Verdi-Liszt (1); also Ampico (2), also known as Augusta Schnabel-Tollefsen
George Frederick Boyle (1886–1948)	12	< 35 mins	Australian	Own works (7), Arensky, Chopin-Sgambati, Moszkowski, Rachmaninoff & Schubert (1); exclusive to De Luxe, pupil of Busoni
Leff Pouishnoff (1891–1958)	16	n/a	Russian-English	Scriabin & own works (3), Albéniz-Godowsky, Chopin, Delibes-Dohnányi, Liszt, Mendelssohn, Paderewski, Poulenc, Rachmaninoff, Schubert-Godowsky & Schumann (1); also Welte-Mignon (5) and Duo-Art (7), see Tables 1.8 and 1.25 (c)
Walter Gieseking (1895–1956)	17	n/a	French-German	Debussy (9), Neimann, Grieg & R. Strauss-Reger (2), Rubinstein, Schubert-Liszt (1); also Welte-Mignon (13) see Table 1.10, and Ampico (4) see Table 1.15
Katherine Bacon (1896–1952)	12	48 mins	English	Liszt & Palmgren (2), Albéniz, d'Albert, Bauer, Chopin, Liapounov, Mendelssohn, Ravel & Rachmaninoff (1); exclusive to De Luxe

[64] The symbol < is used in lieu of 'greater than'.

Pianists – twenty or more recordings

Figure 1.16 lists the De Luxe artists who made twenty or more roll recordings. Many of these pianists are unknown today, yet they made around 40 percent of all De Luxe roll recordings of art music. Georg Liebling (1865–1946) studied piano with Theodor Kullak (1818–1882) and later with Liszt,[65] Richard Singer (1879–1961) received his piano training under Busoni and Leschetizky.[66] Volavy made many recordings for Ampico and a few for the Duo-Art.

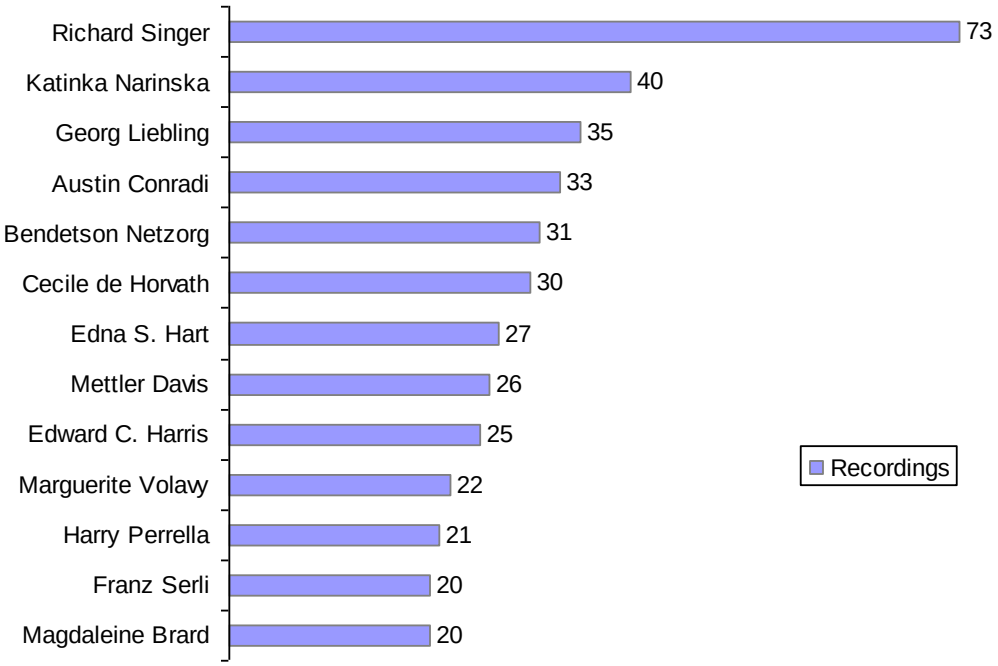

Figure 1.16 *Recordings by these thirteen pianists comprise nearly forty percent of all De Luxe recordings of art music*

Magdaleine Brard (1903–?) is not mentioned in published literature other than piano roll catalogues. According to entries about her in the De Luxe and Duo-Art roll catalogues, Brard was born in France and admitted to the Paris Conservatory at age eleven where she became Alfred Cortot's (1877–1962) "most brilliant pupil."[67] She married in 1920 and later joined the faculty of the Conservatory. Mettler Davis was in charge of the De Luxe recording studio.

[65] Nicolas Slonimsky, *Baker's Biographical Dictionary of Musicians* (New York: Schirmer Books, 1997), 796.
[66] Smith and Howe, *The Welte-Mignon*, 468.
[67] Smith and Howe, *The Welte-Mignon*, 337.

Pianists – fourteen to seventeen recordings

Figure 1.17 lists the De Luxe artists who made fourteen to seventeen roll recordings.[68] An asterisk beside a name indicates the pianist also made Welte-Mignon recordings.

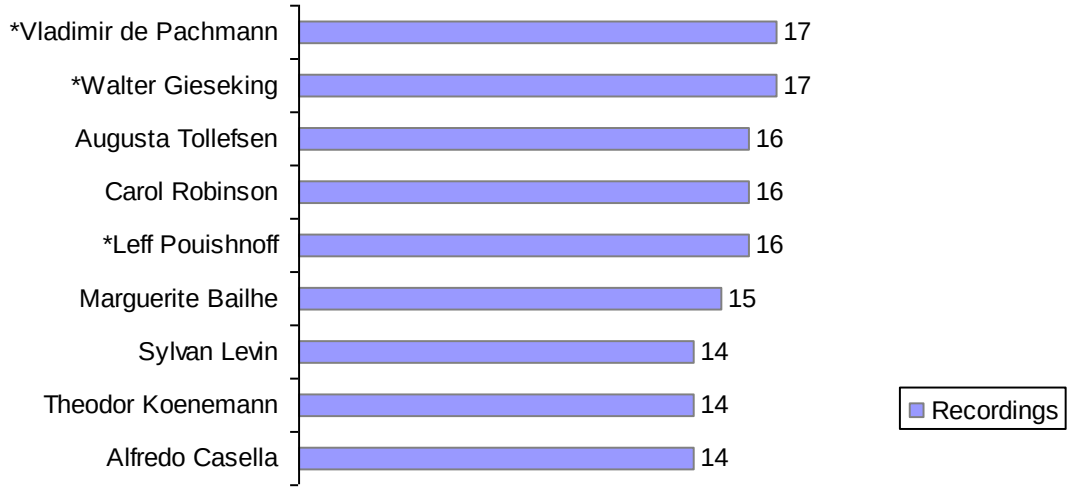

Figure 1.17 *Recordings by these pianists comprise nearly fourteen percent of all De Luxe recordings of art music*

Pouishnoff was a student of Essipoff, and won the Rubinstein Prize at the St Petersburg Conservatory in 1910. Tollefsen was a child prodigy who became a pupil of Godowsky in Berlin and Paolo Gallico (1868–1955) in New York. Casella's recordings include three he made with Respighi. Table 1.13 (page 57) lists the composers whose works were recorded by these three pianists.

[68] No pianist made eighteen or nineteen De Luxe recordings.

Pianists – ten to thirteen recordings

Figure 1.18 lists the De Luxe artists who made ten to thirteen roll recordings. Saar (mentioned previously in the context of a composer), Bacon, Boyle and Carreras are listed in Table 1.13 (page 57). Guy Maier (1892–1956) studied with Schnabel and was often heard with Lee Pattison (1890–1966); the duo made recordings for Ampico.[69]

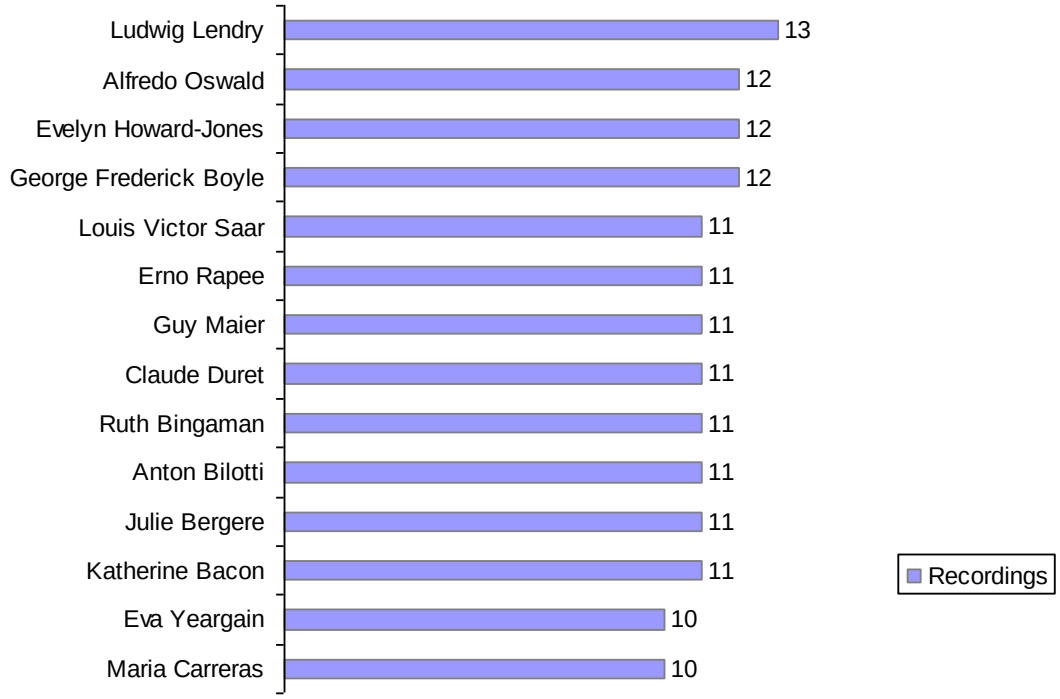

Figure 1.18 *Recordings by these pianists comprise nearly fifteen percent of all De Luxe recordings of art music*

Summary – pianists

There are at least 80 De Luxe artists who made less than ten recordings, some of whom have been previously mentioned, such as Bloomfield Zeisler and Milhaud, both of whom made eight De Luxe roll recordings. Birthdates could be established for 50 of the 116 De Luxe artists, in which the youngest pianist was six-year old Miss Mickee Graham (1915–?), who recorded five works. The most senior pianist is Pachmann, followed by Harriet Cady (1856–1944), who recorded twelve works, five of which are arrangements of traditional songs that have been categorised as popular works.

[69] David Dubal, *The Art of the Piano Its Performers, Literature and Recordings* (New Jersey USA and Swavesey UK: Amadeus Press, 2004), 233.

An interesting De Luxe artist is Grace Hamilton Morrey (1877–1962), who was a pupil of Leschetizky for nearly three years. She founded the Morrey School of Music in Columbus (1916–1935) and published a textbook on the Leschetizky-Morrey method of piano playing.[70] She recorded five works for De Luxe and one work for Ampico.

Conclusion – art music catalogue

The De Luxe recordings, combined with the Licensee issues of Welte-Mignon recordings, give a catalogue of over 2000 titles. When viewed in its entirety, the De Luxe catalogue has many qualities in terms of range of repertoire, artists and number of titles, making the Welte Licensee instrument a serious competitor to the Ampico or Duo-Art instruments. The De Luxe recordings provided customers with recordings made by local pianists, some of whom were concertising at the time. Additionally, the choice of music was aimed at providing repertoire to suit American tastes.

Although De Luxe recorded a number of exclusive and respected artists, these are far fewer than found in the catalogues of other roll companies. It may be that some of the relatively unknown pianists were especially skilled at their chosen repertoire. For example, Angelo Patricolo (dates unknown) performs four of the six works in the catalogue by Louis Moreau Gottschalk (1829–1869). In any case, De Luxe piano rolls provide recordings made by over 100 pianists, covering works written by nearly 300 composers. There are a number of artists, in particular composers, whose playing can only be heard through De Luxe piano rolls.

[70] *Grace Hamilton Morrey*, https://beta.worldcat.org/archivegrid/collection/data/5862015 (accessed 24 September 2015).

Ampico

Brief history

The American Piano Corporation was formed in June 1908, capitalised to twelve million dollars. The company was set up by three major American piano manufacturers (Chickering, Knabe and Foster-Armstrong) to control the manufacture and sale of their products.[71] In April 1910, the company acquired the rights to the Electrelle player system, a retrofit electro-pneumatic system developed in 1907 that could play standard size player piano rolls.[72]

An article in *The Music Trade Review* (1911) states that "on October 1, the American Piano Co., New York will have ready […] their Artigraph and Special Artigraph music rolls." The article further explains that the Special Artigraphs can "render the precise expression, tone colouring and emphasis of the artist in every detail," and can be used only in connection with the company's Artigraph player.[73] It is clear that by 1911, the American Piano Corporation had developed a reproducing piano and rolls to suit the instrument.

The following edition of this publication lists pianists who were to appear on Special Artigraph rolls, most of them from Hupfeld recordings.[74] Unfortunately, more than half those listed have never appeared on an Ampico roll or in Ampico literature. Missing artists include Francis Planté (1839–1934), Sophie Menter (1846–1918) and Gabriel Pierné (1863–1937). It may be that some of these artists were issued on undiscovered Artigraph rolls, possibly accounting for some missing roll numbers in Obenchain's Ampico roll catalogue.[75]

The introduction of the Rythmodik roll was announced in March 1912. Although a standard player roll, Rythmodik rolls were hand-played recordings that the company claimed to be "the 'last word' in music rolls."[76] Expression was shown by a 'dynamic' line the playerist could follow. Some Rythmodik roll recordings were later adapted to play on an Ampico reproducing piano by adding expression perforations.

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[71] "A Twelve Million Dollar Combination," *Music Trade Review*, vol. 46 no. 24 (June 13, 1908), 7.
[72] "Buy Electrelle Co. Player," *Music Trade Review*, vol. 50 no. 17 (April 23, 1910), 29.
[73] "Special Artigraph Music Rolls," *Music Trade Review*, vol. 53 no. 11 (September 16, 1911), 33.
[74] "Orders Coming at Lively Rate," *Music Trade Review*, vol. 53 no. 12 (September 23, 1911), 37.
[75] Elaine Obenchain, *The Complete Catalog of Ampico Reproducing Piano Rolls* (New York: William H. Edgerton, 1977, PDF electronic version 2009), 8.
[76] "To Feature Rythmodik Rolls," *Music Trade Review*, vol. 54 no. 10 (March 9, 1912), 37.

Some writers claim that the Ampico reproducing piano was first marketed in 1916, suggesting that prior models of the Ampico had little market success.[77] Ampico reproducing piano rolls first appeared in late 1911. A few of these early recordings were derived from Hupfeld masters, and most were recorded by in-house pianists. Some were recorded by noted artists such as Leopold Godowsky (1870–1938). By 1916, a substantial number of rolls had been recorded, grouped by Obenchain as Stoddard-Ampico rolls, many of which were later reissued under different roll numbers.[78]

All Ampico roll recordings were made in New York and were produced from 1911 until around 1930. In 1932, Aeolian purchased the American Piano Corporation, with popular rolls to suit the Ampico and Duo-Art reproducing pianos being issued in ever decreasing numbers until mid-1941. Several Duo-Art rolls of art music were reissued in Ampico format during the 1930s, although few if any recordings of art music were made after 1930.[79] Several recordings made in the 1920s by artists such as Rachmaninoff and Benno Moiseiwitsch (1890–1963) were issued in the early 1930s.[80]

Statistics – art music catalogue

Table 1.14 gives the statistics of the Ampico catalogue of recordings of art music issued from January 1911 to 1941.

Table 1.14 *Statistics of Ampico library of art music*

Aspect	Quantity	Comments
Recordings	1480	Earliest issues were from Hupfeld recordings, first issued 1911, last art music rolls issued from recordings made in the late 1920s
Works	1255	Around 15 percent of the catalogue contains multiple recordings of a work by different artists
Rolls	1450	▪ Approximate value, as some recordings on single roll were later reissued on long play rolls ▪ Excludes duplicates, such as Stoddard-Ampico rolls reissued with standard numbering
Composers	365	Includes 22 female composers
Pianists	262	Includes 28 pianists via their Hupfeld recordings and accounts for pseudonyms used by in-house pianists
Playing time	over 100 hours	Approximate value, based on known playing time of 1300 Ampico rolls

[77] Broyles and Von Glahn, *Leo Ornstein*, 198.
[78] Obenchain, *Catalog*, 9-28.
[79] Larry Givens, *Re-Enacting the Artist* (New York: Vestal Press, 1970), 47.
[80] From copies of original ledgers showing roll recording and issue dates. Documents held by the author.

Composers in the Ampico art music catalogue

Of the 365 composers listed in the catalogue, at least 22 are female.[81] The most represented female composer is Chaminade with twenty recordings covering fifteen works. The bar graphs in Figure 1.19 show that more than half the composers (196) have only one composition in the catalogue, with only eleven composers having twenty or more. The Welte-Mignon catalogue has twenty composers in this category.

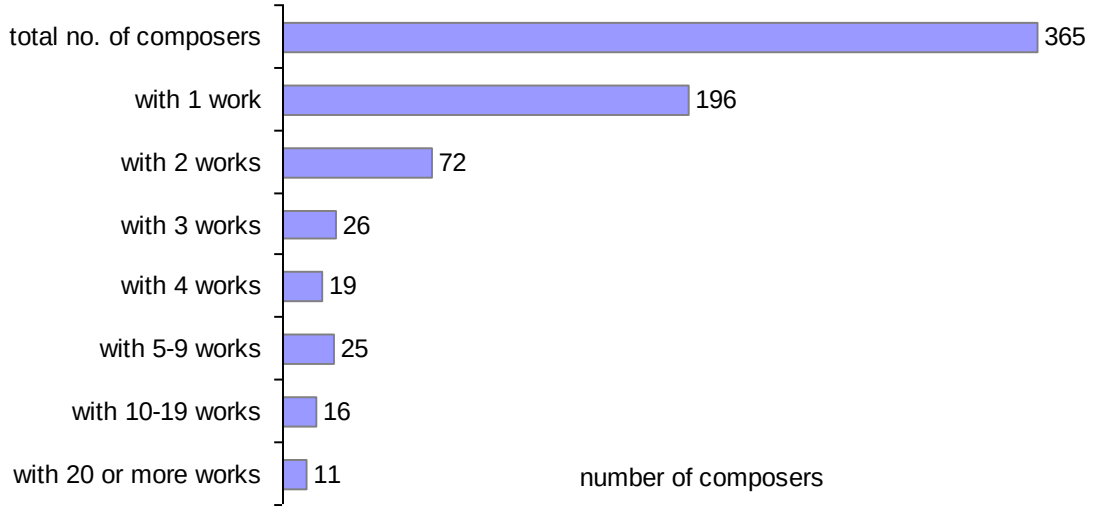

Figure 1.19 *Number of composers by number of their works (Ampico art music catalogue)*

[81] The gender of nine composers could not be established.

Composers – twenty or more works

Figure 1.20 lists the composers with at least twenty compositions in the Ampico art music catalogue; the bar graphs show the number of their works and related recordings.

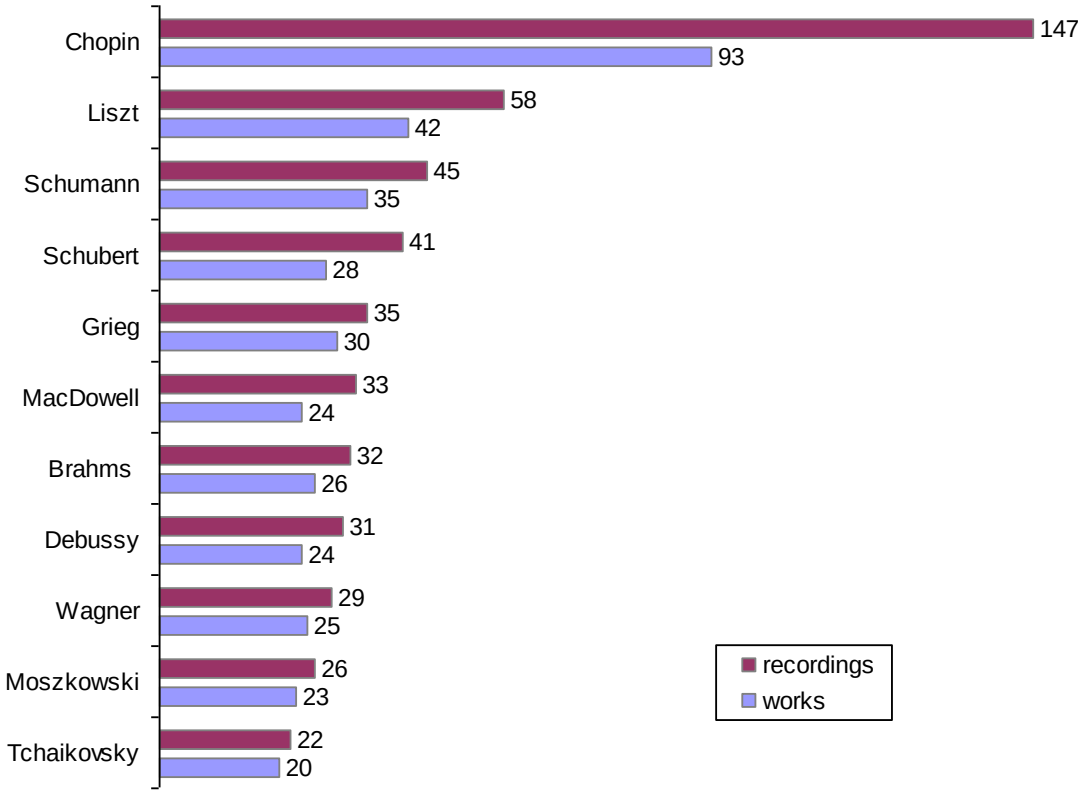

Figure 1.20 *Recordings of works by these eleven composers comprise a third of the Ampico art music catalogue*

Recordings of works by Moszkowski were more in demand than those by Tchaikovsky. The popularity of music by MacDowell exceeds that of music by Debussy. Today, Debussy's music is held as part of the canon of piano music while MacDowell is remembered primarily for his second piano concerto, now relegated to student performances.

Composers – ten to nineteen works

Figure 1.21 shows the composers who have ten to nineteen works in the catalogue, contrasted with the number of recordings of their works. Unknown American composers Louis Leslie Loth (1888–?) and McNair Ilgenfritz (1889–1953) perform their own works in the light classical music vein. Loth composed over 500 works.[82]

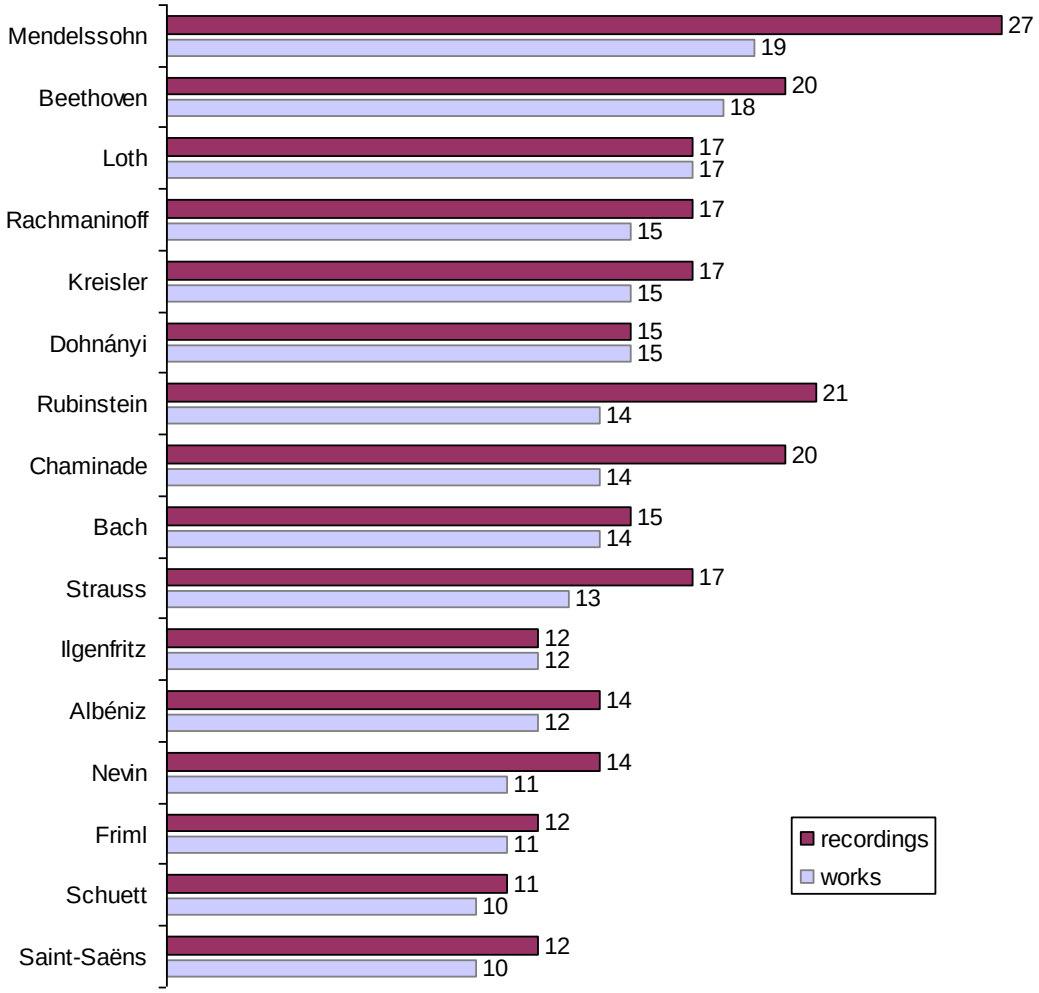

Figure 1.21 *Recordings of works by these sixteen composers comprise nearly nineteen percent of the Ampico art music catalogue*

According to Scholes, American composer Nevin achieved considerable fame with his "many graceful piano compositions of the better 'salon' type."[83] Composers who wrote similar music include Friml, Chaminade and Eduard Schuett (1856–1933). That Chaminade is almost as popular as Beethoven shows the difference in musical tastes of that era compared with today.

[82] Obenchain, *Catalog*, 483.

Composers – five to nine works

Figure 1.22 lists the composers with five to nine works in the Ampico catalogue.

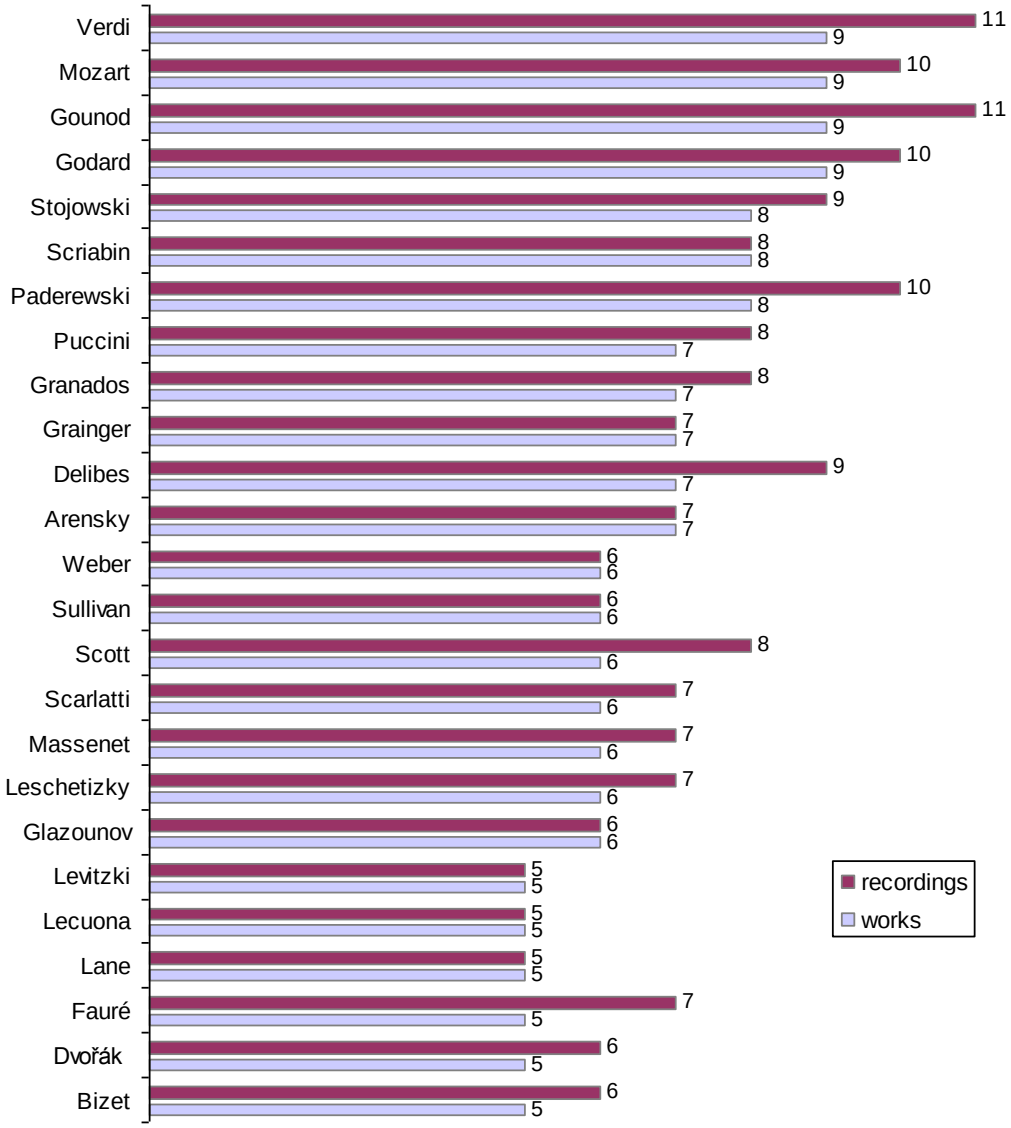

Figure 1.22 *Recordings of works by these 25 composers comprise nearly thirteen percent of the Ampico art music catalogue*

Godard was a highly regarded nineteenth-century composer whose music was among the first to be recorded on the "earliest truly significant commercial solo piano records" made by Gramophone and Typewriter in the first decade of the twentieth century.[84]

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[83] Percy Scholes and John Owen Ward, eds., *The Oxford Companion to Music*, 10th edn. (London: Oxford University Press, 1977), 676.
[84] Steven Permut, "Recordings," in *Encyclopedia of the Piano*, ed. Robert Palmieri (New York and London: Garland Publishing Inc, 1996), 312-13.

Godard has as many works and recordings of his works in the catalogue as Mozart, yet unlike Mozart, Godard is now largely forgotten.

Summary – composers

Figure 1.23 summarises the contents of the Ampico art music catalogue in terms of composers and the extent of their presence. Recordings of works by the eleven composers with 20 or more works (Figure 1.20, page 65) occupy a third of the catalogue. These recordings and those of works by the sixteen composers who have ten to nineteen works in the catalogue (Figure 1.21, page 66) account for over half the recordings in the catalogue. Composers represented by five to nine recordings (Figure 1.22, page 67) make up an eighth of the catalogue. A quarter of the catalogue is made up of works by composers represented with only one or two works.

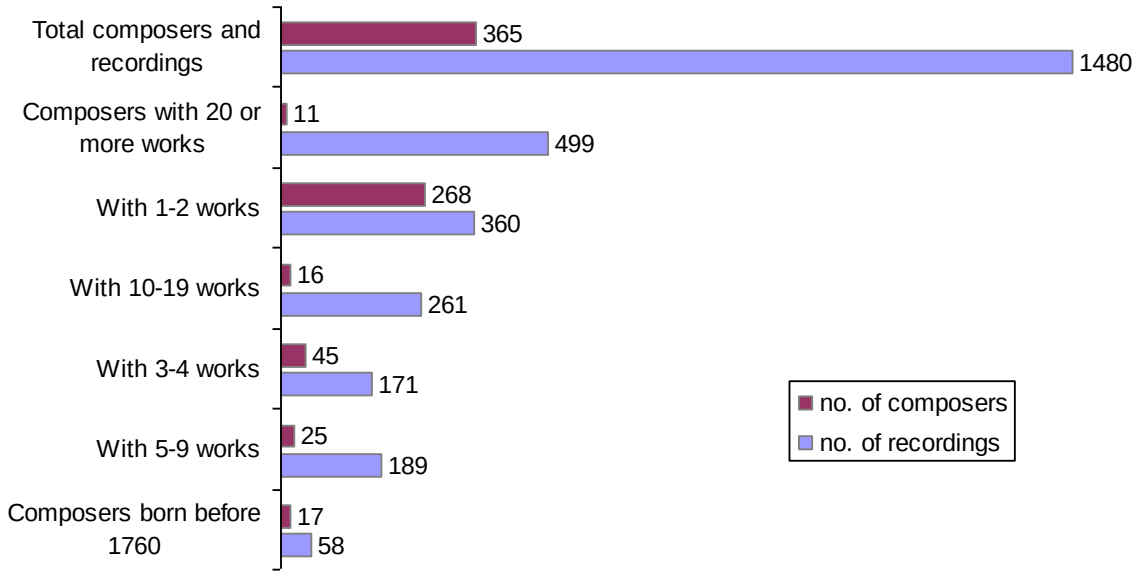

Figure 1.23 *Summary of composer content in the Ampico art music catalogue*

There are 58 recordings of music by the seventeen composers from the Baroque and Art music eras, shown in Figure 1.23 as composers born before 1760,[85] less than four percent of the catalogue. J. S. Bach is the most popular with fifteen recordings, followed by Mozart (ten) and Domenico Scarlatti (1685–1757) with seven. Early music obviously had limited popularity in the US at the time.

[85] The bar graph of works by composers of the Baroque and Art music eras is shown separately for comparison. The number of recordings of these works is included in other applicable bar graphs.

Of the composers in the catalogue, all but 43 were found to have a presence in written literature or on the internet. Of those found, nearly 260 were born prior to 1880, suggesting that they were trained or composing in the nineteenth century. Only two composers were born in the twentieth century: Abram Chasins (1903–1987) and Aaron Copland (1900–1990).

Famous composers who recorded their own works such as Edvard Grieg (1843–1907), Fauré, Scriabin and Camille Saint-Saëns (1835–1921) appear on Ampico rolls through their Hupfeld recordings. Rachmaninoff recorded eleven of his works for the Ampico. There are many compositions by respected composers of the day such as Sgambati, Adolph von Henselt (1814–1889), Constantin von Sternberg (1852–1924) and Sigismund Stojowski (1870–1946).

Ampico and Aeolian sought feedback from their customers by way of regular bulletins, mail-outs and sales people following up a sale. Therefore, the content of the Ampico library can be seen as a response to market demand, with American musical tastes being a predominate influence. Nonetheless, in response to other markets, the catalogue also contains works by the Chilean composer Enrique Soro (1884–1954) and the Cuban composer Ignacio Cervantes (1847–1905).

The music recorded on Ampico piano rolls gives a snapshot of musical tastes of the era. It gives a clear insight into the type of piano music that was sought after in the US in particular, and also in countries where the Ampico was sold during the first 30 years of the twentieth century.

Pianists on Ampico piano roll

Pianists supplied by Hupfeld recordings

The association with Hupfeld resulted in 53 of that company's recordings being converted to Ampico format. The 28 Hupfeld artists are listed in Table 1.15 alongside the total playing time of their recordings and the composers of the works they recorded. None of the Hupfeld artists recorded for Ampico, although all except Mascagni recorded for either Welte or Aeolian (Duo-Art), sometimes for both companies.

Significantly, the Hupfeld connection provides seventeen pianists born before 1870. Unfortunately, nearly half the Hupfeld artists have only one work in the catalogue. The Hupfeld-Ampico rolls are the most historically interesting group in the Ampico catalogue.

Table 1.15 *Hupfeld pianists on Ampico roll (chronological order)*

Pianist	No. of works	Playing time min:sec	Nationality	Composers represented
Carl Reinecke (1824–1910)	1	4:43	German	Mozart
Camille Saint-Saëns (1835–1921)	2	9:39	French	Saint-Saëns (2)
Edvard Grieg (1843–1907)	3	9:44	Norwegian	Grieg (3)
Gabriel Fauré (1845–1924)	1	3:00	French	Fauré
Xaver Scharwenka (1850–1924)	1	2:47	Polish	Scharwenka
Alfred Grünfeld (1852–1921)	1	5:01	Austrian	Strauss-Grünfeld
Raoul Pugno (1852–1914)	1	1:57	French	Schumann
Teresa Carreño (1853–1917)	4	19:14	Venezuelan	Carreño, Chopin, Schubert, Tchaikovsky
Arthur Friedheim (1859–1932)	1	6:51	German	Liszt
Emile Sauer (1862–1942)	1	6:26	German	Sauer
Pietro Mascagni (1863–1945)	2	n/a	Italian	Mascagni (2)
Alfred Reisenauer (1863–1907)	1	7:16	Russian	Chopin
Eugene d'Albert (1864–1932)	1	1:34	Scottish-German	Chopin
Ferruccio Busoni (1866–1924)	4	21:23	Italian	Liszt (3), Chopin (1)
Max Pauer (1866–1945)	1	3:29	Austrian	Field
Frederic Lamond (1868–1948)	2	13:47	Scottish	Brahms, Beethoven
Vassily Sapellnikoff (1868–1941)	1	2:50	Russian	Sapellnikoff
Carl Friedberg (1872–1955)	2	9:04	German	Haydn, Liszt
Alexander Scriabin (1872–1915)	1	2:52	Russian	Scriabin
Harold Bauer (1873–1951)	4	26:47	English	Beethoven, Liszt, Schubert, Schumann
Josef Hofmann (1876–1957)	2	11:58	Polish-American	Mendelssohn, Wagner
Alfred Cortot (1877–1962)	2	15:36	Swiss-French	Liszt, Mendelssohn
Rudolph Ganz (1877–1972)	3	< 9:00	Swiss-French	Blanchet, Chopin, Ganz
Wanda Landowska (1877–1959)	1	n/a	Polish-French	Mozart
Cyril Scott (1879–1970)	1	3:34	English	Scott
Ignaz Friedman (1882–1948)	2	8:12	Polish	Friedman, Strauss-Schuett
Wilhelm Backhaus (1884–1969)	3	14:56	German	Chopin, Rubinstein, Schubert-Liszt
Walter Gieseking (1895–1956)	4	24:18	French-German	Debussy (2), Chopin & Neimann (1)

Pianists exclusive to Ampico

The ten pianists in Table 1.16 were exclusive to Ampico. They recorded around fifteen and a half hours of music, which is nearly fifteen percent of the total playing time of all Ampico recordings of art music.

Table 1.16 *Notable pianists exclusive to Ampico (chronological order)*

Pianist	**No. of works**	**Playing time** (*approx*)	**Nationality**	**Composers represented**
Moriz Rosenthal (1862–1946)	12	37 mins	Polish-American	Chopin, Mendelssohn & Rosenthal (2), Albéniz, Bortkiewicz, Chopin-Rosenthal, Handel, Rubinstein & Strauss-Rosenthal (1)
Sergei Rachmaninoff (1873–1943)	35	2 hrs	Russian-American	Rachmaninoff (12), Chopin (5), Schubert (3), Kreisler-Rachmaninoff & Tchaikovsky (2), Bach, Beethoven, Bizet, Gluck-Sgambati, Henselt, Mendelssohn, Mussorgsky, Paderewski, Rimsky-Korsakov & Rubinstein (1)
Benno Moiseiwitsch (1890–1963)	29	2 hrs 25 min	Russian-British	Brahms (10), Chopin (4), Debussy, Palmgren & Wagner-Liszt (2), Delibes, Granados, Ibert, Leschetizky, Ravel, Schubert-Liszt, Schumann, Scriabin & Tchaikovsky (1)
Nikolai Orloff (1892–1964)	10	40 mins	Russian	Chopin (4), Brahms, MacDowell, Raff, Scarlatti, Schubert-Liszt & Scriabin (1)
Leo Ornstein (1892–2002)	25	1 hr 45 mins	Russian-American	Chopin & Schumann (4), Liszt (3), Debussy, Leschetizky, Ornstein & Rubinstein (2), Dvořák, Grieg, Mendelssohn, Scott, Scriabin & Zeckwer (1)
Arthur Loesser (1894–1969)	10 (solo) 15 (duo)	40 mins 3 hrs	American	Chopin & Schubert (2), Liszt, Mendelssohn, Nevin, Schubert-Liszt, Schuett & Stanford-Grainger (1); for solo works only
Alexander Brailowsky (1896–1976)	19	1 hr 20 mins	American	Chopin (5), Mussorgsky & Liszt (2), Beethoven, Borodin, Falla, Fauré, Grieg, Mendelssohn, Saint-Saëns, Schumann, Stravinsky & Wagner (1)
Mischa Levitzki (1898–1941)	39	3 hrs 25 mins	American	Chopin (11), Levitzki (6), Schumann (5), Schubert-Liszt (2), Beethoven, Liszt & Rubinstein (2), Debussy, Gluck-Brahms, Godowsky, Mendelssohn, Moszkowski, Saint-Saëns, Scriabin, Stojowski & Strauss–Shultz-Evler (1)
Mieczyslaw Münz (1900–1976)	18	40 mins	Polish-American	Chopin (12), Delibes, Dohnányi, Fauré, Paganini-Liszt, Sgambati & Strauss Jr-Tausig (1)
Ervin Nyiregyházi (1903–1987)	12	1 hr 5 mins	Hungarian-American	Liszt (2), Blanchet, Brahms, Cleve, Glazounov, Granados, Grieg, Kowalski, Leschetizky, Sinding & Tchaikovsky-Grainger (1)

Notable pianists on Ampico and also on Duo-Art or Welte rolls

Notable pianists who recorded for the Ampico as well as the Duo-Art or Welte reproducing pianos are listed in Tables 1.17 (a) and (b).[86] Bolded figures indicate the company that issued the greatest number of recordings for each pianist; playing times are for Ampico rolls only.

Table 1.17 (a) *Notable non-exclusive Ampico pianists born before 1880*

Pianist	**Number of works**			**Nationality**	**Composers represented** (on Ampico rolls only); **comments**
	Ampico	Duo-Art	Welte		
Cornelius Rybner (1855–1929)	**6** (38 min)	-	5	Danish-American	Wagner-Rybner (5), Donizetti-Liszt (1); similar works recorded for Welte, pupil of Reinecke, von Bülow and Rubinstein
Harriet Cady (1856–1944)	2 (6 min)	-	**7**	American	arrangements by Cady; recorded for De Luxe, including her own arrangements and works by other composers, pupil of Leschetizky
Fannie Bloomfield Zeisler (1863–1927)	5 (18 min)	-	**33**	Austrian-American	Chopin (2), Liszt, Poldini & Scarlatti-Tausig (1); see Tables 1.7 and 1.13
Antoinette Szumowska (1868–1938)	6 (14 min)	-	**10**	Polish-American	Chopin (4), Gluck-Sgambati & Paderewski (1); see Table 1.10, pupil of Michalowski and Paderewski
Leopold Godowsky (1870–1938)	**21** (88 min)	8	-	Polish-American	Chopin (11), Liszt & Schumann (2), Bishop-Godowsky, Bohm-Godowsky, Godowsky, MacDowell, Schubert & O. Straus (1); see Table 1.25 (b)
Karl Friedberg (1872–1955)	2 (9 min)	9	**11**	German	Haydn & Liszt; see Tables 1.5 (a) & 1.25 (b), pupils include Grainger, Ney and Leginska
Katharine Goodson (1872–1958)	4 (13 min)	**14**	-	English	Debussy, Brahms, Rachmaninoff & Schumann; see Table 1.25 (b)
Ernő Dohnányi (1877–1960)	**18** (78 min)	-	12	Hungarian-American	Dohnányi (14), Schubert (2) Brahms & Delibes (1); see Table 1.5 (a)
Ossip Gabrilowitsch (1878–1936)	4 (35 min)	**15**	9	Russian-American	Bach, Glazounov, Schumann & Tchaikovsky; see Tables 1.5 (a) and 1.25 (b), pupil of Leschetizky
Mark Hambourg (1879–1960)	2 (6 mins)	6	**7**	Russian-English	Chopin & Liszt; see Tables 1.5 (a) and 1.25 (b), pupil of Leschetizky
Josef Lhévinne (1874–1944)	21 (2 hrs)	-	**27**	Russian-American	Chopin & Liszt (4), Albéniz & Schubert (2), Beethoven, Cui, Mendelssohn-Liszt, Rubinstein, Schuett, Schumann, Sinding, Strauss–Schulz-Evler & Tausig (1); see Tables 1.8 and 1.10

[86] Includes rolls for Welte-Mignon and Welte Licensee instruments.

Table 1.17 (b) *Notable non-exclusive Ampico pianists born 1880 or after*

Pianist	**Number of works**			**Nationality**	**Composers represented** (on Ampico rolls only)**; comments**
	Ampico	Duo-Art	Welte		
Richard Bühlig (1880–1952)	**8** (61 min)	-	7	American	Chopin, Liszt & Schubert (2), Brahms & Glinka (1); also for Welte-Mignon, Debussy (5), Schubert and Zanella (1); pupil of Leschetizky, pupils include John Cage (1912–1992) and Earl Wild (1915–2010)
Olga Samaroff (1880–1948)	4 (22 min)	-	**9**	American	Beethoven, Chopin, Debussy & Gabrilowitsch; see Table 1.8
George Copeland (1882–1971)	**16** (50 min)	5	-	American	Albéniz (3), Chopin & Debussy (2), Chabrier, Grainger, Granados, Grovlez, Ippolitiv-Ivanov, Lane, Satie, Scarlatti-Tausig & Zuera (1); for Duo-Art, Debussy (4), Albéniz (1)
Elly Ney (1882–1968)	6 (27 min)	3	**13**	German	Beethoven, Brahms, Liszt, Rameau-Godowsky, Schubert & Schumann; see Tables 1.5 (b) and 1.25 (c)
Artur Schnabel (1882–1951)	6 (39 min)	-	**13**	Polish	Beethoven (2), Bach, Brahms, Schubert & Weber (1); see Table 1.5 (b)
Michael von Zadora (1882–1946)	4 (13 min)	11	**37**	American	Bizet, Heller, Raff, Schubert; see Tables 1.5 (b), 1.10 and 1.25 (c)
Clarence Adler (1886–1969)	**29** (2 hrs approx)	23	2	American	Chaminade & Moszkowski (4), Grieg (3), Chopin (2), Beethoven, Field, Godard, LaForge, Lassen, Massenet, Mendelssohn, Paderewski, Raff, Rubinstein, Saint-Saëns, Schlözer, Schubert, Schuett, Scott & Sinding (1); see Table 1.25 (c)
Marguerite Volavy (1886–1951)	**145** (9 hrs approx)	7	22	Czech-American	90 composers, also 5 duets with Brockway; recorded works by 20 composers for De Luxe in the 1920s, also works by 7 composers for Duo-Art in 1914
Yolanda Mérő (1887–1963)	3 (6 min)	4	**27**	Hungarian-American	Grieg, Moszkowski, Rubinstein; see Tables 1.5 (b), 1.8 and 1.25 (c), recorded over 25 works on Artrio roll
Arthur Rubinstein (1887–1982)	9 (44 min)	**22**	**-**	Polish-American	Albéniz, Chopin, Schumann (2), Debussy, Liszt & Rubinstein (1); see Table 1.25 (c)
Germaine Schnitzer (1888–1982)	**11** (38 min)	-	9	French	Chopin & Mendelssohn (2), Bach, Drdla, Frey, Paderewski, Schubert-Tausig, Staub & Weber (1); see Table 1.5 (b)
Elie Robert Schmitz (1889–1949)	**20** (85 mins)	9	-	French	Debussy (10), Albéniz, Chopin, Falla, Ravel (2), Bach-Liszt & Verdi-Liszt (1); see Table 1.25 (c)
José Echániz (1905–1969)	**9** (23 mins)	2	-	Cuban	Cervantes (3), Fuentes, Infante, Larregla, Schipa, Soro, Valle (1); see Table 1.25 (c)

Pianists – twenty or more recordings

The bar graphs in Figure 1.24 show all pianists who made twenty or more Ampico roll recordings of art music. These pianists account for over 660 recordings, or nearly half the catalogue. An asterisk beside a name indicates the pianist is listed in Table 1.16, or Table 17 (a) or (b).

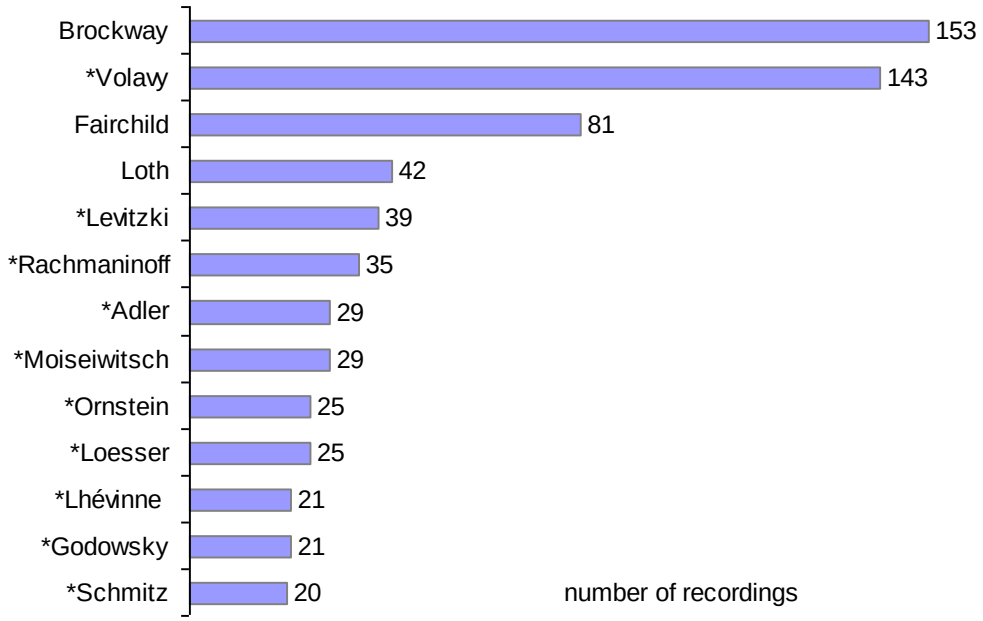

Figure 1.24 *Recordings by these thirteen pianists comprise 45 percent of the Ampico art music catalogue*

Prominent in Figure 1.24 are Brockway, Volavy and Fairchild, three Ampico 'in-house' pianists who collectively made nearly one quarter of all art music recordings in the Ampico library. Their duo recordings are included in their total recordings.

Volavy was twelve when admitted to the Vienna Conservatory, later studying with Schuett and Leschetizky. After her debut in 1902, she toured Europe and Russia and in 1914 gave a series of concerts and recitals in New York.[87] She appeared as soloist at Carnegie Hall in New York in 1915 with the Russian Symphony Orchestra conducted by Modest Altschuler (1873–1963), playing the first American performance of Scriabin's *Prometheus—A Poem of Fire* performing on a 'chromola', otherwise known as a 'colour keyboard'.[88]

[87] Obenchain, *Catalog*, 542.
[88] *Modest Altschuler*, https://en.wikipedia.org/wiki/Modest_Altschuler (accessed 24 February 2016).

Pianists – ten to nineteen recordings

Figure 1.25 shows the Ampico artists with ten to nineteen recordings, in all totalling over 250 recordings. An asterisk beside a name indicates the pianist is listed in Table 1.16, or Table 17 (a) or (b). Fritz Kreisler (1875–1962), better known as a violinist recorded only his own compositions. Obenchain cites a 1925 article in *The Musician* magazine in which John Tasker Howard analysed Kreisler's rendition of *The Old Refrain*, concluding that "Kreisler used the same nuances and showed the same individuality at the piano as on the violin."[89]

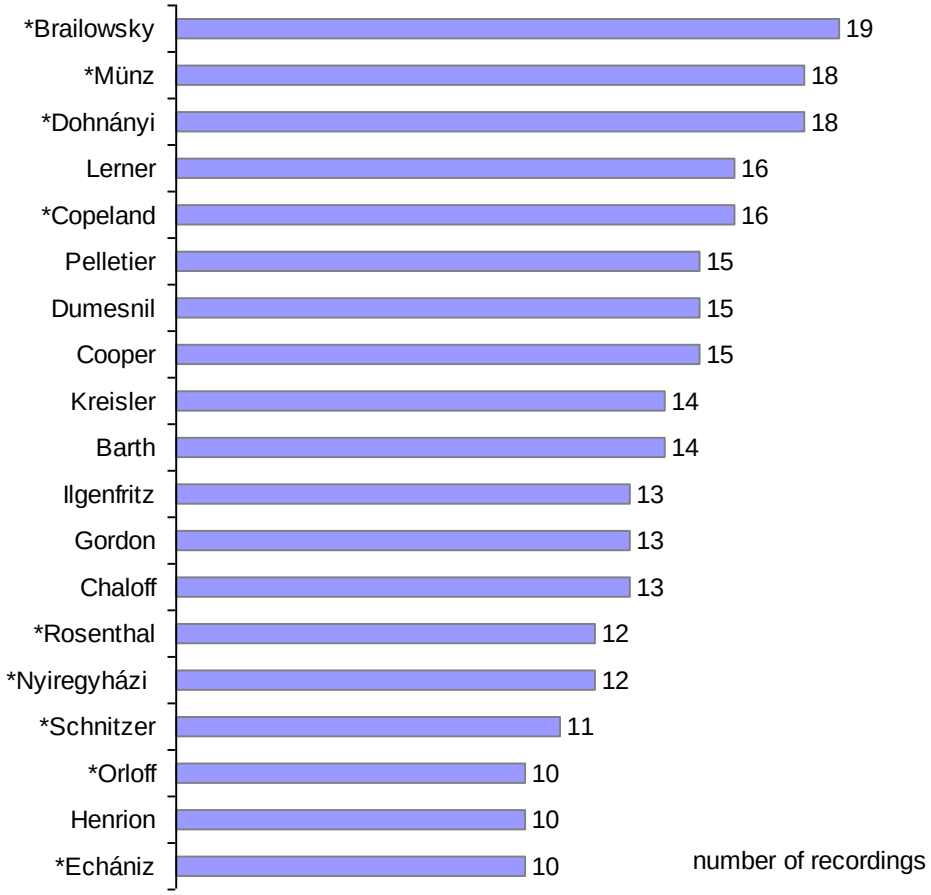

Figure 1.25 *Recordings by these eighteen pianists comprise seventeen percent of the Ampico art music catalogue*

[89] Obenchain, *Catalog*, 268.

Pianists – eight or nine recordings

Pianists who recorded eight or nine works for Ampico are listed alphabetically in Table 1.18, along with the composers whose works they recorded. Not shown are Bühlig and Rubinstein, who are listed in Table 1.17 (b). Interesting musicians in the table include Chiapusso and Stojowski, the latter better known as a composer. Most of the pianists listed in the table are unknown today.

Table 1.18 *Pianists who made eight or nine Ampico roll recordings*

Pianist	Playing time	Nationality	Composers represented
Adolphe Borchard (1882–1967)	31 mins	French	Chopin (6), Liszt & Mendelssohn (1); also a composer associated with film music
Wilbur Chenoweth (1899–1980)	40 mins	American	own works and arrangements
Jan Chiapusso (1890–1969)	23 mins	Dutch-Italian	Chopin (5), Couperin-Chiapusso (2), Liszt (1); pupil of Lamond, pupils include Rosalyn Tureck (1914–2003)
Werner Janssen (1899–1990)	30 mins (approx)	American	Gilbert and Sullivan (4), Jansenn (3), Kalman (2)
Alfred Mirovitch (1884–1959)	53 mins	Russian-American	Chopin, Liadov & Mirovitch (2), Liszt, Paganini-Schumann & Tchaikovsky (1)
Frances Nash (1895–?)	31 mins	American	Juon (2), d'Ambrosio, Korngold, Saint-Saëns, Sapellnikoff, Schuett & Thuille (1)
Helen Norfleet	32 mins (approx)	American	Bach (5), Purcell, Byrd, Haydn
Frank Sheridan (1898–1962)	37 mins	American	Grieg (3), Chasins (2), Brahms, Schumann-Liszt, Tchaikovsky (1)
Sigismund Stojowski (1869–1946)	25 mins	Polish-American	Stojowski (7), MacDowell (1)

Pianists – six recordings

Six of the ten pianists who each recorded six works for Ampico are listed in Table 1.19. Missing are Ney, Rybner, Schnabel and Szumowska, who are listed in Tables 1.17 (a) and (b). Those listed in Table 1.19 have little presence in the published literature, yet all would have had to satisfy Ampico's audition panel to be accepted as recording artists.

Table 1.19 *Pianists who made six Ampico roll recordings*

Pianist	Playing time	Nationality	Composers represented
Dai Buell (?–1939)	19 mins	American	Grieg, Debussy, MacDowell, Schubert, Paradies & Beethoven (1)
Hans Hanke	25 mins	American	Bach-Gounod, Chaminade, Gottschalk, Handel, MacDowell & Schuett (1)
Frederick Hoschke (1876–1936)	18 mins	American	Hoschke (4), Grieg & Schuett (1)
Earle Douglass Laros (1887–1934)	18 mins (approx)	American	Cadman, Grainger, Henselt, Laros, Martini & Tchaikovsky (1)
Wynne Pyle	24 mins (approx)	American	Debussy (2), Poldini, Rachmaninoff, Sauer & Schumann (1)
Guy Bevier Williams	10 mins	American	Goossens & Moszkowski (2), Friml & Schmitt (1)

- **Pianists with five or less Ampico roll recordings**

Thirteen pianists made five Ampico roll recordings, including Carolyn Cone Baldwin (1894–1946) who studied with Bloomfield Zeisler. She also recorded fourteen works for the Duo-Art and, as Carolyn Cone, four works for the Welte-Mignon. Leschetizky student Sidney Silber (1881–1959) recorded works by Bach, Christoph Gluck (1714–1787) and Preston Ware Orem (1865–1938). John Tasker Howard (1890–1964) recorded four works by Grieg and a sonata by Mozart.

The remaining 196 pianists made four or less Ampico roll recordings, of which 49 pianists made two recordings and over 100 pianists made one recording. These figures include the Hupfeld roll recordings. Among the pianists are historical figures such as Richard Strauss (1864–1949), who recorded two stand-alone works of his own composition and a number of accompaniments to his songs.

A little-known pianist who appears on two Ampico rolls is Marie Gabrielle Leschetizky (née Rozborska, 1880–1954), Theodor Leschetizky's fourth and last wife. Cuban composer and pianist Ernesto Lecuona (1895–1963) recorded four of his works, including his well-known *Malaguena*. Lecuona also recorded for the Duo-Art.

Summary – pianists

Of the 262 pianists who appear on Ampico roll recordings, the birth dates of 184 pianists could be established. The youngest pianist is prodigy and Hofmann student Lucie Stern (1913–1938), who was thirteen when her one Ampico recording was issued. The most senior is Reinecke, whose Ampico roll is from his Hupfeld recording.

There are 70 female artists, the eldest of which (from the available data) is American composer and Leschetizky student Harriet Cady. The female pianists account for 335 recordings, although Volavy made 143 of them. The next most prolific female Ampico artist is Lerner, with sixteen recordings, followed by Schnitzer with eleven.

Unusual recordings include Copland playing his first published composition titled *Cat and the Mouse*, and Morton Gould (1913–1996) performing his own arrangement of Ravel's *Bolero* on a roll issued in December 1932. Another is the four-roll set issued in 1922 of *Scheherazade* by Nikolai Rimsky-Korsakov (1844–1908), played by duo-pianists Guy Maier (1892–1956) and Lee Pattison (1890–1966).

At least 190 of the 266 pianists who recorded for Ampico were American or based in the US. Most of the pianists can be classified as twentieth-century performers. Pianists whose careers span the nineteenth and twentieth centuries include Brockway and Godowsky, who were both born in 1870. At least 32 pianists were born before 1870, including seventeen from Hupfeld recordings. Over 60 pianists have been identified as notable and are listed in Tables 1.15 to 1.17 (b). (Pages 70 to 73.)

As well as those highlighted, there are 200 or more Ampico pianists who may have had some notoriety at the time, although many are now forgotten. Among these pianists are possibly some who specialised in certain composers or musical styles.

Conclusion – Ampico art music catalogue

In comparison to the piano roll recordings made by other major companies, the Ampico art music catalogue was focused on satisfying American musical tastes. It contains numerous recordings of music that is unfamiliar today, as are many of the pianists and composers. Some of the pianists exclusive to Ampico had significant teaching careers (such as Chiapusso and Münz), giving a link from the past to the present. Compared to other reproducing piano roll companies, Ampico recorded the greatest number of pianists whose careers took place in the twentieth century.

Duo-Art

Brief history

The Duo-Art reproducing piano was developed and marketed by the Aeolian Company, or Aeolian, as the organisation was generally known. The company was formed in July 1887 as the result of a merger between the Mechanical Orguinette Company and the Automatic Music Paper Company giving a company name at the time of Aeolian Organ and Music Company. The main product line was roll-playing reed organs, which were produced in many forms, including the company's Orchestrelle, a trade name for a range of large reed organs that could be played by hand or from roll. Residential pipe organs were also produced.[90]

In 1895 Edwin Votey (1856–1931) developed a roll-operated push-up player that sat externally to the piano. Votey later joined Aeolian and the instrument, trade marked as the Pianola, was first marketed in 1897. The Pianola Piano, in which the player mechanism was built into the piano, began appearing in the early part of the twentieth century.[91]

Aeolian acquired the Weber Piano Company in 1903, becoming the Aeolian-Weber Piano and Pianola Company. It gave the company increased manufacturing capacity locally and abroad, plus a well-regarded piano brand.[92] An agreement was made with Steinway in 1909 in which Aeolian had exclusive rights to incorporate their player mechanisms into Steinway pianos.[93]

The Duo-Art reproducing piano was first marketed in March 1914. An article in the March 1914 issue of *Music Trade Review* announces that "sample instruments are only starting to go out to the trade this week."[94] The reproducing mechanism remained largely unchanged over the lifetime of the company, and was available in various brands of pianos, all of which, other than Steinway were owned by Aeolian.

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[90] Bowers, *Encyclopedia of Automatic Musical Instruments*, 740.
[91] *History of the Pianola - An Overview*, http://www.pianola.org/history/history.cfm (accessed 30 April 2015).
[92] "Controls the Aeolian-Weber Destiny," *Music Trade Review*, vol. 37 no. 6 (Aug 8, 1903), 15.
[93] "The Steinway Pianola Piano," *Music Trade Review*, vol. 50 no. 8 (Feb 19, 1910), 26.
[94] "Aeolian Hall Gleanings," *Music Trade Review*, vol. 58 no. 11 (Mar 14, 1914), 38.

Duo-Art rolls

Recordings for the Duo-Art were initially made only at Aeolian Hall in New York, the first rolls appearing in early 1914 starting with roll number 5501. The recording producers were W. Creary Woods (1881–1967) and Arno Lachmund (dates unknown). Lachmund's father, Carl V. Lachmund (1853–1928), was a concert pianist and a pupil of Liszt. Woods went on to become the Principal of the Delaware College of Music. In 1919 a recording studio was established in London, with Reginald Reynolds (1877–1959) appointed as recording producer.[95]

Rolls for the Duo-Art were therefore recorded in London and New York. The recording studios were relatively independent, each aiming to satisfy the customer base in its sales area. As a result, the art music content of the Duo-Art roll library reflects both American and British musical tastes, and includes recordings by European-based pianists who did not visit America.

- **Audiographic rolls**

In 1927, Aeolian introduced its Audiographic rolls for the Duo-Art and Pianola. These elaborately produced rolls combined music, text and illustrations. Percy Scholes (1877–1958) was the general editor and writer for many of the Audiographic rolls. Committees of eminent musicians were established in many parts of the world, allegedly to select the works to appear on the series.

The same performance often appeared on different versions of Audiographic roll. Variations include the author of the text on the roll, or the category of the roll. For example, analytical rolls gave an analysis of the music while running commentary rolls presented a story that could be read while the music played. Biographical rolls combined information about a composer and selections of works by the composer. Other categories included rolls for children. In some cases, Audiographic rolls provide the only recording of a work, such as *The Fire Bird* by Igor Stravinsky (1882–1971) which appears only on a set of six Audiographic rolls annotated by the composer.

[95] *The Reproducing Piano – Duo-Art*, http://www.pianola.org/reproducing/reproducing_duo-art.cfm (accessed 24 February 2016).

- **Miscellaneous rolls**

The Special Duo-Art Roll series was announced in early 1922 as comprising roll recordings made "especially and specifically for Aeolian Company Dealers […] whose customers have requested the particular pieces thus recorded."[96] The series contains twenty rolls known as 'alternating records' where parts of the recording are silent so a student can supply the missing phrases. It also contains demonstration rolls for dealers, and rolls given to customers promoting excerpts of upcoming releases.

Due to the localised distribution and reduced production numbers of special rolls, they are comparatively hard to find. Davis Smith lists 89 special number Duo-Art rolls that contain a complete performance of art music, and all are included in the Duo-Art database.[97]

The Davis Smith catalogue also includes a list of rolls under the heading Miscellaneous Numberings, which includes alternating and accompaniment rolls, and three rolls of solo piano works. Two of these rolls have been located, while a third remains to be found, and all three roll recordings are included in the database.

Another group within the Davis Smith catalogue is a list of roll masters that are known to exist in collections held by Maryland University and similar institutions, and private collections.[98] Recordings from some of these masters were never issued, and are therefore not included in the database unless a recut roll has been produced from these masters and made available to the market.[99]

A fourth group is the 8000 series described as Duo-Art rolls cut from unpublished masters by Artona Rolls, a company headed by Gordon Iles (1908–1983), a former employee of Aeolian in England. Artona rolls were issued during the 1960s and later, and 23 of these are included in the database.

There are many instances of a Duo-Art recording appearing under different roll numbers. A roll produced in America might be reissued in England with a different roll number, or vice versa. More typically, a standard Duo-Art roll might appear as three or four categories of Audiographic roll. In this research, each roll title is considered once. Variations between the different issues of a recording are therefore not considered.

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[96] Davis Smith, *Duo-Art Piano Music*, 218.
[97] Davis Smith, *Duo-Art Piano Music*, 218-20.
[98] Davis Smith, *Duo-Art Piano Music*, 218-20.
[99] An example is the three-roll set of Grainger playing Tchaikovsky's First Piano Concerto, since made available in limited numbers as recut rolls.

Duo-Art rolls containing a medley of works required special attention for classification purposes. These include five rolls that contain recordings of a mixture of popular and art music, where the intention is to provide easy listening. Each of these rolls has been included in the database, each one listed as a single work. Roll number 8001 entitled *Variations on Chopsticks* (*The Cutlet Polka*) was issued by Artona from discovered masters, and contains ten variations written by five composers which is included in the database as a single work.

Statistics – art music catalogue

Table 1.20 gives the statistics of the Duo-Art art music catalogue, listed alongside the figures associated with the Ampico art music catalogue. Both catalogues were developed over a similar time frame and starting date, however there were two Duo-Art recording studios, while Ampico had one.

Table 1.20 *Statistics of Duo-Art and Ampico rolls of art music*

Aspect	Duo-Art	Ampico	Comments
Recordings	**1980**	1480	Duo-Art recordings of some works occupy up to six rolls, Ampico recordings rarely exceed four rolls
Works	**1615**	1255	Duo-Art recordings include medleys of art music and compared to Ampico, a much wider range of selections from operas. Around 18.5 percent of the catalogue contains multiple recordings of a work by different artists.
Rolls	**2070**	1450	▪ Approximate value, based on individual releases. Some recordings were later reissued on long play rolls, reducing the roll count ▪ Excludes duplicates, such as Audiographic rolls reissued from prior recordings
Composers	**442**	365	▪ Over 210 composers in the Duo-Art catalogue do not appear in the Ampico catalogue ▪ At least 130 composers in the Ampico catalogue are not present in the Duo-Art catalogue
Pianists	**298**	262	▪ Accounts for pseudonyms used by in-house pianists ▪ Over 230 pianists in the Duo-Art catalogue did not record for Ampico ▪ Over 200 pianists in the Ampico catalogue did not record on Duo-Art roll
Playing time	**over 155 hours**	over 100 hours	Approximate value, known playing time of 1730 rolls used to determine average playing time of rolls where playing time not known

Composers in the Duo-Art art music catalogue

As in the Ampico and Welte catalogues, male composers in the Duo-Art art music catalogue predominate, in which only 24 women are represented, compared to over 420 men. Chaminade is again the most represented with 26 recordings covering twenty works, Mana-Zucca (1885–1981) is next,[100] with four works and four recordings.

The bar graphs in Figure 1.26 depict the number of composers with particular numbers of works in the catalogue. Well over half the composers (56 percent) have one composition in the catalogue, with only fifteen composers having 20 or more. These figures are similar to those for the Ampico catalogue.

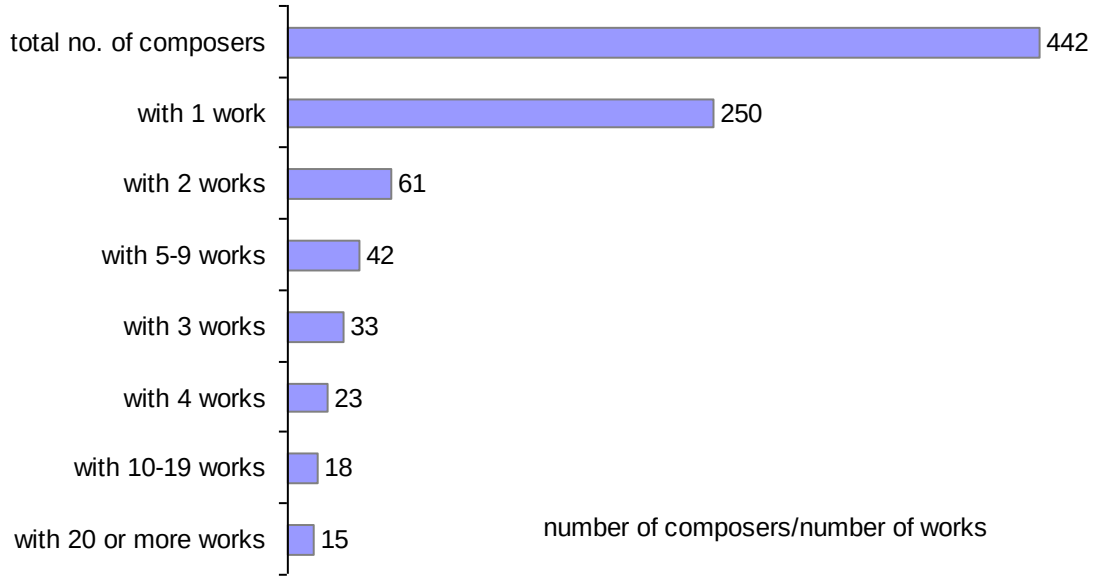

Figure 1.26 *Number of composers by number of their works (Duo-Art art music catalogue)*

[100] Born Gussie Zuckermann.

Composers – twenty or more works

Figure 1.27 lists the composers with at least twenty works in the Duo-Art catalogue. Compared to Ampico, there is a greater representation of works by J. S. Bach and Beethoven; both catalogues have a similar number of works by Brahms, Schubert and Schumann.

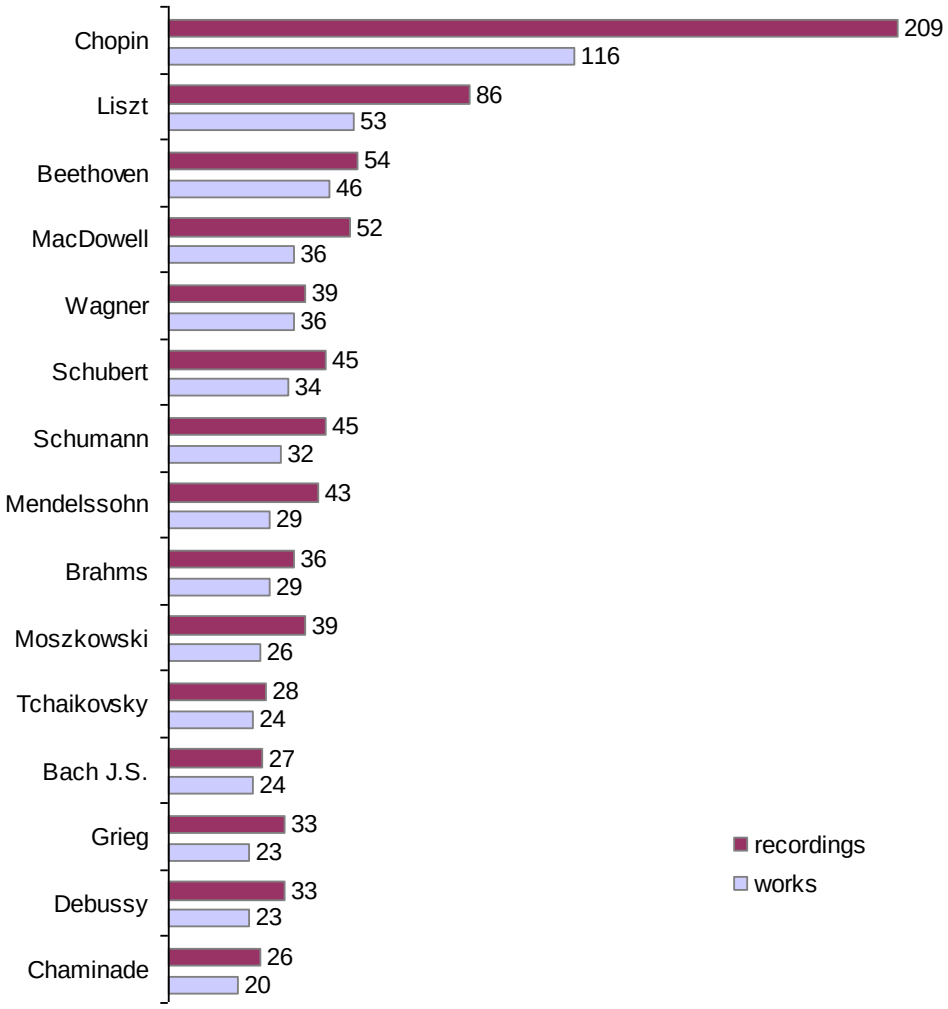

Figure 1.27 *Recordings of works by these fifteen composers comprise nearly forty percent of the Duo-Art art music catalogue*

Although there are fewer of Beethoven's works than Liszt and Chopin, their playing time exceeds eleven hours, compared to eight and half hours for Liszt's works and fifteen hours for those by Chopin's. Of Beethoven's 32 sonatas, 28 were recorded for the Duo-Art.[101] The focus on Beethoven appears to have been driven by the London studio, as sixteen sonatas were recorded there but were not issued in the US.

[101] Only the second movement of Sonata Op. 106 was recorded.

Composers – ten to nineteen works

Figure 1.28 list the composers with ten to nineteen works in the Duo-Art library. Works by Percy Grainger (1882–1961) and Prokofiev were recorded only by their composers. Granados and Scott play some of the recordings made of their works.

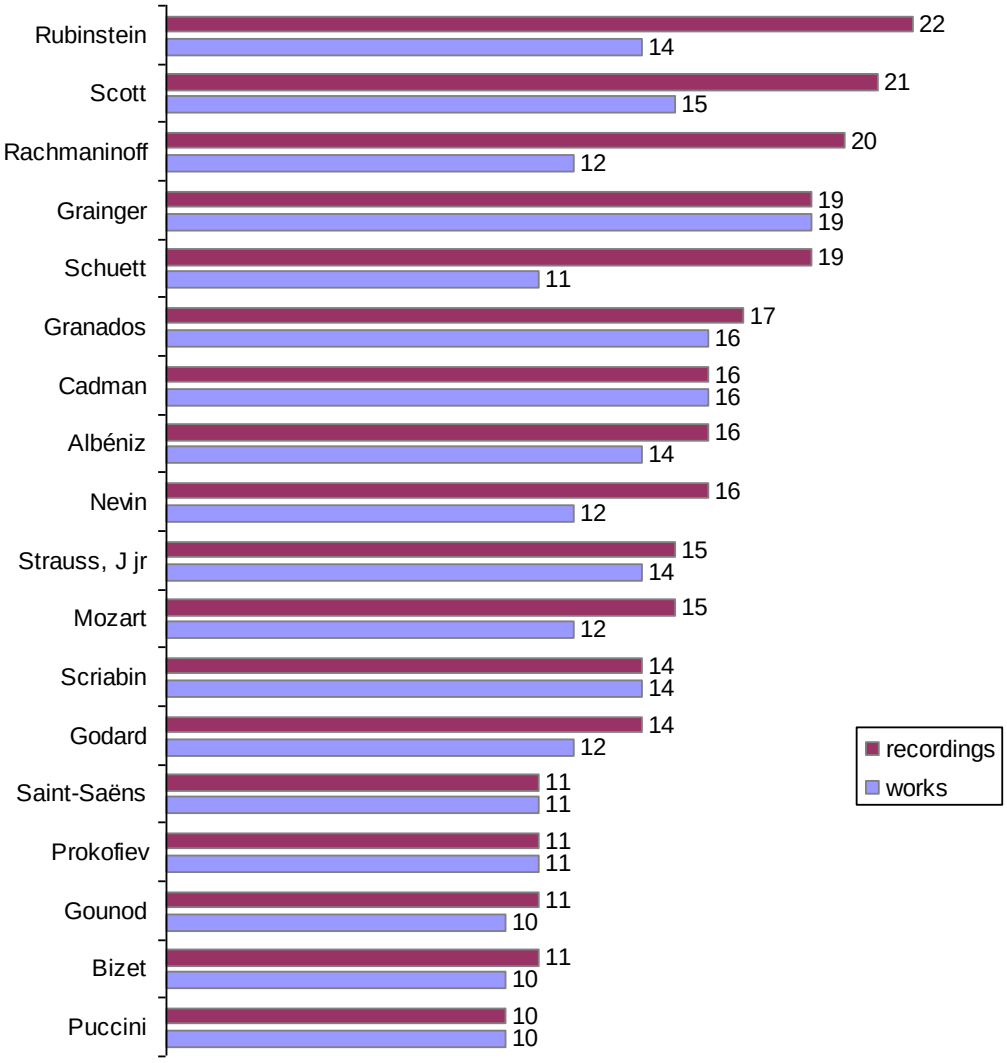

Figure 1.28 *Recordings of works by these eighteen composers comprise fourteen percent of the Duo-Art art music catalogue*

Charles Wakefield Cadman (1881–1946) is well represented in the Duo-Art catalogue. His works are classified as art songs, as they are played by Cadman in this style, and were popular with operatic singers.[102] Composers who wrote lighter works, such as Nevin, Schuett and Godard, each have a similar number of works as in the Ampico catalogue.

Composers – seven or eight works

Figure 1.29 lists the composers with seven or eight works in the Duo-Art catalogue.[103] Among these are Ganz, Friedman and the American John Powell (1882–1963), all of whom are better known as pianists. They recorded their own compositions.

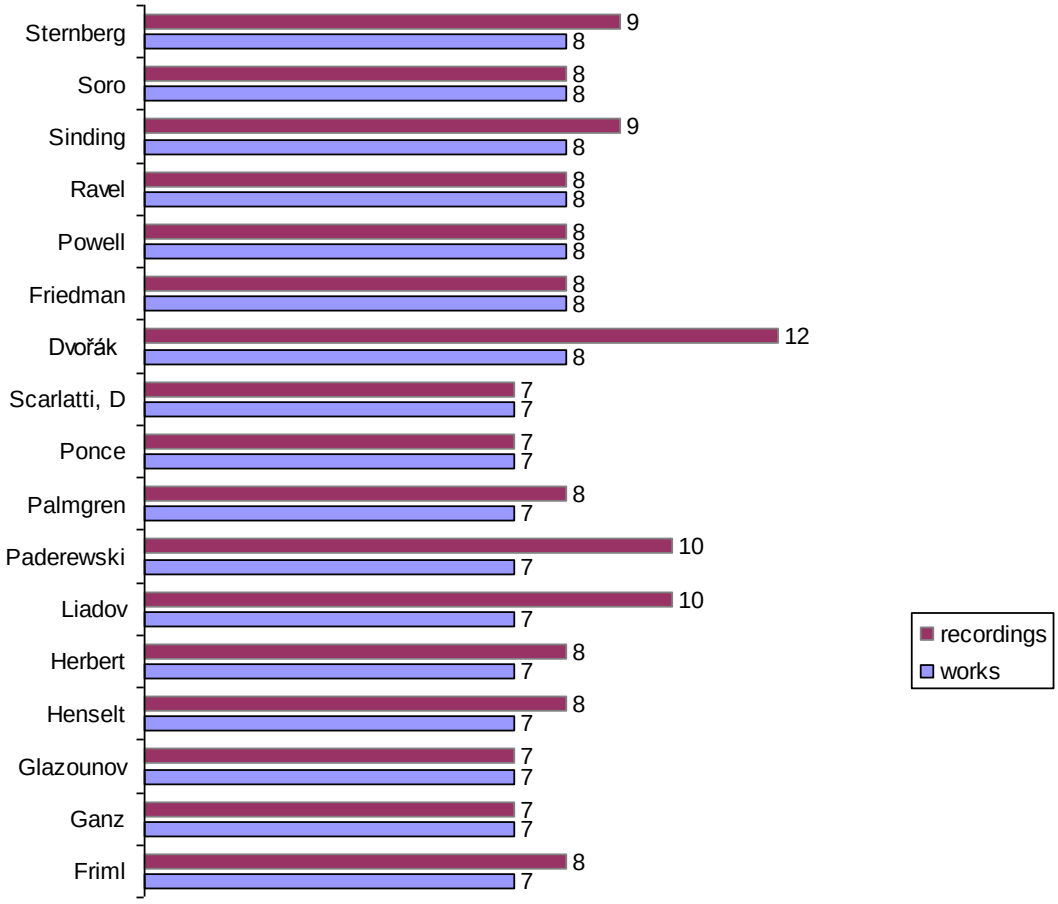

Figure 1.29 *Recordings of works by these seventeen composers comprise seven percent of the Duo-Art library*

[102] Soprano Lillian Nordica recorded Cadman's *From the Land of the Sky Blue Water*, reissued by Marston.
[103] There are no composers with nine works in the Duo-Art art music catalogue.

Composers – less than seven works

Table 1.21 lists the composers with six works in the catalogue. All of these composers except Alberto Jonas (1868–1943) are represented in the Ampico catalogue, generally with fewer works. Ilgenfritz is an exception with twelve works for Ampico compared with six for Duo-Art. Kreisler recorded exclusively for Ampico, making fourteen recordings of his works, hence his greater presence in the Ampico catalogue.

Table 1.21 *Composers with six works in the Duo-Art catalogue*

Composer	Nationality
Anton Arensky (1861–1906)	Russian
Carl Bohm (1844–1920)	German
Léo Delibes (1836–1891)	French
Gabriel Fauré (1845–1924)	French
Edward German (1862–1836)	English
Henry Hadley (1871–1937)	American
Joseph Haydn (1732–1809)	Austrian
McNair Ilgenfritz (1889–1953)	American
John Ireland (1879–1962)	English
Alberto Jonas (1868–1943)	Spanish
Fritz Kreisler (1875–1962)	Austrian
Raoul Laparra (1876–1943)	French
Theodor Leschetizky (1830–1915)	Polish
Arthur Sullivan (1842–1900)	English
Giuseppe Verdi (1813–1901)	Italian

Composers with five works in the catalogue are listed in Table 1.22. Like many pianists of the day, Bauer and Hofmann wrote works for the piano, some of which they also recorded for the Duo-Art. Some of Hofmann's works appear under the pseudonym of Michel Dvorsky.

Table 1.22 *Composers with five works in the Duo-Art catalogue*

Composer	Nationality
Harold Bauer (1873–1951)	English
Ignacio Cervantes (1847–1905)	Cuban
Fred Colber (dates unknown)	American
Ernő Dohnányi (1877–1960)	Hungarian
Josef Hofmann (1876–1957)	Polish-American
Pietro Mascagni (1863–1945)	Italian
David Sequeira (dates unknown)	Spanish-American
Richard Strauss (1864–1949)	German
Carl Maria von Weber (1786–1826)	German

There are 24 composers with four works in the Duo-Art catalogue. These include musical figures such as Korngold, Frederick Delius (1862–1934), Nikolai Medtner (1880–1951) and Peruvian composer Carlos Valderrama (1892–1950), who wrote works based on Inca melodies.[104] Two pianists—d'Albert and Sauer—are also in this group, providing further examples of pianists who recorded their own works. Works by Edward Elgar (1857–1934) include a complete two-piano performance of his *Enigma Variations* on a set of five rolls recorded in London.

[104] During July 1920 Valderrama also recorded many of the same works for Edison on diamond disc.

Summary – composers

Figure 1.30 shows that the fifteen composers with 20 or more works in the Duo-Art catalogue feature on 40 percent of all recordings, while eighteen composers with ten to nineteen works account for another fifteen percent. These composers are listed in Figures 1.27 and 1.28, on pages 84 and 85, and recordings of their works constitute well over half the Duo-Art library. Composers with one or two works account for around twenty percent of the recordings in the catalogue.

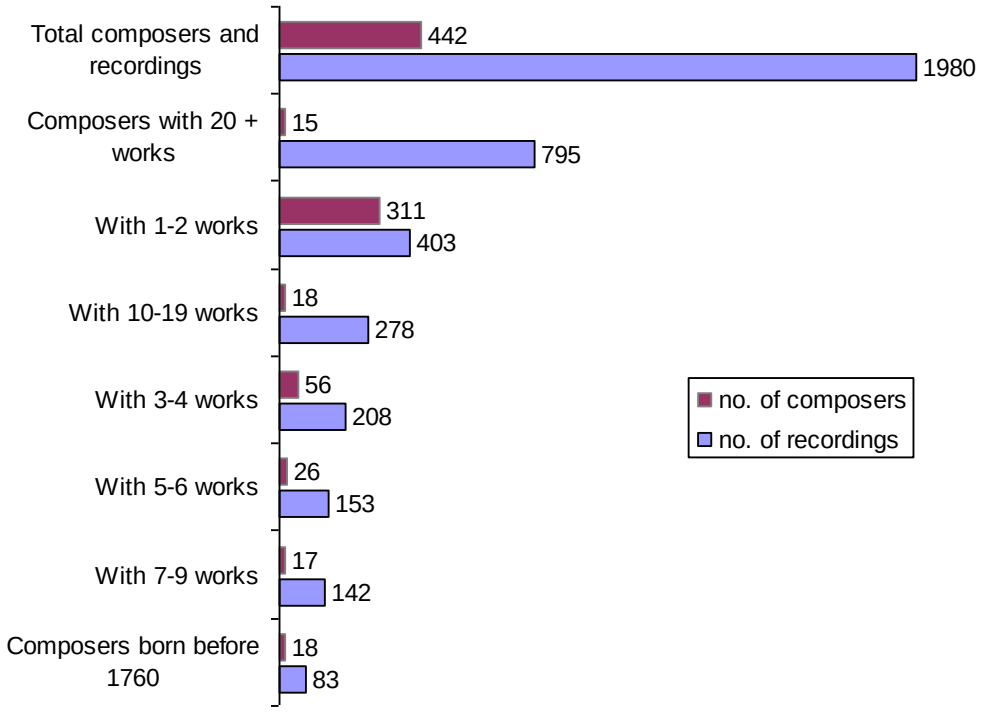

Figure 1.30 *Summary of composer content (Duo-Art art music catalogue)*

There are 83 recordings by the eighteen composers born before 1760, about four percent of the total recordings, indicating the low level of popularity of early music in both the US and UK. Even so, it's worth noting that 27 Duo-Art recordings (or over two hours of listening) were made of J.S. Bach's music, making him by far the most popular of the eighteenth-century composers. Mozart appears on fifteen recordings with a total playing time of nearly two hours.

Information was found about all except 46 of the 442 composers represented in the Duo-Art catalogue. Over 300 composers were born before 1880, which shows that much of the music in the catalogue was written by composers who were trained or composing during the nineteenth century. The Ampico catalogue yielded similar

statistics proving that, as far as piano music was concerned, musical tastes in the early part of the twentieth century favoured music written in the nineteenth century.

Nine composers were born in the twentieth century; only Chasins is likely to be known today. Composers who recorded on Duo-Art roll include Soro, the Mexican Manuel María Ponce (1882–1948), Cervantes and the Finnish Selim Palmgren (1878–1951), generally playing their own works. Better-known composers performing their own works include Prokofiev, Chaminade, Granados, Grainger, Scott and Stravinsky. Pianists who recorded works they wrote for the piano include Busoni, Paderewski, Powell, Hofmann and many others.

Sternberg, while largely forgotten today, recorded six of his works for the Duo-Art, and established the Sternberg School of Music in Philadelphia in 1890. He studied with Ignaz Moscheles (1794–1870), Reinecke, Kullak and Liszt. He was a highly regarded piano teacher.[105]

Like the Ampico catalogue there are numerous examples of works often referred to as salon music. Collectively, the Ampico and Duo-Art roll libraries provide an extensive coverage of salon and light classical music, which is found on no other form of recording and is rarely heard today. Talk of such music is usually accompanied by disparaging comments, and yet it once formed a major part of the piano repertoire.

[105] Slonimsky, *Baker's Biographical Dictionary of Musicians*, 1309.

Pianists on Duo-Art roll

Unlike Ampico with its selection of pianists through Hupfeld recordings, every pianist to appear on a Duo-Art roll recorded for the company, in New York or London, or both.

Pianists exclusive to Duo-Art

The pianists listed in Table 1.23 recorded only for the Duo-Art, providing over 130 works and nearly 15 hours of music. Grainger was exclusively contracted in May 1915 to record for the Duo-Art, and became one of the company's top artists.

Table 1.23 *Notable pianists exclusive to Duo-Art (chronological order)*

Pianist	**No. of works**	**Playing time** (approx)	**Nationality**	**Composers represented; comments**
Alexander Siloti (1863–1945)	7	< 30 mins	Russian	Bach-Siloti & Liszt (2), Bach-Szanto, Liadov & Schubert (1); pupil of Liszt
Ernest Hutcheson (1871–1951)	12 solo 3 duo	47 mins 20 mins	Australian	Liszt (3), Schubert (2), Alkan-MacDowell, Debussy, Mendelssohn, D. Scarlatti, Schubert-Liszt, Stavenhagen & Wagner-Liszt (1); pupil of Reinecke and Stavenhagen, later president of the Juilliard School
Percy Grainger (1882–1961)	50 solo 9 duo	4 hrs 50 mins 56 mins	Australian	Grainger (16), Grieg (8), Schumann, Stanford-Grainger & Tchaikovsky (3), Bizet, Guion, Liszt & Scott (2), Bach-Liszt, Brahms, Chopin, Debussy, Dett, Fauré, Gardiner, Handel & R. Strauss (1)
John Powell (1882–1963	23	< 1 hr 35 min	American	Powell (8), MacDowell & Schumann (3), Beethoven & Chopin (2), M. Bauer, Guion, Ilyinsky, Liszt & Mason (1); pupil of Leschetizky
Myra Hess (1890–1965)	11	41 mins	English	Brahms & Debussy (2), Bach, Bach-Busoni, Beethoven, Paradies, Rachmaninoff, D. Scarlatti & Szymanowski (1)
Sergei Prokofiev (1891–1953)	18	52 mins	Russian	Prokofiev (10), Mussorgsky & Scriabin (2), Glazounov, Miaskovsky, Rachmaninoff & Rimsky-Korsakov (1)
Rosita Renard (1894–1949)	17	56 mins	Chilean	Chopin (5), Mendelssohn (3), Liszt & Renaud (2), Rosa, Sauer, Schumann, Sgambati & Strauss Schultz-Evler (1); limited career
Guiomar Novaes (1895–1979)	29	< 1 hr 55 mins	Brazilian	Chopin (5), Gluck & Gottschalk (2), Albéniz-Godowsky, Beethoven, Grünfeld, Handel, Ibert, Leschetizky, Levy, Liszt, MacDowell, Mendelssohn, Moret, Moszkowski, Niemann, d'Orso, Oswald, Paderewski, Philipp, Rubinstein, Schumann & Sgambati (1); pupil of Philipp
Paquita Madriguera (1900–1965)	20	< 1 hr 10 mins	Spanish	Moszkowski (4), Albéniz & Madriguera (3), Granados (2), Castro, Chaminade, Debussy, Delahaye, Liszt, MacDowell Olsen & Raff (1); pupil of Granados
Shura Cherkassky (1909–1995)	6	25 mins	Russian-American	Cherkassky, Moszkowski, Rachmaninoff, Schumann-Liszt, Tchaikovsky & Verdi-Liszt; recorded rolls at age 15, large discography

Lesser known pianists exclusive to Duo-Art

Table 1.24 lists seven lesser-known pianists who recorded exclusively for the Duo-Art. Some are forgotten today, yet all had distinguished careers.

Table 1.24 *Lesser known pianists exclusive to Duo-Art (chronological order)*

Pianist	No. of works	Playing time (approx)	Nationality	Composers represented; comments
Cécile Chaminade (1857–1944)	12	40 mins	French	Own works only, rolls issued early to mid-1920s, made six sound recordings in 1901
Arthur Shattuck (1881–1951)	8	26 mins	American	Sinding (2), Chopin, Liszt, Offenbach, Poldini, Schumann-Liszt & Woodman (1); pupil of Leschetizky
Alexander Raab (1882–1940)	12	< 52 mins	Hungarian-American	Schuett (4), Frommel (2), Brahms, Chopin, Liszt, Mozart, Schubert-Liszt & Volkmann (1); pupil of Leschetizky
Robert Lortat (1885–1938)	9	51 mins	French	Fauré (2), Chabrier, Debussy, Delibes, Franck, d'Indy, Séverac & Widor (1); pupil of Diémer, lifetime bond with Fauré
William Murdoch (1888–1942)	20	< 2 hours 10 mins	Australian	Debussy (4), Beethoven (3), Ireland (2), Bowen, Carse, Dunhill, Dyson, Lee, Morgan, Poldini, Rowley, Séverac, Swinstead & Walther (1); rolls include works he did not record on disc
Nadia Reisenberg (1904–1983)	12	37 mins	American-Lithuanian	Liadov, Moszkowski & Tchaikovsky (2), Blumenfeld, Chopin, Glazounov, Godard, Mozart & Rameau-Godowsky (1); pupil of Lambert, made sound recordings, concert pianist
Jeanne-Marie Darré (1905–1999)	5	< 25 mins	French	Beethoven, Couperin, Mendelssohn, Philipp & Rameau-Godowsky; pupil of Philipp, extensive discography

Notable pianists on Duo-Art and also on Ampico or Welte rolls

The 33 pianists listed in Tables 1.25 (a), (b) and (c) recorded for the Duo-Art, and also appear on Ampico and/or Welte roll recordings. Fourteen of these pianists made the majority of their roll recordings for the Duo-Art. The pianists are listed in chronological order, and the three tables are presented chronologically.

Most of the pianists in the following tables did not record for Ampico, rather their Ampico rolls are from Hupfeld recordings, as listed in Table 1.15 (page 70). The number of Welte recordings is the total of the pianist's Welte-Mignon and Welte Licensee recordings. Bolded numbers indicate the roll brand with the majority of recordings for a pianist. Playing times are from actual values, unless indicated.

Table 1.25 (a) *Notable non-exclusive Duo-Art pianists (born 1835–1869)*

Pianist	**Number of works**			**Nationality**	**Composers represented** (Duo-Art only)**; comments**
	Ampico	**Duo-Art**	**Welte**		
Camille Saint-Saëns (1835–1921)	2	6 (23 mins)	**13**	French	Own works, one work by Chopin; see Table 1.2
Vladimir de Pachmann (1848–1933)	-	12 (53 mins)	**37**	Russian	Chopin (11), Mendelssohn (1); see Table 1.2
Xaver Scharwenka (1850–1924)	1	6 (27 mins)	**14**	Polish	Scharwenka (3), Chopin, Mendelssohn & Schumann (1); see Table 1.2
Teresa Carreño (1853–1917)	4	7 (40 mins)	**11**	Venezuelan	MacDowell (2), Beethoven, Carreño, Chopin, Handel & Rubinstein (1); see Table 1.3
Arthur Friedheim (1859–1932)	1	**15** (71 mins)	5	German	Liszt (10), Chopin (2), Gottschalk, Henselt & Rosenthal (1); pupil of Liszt, see Table 1.3
Ignace Jan Paderewski (1860–1941)	**-**	**33** (2 hrs 47 mins)	14	Polish	Chopin (11), Paderewski (6), Liszt (3), Chopin-Liszt, Schubert, Schubert-Liszt & Schumann (2), Beethoven, Debussy, Mendelssohn, Schelling & Wagner-Liszt (1); pupil of Leschetizky, see Table 1.4
Emile von Sauer (1862–1942)	1	6 (30 mins)	**10**	German	Sauer (3), Beethoven, Hummel & Liszt (1); pupil of Liszt, see Table 1.4
Eugen d'Albert (1864–1932)	1	8 (50 mins)	**45**	Scottish-German	Beethoven (3), Chopin (2), d'Albert, Debussy & Liszt (1); pupil of Liszt, see Tables 1.4 and 1.7
Ferruccio Busoni (1866–1924)	4	**30** (77 mins)	13	Italian	Chopin (25), Liszt (4), Bach-Busoni (1); see Table 1.4
Enrique Granados (1867–1916)	-	**10** (43 mins)	9	Spanish	Granados (10); see Table 1.2
Frederic Lamond (1868–1948)	2	**15** (< 2.5 hours)	8	Scottish	Beethoven (4), Glazounov & Liszt (2), Beethoven-Liszt, Glinka-Balakirev, Rossini-Liszt, Strauss-Grünfeld, Strauss-Tausig, Tchaikovsky & Weber (1); pupil of Liszt, see Table 1.4

Table 1.25 (b) *Notable non-exclusive Duo-Art pianists (born 1870–1879)*

Pianist	**Number of works**			**Nationality**	**Composers represented** (Duo-Art only)**; comments**
	Ampico	**Duo-Art**	**Welte**		
Leopold Godowsky (1870–1938)	**21**	8 (32 mins)	-	Polish-American	Chopin (3), Henselt (2), Moszkowski, Rubinstein & Schumann (1); see Table 1.17 (a)
Maria Carreras (1872–1966)	-	9 (44 mins)	**24**	Italian-American	Chopin (2), Albeniz, Falla, Liszt, Nepomuceno, Schubert-Liszt & W. Bach-Zadora (1); pupil of Sgambati, see Tables 1.10 and 1.23
Katharine Goodson (1872–1958)	4	**14** (67 mins)	-	English	Chopin (5), Hinton (2), Brahms, Gernsheim, Gretchaninoff, MacDowell, Palmgren, Schubert & Schumann (1); pupil of Leschetizky, see Table 1.17 (a)
Carl Friedberg (1872–1955)	2	9 (32 mins)	**11**	German	Chopin (3) Brahms, Moszkowski, Schubert, Schubert-Liszt, Schumann & Tchaikovsky (1); see Tables 1.5 (a) and 1.17 (a)
Harold Bauer (1873–1951)	4	**80** (solo) (approx 8 hrs) **4** (duo)	-	English	Chopin (17), Beethoven, Brahms & Schumann (7), Bauer (5), Bach (4), Haydn & Schubert (3), Handel, Liszt, Mendelssohn, Moszkowski & Mozart (2), 17 works by 17 composers; see Table 1.15
Maurice Ravel (1875–1937)	-	**5** (25 mins)	2	French	own works only; also Welte-Mignon recordings of own works totalling 17 mins
Josef Hofmann (1876–1957)	2	**52** (5 hrs 7 mins)	21	Polish-American	Chopin (14), Hofmann & Liszt (5), Beethoven, Mendelssohn & Moszkowski (4), Rubinstein (3), Rachmaninoff (2), 11 works by 11 composers; see Tables 1.5 (a) & 1.8
Ernest Schelling (1876–1939)	-	6 (53 mins)	**12**	American	Chopin (3), Liszt (2), Granados (1); pupil of Leschetizky and Mathias, see Table 1.8
Alfred Cortot (1877–1962)	2	**27** (1 hr 53 mins)	-	French	Chopin (11), Liszt (4), Beethoven, Chabrier & Schubert (2), Albeniz, Bach, Fauré, Purcell, Saint-Saëns & Scriabin (1)
Herbert Fryer (1877–1957)	-	10 (40 mins)	**23**		Chopin (3), Fryer (2), Beethoven, Debussy, Liszt, Munro & Schumann (1); see also Table 1.8
Rudolph Ganz (1877–1972)	3	**66** (solo) (< 5 hrs) **3** (duo)	54	Swiss-American	Liszt (7), Ganz (5), Chopin (4), Grieg, MacDowell & Rachmaninoff (3), Chaminade, Dvořák, Moszkowski, Mozart, Schubert & Wagner (2), 29 works by 25 composers; see Tables 1.8 & 1.10
Ossip Gabrilowitsch (1878–1936)	6	**13** (solo) (37 mins) **2** (duo)	9	Russian-American	Chopin (4), Fauré, Gabrilowitsch, Haydn, Leschetizky, Mendelssohn, Rachmaninoff, Sapellnikoff, Schubert & Schumann (1); see Tables 1.5 (a) and 1.17 (a)
Mark Hambourg (1879–1960)	2	6 (16 mins)	**7**	Russian-English	Rubinstein (2), Hambourg, Henselt, Leschetizky & Tchaikovsky (1); see Tables 1.5 (a) & 1.17 (a)
Wanda Landowska (1879–1959)	2	4 (45 mins)	**12**	Polish-French	Beethoven (2), Mozart & Lanner (1); see Table 1.5 (a)

Bauer and Ganz both made a substantial number of roll recordings, in Bauer's case primarily for the Duo-Art. His Ampico rolls are from Hupfeld recordings, although he also appears on Artrio, Artecho and Apollo rolls. Bauer pairs with Gabrilowitsch on two Duo-Art recordings and with Hess on two recordings.

Table 1.25 (c) *Notable non-exclusive Duo-Art pianists (born 1880–1905)*

Pianist	**Number of works**			**Nationality**	**Composers represented** (Duo-Art only)**; comments**
	Ampico	**Duo-Art**	**Welte**		
Ignaz Friedman (1882–1948)	2	**32** (3 hrs 13 mins)	-	Polish	Friedman (8), Chopin (7), Liszt (3), Schubert, Schumann & Wagner (2), Alabieff-Liszt, Bach-Tausig, Beethoven, Moszkowski, Rubinstein, Strauss, Tchaikovsky & Weber (1)
Elly Ney (1882–1968)	6	3 (26 mins)	**13**	German	Beethoven, Chopin & Schubert; pupil of Leschetizky and Sauer, see Tables 1.5 (b) & 1.17 (b)
Michael von Zadora (1882–1946)	4	11 (49 mins)	**36**	American	Chopin (5), Schumann (2), Bach, Beethoven, Franck & Liszt (1); pupil of Essipoff & Leschetizky, see Tables 1.5 (b), 1.10 & 1.17 (b)
Wilhelm Backhaus (1884–1969)	3	**15** (1 hr 42 mins)	3	German	Mendelssohn & Wagner (2), Chopin-Backhaus, Mozart and R. Strauss, Beethoven, Brahms, Delibes, Kreisler, Liszt, Pick-Mangiagalli, Schumann-Liszt & Smetana (1); see Table 1.10
Clarence Adler (1886–1969)	**29**	23 (82 mins)	2	American	Moszkowski (4), Chaminade (3), Bruch, Friml, Godard, Gottschalk, Gounod, Grieg, Grünfeld, Herbert, Lassen, Leybach, MacDowell, Paderewski, Rubinstein, Seeling & Thome (1); see Table 1.17 (b)
Arthur Rubinstein (1887–1982)	9	**22** (1 hr 43 mins)	**-**	Polish-American	Chopin (9), Albéniz, Brahms & Debussy (3), Falla, Prokofiev, Rimsky-Korsakov & Schumann (1); see Tables 1.5 (b), 1.17 (b)
Yolanda Mérő (1887–1963)	3	4 (n/a)	**27**	Hungarian-American	Beethoven, Dohnányi, Sinding & R. Strauss; see Tables 1.5 (b), 1.8 & 1.17 (b)
E. Robert Schmitz (1889–1949)	**20**	9 (70 mins)	-	French	Debussy (3), Pierne, Ravel, Schumann, Séverac, Whithorne & Wieniawski (1); see Table 1.17 (b)
Leff Pouishnoff (1891–1958)	**-**	7 (n/a)	**21**	Russian-English	Scriabin (3), own works (2), Bach and Liadov, see Tables 1.8 & 1.13
Magdeleine Brard (1903–)	**-**	6 (23 mins)	**19**	French	Liszt (3), Chopin, Fauré & Pierne (1); pupil of Cortot, did not pursue a concertising career
Vladimir Horowitz (1903–1989)	-	7 (37 mins)	**15**	Russian-American	Rachmaninoff (2), Bizet-Horowitz, Chopin, Horowitz, Saint-Saëns-Liszt, Schubert-Liszt & Tchaikovsky (1); see Table 1.10
José Echániz (1905–1969)	**9**	2 (n/a)	-	Cuban	Cervantes & Vogrich; prodigy, championed Cuban composers, see Table 1.17 (b)

Pianists – twenty or more recordings

Figure 1.13 lists all pianists who made twenty or more Duo-Art roll recordings. Pianists marked with an asterisk are listed in Tables 1.23, 1.24 or 1.25 (a) to (c). (Pages 91-95.)

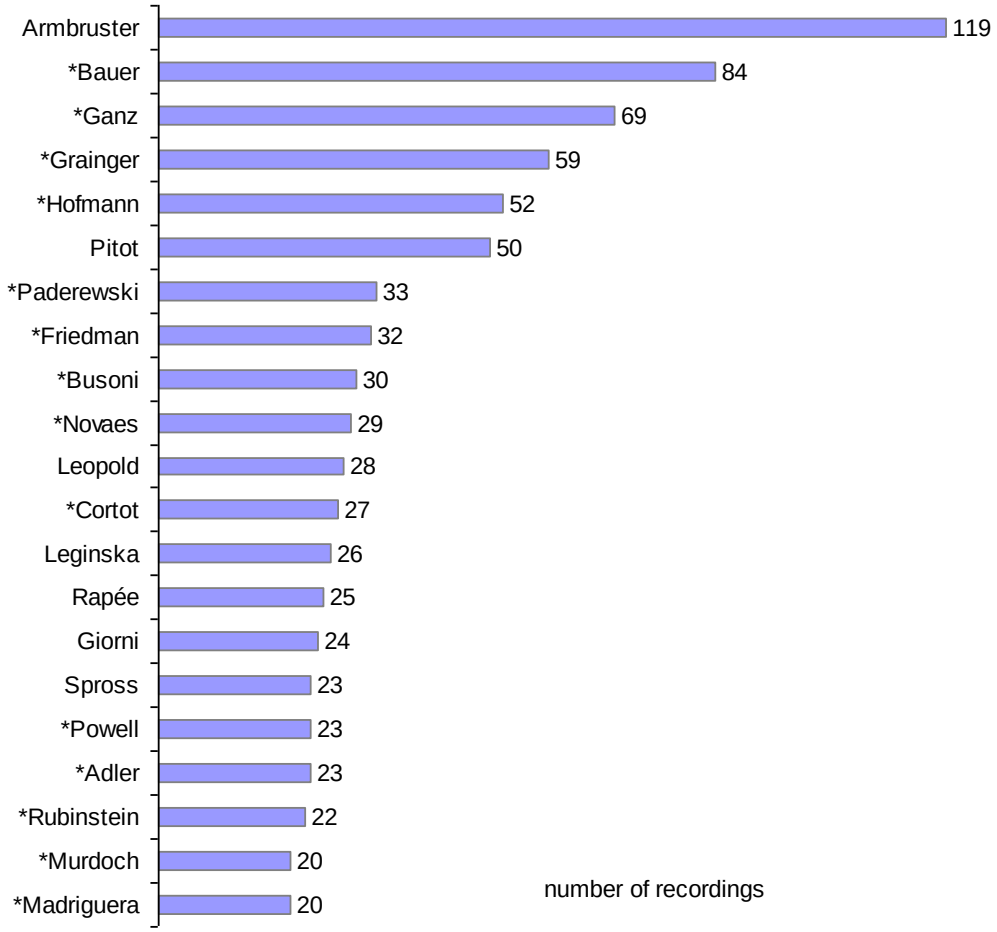

Figure 1.31 *Recordings by these 21 pianists comprise over 40 percent of the Duo-Art art music catalogue*

Lesser-known pianists include Robert Armbruster (1896–1994), an American pianist employed by Aeolian from 1915 to 1930 as an in-house artist.[106] He recorded under his own name and various pseudonyms.[107] Genevieve Pitot (1901–1980) recorded on piano roll only for the Duo-Art and made no sound recordings. Born in New Orleans of French parentage, at age twelve she began lessons with Cortot in Paris. Her playing style is, in my opinion, highly suited to the salon style of music she recorded.

[106] Davis Smith, *Duo-Art Piano Music*, 22.
[107] Pseudonyms used by Armbruster include Gene Waldron, Henri Bergman and Robert Summers.

Ralph Leopold (1884–1955) recorded numerous selections from Wagner operas, and also recorded two piano works with Grainger, in particular a number of works by Frederick Delius (1862–1934). Ethel Leginska (1886–1970) studied for four years with James Kwast (1852–1927) in Frankfurt, afterwards spending three years with Leschetizky. Hungarian-born Ernö Rapée (1891–1945) participated in a wide range of musical activities, including conducting and composing popular songs that included *Dianne* and *Charmaine.*

Italian-born Aurelio Giorni (1895–1938) was a pupil of Sgambati at age eight, later studying with Humperdinck and Busoni.[108] American pianist and composer Charles Gilbert Spross (1874–1961) studied with a number of teachers, including Scharwenka. He became a successful accompanist, working with singers such as Nellie Melba (1861–1931).

Pianists – fifteen to eighteen recordings

The eight pianists who recorded between fifteen and eighteen works on Duo-Art roll are shown in Figure 1.32. Pianists marked with an asterisk are listed in Tables 1.23, 1.24 or 1.25 (a) to (c). (Pages 91-95.)

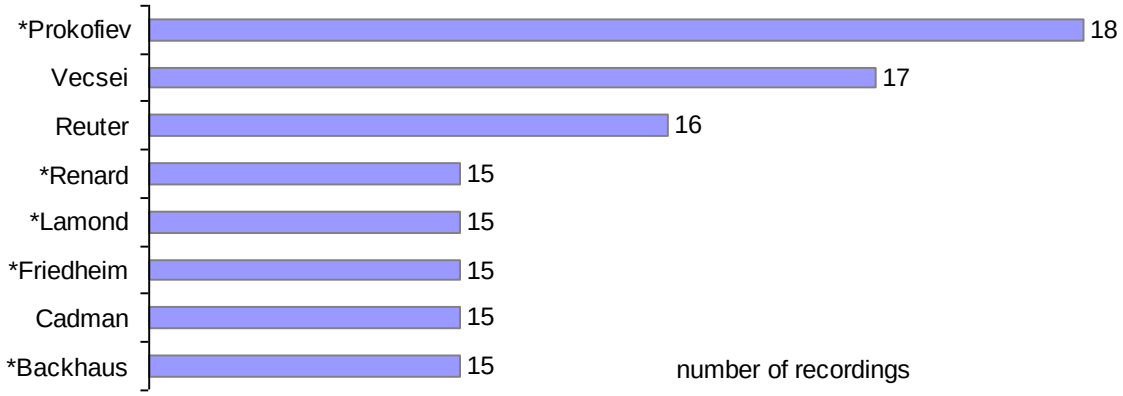

Figure 1.32 *Recordings by these eight pianists comprise just over six percent of the Duo-Art art music catalogue*

Hungarian-born Desider Vecsei (1882–1966) was a child prodigy who studied with Sauer, settling in America around 1915. Rudolph Reuter (1888–1953) was an American pianist who studied in Berlin, winning the Mendelssohn Prize on his graduation in 1910. He was director of musical departments at the Imperial Academy in Tokyo for 1910-13.

[108] Slonimsky, *Baker's Biographical Dictionary of Musicians*, 468.

Pianists – ten to fourteen recordings

The 23 pianists who recorded between ten and fourteen works are listed in Figure 1.33. Asterisk indicates pianist is listed in Tables 1.23, 1.24 or 1.25 (a) to (c). (Pages 91-95.)

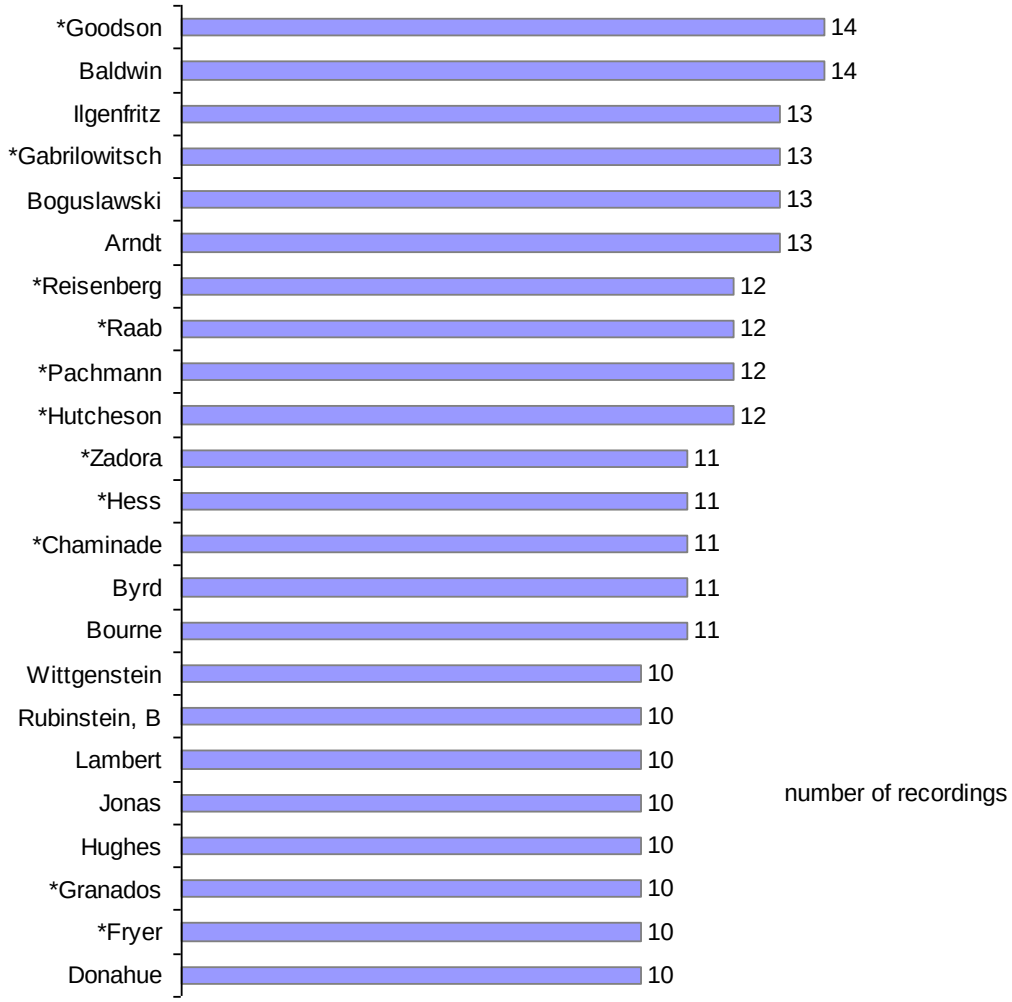

Figure 1.33 *Pianists who made ten to fourteen Duo-Art recordings*

Lesser known pianists in Figure 1.33 include American Moissaye Boguslawski (1888–1944), a pupil of Ganz who later became a professor at Chicago Musical College, and Beryl Rubinstein (1898–1952), who studied with Busoni and became Head of Cleveland Institute of Music (1921–25) and later Director in 1932.[109] Alexander Lambert (1862–1929) spent time with Liszt, toured widely, and became Director of New York College of Music. He was known as a piano teacher.[110] Edwin Hughes (1884-1965) was a pupil of Leschetizky, becoming his assistant from 1909.[111]

[109] Wilson Lyle, *A Dictionary of Pianists* (London: Robert Hale, 1985), 243.
[110] Lyle, *A Dictionary of Pianists*, 161.
[111] Lyle, *A Dictionary of Pianists*, 135.

Notable and exclusive pianists with few recordings

The pianists that have been presented so far made well over 60 percent of all Duo-Art recordings. The remaining Duo-Art recordings were made by around 240 pianists, some of whom are notable, but who made only a few roll recordings. Those that were exclusive to Duo-Art are listed in Table 1.26, with brief comments.

Table 1.26 *Exclusive and notable artists with less than ten Duo-Art recordings*

Pianist	**No. of works**	**Playing time** (min:sec)	**Nationality**	**Composers represented; comments**
Claudio Arrau (1903–1969)	2	9:47	Chilean	Recorded works by Menter & Schubert; made his roll recordings at age 19
Abram Chasins (1903–1987)	3	6:35	American	Composer/pianist, recorded his Op. 5 No. 1 and 2, and his Op. 7; examples of fast piano, wrote book *Speaking of Pianists* (1961) which makes no mention of piano roll recordings made by the author or the pianists he discusses
Anis Fuleihan (1900–1970)	6	16 mins	Cypriot-American	Chopin and own works (3); pupil of Jonás, wrote two piano concertos and many piano works of technical difficulty.[112]
Eugene Goossens (1893–1962)	2	14 mins	English	Recorded his *Kaleidoscope* Op. 18 and his Op. 38 No. 1 Folk Tune
Gitta Gradova (1904–1985)	6	20 mins	American	Arensky, Bentz, Chopin, Moszkowski, Mussorgsky-Rachmaninoff & Tchaikovsky; child prodigy, "a somewhat legendary figure in the pf [piano] world."[113]
John Ireland (1879–1962)	2	4:46	English	Composer, recorded his own works in London, rolls issued mid 1920s
José Iturbi (1895–1980)	4	33 mins	Spanish	Albéniz, Beethoven, Liszt & Mozart, recorded in the late 1920s
Selim Palmgren (1878–1951)	3	9:19	Finnish	Composer, recorded his own works
Harold Samuel (1879–1937)	5	26 mins	English	Bach (4), Paradies (1); noted performer of Bach, made sound recordings

[112] Lyle, *A Dictionary of Pianists*, 101.
[113] Lyle, *A Dictionary of Pianists*, 113.

Summary – pianists

The birth dates of 186 of the 298 artists who recorded for the Duo-Art could be determined. Of those, Saint-Saëns is the most senior; there are 24 pianists born before 1870 and fourteen pianists made some of their roll recordings as teenagers.

The gender of all but two artists could be identified, showing there are 97 female pianists, with Chaminade the eldest, followed by Carreño. The female pianists recorded nearly a quarter of the Duo-Art catalogue, in which Pitot was the most recorded with 50 titles; Novaes and Leginska were responsible for another 55 recordings.

There are numerous historically significant artists who recorded on Duo-Art roll, some of them exclusively. An interesting group are those who recorded for Welte in 1905-06 and later recorded the same works for the Duo-Art. Examples are Saint-Saëns, Pachmann and Paderewski. There are also a number of notable composers who recorded for the Duo-Art, in particular Ravel and Prokofiev, also Grainger.

As with Ampico, there are many Duo-Art artists who had flourishing careers at the time, and who can provide interesting insight into early twentieth-century performance practice. Their choice of works also gives a guide to the popularity of particular works at the time.

Conclusion – Duo-Art art music catalogue

The Duo-Art library is a reflection of the musical tastes of Duo-Art owners in both the US and Britain. Compared to Ampico, Duo-Art roll recordings cover more composers and a greater number of works. The two roll libraries collectively contain music by over 570 composers, played by over 500 pianists and together the recordings provide over 250 hours of listening. As with Ampico, some of the works recorded for the Duo-Art have limited musical merit, and certainly there are numerous works that are forgotten today. Duo-Art roll recordings cover a wide range of music, much of which has historical interest either by virtue of the performer or the work itself.

Chapter summary

Table 1.27 shows the statistics for each of the piano roll catalogues discussed in this chapter. These four catalogues offer nearly 6,700 recordings with an estimated playing time of 500 hours, compared to an estimated 50 hours of disc or wax cylinder recordings of solo piano works made up to 1930. Collectively, the piano roll catalogues offer works by 850 individual composers, and recordings by 760 individual pianists.

Table 1.27 *Statistics of Welte, Duo-Art and Ampico rolls of art music*

Aspect	Welte-Mignon	De Luxe	Duo-Art	Ampico	Totals
Recordings	2220	1011	1980	1480	**6671**
Works	1936	980	1615	1255	**-**
Rolls	2295	1035	2070	1450	**6850**
Composers	388	294	442	365	**850**
Pianists	243	116	298	262	**760**
Playing time	< 180 hrs	< 70 hrs	< 155 hours	< 100 hours	**500 hours**

Roll recordings for the Welte-Mignon are undoubtedly the most historically important. They are the only type of recording made by many of the nineteenth-century pianists who recorded for the instrument. The Duo-Art catalogue contains nearly as much music as recorded for the Welte-Mignon, and in many cases pianists recorded for both companies, often up to twenty years apart.

The Ampico catalogue offers a greater range of recordings by twentieth-century artists, complementing similar recordings for the Duo-Art. Therefore, the Duo-Art catalogue sits between those for the Welte-Mignon and the Ampico instruments. The De Luxe catalogue contains a greater range of recordings by unknown pianists, however it has a number of notable artists that were exclusive to the company.

In all cases, a substantial amount of each catalogue was recorded by notable artists playing works by major or well-known composers, as well as a range of serious works by lesser-known composers. Recordings of salon and light music also form a good part of each catalogue, along with transcriptions of operatic tunes, operettas, symphonies and overtures. It may be that some of the works recorded on piano roll were not published, and certainly there are many works that today, like their composer, are unknown.

Chapter conclusion

No other resource provides such documentation of the performance practice of nineteenth-century pianists than piano roll recordings. The four catalogues examined in this research contain recordings of around 100 pianists born before 1870, of whom some were pupils of Liszt, or Leschetizky, some with links to composers such as Wagner. There are many instances of famous nineteenth-century pianists who only recorded on piano roll, such as Leschetizky, Carreño, Essipoff and Bloomfield Zeisler. There are also a number of well-known composers (Scriabin, Debussy and Granados) who recorded their own works only on piano roll. Numerous pianists made piano roll recordings at the start of their career, later making sound recordings, sometimes in stereo, giving a wide ranging documentation of how their playing style may have changed over their career. Several generations of pianists recorded on piano roll, giving a wide view of performance practice as it evolved from the Romantic style of the nineteenth century to today's style of playing.

Recordings of works by major or known composers constitute nearly half the content of the libraries examined in this research. Because much of this music remains in the repertoire, comparisons can be made of today's playing style and that of the nineteenth century. Furthermore, recordings by notable artists comprise nearly half of all the roll recordings in these libraries, proving the musical worth of these catalogues.

Piano roll libraries also contain numerous works by now-forgotten composers, many of who were famous in their day. It is likely that much of this music was only recorded on piano roll. These recordings therefore provide documentation of a musical past that is worthy of exploration and study and, perhaps in some cases, revival.

As expected, there are many unknown pianists who recorded on piano roll. During my research into these pianists I found some of them to have had an interesting background, and that had they made sound recordings, perhaps they may not be so forgotten today.

In conclusion, as Goldberg, who introduced this thesis, might have otherwise remarked: "In short, [piano roll recordings] are a documentation that no historian can afford to neglect."

Chapter 2 – Piano roll technology

Overview

By comparing piano roll recording and playback technologies to contemporary technologies, I aim to determine the limitations and strengths of piano roll recordings. The methods used by Welte, De Luxe, Ampico and Aeolian to make and produce piano roll recordings therefore form a major part of this chapter.

As explained in the Introduction (see page 5), Leikin, Peres Da Costa and Ho make similar conclusions concerning the limitations of reproducing piano rolls. Peres Da Costa refers to dynamics, tone, touch and pedalling;[114] Leikin cites dynamic nuances, pedalling, phrase shadings, chord voicings and tone colours;[115] Ho questions the accuracy of dynamics and pedalling.[116] Roy Howat, when writing about Debussy's Welte-Mignon piano rolls refers to the 'system' being "easily confused by Debussy's mostly low dynamics and any tendency to work at points of escapement and half-pedal."[117] As pointed out in the Introduction (page 6), some writers question the reliability of a piano roll recording because of the potential to edit the recording.

Howat also regards the playback instruments as a source of potential error, particularly in regard to tempo, citing two Welte-Mignon instruments that gave different playing times for the same roll. He concludes that the multitude of hidden variables that affect what we hear from rolls is "probably dominated above all by the condition and fine-tuning of the replaying instrument and mechanism."[118]

My experience with piano rolls and associated pianos has convinced me that the limitations are not always as significant as some writers suggest. As Howat recognises, more often the condition of the play-back instrument is a significant factor affecting the reproduction. Reviewers of audio recordings made of piano rolls played on original instruments have often noted the poor quality of reproduction. Therefore, it is important to look at roll recordings separately from the instruments that play them.

Concerning the instruments, the benchmark is today's player piano technology, which encompasses a range of systems with different levels of sophistication and

[114] Peres Da Costa, *Off the Record*, 40.
[115] Leikin, *The Performing Style of Alexander Scriabin*, 16.
[116] Ho, "Debussy and late-Romantic Performing Practices," 4.
[117] Roy Howat, *The Art of French Piano Music. Debussy, Ravel, Fauré, Chabrier* (New Haven: Yale University Press, 2009), 316.
[118] Howat, *The Art of French Piano Music*, 317.

capabilities. My experience is that a well-adjusted pneumatic reproducing piano has a performance capability equal to many modern MIDI player pianos, implying that the data on piano rolls is similar to the data stored in computer files that play on modern instruments. Of particular interest is the type of data that is *not* recorded on a piano roll when compared to a recording made for the most advanced contemporary player piano.

Determining how the data stored on a piano roll was obtained is especially important. Some aspects of the recording methods used by piano roll companies remain unpublished, and because the four companies under examination in this thesis had different recording and production techniques, I examine each one separately.

Background – playback technologies

The first pianos that could be played mechanically date to the early 1800s and had a rotating barrel to actuate the piano keys.[119] Roll-playing instruments began to appear in experimental form during the latter half of the nineteenth century, culminating in the Votey 'push-up player' described in Chapter 1, which was marketed as the Pianola by Aeolian from the late 1890s. The reproducing piano took piano roll technology to its highest form by introducing dynamic control of playing notes from expression data stored on the roll.[120] It was not until the late 1970s that this technology was superseded, when the Pianocorder produced by US company Superscope was first marketed.[121]

Unlike pneumatically-powered players and reproducing pianos, the Pianocorder player system used electrical power to operate solenoids to play the piano keys. A solenoid is a coil of wire wound on a cylindrical former which houses an iron core. The core moves due to the magnetic field set up by the coil when an electric current flows through the coil. The velocity of the moving iron core, and therefore the volume of playing notes can be controlled with electronic circuitry. The Pianocorder played from recordings stored on cassette tapes, with much of the recorded material derived from piano roll recordings. It was the first break from the traditional pneumatic technology found in virtually all player pianos up until that time.[122]

[119] Bowers, *Encyclopedia of Automatic Musical Instruments*, 364.
[120] The operating principles of a pneumatic reproducing piano are examined in Chapter 3.
[121] Mark Andrew Fontana, *Preservation and MIDI Translation of the Pianocorder Music Library*, http://pianocorder.info/pdf/mark_fontana_thesis.pdf (accessed 21 October 2015).
[122] Solenoid-powered player pianos with limited expression capability were manufactured in the early 1900s, such as the Electrelle player system mentioned in Chapter 1, and the Telektra system.

In the mid-1980s, Yamaha began marketing its version of a player piano, called the Disklavier. Like the Pianocorder, the playback system consisted of solenoids, but unlike the Pianocorder, the Disklavier conformed to the MIDI standard (see below), which had been established a few years before and remains current today. To ensure it had the entire market, Yamaha purchased the company producing the Pianocorder and closed its operations. A consequence was that a US-based company affected by the loss of sales of the Pianocorder went on to develop the PianoDisc MIDI player system, which is now the Disklavier's largest competitor.

MIDI-based solenoid player instruments are analogous to pneumatic reproducing pianos in that both types have similar playing characteristics, as explained later. It is only the high-end instruments that take playback technology to a higher level.

High-end MIDI solenoid pianos

Solenoid player pianos that can reproduce a pre-recorded performance with a high degree of accuracy began with Wayne Stahnke's SE instrument, marketed by Bösendorfer during the late 1980s.[123] Yamaha began marketing its Disklavier Pro series of MIDI solenoid pianos in 1998. The current range of Pro instruments can demonstrably record every aspect of a pianist's playing, and reproduce the performance with an almost absolute accuracy.[124] Other instruments with similar specifications are Bösendorfer's CEUS-equipped series of pianos.[125] The SE instrument has since been developed further by Richard Shepherd in England and is used in special projects, but is no longer commercially available.

There is little information that details the operation of high-end mechanical player pianos. Yamaha provides a website that outlines aspects of the company's Pro series, explaining that "the Pro models are distinguished by key sensors, pedal sensors, hammer sensors, moving magnet sensors with key sensor servos, […] and the ability to record and play extended precision MIDI data, known as XP data."[126]

The complexity of a high-end mechanical player piano is associated with its feedback and measuring systems that, combined with sophisticated software, gives it the

[123] Wayne Stahnke, *Live Performance*, http://www.live-performance.com/about.html (accessed 28 January 2016).
[124] I have tested this aspect of my own Pro instrument on numerous occasions with skilled participants.
[125] *CEUS Reproducing System*, http://www.boesendorfer.com/en/ceus-reproducing-system (accessed 4 December 2016).

ability to accurately control a relatively simple solenoid to recreate the movement of each piano key. Although this technology is best exploited by recordings made on the particular instrument, it also ensures a high accuracy of playing of a standard MIDI file.

Background – recording technologies

Prior to the introduction of hand-played roll recordings, rolls were produced mechanically from a score by marking lines on a stencil which was later punched to become a master roll. It is probable that the first piano roll recordings to qualify as being made by a live pianist were produced for the Welte-Mignon in 1904, as described later in this chapter. In 1905, Hupfeld introduced the *Artistic Hand-Played Music Roll*, a series of piano rolls for the company's *Phonola* player piano.[127] Dynamics were shown only as a wavy line along the length of the roll, however the pianist's tempo-related nuances were now captured on the roll.

As later explained, the Welte recording system not only recorded note pitches and durations, it also recorded the dynamics of each note, as well as damper and soft pedal operations. Following the introduction of the Welte-Mignon, other companies sought ways of recording piano dynamics. Unfortunately, the only documented method is that used by Ampico after 1926.

The biggest limitation of piano roll recording technology is that the owner of a reproducing piano could not themselves make recordings for the instrument. The Pianocorder was the first mechanical player piano to incorporate a recording system. Contacts under the keys provided signals which were recorded on cassette tape using a data format developed by the company. The dynamics were recorded by a microphone that hung inside the piano. The results, though often quite poor, represented a new approach to making recordings of a live pianist for playback on a mechanical piano.

The recording technologies used in the Disklavier, PianoDisc and other systems differ in their implementation and accuracy. Importantly, all these systems conform to the MIDI standard.

The MIDI standard

The MIDI standard supports a 128-note keyboard and 127 dynamic levels, called 'velocity' levels. The loudest level is 127, the softest is 1, and level 0 means the note is

[126] George F. Litterst, *Anatomy of a Disklavier*, http://yamahaden.com/anatomy-of-a-disklavier (accessed 19 April 2016).

turned off. When a key is depressed on a MIDI keyboard, the resulting MIDI data, called note data, comprises a standard digital code for that key and a velocity level expressed as a digital value.[128] When the key is released, the resulting note data now has a velocity of 0. That is, MIDI note data controls when and how loudly a key is played and how long it remains held.

MIDI control data operates the pedal actuators. In its simplest form, a MIDI code with a position value of 127 turns on the solenoid operating a pedal, and a position code of 0 turns the solenoid off. This type of pedal data, called on-off pedalling, causes the solenoid to move through its full stroke and is the arrangement used in MIDI player mechanisms made by PianoDisc and other companies. A more precise system, called positional pedalling is fitted to Disklaviers, in which position codes other than 0 and 127 cause the pedal solenoid to move to a position between its two limits.

There are numerous other functions supported by the MIDI standard, but in the case of a mechanical player piano playing from a MIDI file, note and pedal data is all that is generally required. The simplest form of MIDI file of a piano work has only note and on-off pedalling data, which is the same information stored on a reproducing piano roll.

In a high-end instrument, the number of velocity levels (note dynamics) is far greater, 1023 in the case of the Disklavier Pro. Interestingly, some types of pneumatic reproducing pianos have an almost infinite number of velocity (dynamic) levels, due to the way the expression regulators work. All brands of high-end instruments use a proprietary form of MIDI and recordings made on a high-end MIDI instrument therefore contain data unique to the instrument. As Yamaha further explains about its Pro series: "Disklaviers use sensors under every key as well as advanced gray-scale sensors on the hammer shanks in order to determine the timing of notes, the velocity with which the hammers hit the strings, and the speed of the release of each key."[129]

A consequence is that the recorded data in a Pro-equipped Disklavier holds *positional* information about each key. I have noted that keys can be held in a fixed position, or are caused on replay to move only part way through their total travel. Brushed notes will be reproduced as they were played, in which the hammer moves but does not hit the strings. This level of technology is the benchmark in MIDI mechanical

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[127] Hans W. Schmitz, in *Famous Pianists at the Hupfeld Recording Salon,* 19.
[128] Some MIDI keyboards are not touch-sensitive, and produce a fixed velocity value for each key press.
[129] Litterst, *Anatomy of a Disklavier,* http://yamahaden.com/anatomy-of-a-disklavier (accessed 20 October 2015).

player pianos, both in terms of the instruments and the data that is captured by recordings made on these instruments.

MIDI solenoid and pneumatic reproducing pianos

As previously explained, a reproducing piano roll contains the same data as a standard MIDI file, assuming on-off pedalling. Differences between the instruments include how the data is read and interpreted. Both MIDI solenoid and pneumatic player pianos operate in a similar way, but with different forms of energy. In both cases, keys are actuated mechanically, and the actuators are turned on or off by the data in a MIDI file or, in a pneumatic piano, by perforations in a piano roll. The velocity of the actuator in either type of instrument is determined by the velocity data in a MIDI file or the expression perforations on a piano roll.

A difference between the technologies is that unlike MIDI pianos, pneumatic reproducing pianos do not have individual dynamic control over each key. Instead, the keyboard is divided into treble and bass sections, with a regulating mechanism controlling each section, which means only two dynamic values can exist at any one time. The point at which the keyboard is split differs between piano roll manufacturers, and is generally a few notes up from middle C. Roll editors used various techniques to make thematic notes sound louder than accompaniment notes when both shared the same part of the keyboard. Methods included advancing a thematic note by a few perforator punch steps, so that the note could be individually accented, but causing the note to be heard slightly ahead of accompaniment notes.

Another difference is the number of notes covered by the player mechanisms. A MIDI mechanical piano has a compass of 88 notes, but most reproducing pianos have a slightly smaller compass, as detailed in Chapter 4.

Pedal data on piano rolls is always on-off. Even so, there are instances where the time between damper pedal perforations on a roll would be insufficient to allow a pneumatic actuator operating the dampers to move through its full travel. On some instruments the slow operation of the actuator might give a form of half-pedalling. The soft pedal in most of the reproducing pianos (grands and uprights) that I have observed is of the half-blow type, in which the pedal moves the hammers closer to the strings. This arrangement has the advantages of being light and quick to operate, ideal characteristics for a suction-powered player system. There are a few reproducing grand pianos in which the soft pedal actuator operates the instrument's *una corda* pedal.

Summary

As a playback instrument, a pneumatic reproducing piano has similar characteristics to a standard MIDI solenoid piano. Both types of instruments play from recordings that cause each note to be played at a specified volume, and both incorporate a means of operating soft and damper pedals in response to the recorded data. A reproducing piano roll stores the same data as a standard MIDI file.

Limitations of piano rolls

The main limitation of a piano roll recording is the lack of data controlling key and pedal positions. Because key release speed is not recorded, passages that rely on keys being partially pressed during playing will lack particular nuances. Although the tonal effects created by positional pedalling techniques were not recorded, roll editors were aware of the limitation and, as later explained in Chapter 4, in some cases attempts were made to recreate lost effects.

A critical aspect of a piano roll recording is the accuracy of notes and their timing in relation to each other. While the original recording might have recorded the notes extremely accurately, the quantising that occurs during perforation of a production piano roll means the timing resolution is reduced, a factor that is examined when discussing each brand of piano roll.

The greatest unknown with reproducing piano rolls is how the expression data was derived. As this aspect of a reproducing piano roll is the differing feature between it and any hand-played piano roll, it is an important consideration. It is also the least documented, as later explained, leading researchers to generally conclude that the dynamics of a reproducing piano roll are unreliable.

Therefore, when examining piano rolls as a form of recording, factors to consider are note timing accuracy, the extent of pedal information, the potential accuracy of the dynamics and the extent of editorial change to the original performance. These factors are associated with the piano roll.

The playback instrument is responsible for reproducing the performance recorded on a piano roll and therefore determines, among other things, the sound quality and tone. Piano roll companies generally fitted their recording apparatus to medium size grand pianos, and it is sometimes argued that for correct reproduction, the replay instrument should be of the same size and have the same tonal qualities as the recording

piano. Most reproducing pianos were either uprights or small domestic grands, although Ampico, Duo-Art and Welte mechanisms were fitted to full-size concert grand pianos for special purposes. Therefore, a limitation of a piano roll recording, and a MIDI file, is that tone is not recorded and is only reproduced accurately if the recording is played on an identical piano to that used to make the recording.

Another factor that is difficult to quantify is the difference between a master roll and the production rolls produced from that master. Therefore, it is only possible to refer to the potential accuracy of a piano roll recording, while acknowledging that production rolls may have errors caused by the duplication process. The types of error depend on the process used to cut production rolls, in which as Stahnke explains, can involve either of two types of masters, and which he refers to as 'prototype' and 'pattern' rolls. Stahnke concludes that most production rolls in the US were produced using pattern rolls, in which sprocket holes either side of the paper caused the pattern roll to move reliably and in synchronism with the paper being perforated, giving the best accuracy.[130]

Welte-Mignon piano rolls

As listed on page 21, there are three types of rolls associated with Welte-branded instruments. Those for the Welte-Mignon are the most significant, as rolls for the Licensee (other than those made by De Luxe) and Green Welte instruments were derived from them. Little is known about the processes used to record Welte-Mignon rolls. The only surviving example of a recording machine used by Welte is held by the Museum of Music Automatons in Seewen, Solothurn, Switzerland. The machine was used to make rolls for the company's range of pipe organs, and probably also for the Welte-Mignon.

Note recorder

A photo of the Welte recording machine, included with David Rumsey's description of the machine,[131] shows that it has a number of inked rubber wheels poised near a roll of paper such that when a key was played, it caused the corresponding wheel to contact the moving paper. As a result, an inked line would be marked on the paper while a key was

[130] Wayne Stahnke, *Prototype Rolls and Pattern Rolls*, http://www.mmdigest.com/Archives/Digests/199708/1997.08.27.17.html (accessed 22 October 2015).
[131] David Rumsey, *Welte's Instruments, Rolls, Recording, Digital Editing*, http://www.davidrumsey.ch/OVERVIEW1.pdf (accessed 29 January 2016), 23.

held down. Another view of the machine is presented on the Pianola Institute website, which shows that the take-up spool had an adjustable flange that could be set to accommodate different paper widths, including that used for Welte-Mignon piano rolls.[132]

A description of the Welte recording machine is given by Ben M. Hall in a booklet accompanying LP recordings of Welte piano rolls.[133] Hall's description is based on information obtained by Richard Simonton (1915–1979), who befriended Edwin Welte after World War II. Simonton maintained that the recording machine could show the dynamics of each note by virtue of the thickness of the line produced by the rubber wheels. According to Simonton, the recording piano had a trough of mercury beneath the keyboard, and each key had a rod attached to it made of conductive material. When a key was depressed, the rod dipped into the mercury, making an electrical circuit that would activate the corresponding inked rubber wheel. The harder the key was pressed, the "deeper the rod would plunge into the mercury, and the stronger the current would be." Therefore, according to Simonton a loud note would be shown by a thicker line than that for a softly-played note, as the inked rubber wheel would be moved with greater energy towards the paper, thereby compressing the rubber to a greater extent.[134]

In my opinion, it is unlikely that a system relying on the compression of rubber wheels would provide sufficiently accurate information concerning dynamics to be of practical use. Nonetheless, Simonton's description supports the view that an inked wheel system was used to make the recordings. In his description, Hall continues with an explanation that cannot be true, but should be mentioned to highlight the extent of misinformation that exists about the Welte recording system:

> After a selection had been finished, the paper roll was removed from the recording machine and run through a chemical bath to fix the colloidal graphite ink which had been printed on it by the rollers. The ink was electrically conductive, and when the roll was ready to play back, it was put into a master reproducing Welte-Mignon piano, which 'read' the markings in much the same manner that the magnetic ink on bank checks is 'read' by automated banking equipment today.[135]

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[132] *The Reproducing Piano - Welte-Mignon,* http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 29 January 2016).
[133] *Welte Legacy of Piano Treasures* series of LP records (Hollywood CA: Recorded Treasures Inc, 1963).
[134] Bowers, *Encyclopedia of Automatic Musical Instruments*, 327.
[135] Bowers, *Encyclopedia of Automatic Musical Instruments*, 327.

Hall further explains that a few days after making a roll recording, the artist would be invited back to hear the roll played on a vorsetzer placed before the piano on which the artist had made the recording. It is most likely that pianists heard a trial roll, as the chemical version Hall describes does not take into account the expression coding, which would need to be added after the recording. This aspect alone invalidates Hall's description of the process.

Roll production

To make production rolls, a roll master was produced from the recording and copies of the master, called a second master, were used on roll perforating equipment to cut production copies.[136] The Welte production process underwent improvements over time. As shown in Figure 2.1 (b), some Welte-Mignon rolls cut prior to 1909-10 have perforations that are not always in a straight line and have inconsistent punch steps. Earlier rolls sometimes have factory edits, in which a punching error was removed by covering part of a perforation, or manually punching extra perforations, explaining the misaligned perforations.

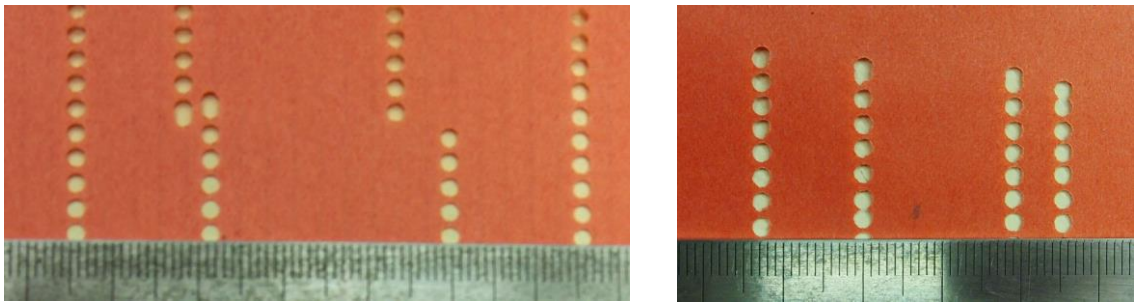

Figure 2.1 (a) *regular chain perforations* ***(b)*** *staggered chain perforations*

The Welte-Mignon roll shown in Figure 2.1 (a) was cut in 1909, the roll in Figure 2.1 (b) was cut in 1910.[137] Although it is a later production, the chain perforations in the roll shown in Figure 2.1 (b) have been cut on an asynchronous perforator as the perforations do not align with each row, showing that this perforator had separate drivers for each punch. The more usual arrangement is the so-called 'ram head' perforator, in which all punches are driven in a synchronous way by the same downward force.

[136] Denis Hall, "How Do You Like Your Debussy," *The Pianola Journal*, no. 23 (2013), 35.
[137] The date the rolls were perforated was written at the end of each roll.

A typical arrangement has a strong metal bar across the width of the perforator, placed above the punches. The bar, or ram head, is moved up and down by a rotating cam, such that the punches triggered to operate during the up cycle of the ram head are pushed during its down cycle, ensuring all required punches operate together. The roll shown in Figure 2.1 (a) was cut on a ram head perforator, as the chain perforations are perfectly aligned across each row. The effect of asynchronous punching is the introduction of small timing differences (usually not audible) between individual perforations that, in a ram head perforator, would not occur. Later rolls were all cut on a ram head perforator, and therefore do not have the timing errors associated with an asynchronous perforator.

Tempo and acceleration

Welte-Mignon rolls generally run at the same paper speed (roll tempo) of three metres or 9.84 feet per minute. Paper speed is set correctly by using the tempo test on a Welte-Mignon test roll, from which I have determined that the roll drive motor should rotate at 120 RPM. The Welte-Mignon tempo scale was marked 'Slow', 'Normal' and 'Fast', with no numerical indication defining the speed of any of the settings. Some rolls were labelled 'Tempo langsamer stellen', which may be translated as 'Make tempo slower'; unfortunately the value of the slower tempo was not published. Denis Hall considers it to be two and a half metres or 8.2 feet per minute.[138] The labelling of a slower tempo appears to have been introduced in the mid-1920s, and applies to long rolls such as roll 3976, issued in mid-1926.[139]

The photo shown on the Pianola Institute website of the Welte organ roll recording machine clearly shows that the machine was fitted with a take-up spool of approximately the same diameter as that used in the Welte-Mignon.[140] The photo also shows that the spool was rotated by a speed-governed motor. During recording, the paper speed would increase due to the build-up of paper on the take-up spool. Because the paper transport geometry in the Welte-Mignon is similar to that in the recorder, the accelerating paper speed does not cause an increase in the tempo of the music.

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[138] Denis Hall, "Piano Roll Speeds," *The Pianola Journal*, no. 22 (2012), 3.
[139] Concerto Op.11 in E minor by Chopin, 1st movement played by Raoul von Koczalski (1885-1948).
[140] *The Reproducing Piano - Welte-Mignon,* http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 16 March 2016).

Timing resolution

To determine the potential timing resolution of a Welte-Mignon roll, I took measurements from two original rolls cut on different paper, both dated on the roll as being perforated in 1912 and punched by a ram head perforator. One roll was punched on lined red paper, the other on blank red paper. In both cases a single punch hole measured 2.19 mm. Measurements of extended perforations involving a number of closely spaced punches showed the smallest distance between punches was 0.47 mm, which in Imperial terms equates to 0.0185 inches or 54 steps per inch.[141]

The timing resolution at the start of a Welte-Mignon roll is therefore 9.4 milliseconds, which is the best of the roll brands in my research. Put into a modern context, if a pianist records a ten-note chord on a MIDI keyboard, the transmission time to send those ten notes to a computer could be 9.6 milliseconds, or on replay, two of the notes could be up to 9.6 milliseconds apart. Therefore, the timing resolution of a Welte-Mignon roll is consistent with current technology. As later explained, a timing difference of ten milliseconds or less is inaudible.

Pedal information

Welte appears to have recorded damper and soft pedal data by means of electrical contacts fitted to the recording piano's pedal trap work. Operating either pedal caused the associated contacts to close, registering as a line on the recording paper. Denis Hall believes that the soft pedal on Welte-Mignon rolls is "believable," but has encountered instances of incorrect damper pedalling in which the pedal contacts may not have operated during a small change of pedal position.[142]

Howat writes, in relation to Debussy's use of the pedal, that the system could not "reliably show exactly how Debussy may have voiced or half-pedalled delicate passages like the start of *Danseuses de Delphes* with its indicated mix of legato and portato."[143] It appears that no attempts were made by Welte editors to re-create pedal effects that were not able to be recorded.

[141] It is not known if the step distance of early (1905) Welte-Mignon rolls differed from the figures given.
[142] Hall, "How Do You Like Your Debussy," 35.
[143] Howat, *The Art of French Piano Music*, 316.

Recording note dynamics

There is no surviving evidence to show how the recording of note dynamics was achieved, but there is little doubt that Welte and Bockisch developed a method to do this. A 1905 article by the company describes a recording session involving the pianist Scharwenka, which probably took place on March 7, 1905:

> In the magnificently furnished parlors of Popper & Co in Reichsstrasse an attentive audience is gathered to hear a concert performed by the noted Berlin professor, Xaver Scharwenka—and also to witness the recording of this performance […] Except for a cable of wires leading from the piano to a recording device that stands nearby there is nothing to betray that in this grand piano and the recording equipment there are wonderful components – devices which work together in an unbelievable and secret way.[144]

The article stresses the secrecy surrounding the process, and also gives insight into the way pianists were recorded. Promotional photos of the time usually show a number of people attending a recording session, including friends and relatives of the artist. The article mentions an audience, and clearly, if the article is to be believed, a recording session was more like a recital:

> The maestro […] plays a few trial chords and runs. Inspired, he gives a signal to Karl Bockisch who now starts the apparatus. […] Scharwenka plays one of his own compositions […] he then goes on to play well-known works of other composers, giving us an evening of musical entertainment we will not forget.[145]

The somewhat relaxed approach to the recording process shows that the inventors had faith in their recording equipment. This is borne out in other ways. In her biography of pianist Bloomfield Zeisler, Beth Abelson Macleod discusses the pianist's correspondence with Edwin Welte following a recording session, in which Bloomfield Zeisler had asserted her legal right to hear the rolls before publication. Welte's response was a reminder that "when our contract was closed there was no condition that you should hear the rolls before they were published."[146] Nevertheless, Welte is reported to have arranged for Bloomfield Zeisler to hear her recordings before their release.

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[144] Bowers, *Encyclopedia of Automatic Musical Instruments*, 323.
[145] Bowers, *Encyclopedia of Automatic Musical Instruments*, 323.
[146] Beth Abelson Macleod, *Fannie Bloomfield-Zeisler: The Life and Times of a Piano Virtuoso* (Chicago: University of Illinois Press, 2015), 89-90.

As Leikin points out, Welte did not "invite its artists to participate in the editing process, since, practically speaking, there was not much editing to begin with."[147] As well, Welte did not employ a full-time recording producer or musical editor until the 1920s when Hans Haass joined the firm. Therefore, there must have been a recording system that captured dynamic data in a form that allowed its translation into perforations to control the expression system in a Welte-Mignon.

The number of recordings listed in the 1911 Welte-Mignon catalogue show that production of new Welte-Mignon rolls was a relatively quick process. According to Smith and Howe, the figure of over eleven hundred titles is "undoubtedly accurate."[148] This number of recordings was produced over a six year period, other companies spent far longer to achieve similar figures.

The Welte dynamic recording system remains an unknown. There are several reasons to doubt the Simonton description that involved inked rubber wheels giving a line thickness proportional to playing dynamics. Translating the thickness of an inked line into expression perforations would be time consuming and the lines would be unlikely to reveal subtle dynamic changes. Additionally, Simonton's explanation does not explain why the Welte recording console had two large holes near the top of the equipment, but only in photos taken after a certain date.

Rex Lawson proposes a theoretical dynamic recording system which explains the purpose of these holes.[149] In principle, Lawson proposes that the recording piano was fitted with two sets of contacts per key, such that depending on the time interval between the operation of each set of contacts, note and dynamic data could be obtained. The recording apparatus, Lawson suggests, was a combination of electro-pneumatic valves, pneumatics and a device Lawson refers to as a 'dynamic rotor'. The position of the rotor was determined by how loudly notes on the recording piano were played.

Lawson suggests the two holes in the recording console were added so the position of the two rotors (one each for bass and treble) could easily be seen, allowing the recording engineer to engage a manual setting called the 'mezzoforte hook' when a rotor was in a particular position.[150] It was necessary to do this during the recording rather than as a later addition on the roll to avoid introducing incorrect dynamic values.

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[147] Leikin, *The Performing Style of Alexander Scriabin*, 12.
[148] Smith and Howe, *The Welte-Mignon*, 25.
[149] *The Reproducing Piano - Welte-Mignon*, http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 29 January 2016).
[150] The mezzoforte hook is a component in a Welte-Mignon expression system that is operated by roll perforations. Its function is discussed in Chapter 4.

In my opinion, the Lawson proposal is plausible. As Lawson explains on the Pianola Institute website, further information came to light in 2014 when Gerhard Dangel of the Augustiner Museum in Freiburg discovered documentation written by an engineer who had dealt personally with Bockisch in the 1930s.[151] The documentation explains that in the early days, a musician would mark a pianist's dynamics on a score, as the earliest recording systems were not able to provide sufficiently musical results. The earliest Welte-Mignon recordings were made by Eugenie Adam-Bernard in 1904.

As the newly-discovered documentation further explains, Welte and Bockisch continued developing the dynamic recording system to achieve accurate recordings that did not require musical judgement. Unfortunately, the term 'early days' is not defined, so we do not know when the improved dynamic recorder was used rather than a musician marking a score. However, it seems this occurred before January 1905, given the number of recordings that were made after that date. Further evidence that such a system existed is also shown by a photo on the Pianola Institute website of a Welte-Mignon master recording. The photo, though faded, shows a dynamic line on the bass side of the recording that is most likely to have been mechanically derived.[152]

The capability of any system to accurately record the dynamics of individual keys was necessarily limited by the 'split-stack' arrangement in the Welte-Mignon, and also found in all types of reproducing pianos. As previously explained, at any one instance, there can only be two dynamic levels, separated in the case of the Welte-Mignon between F# and G above middle C.[153]

I have often noted the dynamic detail recorded on some Welte-Mignon rolls. For example, a series of repeating notes will typically each have a different dynamic level. Other brands of rolls usually play these notes at the same volume. Thematic notes being picked out among accompaniment notes will also often have individual dynamics.

In my opinion, the dynamics on some Welte-Mignon rolls are clearly those of the pianist and are not contrived by an editor, a view also shared by Lawson.[154] When comparing sound recordings and Welte-Mignon roll recordings of the same work played by the same pianist, the similarities of the dynamics in both recordings are obvious.

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[151] *The Reproducing Piano - Welte-Mignon*, http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 29 January 2016).
[152] *The Reproducing Piano - Welte-Mignon*, http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 29 January 2016).
[153] The Welte-Mignon expression system is discussed in Chapter 4.
[154] Rex Lawson, "On The Right Track: The Recording of Dynamics for the Reproducing Piano - Part One," *The Pianola Journal*, no. 20 (2009), 4.

Editorial interference

The process of taking a recording and producing a roll master is generally referred to as 'editing', a term that implies making changes to a recording. When referring to Welte, the intent seems to have been only to adapt the recorded data into the format required by the Welte-Mignon. Despite their background, neither Welte nor Bockisch had musical credentials, and yet they appear to have been in charge of the recording sessions, Bockisch usually standing near the recording console.[155] It is therefore probable that they also managed the process of translating the recorded dynamics to a roll master.

I have found no evidence that Welte-Mignon recordings were edited to the point of changing the recording beyond correcting wrong notes, or in later years making small adjustments to the roll masters. Even then, the editors were not always sure. As Leikin points out, there are three wrong notes in the Welte-Mignon recording Scriabin made of his Poem Op. 32 No. 1 on roll 2068.[156] When comparing Scriabin's recordings made for Hupfeld and Welte, Leikin concludes that the "heavy editing" he noted on Hupfeld rolls was not apparent on Welte rolls, making the latter "more reliable."[157] The absence of a musical editor, certainly in the early days, is shown by the lack of correcting missed data involving operation of the damper pedal, as noted earlier.

The Welte recording contract signed by British pianist Fanny Davies is held by the Royal College of Music in London, and according to Macleod, it "contains no suggestion that the pianist could alter the rolls in any way, beyond recording them again."[158] Repeating a recording was evidently the practice. For example, Busoni had three attempts at recording Liszt's *Paraphrase de concert sur Rigoletto*, S.434, and two at recording Liszt's *Grandes études de Paganini* No. 3, S.141.[159]

According to the published recording dates, artists usually made all their Welte-Mignon recordings over one or two days. As an extreme example, d'Albert made 34 recordings on June 2, 1913,[160] strongly suggesting that the recording sessions did not involve the artist re-recording particular passages to achieve best effect, as is often the case in a modern recording studio. Instead, it seems likely that an artist would simply record each work, and if dissatisfied with his/her playing, would re-record the entire work, either on the day, or after hearing the roll recording at a later date.

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[155] Welte and Bockisch would, however, have had a musical background as a result of their work.
[156] Leikin, *The Performing Style of Alexander Scriabin*, 70.
[157] Leikin, *The Performing Style of Alexander Scriabin*, 33.
[158] Macleod, *Fannie Bloomfield-Zeisler*, 90.
[159] Smith and Howe, *The Welte-Mignon*, 344.
[160] Smith and Howe, *The Welte-Mignon*, 327-28.

Sigmund Zeisler reported that his wife Fannie Bloomfield Zeisler would practice several hours a day for a week before making recordings for the Welte-Mignon. She was very nervous on the basis that "an interpretation once recorded is fixed and unchangeable forever; it was the interpretation by which future generations would judge her artistic merit."[161] Although piano roll technology allowed a recording to be edited, it appears editing to enhance or change a recording was not an established practice in the production of Welte-Mignon rolls. If so, Bloomfield Zeisler would have felt more relaxed knowing that mistakes could be removed.

Welte and Bockisch were engineers rather than trained musicians; and they would have preferred to rely on the recording equipment rather than their musical judgement. Recording dates show that if an artist disapproved of a recording, it was done again, not edited to the artist's wishes. Disc and cylinder recordings of the times were made in a similar way, in which engineers rather than trained musicians supervised the process and the artist would generally make the musical decisions, such as approving the final recording.

Welte-Mignon rolls of transcriptions of operas and operettas are, however, a different category, many of which were made during the 1920s. This category of rolls could be described as musical constructs, as the recordings were enhanced by additions that would be impossible for a single pianist to play. Earlier examples issued in 1916-17 include operatic selections recorded by duo-pianists Gustav Starke (1862–1931) and his pseudonym Gustav Reinert.

[161] Macleod, *Fannie Bloomfield-Zeisler,* 89.

Confirming expression accuracy

From an engineering perspective, it seems likely that there was a form of feedback used to check the translation of recorded dynamic data to expression perforations on a roll master. A clue is the expression lines found on some Welte-Mignon rolls produced after 1922, as shown in Figure 2.2. These lines appear to have been drawn by styli attached to pneumatics that were connected to the bass and treble expression regulators of a Welte-Mignon that was playing the roll.[162]

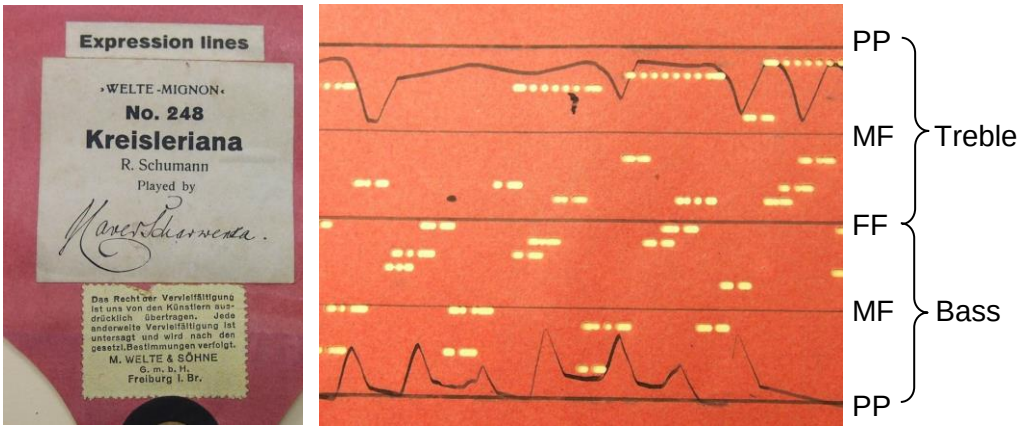


Figure 2.2 *Left shows roll label, centre shows expression lines, right shows explanation*

The purpose of the lines was so a playerist could follow the original dynamics when pedalling the roll. Photographic evidence, as previously explained suggests that the dynamic recording system produced dynamic lines on the recording sheet of a similar nature to those shown in Figure 2.2.[163] If such a trace was a normal outcome of a recording session, it would have been possible to check the expression coding added to a roll by playing it on the recording piano and comparing the dynamic lines produced by the original playing and the roll recording, explaining the confidence Welte and Bockisch had in their product.

[162] This conclusion is based on research described in Chapter 4.
[163] *The Reproducing Piano - Welte-Mignon*, http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 29 January 2016).

Green Welte rolls

During the 1920s, Welte began production of the Green Welte instrument, as it is known today. This instrument incorporated the same expression system as that in the Welte-Mignon, but with a different method of controlling the expression functions and pedals. Welte-Mignon (and Licensee) instruments had a lock-and-cancel system to operate these functions, in which a perforation in one track of the roll turned a function on, a perforation in an adjacent track turned it off. The distance between the two perforations determined the length of the time the function was operated.

In the Green Welte instrument, each function was controlled by a single continuous roll perforation. That is, a function was held on for the length of a perforation, thereby reducing the number of roll tracks dedicated to controlling pedals and the expression system, and allowing an 88-note compass that suited player rolls, but which was never exploited by Welte rolls.

A slower paper speed of seven feet per minute was applied to Green Welte rolls, compared to a speed of nearly ten feet per minute for Welte-Mignon rolls. Therefore, Green Welte rolls have a less accurate timing resolution of around thirteen milliseconds, compared to just over nine milliseconds for the Welte-Mignon, assuming identical perforator step distances. Despite the differences, rolls for both instruments were cut from the same masters. As a result, when production of rolls for the Green Welte instruments began in the early 1920s, some of the original master rolls were re-examined and in some cases, changes were made.

Changes to master rolls

The University of Southern California has a number of Welte-Mignon master rolls, many of which have a circled 98 on the leader, meaning they were for use in producing rolls for the Green Welte instrument. During a visit to the university in 2013, I examined and photographed a number of these masters to determine the extent of the changes that were made. In all cases that I noted, the changes were minor, and typically involved expression coding modifications. Figure 2.3 shows an example of changes made to roll number 1277.[164]

[164] Roll number 1277: *Vöglein* Op. 43, No. 4 composed and played by Grieg.

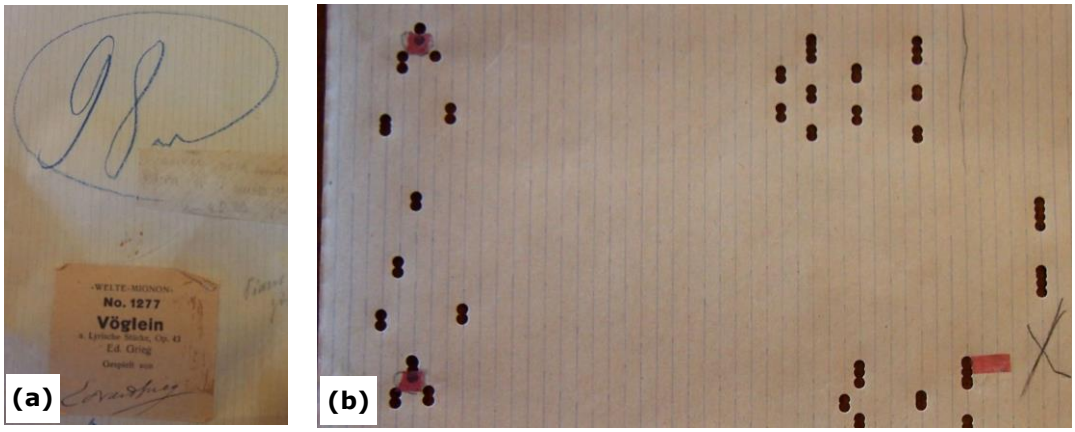
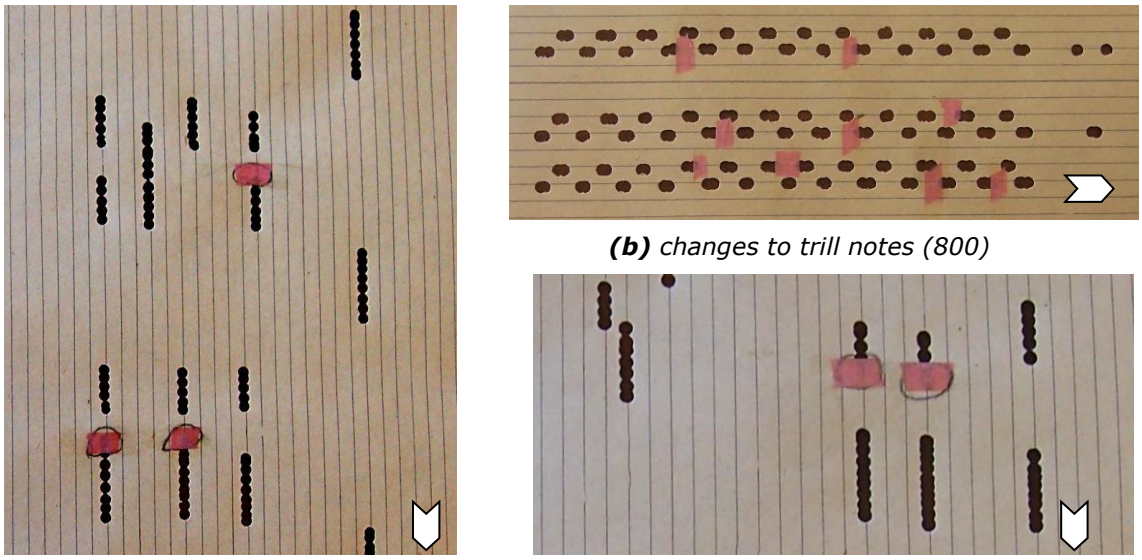


Figure 2.3 (a) *shows leader of master roll 1277,* ***(b)*** *shows edits to the bass expression*

The changes made to the expression coding on the left of the roll in Figure 2.3 (b) would have increased the play-back volume of several notes in the bass side of the keyboard. In one case on this roll master, I noted the start time of a note perforation was altered to make the note play slightly later.



(b) *changes to trill notes (800)*

(a) *reduced note lengths (964)*

(c) *altered start time of two notes (964)*

Figure 2.4 *Examples of changes made to playing notes from master rolls 964 and 800. Arrows show direction of paper movement when playing the roll.*

The photos in Figure 2.4 show examples of changes made to playing notes. Figure 2.4 (a) and (c) are of master roll number 964,[165] and show edits made to the start and end times of several notes. I found few examples of changes being made to the start time of

[165] Roll number 964: Waltz Op. 69 No. 2, composed by Chopin, played by Landowska.

a note, as in 2.4 (c), although (b) shows this was done to improve the trill notes on master roll number 800.[166]

Welte Licensee rolls

The Welte Licensee instrument, as it was known, was made for the US market by a third-party company,[167] which competed with a similar instrument referred to as the Original Welte-Mignon made by M. Welte and Sons. For the purposes of this chapter, I refer to rolls for both instruments as 'Licensee' rolls. They differ from Welte-Mignon rolls in paper size and playing speed, and have 98 tracks compared to 100 tracks, while maintaining the same type of expression coding. The process to produce Licensee rolls would have been similar to producing Green Welte rolls, and was initially carried out by M. Welte and Sons at Poughkeepsie from around 1916, then from 1920 by third-party company De Luxe.

In many cases the Licensee adaptations have a different playing time compared to the original Welte-Mignon roll, sometimes dramatically so. For example, Paderewski's Welte-Mignon recording of Schubert's Impromptu Op. 142 No. 3, D.935 takes nearly eleven and a half minutes to play, while the Licensee version takes just over eight minutes.[168] Friedheim's Welte-Mignon recording of Liszt's Ballade No. 2, S.171 takes slightly more than twelve minutes to play, the Licensee adaptation lasts for just seven and a half minutes.[169]

The shorter playing time in these examples is caused by cuts to the music. The reason may have been because the Licensee instrument could not handle rolls that lasted for twelve minutes or so, as shorter works are not so severely affected. Even so, it is common to find Licensee rolls produced from a Welte-Mignon master where the tempo differences are ten percent or more. An example is the slower tempo adopted for the Licensee issues of Debussy's recording of his *Children's Corner Suite*. Howat remarks that while the slower tempo improves some parts of the work, it causes two of the parts to be "suspiciously slow."[170]

[166] Roll number 800: *Rhapsodie d'Auvergne* composed and played by Saint-Saëns.
[167] Auto Pneumatic Action Company, part of Köhler Industries, made Welte Licensee mechanisms that were fitted to numerous brands of pianos.
[168] Roll number 1248.
[169] Roll number 214.
[170] Howat, *The Art of French Piano Music*, 318.

Figure 2.5 shows an example of editorial changes made to the Licensee issue of Paderewski's 1906 Welte-Mignon recording of Liszt's transcription of the song *Erlkönig* by Schubert.[171] The first two bars of the work are shown, in which the Licensee issue reduces Paderewski's octave triplets by half, leaving only the bottom note intact. Similar treatment occurs in many other places in the roll.

The images are of MIDI files of the rolls produced as detailed later in Chapter 3, in which (a) is of a Welte-Mignon roll with a playing time of 4:52, compared to the Poughkeepsie Licensee issue in (b), which plays for 4:14. It may be that Poughkeepsie editors reduced the number of fast repeating notes for better effect on local instruments. The De Luxe issue of this roll has an even shorter playing time of 4:06, a similar treatment to the octave triplets and several instances of notes having been realigned.

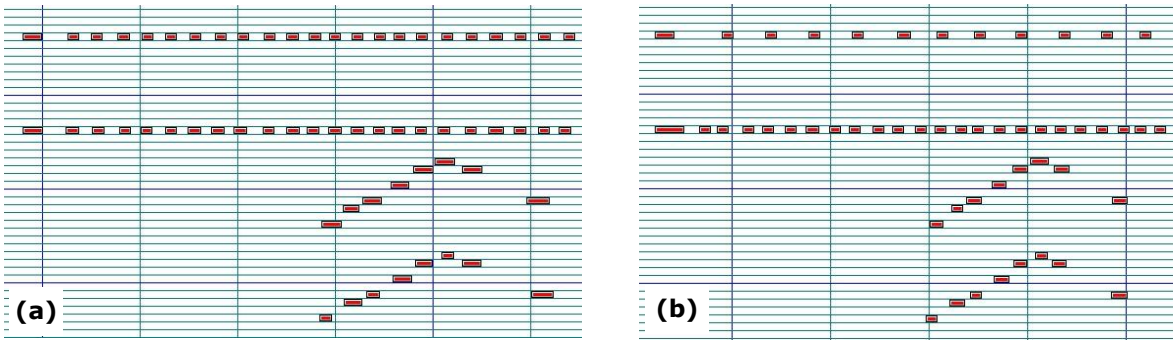


Figure 2.5 *Example of changes made to a Licensee issue of a Welte-Mignon recording,* ***(a)*** *as issued on Welte-Mignon roll,* ***(b)*** *the Poughkeepsie Licensee version*

De Luxe rolls for the Licensee

Prior to producing expression rolls, De Luxe manufactured hand-played player piano rolls, issued on the Republic label. Little is written about the technology De Luxe used to record and produce rolls for the Welte Licensee. A 1923 *Music Trade Review* article stressed that "no effort has been spared to create a truly musical atmosphere" in the new De Luxe recording laboratories established in the factory where the Welte Licensee reproducing mechanisms were manufactured. The article explained that the recording staff was headed by Dr Mettler Davis, described as a "musician of long experience, he was educated abroad by […] Max Reger, Max Bruch, Englebert Humperdink […] finally receiving a degree of Doctor of Music from the University of Berlin."[172]

[171] From Welte-Mignon roll number 1260.
[172] "De Luxe Welte-Mignon (Licensee) Recording Roll Laboratories in New York," *Music Trade Review*, vol. 76 no. 5 (February 3, 1923), 47.

The recording piano is described as a Stieff concert grand equipped with the "Welte-Mignon recording devices and connected with the recording mechanism placed in the room adjoining."[173] Mark Reinhart writes that initially the dynamics were not recorded, however the system that was eventually used came about through "a newspaper article showing a seismograph recording earthquake movement about 1923."[174]

As evidence of such a system, De Luxe published an image of a roll master which had dynamic lines of a seismographic nature on either side that, as Reinhart remarks, were "remarkably similar to that of the Binet and Courtier [dynamic recording system]."[175] The roll recording is identified as "a section from an original recording of Chopin's Etude in F Major,"[176] actually his Etude Op. 25 No. 3. This work was not issued as a Licensee roll, although it was issued on Welte-Mignon roll 1446, recorded by Ernest Schelling. Reinhart confirms that the image is not of the Schelling recording. It could therefore be of a recording that was never issued, or just a promotional exercise.

A dynamic recording system is known to have existed, as it was described by Bockisch as "inferior to the system and method he used."[177] Its results must have satisfied artists such as Welte-Mignon recording artists Pachmann, Gieseking and Bloomfield Zeisler, who among other notable pianists, recorded for De Luxe. In a different approach to that taken by the German company, it is possible that pianists were encouraged to participate in the production of their roll recordings, as per the usual practice in other US-based companies.

Like the American Piano Company and Aeolian, De Luxe held comparison concerts, where a pianist's live playing was compared to the pianist's roll recordings. Trade publication *Presto* describes such a concert held at a department store in Pittsburgh on October 4, 1923.[178] As early as 1920, when De Luxe began producing Welte Licensee rolls, the company's promotional displays at music shows featured comparison concerts involving a "large audience."[179]

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[173] *Music Trade Review*, vol. 76 no. 5 (February 3, 1923), 47.
[174] Mark Reinhart, "The Welte-Mignon Recording Process in Germany," *The Pianola Journal*, no. 16 (2005), 10.
[175] Reinhart, "The Welte-Mignon Recording Process in Germany," 11.
[176] Bowers, *Encyclopedia of Automatic Musical Instruments*, 335.
[177] "Letter from Richard Simonton to Larry Givens of 15 August 1963," *AMICA Bulletin*, vol. 37 no. 2 (March-April 2000), 84.
[178] "Effective Demonstration in Pittsburgh Store," *Presto*, no. 1942 (October 13, 1923), 12.
[179] "Auto De Luxe Player Action at the Show," *Presto*, no. 1750 (February 5, 1920), 11.

De Luxe rolls appear to have been cut at three different step rates, the lowest giving a timing resolution of 18.6 milliseconds for a roll speed of eight feet per minute. Roll speed is variable and ranges from five feet per minute (tempo 50) to twelve feet per minute (tempo 120). De Luxe was the last of the US-based reproducing piano roll companies, entering the market when piano roll technology was well developed.

Summary

The library of art music established by April 1906 for the Welte-Mignon shows that from the start, Welte and Bockisch had an idealistic approach to its content and quality. The same attitude is reflected in the way recordings were made, in which the aim appears to have been to use technology to make the recordings, with minimal human decision-making being needed. The instruments and rolls were expensive, and surviving factory test rolls show that the piano action, player action and the expression system in each Welte-Mignon were adjusted to within tight parameters.

From the outset, the Welte-Mignon was designed to give the best possible reproduction. The rolls played at a relatively fast speed and were punched with a high number of steps per inch to give a timing resolution that is superior to the other brands of rolls in this research. The Mignon's spool box was designed to accept large rolls, allowing playing times of fifteen minutes or more, and a high quality of roll paper was used.

Because the technology could not record positional data, some of the effects created by pedalling techniques and touch are lost, a fact that applies to all piano roll recordings. Welte editors do not appear to have made changes to the recordings to somehow compensate for the lost effects. Howat refers to the inability of the system to record or reproduce Debussy's attempts at 'points of escapement and half-pedal."[180] Unfortunately, the technology could not capture such detail, and neither could it be reproduced by the instruments.

It is clear that playing dynamics were recorded and that these satisfied the artist. Numerous musicians wrote testimonials about the Welte-Mignon, although some may have been written by the company, others may be 'cash for comment'. Testimonials written in 1905 when the Mignon was indeed incomparable could also be a true account of the writer's opinion of the instrument. These testimonials were widely used in

[180] Howat, *The Art of French Piano Music*, 316.

advertising material that promoted the Welte-Mignon. In several brochures in my possession, Pachmann writes that "The Welte-Mignon reproduces the living soul of the artist", d'Albert claims "It reproduces compositions, as played by the most eminent artists, in a truly surprising manner", and Scharwenka concludes that "It would be difficult to conceive anything more perfect."

Perfecting a recording by repeated attempts at certain passages, or by altering perforations on a roll master do not seem to have been practiced. Whether artists were recorded at their best is difficult to determine, as attitudes to recording were clearly more relaxed in the early 1900s. What is known is that a pianist would be booked in for a recording session which rarely lasted more than one or two days, and a number of works would be recorded.

Conclusion

Welte-Mignon roll recordings are a potentially honest documentation. While the technology could not capture every aspect of a performance, what was recorded appears to be faithful to the artist. Welte eschewed the concept of editorial change to a recording, and in some cases the lack of editing has left errors in pedalling and dynamics that might have been picked up by a musical editor rather than a technician.

Although Welte produced roll recordings of dubious provenance by unknown pianists, it is the recordings made by known artists that are important, and everything points to Welte and Bockisch having confidence in the recordings they made of these artists. That aspect combined with their historical significance makes Welte-Mignon rolls the most important library of all piano roll recordings.

Ampico

Roll recordings for the Ampico reproducing piano were produced from 1911 to 1941, although no recordings of art music were made after 1930. The Ampico instrument underwent numerous changes in the first ten years of its life, although most of these improvements were in its design and construction rather than changes to how it functioned.[181] Richard Howe and Jeffrey Morgan published an article in 1991 detailing eight different variations of the Ampico reproducing piano.[182]

Reflecting the names given to the company's reproducing piano, rolls produced from 1911 to 1916 were first known as Artigraph or Artigraphic rolls, later as Stoddard-Ampico rolls. After 1916, Stoddard's name was dropped in advertisements, instead the instrument and its rolls were identified as Ampico.

Charles Fuller Stoddard (1876–1958) is largely credited as the inventor of the Ampico reproducing mechanism, and was a key figure in an engineering capacity during the lifetime of the company. His name remained on the instruments until the early 1920s, after which the instrument known today as the model A Ampico finally emerged, remaining in production until 1929.

However, development of a new Ampico (as the company named it, now referred to as the model B Ampico) began in 1926. It had a number of differences to the previous model that included changes in the way the expression regulators operated. As a result, rolls for the model A Ampico do not perform as well on the new instrument, and rolls for the model B Ampico are best heard on that instrument.

Another key figure in the engineering side of the company, and primarily responsible for the design of the model B Ampico, was Dr Clarence Hickman (1889–1981), a physicist with experience in measuring the speed of projectiles. He was hired by the American Piano Company in 1924, and his diaries outline the activities in which he was involved.[183] Not long after his arrival, Hickman began developing a means of recording piano dynamics, by way of measuring hammer velocity. The technology Hickman used is described later in this chapter, and the introduction of the new dynamic recorder around 1926 meant the method of recording a pianist changed from that point.

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[181] Bowers, *Encyclopedia of Automatic Musical Instruments*, 227.
[182] Richard Howe and Jeffrey Morgan, *The Evolution of the Ampico* (1991) http://www.amica.org/Live/Publications/Past-Bulletin-Articles/EvolutionOfTheAmpico.pdf (accessed 23 January 2016).

Ampico roll recording technology prior to 1926

The first recordings to be issued included Hupfeld roll recordings adapted to play on the Ampico (Artigraphic) reproducing piano.[184] Details of how the early adaptations were made are not known, although Angelico Valerio (dates unknown) explained in a 1969 interview with Nelson Barden that the method used was to mark up a master roll from the Hupfeld roll.[185] A five-year contract was signed between the companies on April 22, 1925 specifying the supply of 220 master rolls, although records show that only 28 Hupfeld transfers were ever issued. There is no documentation explaining how the expression coding was converted from Hupfeld to Ampico format.

Also among the first rolls for the Ampico were those derived from the Rythmodik label. As explained in Chapter 1 (page 62), Rythmodik rolls were hand-played recordings for use with a player piano. By adding expression coding, these rolls could be adapted to suit the Ampico. Rolls for the instrument were also made from 1912 in increasing numbers by in-house pianists and contracted pianists such as Godowsky and Adler.

Rolls made up to around 1916 were later reissued. The early rolls generally had a smaller punch size and some perforations were a series of single punches, spaced to suit the corresponding extended holes in the Ampico tracker bar. Later editions of the early rolls have a larger punch size and modified expression coding, although the differences are generally minor.

Note recorder

The note recorder used by the company to record key strokes was described by Hickman as being in "existence long before I came and I don't think you could improve much on it."[186] Designed by Stoddard, the arrangement used was similar to the Welte note recorder in which styli actuated by solenoids would cause a line to be marked on a moving sheet of paper. Hickman explained that the marking styli rested gently on the note sheet, such that when a stylus was energised, the delay caused by the time constant

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[183] Richard Howe, ed., *The AMPICO Reproducing Piano* (St Paul, Minnesota: Musical Box Society International, 1987), 237-316.
[184] Obenchain, *Catalog*, 10.
[185] Howe, ed., *The AMPICO Reproducing Piano*, 162-3.
[186] Howe, ed., *The AMPICO Reproducing Piano*, 73.

of the actuating solenoid had negligible effect. He concluded: "So you got all the notes and pedaling very, very accurately."[187]

An unknown aspect with the note recorder is the paper feed geometry, an issue mentioned by Denis Hall, who notes that the music on some Ampico rolls played on a model A Ampico can "sound unnaturally fast towards the end of the roll."[188] Hall concludes this might be due to a lack of compensating for the increase in paper speed when a roll is played. The issue is also raised by Stahnke who, as a result of a patent search suggests that the note recorder "in the early days, pulled the paper using a capstan, or constant-speed roller. […] This arrangement caused the paper to feed at a constant linear velocity."[189]

Take-up spool diameters

The paper feed system in the Ampico (and in all types of player pianos at the time) had a take-up spool rotated at a constant speed by a suction-powered air motor, which meant the build-up of paper on the take-up spool caused the paper speed to incrementally accelerate as the roll played. Therefore, the music on production rolls recorded the way Stahnke describes would also accelerate. As Stahnke further explains, the note recorder was replaced "around 1925" in which the paper handling geometry matched that of the "playback instruments."[190]

The model A Ampico was fitted with a take-up spool with a diameter of 46.3 millimetres (1.8 inches), the model B Ampico had a larger take-up spool with a diameter of around 69 millimetres (2.72 inches). In regard to the note recorder, Barden asked Hickman: "Were the take-up spools on the recording machine the same size as they were on the piano?" While Hickman's recollection is vague, he stated that the take-up spool was "very large" referring to Barden's Ampico (presumed to be a model B Ampico) saying "you know from your own piano which has a great big spool in it."[191]

Hickman acknowledged that earlier instruments had a smaller take-up spool, and remarked that "as far as I know [the recorder] was always a big spool." He also suggested that "it may be that when they were making the note sheet for the A that they

[187] Howe, ed., *The AMPICO Reproducing Piano*, 73.
[188] Hall, "Piano Roll Speeds," 7.
[189] Wayne Stahnke, liner notes to *A Window in Time, Sergei Rachmaninoff* (Telarc CD-80491, 1998), 11-12.
[190] Stahnke, liner notes to *A Window in Time*, 11.
[191] Howe, ed., *The AMPICO Reproducing Piano*, 109.

did use the same size take-up spool as they used on the piano and then when they went to the other one, they used the bigger spool."[192]

Hickman made no mention of a capstan drive on the note recorder during the interview. When Stahnke met Hickman in 1979, Hickman could not recall any details about roll paper acceleration, but agreed with Stahnke, (who showed Hickman the patents) that rolls made prior to 1926 should be played at a constant paper speed.[193]

Acceleration – dance music rolls

To establish more data about musical acceleration due to paper speed acceleration I referred to a number of popular dance music rolls on the basis that these would possibly have a constant musical tempo. In seeking strict tempo for dance music, Stoddard designed equipment to correct inconsistent beats on roll masters,[194] suggesting he would also have addressed roll paper acceleration. However, after measuring the tempo at the start and end of over 50 MIDI files of Ampico dance rolls played on a model B Ampico paper transport system, it was clear that most of them accelerated musically by eight to ten percent, regardless of when they were issued.

I concluded that the acceleration was caused by the build-up of paper on the 69 millimetre diameter take-up spool, and that therefore the rolls being examined were produced using a process involving paper moving at a constant speed, such as might occur when rolls are produced mechanically. The use of mechanical means to produce rolls of popular music was commonplace in the piano roll industry, and further observations confirmed the strong likelihood that this was the case with the rolls I had examined. Therefore, tests using piano rolls of popular music could not be regarded as indicative of how rolls of art music were recorded.

[192] Howe, ed., *The AMPICO Reproducing Piano*, 109.
[193] Stahnke, liner notes to *A Window in Time*, 12.
[194] Howe, ed., *The AMPICO Reproducing Piano*, 108.

Acceleration – art music rolls

A greater change of paper speed occurs when a roll is played on a model A Ampico compared to a model B Ampico, due to the differing sizes of the take-up spool. In my opinion, this explains why Denis Hall noted that some Ampico rolls exhibited musical acceleration. On average, when played on a model A Ampico, and assuming the roll drive motor does not slow down, the paper speed of a three-minute roll playing at eight feet a minute (tempo 80) increases by around fifteen percent over the length of the roll. While a fifteen percent increase in tempo might go unnoticed in a snappy three-minute foxtrot, it would be noticed with rolls that played for longer periods, where the acceleration would be even greater. Confirming that musical acceleration does not occur in art music recordings is difficult, due to the type of music.

Schnabel's 1922 Ampico roll recording of Weber's *Invitation to the Dance* offered one opportunity, as the first sixteen notes in the work are repeated in an identical way in the coda nearly six minutes later. The notes in the coda take 9.3 seconds to play, about half a second longer than the same notes at the beginning of the roll. Measurements taken on the roll show that the first set of notes occupy around 500 millimetres of paper; the same notes in the coda occupy more than 680 millimetres. Because almost identical playing times of these sixteen notes are found in Schnabel's 1947 disc recording of the work, it is obvious that the roll recording was made in a way that compensated for acceleration. The recording method used is therefore likely to have involved a note recorder with the same paper feed geometry as in the model B Ampico, as Hickman believed.

Acceleration – summary

The issue of acceleration is more complex when the three possible paper feed geometries are considered. Table 2.1 summarises the changes in paper speed for the various combinations of geometries for a roll with a paper thickness of 0.07 millimetres (0.003 inches) played at a speed of eight feet per minute (tempo 80). Spool sizes are 46.3 mm and 69 mm. Values were determined by measurements and calculations.

Table 2.1 *Tempo changes during play for a roll tempo of eight feet per minute*

Ampico reproducing piano		**Note recorder paper feed geometry**		
		Constant speed	*as in model A Ampico*	*as in model B Ampico*
Model A – speed change after:	*24 feet (3 mins)*	15.5%	0	8.2%
	48 feet (6 mins)	29%	0	15.1%
Model B – speed change after:	*24 feet (3 mins)*	7.3%	-8.2%	0
	48 feet (6 mins)	13.9%	-15.1%	0

Table 2.1 shows there is no simple answer to acceleration with Ampico piano rolls recorded prior to 1926. Nonetheless, the figures support the use of either a model A or model B paper geometry in the note recorder, not a constant paper feed geometry. When playing Ampico rolls of art music using the paper feed geometry of a model B Ampico, I have found only a small number of cases where the playing appears to accelerate. I have not encountered a roll in which the music appeared to be slowing towards the end.

The Ampico recording setup was changed in 1926. After this date, as Hickman pointed out in his diary, a new recording piano was in use,[195] although according to Valerio, it was not a new piano, simply a new piano action fitted with the revised recording system.[196] Adam Carroll asserted there was only ever one recording piano, which he described as a "6-foot grand, without a name on it."[197] Photos of the recording setup at the time show the spark chronograph and a note recorder with a take-up spool that appears to be the same size as the spool in a model B Ampico.[198]

The issue of acceleration would have been known and it seems unlikely it was not addressed. Using a model B geometry in the note recorder would compensate for any tendency of a roll, when played on a model A Ampico, to slow down towards the end due to insufficient roll motor torque. Using a model A geometry in the recorder would mean rolls would have inbuilt deceleration when played on the model B Ampico.

[195] Howe, ed., *The AMPICO Reproducing Piano,* 276.
[196] Howe, ed., *The AMPICO Reproducing Piano,* 185-6.
[197] Howe, ed., *The AMPICO Reproducing Piano,* 19.
[198] *The Reproducing Piano – Ampico,* http://www.pianola.org/reproducing/reproducing_ampico.cfm (accessed 18 March 2016).

Acceleration – conclusion

Although Stahnke cites Stoddard's patents, it does not necessarily follow that the Ampico note recorder was made according to these patents, as Stoddard was well-known as a collector of patents.[199] It seems more likely, regardless of how notes were recorded, that acceleration in production rolls of art music was compensated for in some way. It may be that the compensation was not always correct, explaining why I, and Stahnke,[200] have found it necessary on a few occasions to decelerate a roll during playing.

Acceleration of the music on Ampico rolls is a topic I cannot further resolve. I have found that rolls for the model A Ampico have no obvious musical acceleration or deceleration when played on a model B Ampico, suggesting its roll transport geometry is the preferred method for playing both types of rolls. Judgement in correcting for acceleration may be necessary with some Ampico roll recordings produced before 1926.

Recording note dynamics

There is little documentation or photographic evidence that shows how dynamics were recorded prior to 1926 when Hickman's dynamic recorder was commissioned. Stoddard patented two designs for recording note dynamics, one in 1908 (US Patent 1,095,128) the other in 1910 (US Patent 1,367,634). It is generally believed that neither of these schemes were used, but an entry in Hickman's diary, February 1925 reads "6:00 P.M. Just thought of excellent scheme to record dynamic of artists by velocity at time hammer is within 1 cm. of string. Using magnets similar to those now used."[201] Hickman later writes: "Mr. Stoddard quite enthusiastic about my scheme for recording dynamics and wants to rebuild machine so that the scheme may be used to record each note." Stoddard's 1910 patent description uses the term 'magnet' when sometimes referring to an electromagnet, so it seems likely this is the system to which Hickman was referring.[202] The patent was renewed in 1920.

Hickman wrote that he made further tests with his scheme of recording dynamics, and later came up with the method that was adopted in 1926. When Hickman was

[199] Howe, ed., *The AMPICO Reproducing Piano*, 149.
[200] Stahnke, liner notes to *A Window in Time*, 12.
[201] Howe, ed., *The AMPICO Reproducing Piano*, 243.
[202] *Method of Recording Music*, http://www.google.com/patents/US1367634 (accessed 21 March 2016).

interviewed in the 1960s he had no recollection of any means of recording dynamics prior to his dynamic recorder. He stated that:

> They tried to record on a phonograph simultaneously, so that the editor could listen to that. You see the trouble with the old system was as soon as the artist got away, it began to take on the tone of the editor rather than the tone of the artist.[203]

In regard to the use of a phonograph, Valerio refuted the idea that phonograph recordings were made, but agreed it would have been a "great help."[204] Later in the interview Hickman explained that:

> [In regard to expression] the editor built it up from nothing […] in dance music all they did was put it in mechanically. But for the other rolls […] they put the expression in according to what they thought it should be. Of course these editors, they weren't dumb, but at the same time who can remember exactly how an artist plays?[205]

Piano roll editors

From the start, the American Piano Company employed musicians as roll editors. The popular and classical departments had their own musical staff and were generally independent from each other. The first editor-in-chief of the classical department was Belgium-American pianist Theodore Henrion (?–1918). After his death he was replaced by Milton Suskind, who had been employed in 1916 to make roll recordings.[206] Suskind trained at the Institute of Musical Art, and according to Obenchain: "Godowsky heard him and pronounced him America's greatest hope for a native virtuoso."[207]

When he joined Ampico, Suskind changed his name to Edgar Fairchild, and as an editor he was responsible for producing roll recordings of Rachmaninoff, Levitzki, Moiseiwitsch and other high-ranking pianists. During the late 1960s, a recording was made of a conversation between Fairchild and piano roll enthusiasts Phil Hill (also a noted racing car driver) and John Farmer. Hill was particularly insistent when seeking an explanation of how the data was recorded, especially the dynamics, expressing the view that Ampico rolls "fooled" people. After pointing out that only notes and pedal data was recorded, Fairchild summed up his explanation:

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[203] Howe, ed., *The AMPICO Reproducing Piano*, 73.
[204] Howe, ed., *The AMPICO Reproducing Piano*, 220.
[205] Howe, ed., *The AMPICO Reproducing Piano*, 74.
[206] Obenchain, *Catalog*, 429.
[207] Obenchain, *Catalog*, 429.

> The important thing is that in recording it, there was enough put down to make it possible for someone like myself to achieve what they [the pianist] were after. […] So that when they heard the end result they themselves approved it and were willing to have that be issued as a representation of their performance. So on that basis you weren't fooling the people after all.[208]

How dynamic data was "put down" is not known. A general view by those whom Barden interviewed was that the editor working with a particular pianist would make notes on a score.[209] Valerio is the only Ampico editor Barden interviewed who had worked as an editor prior to the introduction of the dynamic recorder. Valerio explained:

> Now if they were in a hurry for a roll we'd know generally what dynamics to put in, because any piece they played we would have the music for it. We would read it over ourselves if we didn't know it, and we'd get a general idea of what they wanted.[210]

Valerio explained that a recording would have been "polished up a little bit, as best we could" and presented to the pianist as "the way we would have liked to hear it played."[211] At this time, the pianist would either approve or request changes to the recording. The time taken to produce a roll recording of art music depended on the length of the work, but, according to Valerio it might take two or three days to edit, followed by further refining as trial rolls were made. Moiseiwitsch recorded Ravel's *Jeux d'eau* on January 16, 1920 (his first roll recording) and the roll was issued a month later.[212] Typically, a roll of art music would be issued several months after the recording was made. Rolls of popular music were produced more quickly to take advantage of a song's popularity at the time.

Pianists and producing their Ampico roll recordings

Both Fairchild and Valerio refer to giving the pianists what they wanted. There is clear evidence that most of the top-ranking Ampico artists participated in the production of their roll recordings. It may have been a contractual requirement, and in any case would be in their best interest. When interviewed in 1962 for a BBC radio programme, Moiseiwitsch was asked "Do you feel that the player piano can ever reproduce faithfully

[208] Recording held by the author.
[209] Howe, ed., *The AMPICO Reproducing Piano,* 44.
[210] Howe, ed., *The AMPICO Reproducing Piano,* 170.
[211] Howe, ed., *The AMPICO Reproducing Piano,* 172-3.
[212] From copies of original ledgers showing roll recording and issue dates. Documents held by the author.

the performance of an artist?" Moiseiwitsch's immediate response was: "Absolutely, if you take great care and patience […] it can be done, it has been done."[213] Moiseiwitsch was very likely referring to the number of visits to the Ampico recording studio he would have made when working with editors on his recordings.

Valerio referred to Fairchild having to edit recordings made by Levitzki after Levitzki had auditioned them.[214] On the other hand, Valerio remarked that Richard Bühlig wanted certain changes to a phrase, and was satisfied after hearing the same phrase some time later without the requested change having been made. Valerio concluded "A lot of it is psychological."[215] He also pointed out later in the conversation that Rachmaninoff was "the only one that was very particular."[216]

Hickman wrote about Rosenthal in his diary:

> May, 1926. Stayed late to see Mr. Rosenthal and hear his criticism of Chant Polonaise record which he had played. Did not leave lab until about 8:00 P.M. […] Gained a great respect for Mr. Rosenthal. He was very much pleased with his record, but offered many good suggestions. Helped edit roll played by Rosenthal.[217]

On Rachmaninoff's pianism, Hickman stated:

> [He was the only pianist] who could play 10-note chords one after another with every single note happening at exactly the same time because that's what sounded right to him. But nobody else could do it. And that's what made him the greatest.[218]

Concerning the pianists and the recording apparatus, Valerio explained that most of the recording artists were not interested in how a recording was made, and few understood that the dynamics were added by an editor. In general, on hearing their roll recording, a pianist would typically suggest some changes, but generally "the playing would sound fine to him."[219]

[213] *Great Piano Roll Mystery* at 12:30 from start.
[214] Howe, ed., *The AMPICO Reproducing Piano,* 173-4.
[215] Howe, ed., *The AMPICO Reproducing Piano,* 173.
[216] Howe, ed., *The AMPICO Reproducing Piano,* 175.
[217] Howe, ed., *The AMPICO Reproducing Piano,* 279.
[218] Howe, ed., *The AMPICO Reproducing Piano,* 88.
[219] Howe, ed., *The AMPICO Reproducing Piano,* 175.

Comparison concerts

Selected Ampico recording artists were obliged to participate in comparison concerts, in which a pianist's live playing and Ampico roll recordings were presented side by side. The first of these was given by Leo Ornstein prior to May 25, 1916 and is discussed by Broyles and Von Glahn in their biography of the pianist. The authors refer to a review that clearly states Ornstein played first, followed by the piano roll recording.[220] Nonetheless, the authors claim that in later comparison concerts, the roll would be played first, stating "the secret of the success of the Ampico concerts, was that the artist listened to, memorized, and then played back what the roll had just played."[221] This argument is refuted by every article or review concerning comparison concerts that I have read in publications of the day such as *Music Trade Review*.[222]

Broyles and Von Glahn quote a reaction by Rubinstein to his participation in a series of comparison concerts, in which Rubinstein refers to the events as a "shameful episode in which I shared with three colleagues. [Godowsky, Levitzki, Ornstein and] I agreed to appear in six cities playing one piece each on a pianola [sic], then treating the public to a repetition of the piece by the machine."[223] The authors conclude that Rubinstein's embarrassment may have been because the piano roll interpretation "was not the artist's but of some member of the Ampico staff."[224] As previously shown, it is clear that Ampico editors sought to produce a roll recording to meet the pianist's satisfaction, not their own. This attitude applied particularly in the case of high-ranking pianists, as has been shown.

Comparison concerts were a marketing ploy, but behind the promotional aspect is the fact that a machine and a pianist where pitched together in front of live audiences. These events took place all over the US and in parts of England, involving hundreds of such concerts. Some were held in music stores, others in large halls, even in private residences. In a few cases, such as a 1920 concert held at New York's Carnegie Hall, a paying audience heard only an Ampico reproducing piano.[225]

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[220] Broyles and Von Glahn, *Leo Ornstein*, 200.
[221] Broyles and Von Glahn, *Leo Ornstein*, 203.
[222] "Great Ampico Concert Reproduced in Washington," *Music Trade Review*, vol. 70 no. 10 (March 6, 1920), 23; "Echoes of the Duo-Art Recital," *Music Trade Review*, vol. 65 no. 22 (December 1, 1917), 42; "Ampico Recital at Biltmore," *Music Trade Review*, vol. 64 no. 11 (March 17, 1917), 36.
[223] Broyles and Von Glahn, *Leo Ornstein*, 203.
[224] Broyles and Von Glahn, *Leo Ornstein*, 203.
[225] "The Ampico Reproducing Piano Featured as Soloist," *Music Trade Review*, vol. 70 no. 19 (May 8, 1920), 36.

The *New York Globe* reported an event held at the Hotel Biltmore, New York on October 8, 1916:

> For fancy, that great pianist Leopold Godowsky actually permitted a music roll record of his renditions to be heard on the Ampico immediately after he personally had performed them. Indeed, as remarkable as the experiment itself is the extraordinary success achieved by the almost human instrument.[226]

The review by the *Daily Express* of a comparison concert involving Moiseiwitsch held at Wigmore Hall, London in 1927 states:

> The Ampico Reproducing Piano made good its claim to give wonderfully faithful reproductions of the pianist's own performances. It was an uncanny experience to see Mr. Moiseiwitsch rise from his seat at the pianoforte and go out and then hear the piano repeat his performance automatically.[227]

It may be that these reviews were sponsored by Ampico, and because of the advertorial approach taken by industry-sponsored trade magazines of the day, it is difficult to extract fact from exaggeration. In a modern day equivalent, in 1982, Denis Condon and I toured Australia and New Zealand with a Duo-Art vorsetzer we had built, performing Grainger's roll recordings of Grieg's Piano Concerto with a range of symphony orchestras. The critical reaction to these concerts is summed up by the following review of a concert in the Sydney Opera House, with the Sydney Symphony Orchestra conducted by John Hopkins (1927–2013):

> That the actual sound was first-rate was not, of course, surprising, for it was made by the best of modern pianos [Steinway]; the amazing feature was the wealth of nuance and subtlety with which every aspect of dynamics, touch, even personality, was turned from holes in a piece of paper to thrilling reality.[228]

This review is similar to reviews of comparison concerts held in the 1920s, and we know the reviewer was independent. I believe there is little doubt that the instruments used at the time produced a performance matching that of the live pianists that were involved. As I noted in 1982, a reproducing piano performing in a concert hall provides

[226] *The Reproducing Piano - Ampico*, http://www.pianola.org/reproducing/reproducing_ampico.cfm (accessed 29 January 2015).
[227] "Moiseiwitsch Appears with Ampico in London," *Presto-Times*, no. 2120 (March 19, 1927), 9.

a different listening experience to hearing it in the home. Under the right conditions, reproducing piano roll recordings can sound indistinguishable from live playing. Therefore, comparison concerts can, and did, prove the worth of the instrument and the roll recordings that were being used.

Editorial changes

As previously pointed out, other than removing wrong notes (usually brushed notes), recordings were not highly edited from the original playing, at least by the roll editor. Some pianists sought changes to their recordings, as already mentioned. However, Ampico rolls issued up to around 1925 often have extended note perforations that are very likely to be an editorial addition.

In 1912, Stoddard was granted US patent number 1,025,077 in regard to extending note perforations on Rythmodik rolls to obtain a "singing tone."[229] Extended notes were incorporated into many Ampico rolls and the concept is highlighted in a manual for Ampico salesmen, in which reference is made to recording the operation of the *sostenuto* pedal.

The article also discusses half-pedalling, and concludes that "the tonal effects created by this process of extended note perforations are identical with those obtained by the artist"[230] As well, notes were also usually extended by the length they would play when the damper pedal was operated. Stoddard's claim was that rolls thus modified could be played on instruments without a damper pedal actuator.

Examples showing extensive use of extended perforations occur particularly in recordings made by Nyiregyházi. It is possible that the *sostenuto* pedal could be recorded, and that pianists such as Nyiregyházi used it. Nyiregyházi was not involved in the production of his rolls,[231] so unless they were recorded, the extended perforations were added by an editor in an attempt to recreate Nyiregyházi's sound.

In summary, roll recordings prior to 1926 can be grouped as those recorded by pianists who worked with an editor to produce their rolls (includes most of the notable artists), those made by pianists who did not work with an editor, and rolls made by in-house pianists who produced their own recordings.

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[228] Fred Blanks, "Relentless Ghost at the Keyboard," *Sydney Morning Herald,* June 15, 1978, (page number not known).
[229] *Music Trade Review*, vol. 54 no. 18 (May 4, 1912), 25.
[230] *Ampico Sales Manual*, "The Singing Tone," page not numbered.
[231] Kevin Bazzana. *Lost Genius - the Curious and Tragic Story of an Extraordinary Musical Prodigy* (New York: Carroll & Graf, 2007), 110.

Ampico roll recording technology after 1926

The introduction of the dynamic recorder was a significant event for Ampico editors, and also significant enough for inclusion as an article in a 1927 issue of *Scientific American*.[232] The article was written with the assistance of Hickman.[233]

The dynamic recorder used the principle of spark chronometry, which Hickman was familiar with through his interest in measuring the velocity of arrows as used in archery.[234] To measure and record the velocity of a piano hammer, a silver contact was attached to each hammer shank and two silver wires were attached to the piano action such that when a hammer moved toward the strings, during the last twelve millimetres of travel, the silver contact would touch each silver wire in turn. At each contact, a spark was generated that created a mark on a moving sheet of paper. The distance between the marks was inversely proportional to the velocity of the hammer.[235]

Therefore, each recording now had a note sheet and a dynamic sheet. To interpret the dynamic data, Hickman developed a ruler with a scale divided into 120 parts, in which each part represented "one tenth of the minimum difference in loudness discernible to the human ear."[236] When questioned about defining the minimum discernible difference in loudness, Hickman's recollection was one decibel.[237] Interestingly, the standard MIDI velocity scale has 127 levels.

While the measured dynamics were to a resolution of 120 parts, the expression coding on the roll was not always so precise. Figure 2.6 shows an image of an Ampico master recording in which some notes have been extended with a pencilled line, dynamic values are written next to each note, and the expression coding to create each dynamic is marked on the paper.

[232] "Recording the Soul of Piano Playing," *Scientific American*, November 1927, 422-23.
[233] Howe, ed., *The AMPICO Reproducing Piano,* 294.
[234] Howe, ed., *The AMPICO Reproducing Piano,* 84.
[235] Givens, *Re-Enacting the Artist*, 31-35.
[236] Givens, *Re-Enacting the Artist*, 36.
[237] Howe, ed., *The AMPICO Reproducing Piano,* 104.

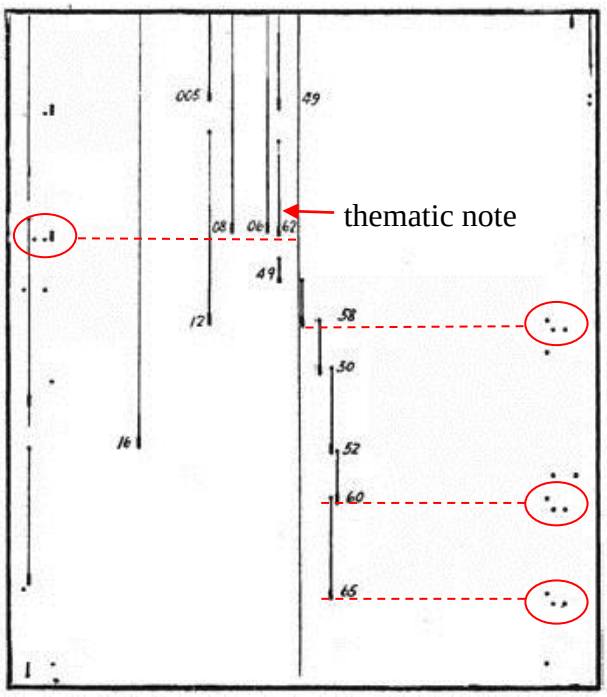

Figure 2.6 *Completed master with dynamic values entered, note extensions added and expression perforations marked in*[238]

The circled dots on the right in Figure 2.6 are the expression coding that is applied to the notes indicated by the dashed lines. The coding is the same for all three notes, which range in dynamic value from 58 to 65.

The circled expression on the left shows how two notes with different dynamic values in the same part of the keyboard were dealt with. The thematic note (dynamic value 62) has been advanced slightly, or the accompaniment notes (dynamic values 06 and 08) retarded, so the applied expression only affects the thematic note. The line in the centre of the sheet shows the division in the keyboard, which for Ampico instruments is between E and F above middle C.

Producing a trial roll

Much of the work to produce a trial roll was routine and carried out by women who were described by Emse Dawson (1901–1976) as not understanding how the Ampico worked, but who regarded their work as "just a paper operation that they did and did well. They were at it all year round."[239] Dawson was a recital pianist, who had trained in Brisbane, later at the Sydney Conservatorium of Music prior to moving to New York.

[238] "Recording the Soul of Piano Playing," *Scientific American*, 423.

She was employed in 1925 as a classical music roll editor and therefore was only involved with rolls recorded with the dynamic recorder.

During her conversation with Barden, Dawson recalled a recording made by Moiseiwitsch of a work by Brahms, in which, on hearing the first trial roll, the pianist approved it immediately.[240] The work was probably Intermezzo Op. 118 No. 6, the only work by Brahms recorded by Moiseiwitsch during Dawson's time at the company. Dawson also explained that "the recording machine was by no means mechanically perfect and things did go wrong sometimes."[241]

Both Dawson and Hickman mentioned recordings made by E. Robert Schmitz that were too loud. While Dawson thought that this stemmed from his playing,[242] Hickman confirmed it, saying "we finally concluded that the trouble was […] his personality permitted him to just play like hell."[243] Hickman's diary entry March 1926 states he was "very busy taking dynamic records of Mr Schmitz."[244]

In terms of working with pianists in producing their rolls, Dawson reflected that the aim was to satisfy the artist and "whatever suggestions he made you would try to do as much as possible." Regarding pianists seeking to improve a recording, Dawson was sceptical, commenting that "there would be a limit as to the suggestions he would have to make and there would also be a limit to the editor's ability."[245]

Valerio also worked as an editor after 1926. When asked about Lhévinne, he recalled "that he was fairly particular" but because of the new recording system it "didn't cause problems."[246] He also described an editing operation to compensate for loudly played notes that were found to be playing in advance of softly played notes. If during live playing, two simultaneously played notes are struck with different forces, the louder note will sound slightly ahead of the softer note, but according to Valerio the effect is exaggerated by the action of the player mechanism. To minimise the effect, affected notes were "moved back a little bit."[247] Valerio also explained that the note

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[239] Howe, ed., *The AMPICO Reproducing Piano,* 34.
[240] Howe, ed., *The AMPICO Reproducing Piano,* 39.
[241] Howe, ed., *The AMPICO Reproducing Piano,* 39.
[242] Howe, ed., *The AMPICO Reproducing Piano,* 41.
[243] Howe, ed., *The AMPICO Reproducing Piano,* 71.
[244] Howe, ed., *The AMPICO Reproducing Piano,* 273.
[245] Howe, ed., *The AMPICO Reproducing Piano,* 46.
[246] Howe, ed., *The AMPICO Reproducing Piano,* 174.
[247] Howe, ed., *The AMPICO Reproducing Piano,* 174.

recorder was very sensitive and although pianists complained about brushed notes being recorded, it was necessary to ensure notes were not lost.[248]

Roll production

The process of making a recording into a production roll involved various stages. As shown in Figure 2.6, dynamic levels derived from either the dynamic record or editors' notes were written on the note sheet, and note extensions were added by pencil. A technician would then mark up the required expression coding. According to Givens, the recording equipment captured the speed in which the damper pedal was operated "so that editors could tell when the pianist had half-pedalled during the course of the recording."[249] Note 'bleeding' was also done to extend notes to accord with the damper pedal operation.

Producing a playable copy of the recording from the note sheet was achieved by punching a series of holes at the start of each line on the note sheet, and a single punch at the end of each line. The sheet was then passed through a complex stencil-making machine to punch out a playable copy of the recording for trial on a piano. During the trial period, a number of trial copies might be made.[250]

Once the recording was approved, several production masters were made. The company adopted three-to-one mastering during the 1920s, so production masters were three times the length of production rolls. Previously, two-to-one mastering had been used.[251] Rolls produced up to around 1920 were punched at a resolution of 20 steps per inch, afterwards at 30 steps per inch.[252] Table 2.2 shows the timing resolution at these two step-rates for various playing tempos.

Table 2.2 *Timing resolution of Ampico rolls for various roll speeds*

Step rate in steps per inch	**Timing resolution**				
	7	8	9	10	Paper speed in feet per minute
20	35.7	31.3	27.8	25.4	Resolution in milliseconds
30	24.1	21.1	18.7	16.9	

[248] Howe, ed., *The AMPICO Reproducing Piano,* 174.
[249] Givens, *Re-Enacting the Artist*, 38.
[250] Givens, *Re-Enacting the Artist*, 41-4.
[251] Givens, *Re-Enacting the Artist*, 44.
[252] Howe, ed., *The AMPICO Reproducing Piano,* 162.

Model A Ampico expression – operating principles

The aim of an expression regulator in a reproducing piano is to control the level of suction that is applied to playing notes. The model A Ampico has one regulator for the bass side of the keyboard and another for the treble side. The higher the level of suction, the louder playing notes will sound. The expression regulators in the model A Ampico, like the models that preceded it, have two main parts. The first is a set of components called 'intensities', which produce step changes in the suction level. Each regulator has three intensities, with each intensity producing a different value of suction, thereby providing eight different suction (or dynamic) levels through various combinations of the intensities.

The second part is called a 'crescendo', and is a component that when operating, causes the suction (and therefore dynamic) level to increase or decrease either slowly or quickly. A 'crescendo' can produce a dynamic level anywhere between the two limits of minimum and maximum playing levels. In the model A Ampico, the crescendo component when operating slowly takes around ten seconds to fully close or open, and around two seconds when operating quickly.

The combination of intensities and crescendos, in theory, provides a full range of dynamic values and the ability to quickly accent thematic notes. As well, Ampico regulators are self-regulating in that the required suction level is maintained regardless of the number of notes being played. The model A Ampico expression regulation system is generally regarded as being reliable and predictable in operation, and is further described in Chapter 4.

Model B Ampico expression – operating principles

The operation of the expression regulators in a model B Ampico is detailed in Chapter 4. Compared to the model A, the model B regulator has a simpler construction and a faster response time while retaining the usual intensity and crescendo components. There are two major differences to the model A regulator: the use of a fourth intensity, called a sub-zero, with the sole purpose of lowering the playing level below the usual softest level, and a single crescendo unit that affects the dynamics of both sides of the keyboard. The theory was that a pianistic crescendo always involved both parts of the keyboard and that separate crescendo units were not necessary.

To make rolls for the model B Ampico compatible with the model A, the crescendo coding was repeated on both sides of the roll. The model B Ampico only reads crescendo data from the treble side of the roll. Therefore, B-coded rolls always cause both crescendos in a model A Ampico to operate together, while A-coded rolls operate the crescendos independently.

Rolls for model B Ampico

Production of rolls for the model B Ampico began in 1927, although the instrument did not go on sale until 1929. B-coded rolls have 100 tracks, compared to 98 tracks for A-coded rolls, leaving only a small margin between the outside perforations and the edge of the paper. The rolls could be played on a model A Ampico, although the differences between the two instruments meant that this was a compromise. It had been found that because the model B regulators had a faster operating time, thematic notes that had been advanced on model A rolls to give individual accents were now being accented too soon, due to the fast response of the regulators. The solution, rather than change the roll production process, was to place the note holes in a model B tracker bar about 0.5 millimetres in advance of the expression holes.

Ampico expression behaviour

As later detailed in Chapter 4, I was able to study the behaviour of Ampico suction regulators, and to observe the dynamic detail in the expression coding of both types of Ampico rolls, by constructing an electronic analogue model of the Ampico expression system. The model produces a voltage in response to the applied expression coding from Ampico rolls recorded as MIDI files. The changing voltage can be monitored on an oscilloscope, giving visual evidence of the behaviour of the two regulators (bass and treble) in response to the expression coding. Although not the only purpose of the analogue model, it has provided a clear way of observing the action of Ampico expression coding.

Expression and model A Ampico rolls

When discussing the use of intensities and crescendo actions in the expression coding for A-coded rolls, Valerio was asked "Did you always think first in terms of intensities and then the crescendo to kind of polish it off?"[253] Valerio confirmed this was the case, but later agreed that most of the rolls produced before 1926 were crescendo orientated, "and some of them sounded atrocious too."[254] To validate Valerio's account, I observed the expression behaviour of hundreds of MIDI files of Ampico rolls made before 1926. While I could not establish a definite pattern, several findings emerged.

1. Editors used a combination of intensities and crescendo action throughout the period and no particular emphasis on which was favoured could be found.
2. A few early-issue rolls tended to favour the use of the crescendo function.
3. In some early-issue rolls by in-house pianists, intensities were used for most of the expression, with reduced use of crescendo.
4. Numerous examples were noted involving independent use of the bass and treble crescendo units.
5. The more important the pianist, the more detail in the expression coding.

[253] Howe, ed., *The AMPICO Reproducing Piano,* 188.
[254] Howe, ed., *The AMPICO Reproducing Piano,* 188.

The photos in Figure 2.7 show how the dynamics change with the expression coding for two model A Ampico rolls.[255] The top trace shows the dynamic level for the treble half of the keyboard, the bass-side dynamic level is shown by the lower trace.

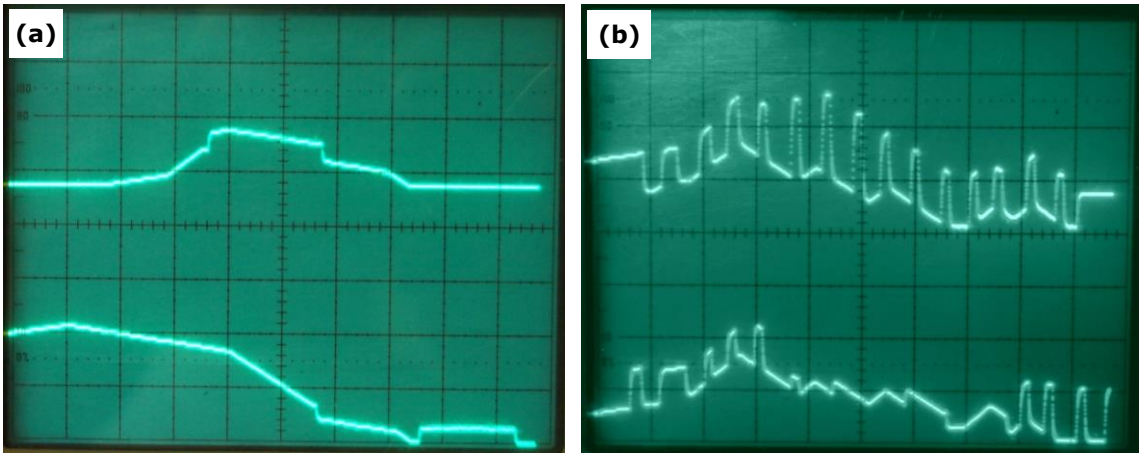

Figure 2.7 (a) *Image of dynamic levels produced by a pre-1916 roll recording that uses crescendo operation more than intensities.* ***(b)*** *Image of dynamic levels produced by a roll recording by Rachmaninoff, issued in 1919.*

The photo in Figure 2.7 (a) shows the behaviour of the expression from a section of a Stoddard-Ampico roll. It shows that the editors used fast and slow crescendos and decrescendos with minimal use of intensities. The crescendo units are operating independently. The photo in Figure 2.7 (b) is from Rachmaninoff's recording of his Prelude in C sharp minor Op. 3 No. 2. The roll was issued in 1919, and the image shows the considerable dynamic detail that editors achieved through a combination of intensities and crescendos. In this case, both crescendos are operating in a similar way.

Expression and model B Ampico rolls

Because of the late arrival of the model B Ampico, the majority of rolls for the instrument were of popular music. I estimate that around 300 rolls of art music were issued for the new instrument, including some that were adapted from earlier recordings. By the time the model B Ampico was introduced, the process of making rolls using the dynamic recorder was well established, requiring only that editors adapt to the model B regulating system. When asked about producing rolls for both Ampico models, Valerio explained that both types of rolls would be edited together, and "you'd

[255] Traces produced by the equipment described in Chapter 4.

use mostly the intensities."[256] To test his recollection, I observed the behaviour of the expression of a range of MIDI files of B-coded Ampico rolls, with the following findings:

1. Intensities were used to a greater extent in B-coded rolls than in A-coded rolls.
2. The sub-zero intensity was used sparingly, and often not used at all.
3. The 1st and 2nd amplification settings were used to a limited extent.
4. The crescendo function was used to a lesser degree than in A-coded rolls.

The photos in Figure 2.8 show how the dynamics change with the expression coding for two model B Ampico rolls, both issued in 1929.[257] The top trace shows the dynamic level for the treble half of the keyboard, the bass-side dynamic level is shown by the lower trace.

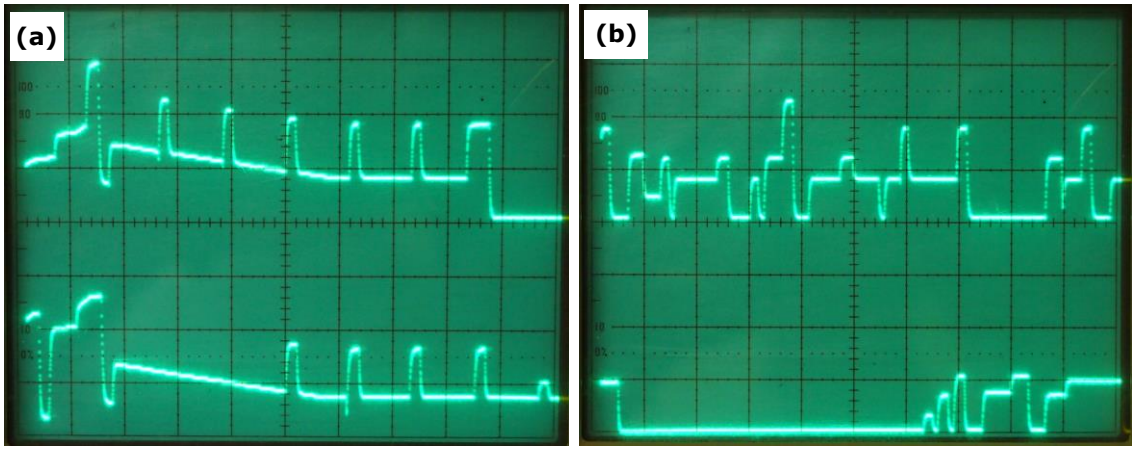

Figure 2.8 (a) *Image of dynamic levels using a combination of crescendo and intensities from a B-coded roll.* ***(b)*** *Image of dynamic levels using only intensities from a B-coded roll recording by Rachmaninoff.*

The photo in Figure 2.8 (a) shows a typical use of intensities and crescendo in a B-coded roll. The photo in Figure 2.8 (b) shows the use of intensities only, in which six of the eight possible levels are used in the treble side, and four are used in the bass. The dynamic level falls to its zero point (softest playing level) at various intervals when the expression coding activates a 'cancel' valve, which turns off all intensities that happen to be on at the time. Figure 2.8 (b) shows that B-coding provides relatively coarse

[256] Howe, ed., *The AMPICO Reproducing Piano,* 187.
[257] Traces produced by the equipment described in Chapter 4.

dynamic values, due to the reduced use of the crescendo. However, there are examples in B-coded rolls that demonstrate how editors could create a wide range of dynamics.

Summary

The process used to produce Ampico rolls involved a large number of tasks and people. Broyles and von Glahn describe Ampico piano rolls as 'constructions' that are "carefully built by an editor, who worked in varying degrees of collaboration with the performer."[258] Kevin Bazzana also refers to 'constructions' and points out that Nyiregyházi "rarely recorded a selection more than once, […] and was not involved in the editing of his rolls."[259] Bazzana further explains that Nyiregyházi was "dismayed by the limitations of the system. It could not replicate his volcanic fortissimos, for instance."[260] Editors, as previously shown, would quieten extremely loud playing in deference to living room acoustics.

While an Ampico roll can legitimately be called a construction, as can all reproducing piano rolls, there is a limit to what roll editors could do. Broyles and von Glahn regard the roll production process as "comparable to a modern electronic recording, where tape or digital slices are compiled to create the finished product."[261] There is no evidence that pianists made separate recordings of sections of a work, instead preferring to re-record the entire work.[262]

The evidence is that notes, rhythms and basic pedalling were accurately recorded, while dynamics prior to 1926 were created by an editor, later polished or changed by the pianist. After 1926, dynamics were also recorded. In terms of producing the recording, the editors sought to recreate the pianist's playing as heard, or as the pianist wished. Changes to the recording appear to be limited to removing wrong notes, tidying some parts of the playing, and fixing errors made by the pianist or the recording equipment. It does not appear that wholesale changes were, or even could be made to a recording.

Roll recordings used in comparison concerts cannot be anything but reasonably true to the pianist's playing. Rolls recorded by Rachmaninoff, Moiseiwitsch, Rosenthal, Levitzki and other notable pianists who were involved in the production of their roll recordings are, if nothing else, accurate to the pianist's wishes.

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[258] Broyles and Von Glahn, *Leo Ornstein*, 200.
[259] Bazzana. *Lost Genius*, 110.
[260] Bazzana. *Lost Genius*, 110.
[261] Broyles and Von Glahn, *Leo Ornstein*, 200.
[262] Howe, ed., *The AMPICO Reproducing Piano*, 101, 167.

The Ampico classical library of recordings contains a mix of roll recordings in which some are, without doubt, representative of the pianist, in particular of the high-ranking pianists. There are hundreds of Ampico rolls of art music made by pianists of lesser fame who recorded works according to market demand, but at a lower cost than having these works recorded by a highly-ranked pianist. These recordings are more likely to be representative of the pianist through the ears of an editor.

In terms of editorial change to a recording, Stoddard required that notes be extended to create a singing tone, a practice that was gradually abandoned in the late 1920s. I have found that in many cases the note extensions have no effect on the music, as they only cover damper pedal operations. There are examples of notes extending well beyond the use of the damper pedal, which unless recorded through use of the *sostenuto* pedal, must have been an editorial addition. I have noticed the soft pedal is sometimes operated for a single note, or for a short passage of notes. Valerio confirms that the soft pedal was used to create expressive effects.[263] I have also observed trill perforations that are too perfect, giving a mechanical sound.

The sole use in expression coding of the eight dynamic levels created by the three intensities can sound dynamically coarse, although it is rare to see a roll that does not use the crescendo function to some extent.[264] Roll speeds vary from five feet per minute (tempo 50) to twelve feet per minute (tempo 120), and some rolls may be subject to acceleration, as previously discussed. The accuracy of roll tempo markings is difficult to ascertain, although, unlike Duo-Art rolls, I have not found any examples of original Ampico rolls that were reissued with different tempo markings.

Conclusion

Ampico rolls are more likely to represent how a pianist wanted to be heard than how the pianist sounded when making the recording. Just how far removed the roll recording is from the original performance depends on factors that include the status of the pianist and the pianist's demands of the editor. The editors were all skilled musicians and appear to have regarded the pianist's wishes as paramount. It is this collaboration that is important, as a widely-held view is that editors reigned supreme in how roll recordings should sound. The evidence does not support this view.

[263] Howe, ed., *The AMPICO Reproducing Piano,* 229-30.
[264] Both models of Ampico used the principle of amplification, which when used extends the number of dynamic levels.

Rolls were produced to cover a wide repertoire of music, often churned out by in-house or lesser-known pianists. These recordings are useful for their musical content and perhaps the interpretation, but may not necessarily be an accurate record of the pianist's original playing. While these rolls have their application, it is the Ampico rolls recorded by the highly-ranked pianists that can be seen as representative of their art and possibly more revealing than their early sound recordings.

Duo-Art

Background

The origins of the Duo-Art reproducing piano are unclear. A contributor to its design appears to have been Joseph Hunter Dickinson, an engineer employed by Aeolian, and whose name is credited on a number of patents relevant to the Duo-Art.[265] However, unlike the Welte and Ampico instruments, which were new designs, the Duo-Art evolved from prior inventions. Aeolian was well established through its line of Pianolas, which were first marketed in 1897. In 1901, a patent was issued to Francis L. Young for an invention Aeolian called the *Metrostyle*,[266] in which a line depicting roll paper speed could be followed by a pointer attached to the player's tempo lever. By following this line, a playerist could introduce artistically appropriate rubato and tempo changes to the music, while pedalling a mechanically-cut piano roll.

Sometime in 1900, a patent was granted to James W. Crooks for his invention of a method of accenting thematic notes in a piano roll. Referred to by Aeolian as the *Themodist*, it was introduced into the Pianola around 1906.[267] The *Themodist* system required specially-cut piano rolls, in which 'theme' perforations were cut to align with the notes to be accented. The theme perforations were punched at the margins of the roll, and comprised two small holes spaced side by side, sometimes referred to as 'snake bites', or 'ditto marks'. The *Themodist* system was widely copied, and became almost an industry standard for player rolls. It also became an integral part of the Duo-Art.

[265] Rex Lawson, "Joseph Hunter Dickinson and the Origins of the Duo-Art," *The Pianola Journal*, no. 24 (2014), 13.
[266] *History of the Pianola - Inventors*, http://www.pianola.org/history/history_inventors.cfm (accessed 10 March 2016).
[267] *History of the Pianola - Inventors*, http://www.pianola.org/history/history_inventors.cfm (accessed 10 March 2016).

Duo-Art expression – operating principles

The basic operating principles of the Duo-Art dynamic regulating system are best described before examining the process Aeolian used to produce Duo-Art rolls. The system, while achieving the same objective as other reproducing pianos, differs from the Welte and Ampico systems in several ways. In the first place, it incorporates an application of the *Themodist* system. As detailed in Chapter 4, in the Duo-Art reproducing piano, the 'snake bite' perforations accent thematic notes by directing the outputs of two suction regulators referred to as 'theme' and 'accompaniment'.[268] Thematic notes can occur in any part of the keyboard, and the theme regulator is therefore switched to either the bass or treble side of the keyboard by the theme perforations. The accompaniment regulator determines the volume of notes that are not being accented.

Both regulators operate in an identical way, except the theme regulator is adjusted so notes are 'one degree' louder.[269] The Duo-Art keyboard is divided at E flat and E above middle C. During the absence of theme holes in a Duo-Art roll, the accompaniment regulator controls the dynamics of the entire 80-note keyboard. A theme hole in the treble side of a Duo-Art roll causes the theme regulator to control note dynamics in the treble side of the keyboard, while the accompaniment regulator controls the dynamics in the bass side. Similarly, a theme hole in the bass side of the roll causes the theme regulator to control note dynamics in the bass side of the keyboard, the accompaniment regulator controlling the dynamics on the treble side. If theme holes appear on both sides of the roll, the theme regulator controls the entire keyboard.

The dynamic regulating principle is based on intensities, as used by Ampico. An assembly, referred to as an accordion pneumatic, provides sixteen levels of dynamics by way of the sixteen possible combinations created by covering or uncovering the four expression holes (per side) in a Duo-Art tracker bar. Because the theme regulator is set to a slightly higher output, the two regulators between them provide 32 possible dynamic levels.

Duo-Art suction regulators have a slower response time than those in other instruments. To compensate, the expression holes in a Duo-Art tracker bar are located

[268] Service Manual - Duo-Art Reproducing Piano (New York: The Aeolian Company, 1927), 15.
[269] Service Manual - Duo-Art Reproducing Piano, 24.

well ahead of the note holes, causing a regulator to be set to its required level before the particular note is played.

The expression tracks on either side of a Duo-Art roll therefore comprise a track for the 'snake bite' theme perforation and four tracks controlling an expression regulator. The bass side tracks control the accompaniment regulator, those on the treble side control the theme regulator. These tracks are referred to as 'powers', in which the outside expression track is power 1, then power 2, power 4 and power 8. The numbers add up to 15, and in combination with power 0, give sixteen intensity levels.[270]

Figure 2.9 shows a section of a Duo-Art roll. The dashed lines show the theme perforations that are aligned with the notes to be accented, which will all play at the dynamic level set by the expression coding on the treble side of the roll. The remaining notes (outlined in red) will play at the level set by the expression on the bass side, in this case, power 6 (sum of powers 2 and 4). The thematic notes in the treble will play at powers 14, 12 and 8 in order of playing; the two thematic notes in the bass will play at powers 14 and 8, thereby matching the dynamics of the thematic notes with which they are aligned. The dashed vertical line shows the division between bass and treble sides of the Duo-Art keyboard.

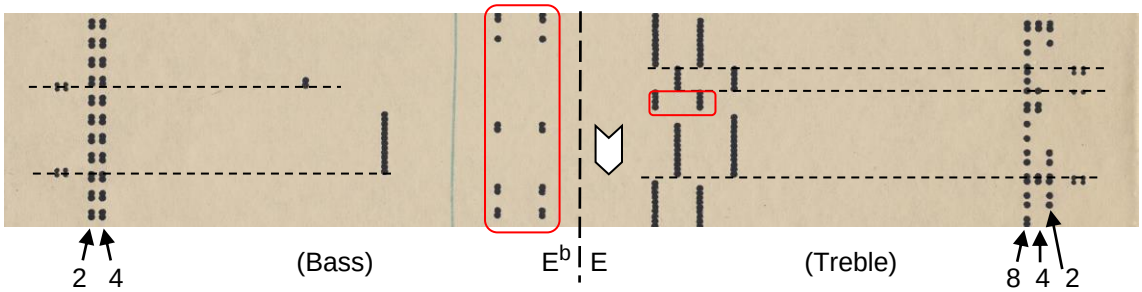

Figure 2.9 *A Duo-Art roll in which the 'snake bite' perforations cause the aligned notes to play at the dynamic level set by the expression on the treble side of the roll, circled notes play at the dynamic level set by the expression on the bass side*

Recording method

Photographs of the London and New York recording studios show a recording producer sitting at a console adjacent to the recording piano, his hands resting on two rotary dials, his attention focused on the pianist's playing. In a 1924 article in *The Gramophone*, Reginald Reynolds, recording producer for the Duo-Art London studio explained that

[270] Power 0 occurs when all four 'intensities' are turned off.

the recording piano was connected to a reiterating perforating machine that was acoustically isolated from the recording studio. He pointed out that the connection was achieved with "160 wires, half of them leading to specially devised contacts under the keys, the remainder running to positions near the point where the hammers strike the strings."[271] As he further explained: "The pianist plays—the punches perforate—the record is produced!"

The dynamics were also recorded by the perforator, in which the position of the two manually-operated dials controlled punches to perforate the various combinations of the four expression 'powers'. That is, the expression coding was largely determined during the recording process by a human interpreter with the skills to equate the position of the dials to the perceived dynamics of accompaniment and thematic notes. In some cases, the roll recording could be played back immediately, but further editing was always needed to add theme perforations, and fine-tune the expression coding.

The skill of the producer was therefore paramount in the process. As explained in Chapter 1 (page 80), these producers were W. Creary Woods (New York) and Reginald Reynolds (London), the London studio starting five years after rolls were first recorded in New York. Both these producers had excellent musical credentials, with the dynamic recording process largely pioneered by Woods, assisted by Lachmund. Prior to the London studio making recordings, Reynolds was sent to New York, where he learnt the process that Woods had developed. Some of the rolls produced in 1914, the first year of production, show it was to take some time before the process was perfected.

In a letter written in 1960, Woods explained that when asked to prepare some roll recordings for the yet-to-be-released Duo-Art, he found that the task of adding expression could be simplified by "cutting the expression into the rolls as the artist played."[272] This is despite a patent for a "tone volume recorder" having been issued to Aeolian employee Philip J. Meahl in 1912. Lawson suggests that the task of converting recorded dynamics was such a major part of the work, that despite having a means of recording them, it was preferable to use the manual dynamic recording system described by Reynolds.[273]

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[271] Reginald Reynolds, "A Note on the Technique of Recording," *The Gramophone*, (February 1924), reprinted in *The Pianola Journal*, no. 7 (1994), 36.
[272] Rex Lawson, "Duo-Art Roll Speeds and Recording Methods," *AMICA Bulletin*, vol. 33 no. 6 (November-December 1996), 299.
[273] Lawson, "Duo-Art Roll Speeds and Recording Methods," 299.

In a 1967 interview, Woods explained how he approached the task:

> The artist played at the recording piano while I sat at my desk. As he played, I traced his dynamics and phrasing, using a series of dials built into my desk with a musical score, previously prepared by the artist, before me. […] When the performance was over the roll was ready immediately for playing. Of course, my tracings were never completely accurate, no matter how many times the artist and I had gone over his conception of the piece beforehand. So we would spend long hours together, playing the roll over and over, changing inaccuracies in my dynamic indications […] and erasing the pianist's mistakes.[274]

According to researcher Joseph Van Riper, unlike Woods, Reynolds did not use a score when recording a pianist, instead he memorised it beforehand.[275] Reynolds explained that he also worked with the pianists:

> Fortunately, there is a means by which the 'Duo-Art' music roll can be edited under the supervision of the pianist, and every blemish easily and effectively removed, while omitted notes can be cut into their proper places; nor do the possibilities of editing end at note corrections; the touch itself and even the rhythm can be improved upon if the artist so desires.[276]

Pianists and producing their Duo-Art roll recordings

Aeolian promoted the concept that pianists worked on their Duo-Art recordings. In an article for the *Music Trade Review*, Woods wrote: "Heretofore no manufacturer has permitted an artist making records to 'correct' his records."[277] His article referred to "the great developments" that have resulted from "enlisting the cooperation of the artists," an oblique reference to Welte, where pianists were not part of the roll editing process. He explained that although the Duo-Art recording system "registers precisely the artist's performance," it was still necessary to further edit the recording, because "comparatively few [artists] are satisfied with their actual performance," concluding that "the artist is afforded unlimited possibilities to present his best work to a greater public."[278]

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[274] W. Creary Woods, "Interview," *High Fidelity*, (July 1967), reprinted in *AMICA Bulletin*, vol. 36 no. 1 (January-February 1999), 14.
[275] Joseph D. Van Riper, "The Reproducing Piano: A Portrait of the Artist" (DMA diss., Illinois State University, 2012), 125.
[276] Reynolds, "A Note on the Technique of Recording." 36.
[277] W. Creary Woods, "Regarding the Art of Reproducing," *Music Trade Review*, vol. 71 no. 24 (December 11, 1920), 57.
[278] Woods, *Music Trade Review*, vol. 71 no. 24 (December 11, 1920), 57.

In a promotional brochure for the Duo-Art, five high-ranking pianists give glowing accounts of the instrument. Hofmann's account— in the form a letter to the president of the company—refers to returning the first of "my completed Duo-Art rolls," then explaining that "the making of these rolls has required hard and painstaking work, and I have spent many hours on each different composition."[279] Reynolds pointed out that Hofmann insisted on editing his own roll recordings, taking considerable time to "obtain precisely the effects he desires."[280] Woods noted that Hofmann "(with his remarkable inventive ability) considers the making of Duo-Art recordings the most interesting work that he has undertaken."[281]

Grainger is featured by Aeolian in a 1916 photograph working with a Duo-Art editor,[282] and is regarded by his biographer John Bird as unique in that he insisted on editing his own rolls.[283] Other promotional photos show Godowsky assisting an editor. On editing his rolls, Prokofiev stressed "I always did that with great interest."[284] A Duo-Art advertisement shows Ganz and Woods editing a roll; the text quotes Ganz: "Thorough work in recording and editing may well bring the interpretation […] to the point where it challenges the artist's performance in the concert hall."[285]

Aeolian sought to create a new aesthetic. As Bauer put it in program notes for a Pianola concert: "This is a new art. When I finally sign the record-roll, it is more than simply my playing. It is my carefully considered artistic conception of the music. As such it is preserved—a new and wonderful form of musical creation."[286] Bauer explained that his editing involved "changing here the length of a note, there the strength of a tone—an accent." Bauer was referring to his roll recording of Chopin's Waltz Op. 42 in A flat, which was issued in 1915.[287]

In 2005, Stephen Husarick presented a paper describing how he derived a score of Horowitz's *Carmen* Variations by referring to Horowitz's sound recordings and a Duo-

[279] Aeolian Company promotional brochure held by the author.
[280] Patrick Handscombe and Terry Broadbent, *The London Duo-Art Pianists* (London: Player Piano Group, 2014), 123.
[281] Woods, *Music Trade Review*, vol. 71 no. 24, 57.
[282] *The Reproducing Piano – Duo-Art*, http://www.pianola.org/reproducing/reproducing_duo-art.cfm (accessed 16 March 2016).
[283]John Bird, *Percy Grainger*, new ed. (New York: Oxford University Press, 1999), 180.
[284] Handscombe and Broadbent, *The London Duo-Art Pianists*, 123.
[285] Smith and Howe, *The Welte-Mignon*, 117.
[286] Elste, "You Had to be Able to Play the Piano," 13.
[287] Duo-Art roll number 5635.

Art master roll of the work held by the University of Maryland, USA.[288] Husarick points out that the master roll contained "numerous editorial changes that affect transcription," such as doubled octaves to achieve a more technical brilliance. He also noted that some very difficult passages contained no editing at all.

Obenchain writes about Paderewski's Duo-Art rolls, explaining that Aeolian was concerned that Paderewski's hands did not play together, which was considered a serious flaw. So "Rudolph Ganz was assigned the near-impossible task of trying to get the hands to play together on Paderewski's Duo-Art rolls."[289] In a letter to the editor of the *AMICA Bulletin*, Ganz's wife Esther writes "I do recall his telling of correcting the Paderewski rolls – that he tried to get the two hands to play more simultaneously."[290] A following article, possibly written by the editor, makes the point that Paderewski had written on a Duo-Art master roll that "I cannot play these passages evenly; can you even them out for me?" When comparing Paderewski's Welte-Mignon recordings of the same works he recorded for the Duo-Art, such as Beethoven's Sonata Op. 27 No. 2, the Welte-Mignon recording of the first movement shows consistent dislocation between the accompaniment and thematic notes, while the Duo-Art recording has fewer examples of dislocation. A comparison of Paderewski's roll recordings of Liszt's transcription of Schubert's *Horch! Horch! die Lerch!* D.889 also shows fewer examples of dislocation in the Duo-Art recording compared to the Welte-Mignon recording. There are additional notes in some chords in the Duo-Art recording, although these could have been played by Paderewski.

Although Aeolian promoted the concept of pianists working with Duo-Art editors, the reality is probably more like the processes at Ampico, in which only some pianists worked with editors. For example, it is probable that Paderewski did not spend much time working with Duo-Art roll editors, given his status and commitments. If his recordings had been edited, which they appear to have been, presumably they met his approval. The extent of editorial involvement by pianists like Bauer and Grainger, who both made well over 50 recordings is also unlikely to be as extensive as the company

[288] Stephen Husarik, "Problems of Transcription, Fingering and Performance Practices in Vladimir Horowitz's Duo-Art Piano Roll Performance of *Carmen* Variations," *ESCOM Proceedings 2005*. http://www.escom.org/proceedings/ESCOM2005_Proceedings_Performance_Matters/html/pdf/StephenHusarik.pdf (accessed 13 September 2015).
[289] Obenchain, *Catalog*, 504.
[290] Esther Ganz, "Letter to Mr. Elfers, Editor," *AMICA Bulletin*, vol. 7 no. 7, July 1970, 1.

suggested. However, there is no doubt pianists were encouraged to participate in the editing process, and some would have been contractually obliged to do so.

Concerts and the Duo-Art

Aeolian, like Ampico, promoted the Duo-Art through concerts. One of the earliest of these took place on November 17, 1917 at Aeolian Hall, New York, involving the (then) New York Symphony Orchestra conducted by Walter Damrosch (1862–1950), and Bauer's Duo-Art roll recording of Saint-Saëns' Piano Concerto No. 2. This concert was clearly a promotional exercise, and full-page advertisements appeared in newspapers, such as the *New York Tribune*,[291] and advertorial commentary praising the event in trade magazines such as *Music Trade Review*.[292]

An unusual twist with these types of concerts occurred on January 14, 1920 at Carnegie Hall, New York. In the first half of this concert, Rudolph Ganz was the soloist in Liszt's Piano Concerto No. 2 with the New York Philharmonic Orchestra conducted by Josef Stránský (1872–1936). In the second half, the audience heard Ganz playing Liszt's Piano Concerto No. 1 from his Duo-Art recordings, while Ganz himself conducted the orchestra.[293]

In April 1921, during 'Music Week' in New York, Grainger was hired to perform before an audience of 5500 at the Capitol Picture Theatre. The concerts were held four times a day for a week, in which Grainger played the first movement of Tchaikovsky's Piano Concerto No. 1, accompanied by the Capitol Theatre Orchestra. On alternate concerts, Grainger's Duo-Art roll recording of the work provided the piano part on a concert grand Steinway fitted with a Duo-Art mechanism.[294] On January 31, 1924, Grainger appeared at Aeolian Hall playing the second part of some of his compositions, his Duo-Art recordings providing the first piano part.

Another key artist for the Duo-Art was Ignaz Friedman, who although not exclusive to Aeolian, made the bulk of his roll recordings for the instrument. In 1921, Friedman gave a two-piano program with himself and a Duo-Art reproducing piano, which was favourably reviewed by Deems Taylor who wrote that, to his surprise, on opening his

[291] "A Notable Presentation of a Notable Instrument," *New York Tribune* (November 25, 1917), 6, http://chroniclingamerica.loc.gov/lccn/sn83030214/1917-11-25/ed-1/seq-6.pdf (accessed 16 November 2016).
[292] *Music Trade Review*, vol. 65 no. 22 (December 1, 1917), 42.
[293] "Ganz Appears in Dual Role at Duo-Art Concert," *Music Trade Review*, vol. 70 no. 4 (January 24, 1920), 79.

eyes to see whether it was Friedman or the Duo-Art playing: "There sat Friedman with his hands in his lap […] while that confounded player-piano thundered away by itself with the very touch and tone of its human instigator." It must also be said that Aeolian paid Taylor for his reviews.[295]

Like the American Piano Company, Aeolian held numerous comparison concerts around the US. At the time, press reviews often spoke of the paranormal aspects surrounding these concerts. A review in the *Pittsburgh Post* of a concert involving Bauer's Duo-Art rolls and the Detroit Symphony Orchestra starts with "We are hearing a good deal about spiritism [sic] in these material days and we are searching betimes about psychic phenomena, the phantoms of the dead and the phantasy [sic] of life. Last night at the Mosque we beheld a miracle of transubstantiation."[296]

Regardless of the hyperbole surrounding these concerts, there is little doubt the piano rolls and the Duo-Art reproducing pianos acquitted themselves admirably, to the point where reviewers, whether sponsored or otherwise, spoke glowingly and sometimes with a sense of hushed awe. As mentioned previously when discussing Ampico, I have never found a review of any of these concerts that condemns them or speaks poorly of the reproducing pianos. My own experiences prove (to me) that under the right conditions, a reproducing piano roll can match the performance of a live pianist. That is, sponsored or not, reviewers were often truly impressed, and rightly so.

Tempo markings on Duo-Art rolls

Duo-Art rolls, like Ampico and De Luxe rolls have the playing tempo stamped on the roll. In the case of Duo-Art rolls, I have encountered a number of cases where the stamped tempo differs between issues of the roll. An unusual example concerns the 1914 recording by Zadora of Chopin's Berceuse Op. 57, issued on Duo-Art roll 5597 in late 1914. Over the time it remained in the catalogue, this roll was issued with at least three different tempo markings, namely 65, 80 and 95, as observed from original rolls. The playing times range from 3:26 to 4:10.

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[294] Bird, *Percy Grainger*, 196.
[295] Allen Evans, *Ignaz Friedman - Romantic Master Pianist* (Bloomington: Indiana University Press, 2009), 104.
[296] "Duo-Art and Detroit Symphony Orchestra Concert," *Music Trade Review*, vol. 70 no. 7 (February 14, 1920), 18.

Another example concerns Duo-Art roll 5696,[297] which was issued in November 1915. I have noted two issues of this roll with different tempo markings, one at tempo 80, another earlier issue marked at tempo 90. A confusing aspect is that the roll marked at tempo 90 takes thirteen seconds longer to play than the roll with the slower tempo of 80. An examination of both rolls shows the recording is identical except for the length of the perforations.

Rolls issued in the UK sometimes had a different tempo marking to the same roll issued in the US. Cortot's recording of Fauré's Berceuse Op. 56 No. 1 appeared on two Audiographic rolls, one for the US that was marked with a tempo of 80, the other for the UK market with a tempo of 70. Rudolph Reuter's (1888–1953) recording of Tchaikovsky's Humoresque Op. 10 No. 2 was issued on two types of Audiographic rolls, one stamped at tempo 100, the other tempo 85.

Denis Hall notes a number of instances concerning Duo-Art roll tempo markings. Concerning Paderewski's recording of Chopin's Etude Op. 25 No. 9 on Duo-Art roll 6097, Hall notes that the roll is marked at tempo 90, but the playing seems too fast when compared to Paderewski's 1905 Welte-Mignon roll recording and his 1924 Victor disc recording of the same work. He found that if the roll was played at tempo 80, it had the same playing time as the other two recordings.[298]

Hall also compared the tempo markings of trial rolls held by the University of Maryland of a recording made by Cherkassky,[299] in which the initial recording was marked tempo 80, which was later changed to 85, and finally to 90, which is the tempo of the issued roll. Hall remarks that at tempo 90, the roll sounds impossibly fast and not like Cherkassky.[300] Duo-Art roll tempo indications are obviously questionable, more so than other brands of rolls.

Acceleration and take-up spool diameter

It is generally believed that the paper transport system in the recording perforator involved a take-up spool rotating at a constant speed. That is, the paper feed geometry was similar to that used by Ampico and Welte in their recording equipment. Reynolds refers to the note paper passing "through the recording machine at a uniform speed

[297] *Samson et Delilah* Improvisation, composed and played by Saint-Saëns.
[298] Hall, "Piano Roll Speeds," 6.
[299] Roll number 7130, *Paraphrase de concert sur Rigoletto*, S.434 by Verdi-Liszt, played by Shura Cherkassky.
[300] Hall, "Piano Roll Speeds," 6.

(usually 8 feet in one minute)." He also states that "when the music roll is placed upon a Duo-Art piano, and caused to play at the same speed, there must result an exact reproduction of all the most subtle nuances of rhythm."[301] These subtleties could not be realised if the original recording was made by passing the note paper through the perforator at a constant speed, then playing it on an instrument where the paper speed accelerates. When mentioning 'uniform speed', Reynolds is probably referring to the motor driving the take-up spool, not the paper speed.

An unknown is the diameter of the take-up spool used in the recording perforator. To find an answer, Lawson took measurements of the length of a slot of 40 punches at various points along the length of a number of rolls cut on the London studio's recording perforator. He concluded from his measurements that the take-up spool used in the recording perforator had a six-inch circumference (diameter of 48.3 mm or 1.90 inches), which is the same size as the spool used in the Duo-Art.[302]

Lawson's evidence is convincing, but I was to find that when an electric roll drive motor was used to drive a 48.3 mm diameter take-up spool, the music on long duration Duo-Art rolls accelerated by a noticeable amount. Lawson claimed to have established that the two Duo-Art air motors he checked maintained their rotational speed under all typical playing conditions.[303] Interestingly, in 1935, Aeolian produced a 'new' Duo-Art that had an identical roll transport system to that used in the model B Ampico, with a large diameter take-up spool and an electric roll drive motor.[304]

By applying a different arithmetic approach to that used by Lawson, I found that Lawson's measurements were giving inconsistent figures concerning the diameter of the take-up spool. When using one set of Lawson's measurements and calculating the percentage changes in spool circumference and comparing these values to the percentage changes in the length of the 40-punch perforation at particular distances, I calculated a spool diameter of 45.5 mm (1.79 inches, circumference of 5.63 inches). Using another set of Lawson's measurements on the same basis gave a spool diameter of 54 mm (2.13 inches, circumference of 6.68 inches). That is, the measurements taken by Lawson were too inconsistent to verify his conclusion concerning the diameter of the take-up spool.

[301] Reynolds, "A Note on the Technique of Recording," 36.
[302] Lawson, "Duo-Art Roll Speeds and Recording Methods," 296.
[303] Lawson, "Duo-Art Roll Speeds and Recording Methods," 294.
[304] Bowers, *Encyclopedia of Automatic Musical Instruments*, 295.

The musical acceleration I found to be occurring when using the smaller six-inch circumference spool was not detectable with a larger size spool (8.5-inch circumference). Nor did I detect musical deceleration. Lawson's evidence must, however, be considered, despite the variations in spool diameter as calculated from his measurements.

Table 2.3 shows the tempo variations that can occur with the two sizes of take-up spool being discussed. The 1935 Duo-Art was the only instrument that used the larger spool. It may be that a different size take-up spool to those given in the table was used in the recording perforator, perhaps with a diameter somewhere between those used in the earlier and 1935 models of the Duo-Art.

Table 2.3 *Tempo changes during play for a roll tempo of eight feet per minute*

Duo-Art take-up spool diameter		**Recording perforator take-up spool diameter**	
		48.3 mm	*69 mm*
48.3 mm Acceleration after:	*24 feet (3 mins)*	0	6.9%
	48 feet (6 mins)	0	12.9%
69 mm Acceleration after:	*24 feet (3 mins)*	-6.9%	0
	48 feet (6 mins)	-12.9%	0

The figures show that an acceleration or deceleration of around thirteen percent occurs after about six minutes of playing (roll tempo 80) if the spool sizes in the perforator and the Duo-Art are not the same. If the diameter of the spool in the perforator was somewhere between those given in the table, the acceleration and deceleration figures would be correspondingly smaller.

In my opinion, small diameter take-up spools were used in reproducing pianos that were equipped to play standard player rolls for consistency with the spool size in standard player pianos. The acceleration that would occur when a reproducing piano roll was played would, in some cases, be offset by the roll drive motor slowing due to the change in torque as the roll neared the end.

Duo-Art roll production

The methods used by Aeolian to produce Duo-Art rolls were similar to those used by Ampico, except a perforated version of the performance was created during the recording, whereas for Ampico and Welte, a note sheet was created that had to be perforated manually for use in later stages of production. As Martin Elste explains, the perforator cutting a Duo-Art recording operated at a rate of 4,000 punches per minute, or at a frequency of nearly 67 Hz. For a paper speed of eight feet per minute (or 1.6 inches per second), the punching resolution gives a minimum time between notes of 0.023 seconds or 23 milliseconds (1.6 divided by 67).[305]

The London recording perforator is said to have operated at a lower frequency of 3,600[306] or 3,400[307] punches per minute, perhaps due to the difference in the frequency of the British and American electrical systems. If so, the punching resolution is less accurate at 26 milliseconds (or 28 milliseconds), assuming the same paper speed.

Production rolls were cut at two step-rates of 21 steps per inch and, sometime later, at 31.5 steps per inch.[308] The perforator punch frequency was 67 Hz in the New York studio, and, in the London studio, either 60Hz or 57 Hz. Table 2.4 summarises the timing resolution for various roll paper speeds and perforator step rates, and compares these values with the timing resolution of the recording perforators used in the New York and London studios. Because it was operating at a fixed frequency, the resolution of the recording perforator becomes coarser as the paper speed is increased. In many cases, the resolution of the recording perforator was not as fine as that of production perforators, an effect that was more problematic for the London studio.

Table 2.4 *Timing resolution–recording and production perforators*

Step rate in steps per inch (production perforator)	**Timing resolution**				
	7	8	9	10	Paper speed in feet per minute
21	33.5	29.3	26.1	23.4	Resolution (milliseconds)
31.5	22.6	19.8	17.6	15.8	
Recording perforator (67 & 57 HZ)	21 & 25	24 & 28	27 & 32	30 & 35	Resolution US & UK (milliseconds)

[305] Elste, "You Had to be Able to Play the Piano," 123.
[306] *The Reproducing Piano – Duo-Art*, http://www.pianola.org/reproducing/reproducing_duo-art.cfm (accessed 18 March 2016).
[307] Lawson "Duo-Art Roll Speeds and Recording Methods," 298.
[308] Lawson "Duo-Art Roll Speeds and Recording Methods," 295.

The roll made by the recording perforator was called the 'original' and would be edited to an extent and marked up for production of a second proof copy. Markings included locations for theme perforations, changes to expression perforations, and note edits. The next copy included the edits, giving a trial copy for closer evaluation.[309] Production masters had sprocket holes either side (pattern rolls) and were initially twice the length of the production roll, later three times as long (three-to-one mastering).

Duo-Art expression behaviour

To investigate the behaviour of Duo-Art expression, I used third-party expression decoding software.[310] Although the expression system appears simple with its sixteen intensity levels, I found that editors appeared to take advantage of the slow response time of the expression regulators. The time taken for a Duo-Art suction regulator to change from a low dynamic value to a higher value is generally consistent and could be taken into account by reading the expression coding before the targeted notes.

As detailed in Chapter 4, the response time for a Duo-Art regulator to change from a high dynamic level to a lower level depends on the number of notes being played at the time. That is, the greater the number of notes, the more rapid the change in dynamic level. This effect would have been understood by Duo-Art editors. Figure 2.10 gives an example of creating a subtle crescendo or decrescendo.[311]

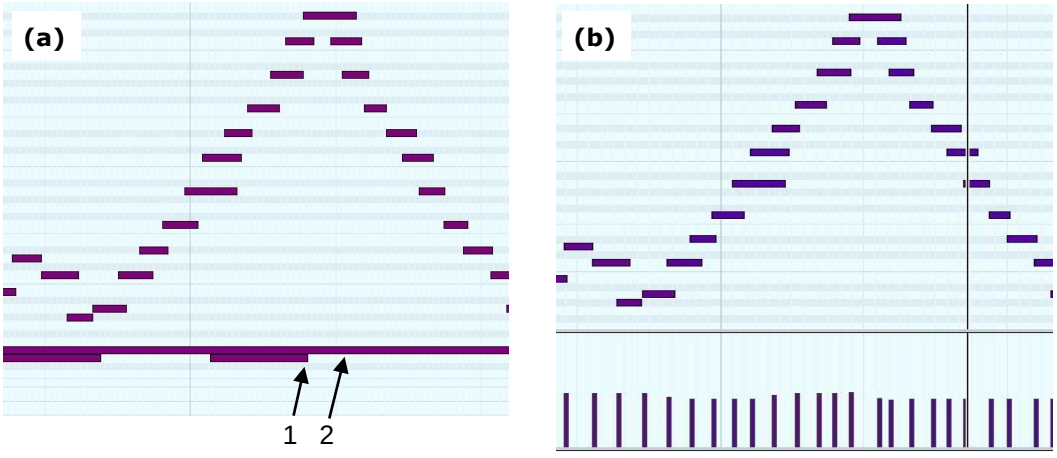

Figure 2.10 (a) *Duo-Art roll showing the expression coding,* ***(b)*** *effects of expression coding on a series of notes, showing a subtle crescendo and decrescendo*

[309] Van Riper, "The Reproducing Piano: A Portrait of the Artist," 128-33.
[310] *Windplay*, written by Richard Brandle (Texas, 1998), analysed in Chapter 4.
[311] MIDI files in Figures 2.10 and 2.11 were produced by the author as explained in Chapters 3 and 4.

The image in Figure 2.10 (a) is of a Duo-Art roll as a MIDI file, where the expression coding applied over the sequence of notes is simply a combination of powers 1 and 2. The image in (b) shows the notes and their MIDI velocity value, depicted by the vertical lines at the bottom of the image. Because the regulator cannot change instantly, a subtle decrescendo and crescendo is produced rather than an instant change in velocity level.

Duo-Art editors also exploited the slow response of the theme regulator by changing the expression coding just prior to the required note. Figure 2.11 (a) shows a section of a Duo-Art roll as a MIDI file in which the dotted lines show the alignment of bass side theme perforations, the notes to be accented, and the expression coding occurring at the time. In all cases, the expression is using powers 2 and 4, but power 4 is switched off at different positions relative to the start of the notes. The effect is shown in Figure 2.11 (b), in which thematic notes have different MIDI velocity values ranging from 69 to 73.

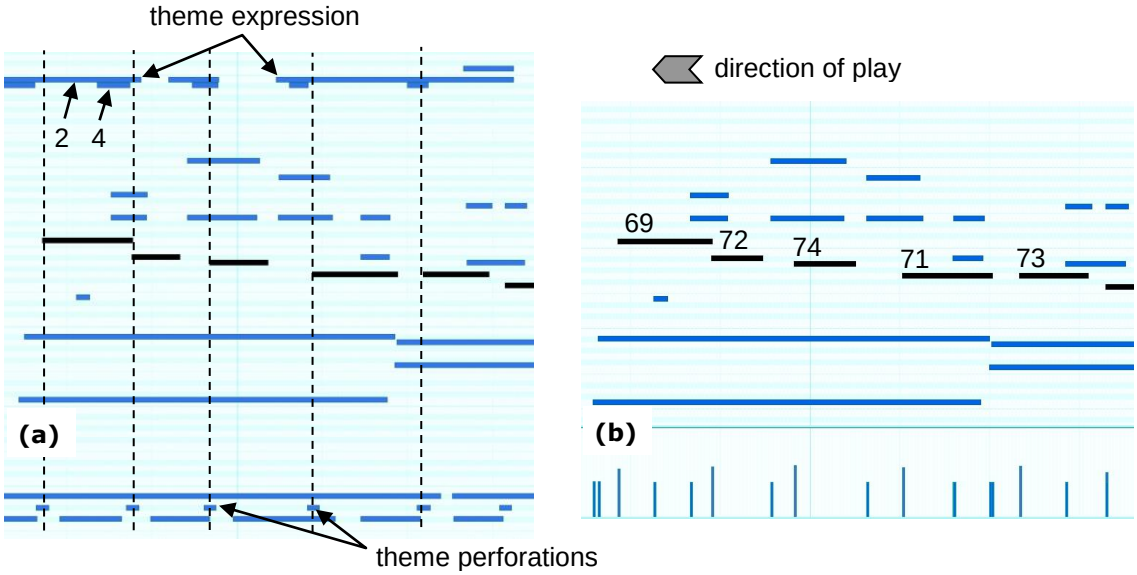

Figure 2.11 (a) *MIDI file of Duo-Art roll showing theme perforations, aligned notes and applicable expression coding,* ***(b)*** *thematic notes all have a different MIDI velocity values as a result of switching power 4 off at differing times relative to the start of the note*

These examples demonstrate that while Duo-Art expression coding looks simple, a range of dynamic effects could be created that relied on the way the Duo-Art expression regulators behaved. My examination of many Duo-Art rolls as MIDI files has shown that editors often used the techniques shown in Figures 2.10 and 2.11, proving that Duo-

Art expression has far more than sixteen steps of loudness. It must have been an exacting task, requiring many hours to achieve, but built upon the expression coding determined by the producer during the recording.

The soft pedal was often used to create expressive effects, such as holding the pedal on during accompaniment notes and releasing it briefly so thematic notes would be louder. In some cases, the soft pedal is operating nearly as often as the damper pedal, which suits pianos with a half-blow soft pedal action. Few Duo-Art instruments were fitted with an *una corda* soft pedal, which would operate more sluggishly and might not always recreate some of the effects.

Summary

The methods used to produce Duo-Art roll recordings are similar to those used by Ampico until 1926, in that human interpreters determined the dynamics of a recording. Both companies invited or obliged their artists to participate in editing their recordings, however unlike Ampico, Aeolian used pianist involvement as a promotional tool. Early publicity material suggests that pianists did most of the actual editing, although it is more likely that pianists advised editors.

The company's publicity made it clear that Duo-Art recordings were not only edited, but were improved. The added octave notes to Horowitz's recording of *Carmen* Variations referred to by Husarick is an example. It may be that Horowitz sanctioned or suggested the additional notes, but it is more likely an editor added the notes without deference to Horowitz. The apparent alterations to Paderewski's recordings are a further example of editing beyond simply tidying up a performance.

On the other hand, Hofmann is said to have edited all his rolls himself. Hofmann was granted, among many patents, US patent 1614984 in 1927 for an invention to record piano dynamics,[312] so he would therefore have understood Duo-Art expression coding and how the roll perforations could be manipulated. Grainger and some other artists might also have understood the technology, and therefore would have known what could be done to bring their recordings to a high standard of reproduction.

Because Duo-Art rolls are acknowledged by the company as being edited, the suspicion is that they are no longer true to the artist. Certainly, there are examples of

[312] Josef Hofmann, *Recorder for Musical Dynamics*, http://www.google.com/patents/US1614984 (accessed 13 March 2016).

recordings with additional notes to enhance tone, such as filling out a chord or adding an octave note. On the other hand, in most cases editing appears to have been limited to changing some notes in terms of length and alignment, tweaking the dynamics and rearranging notes in a short passage to achieve a different rhythm. Similar editing was applied to Ampico rolls, because piano roll technology at the time did not support gross changes to a performance. Neither Woods nor Reynolds mention having pianists repeat particular passages, instead it appears a recording would be made as a whole, perhaps repeated in its entirety as the pianist might wish.

Welte and Ampico made high-resolution recordings of their artists, with production rolls quantised by the step rate of the production perforator. Duo-Art recordings were quantised to start with by the recording perforator, and then later quantised at a different rate during production. The London studio had the greatest conflict between step rates due to the lower operating frequency of the recording perforator.

In their summary of the capabilities of the Duo-Art, Handscombe and Broadbent conclude that in New York, the quality of the editing constantly improved, so that by the late 1920s, rolls embodied "remarkable, life-like performances entirely characteristic of the pianists, with nuances equal to those heard on contemporary gramophone records."[313] The authors are not so enthused about the London recordings: "Surprisingly Reynolds, a somewhat impatient perfectionist, was not perhaps entirely sympathetic with the Duo-Art, and many of the rolls he edited sound indifferent."[314]

Conclusion

Duo-Art rolls, like those for the Ampico were edited to give the best reproduction, where some of the editorial changes may also have modified the original performance. If pianists were responsible for changes to their recordings, it could be argued that these were appropriate. The extent editors made changes to a performance without a pianist's approval or involvement is not known.

As a form of recording, Duo-Art rolls offer a documentation that presents notable pianists at their best. When I compare disc and Duo-Art roll recordings made by pianists such as Grainger, I find little difference between them. Roll recordings by Hofmann and Prokofiev were edited by the pianists themselves, so these recordings can be seen as accurate to the pianist's wishes.

[313] Handscombe and Broadbent, *The London Duo-Art Pianists*, 123.
[314] Handscombe and Broadbent, *The London Duo-Art Pianists*, 123.

Chapter summary

The technologies used by the companies to record their artists are similar, in that each system recorded pitches and rhythms with an accuracy often commensurate with modern keyboard recording techniques. The note data on production rolls is quantised, but often so finely that the effect is musically insignificant. Welte-Mignon rolls are quantised to a spacing of less than ten milliseconds, although early Ampico and Duo-Art rolls have a spacing that exceeds 30 milliseconds.

The dynamics of a performance were established either by measurement or by human judgement. Welte had a means of recording dynamics, and relied on the recorded data to produce each recording without the pianist's participation. Ampico and Aeolian encouraged or obliged their artists to help produce their recordings, for which the dynamics were determined initially by a musically-trained editor/producer.

Pedalling techniques such as flutter pedalling or half-pedalling were not recorded. Ampico claimed that by extending notes, pedal effects could be recreated, and there are suggestions (not proved) that Ampico recorded *sostenuto* pedal operations and the speed at which the damper pedal was operated. Hofmann, who wrote about pedalling,[315] and who edited his own Duo-Art rolls, must have been satisfied with how the rolls reproduced his pedalling.

The company philosophies were different. For Welte, it was preserving the art of the pianists as faithfully as possible. Ampico and Aeolian were more commercial, and rolls were often edited to enhance a performance, sometimes under guidance of the pianists. The three companies did not make a profit from producing rolls, instead the rolls were to sell reproducing pianos to a discerning market. Prospective purchasers may well have attended recitals by some of the artists available on piano roll recordings. Therefore, if these recordings were significantly different to how the artist sounded in concert, complaints would have been made. For example, Nyiregyházi's first Ampico recording was issued in November 1920.[316] This recording nearly ended his Ampico career, as the company received numerous complaints that "Nyiregyházi's interpretation often strayed from Sinding's score."[317]

[315] Josef Hofmann, *Piano Playing: With Piano Questions Answered* (New York: Dover Publications, 1976), 41.
[316] Christian Sinding, Prelude Op. 34 No. 1, roll number 60131H.
[317] Bazzana. *Lost Genius*, 107.

Chapter conclusion

The invention of the reproducing piano was a milestone in the development of high fidelity audio.[318] It is the fidelity that allows us to hear so much of a performance, although it can also expose the shortcomings of piano roll recordings. Dynamic nuances and touch effects such as holding keys near the point of escapement were not recorded, nor were pedalling effects involving complex movements of the damper pedal. The reproduction of the expression coding of a piano roll depends on the reproducing piano, making it impossible to know exactly how loudly or softly a pianist actually played.

Despite their shortcomings, much of the original recording remains, in particular pitches and rhythms. Dynamics and pedalling, while not precise, are often close enough to allow a full appreciation of the performance, and to gauge the individualities of the pianists. Editing to the extent of changing a performance was certainly practiced, at least by Ampico and Aeolian. However, in most cases, editing was aimed at bringing a roll recording to a state where it best reproduced a pianist's playing.

The challenge is achieving the best reproduction from piano roll recordings. As a form of recording, they store the same information as standard MIDI files. There is no doubt that piano roll recordings are an important resource, as, despite their limitations, they offer a high-fidelity pathway into an historic, musical past, shared only by a relatively small number of early sound recordings.

[318] *The Denis Condon Collection*, http://efemera-ephemera.org/CondonCollection/indexx.html (accessed 17 March 2016).

Chapter 3 – Archiving piano rolls

Overview

The importance of piano rolls as an historical musical resource has been established in the first two chapters. This chapter discusses methods of archiving piano rolls, a topic that does not appear to have been addressed in academic literature. Unlike a piano roll recording, sound recordings made on a disc or cylinder are complete in themselves, requiring only that the replay device traces the grooves etched into the medium.

A piano roll can be described as a data sheet. The performance data is created when the piano roll is 'read' by the pneumatic interface associated with a pneumatic player piano. The pneumatic signals from the interface operate the notes, pedals and control the expression regulators in the instrument. The piano roll 'data' (perforations on the roll) and piano roll 'performance data' (pneumatic signals) differ in many respects, as later explained. Therefore, when discussing methods of archiving piano rolls, two aspects have to be considered: archiving the roll as a data sheet, and archiving the performance recorded on the roll.

An archive of a piano roll should ideally result in its greater accessibility, as has been the case with early sound recordings. In recent years, enthusiasts have developed methods that use MIDI technology to produce accurate reproductions of existing rolls. The methods used are discussed, as it could be argued that this is the fundamental way of archiving a piano roll, even if it can only be played on an original reproducing piano.

The issue of accessibility is very important. Photo imaging offers a means of storing an image of an entire roll as a computer file, giving ready visual access to all parts of the roll. Accessibility to piano roll recordings can be achieved by transferring the performance recorded on a piano roll to a MIDI file. Chapter 2 showed that a MIDI file and a piano roll have great similarity.

Mention has been made of piano roll 'data' and piano roll 'performance data'. Both can be archived as MIDI files, and both have specific applications. I refer to these two types of piano roll MIDI files as 'data files' and 'performance files'. The focus of my research has been about producing performance files, which is the main topic of this chapter. Also discussed are archiving technologies that others have created, or are developing. The concept of converting roll perforations to electronic data has attracted a number of experimenters, and considerable progress has been made in recent years.

Optical technologies and piano roll data

The concept of reading piano roll perforations using an optical system has a history dating to the 1970s, possibly earlier. An early method involved small light-sensitive components called photodiodes. These were small enough to be fitted into a player piano's tracker bar, such that roll perforations during playing would expose the uncovered photodiodes to a light source, thereby producing an electrical signal. This implementation suffered from light source variations and insufficient sensitivity to differentiate between slightly transparent paper and perforations. Although generally unsuccessful, it was a forerunner to adapting the technology used in optical document scanners. The advent of digital cameras has provided another means of capturing piano roll data using optical technology.

Roll scanning

In early 2001, Richard Stibbons in the UK established an internet-based group of like-minded enthusiasts.[319] Stibbons promoted the use of a Contact Image Sensor (CIS) of the type used in flatbed scanners. Hence the term 'roll scanning'. When Stibbons published the construction details of a roll scanner, numerous people took up the challenge and began offering MIDI files of piano rolls over the internet.

In principle, a roll is arranged to pass over a scanning element, and is driven by a stepper motor which advances the roll a specific distance per step. A monochrome image of the roll and the matrix data related to the step distance are stored in a computer.[320] Software converts the image data to a MIDI file, in which dark spots are identified as notes and timing is derived from the matrix data.

Early roll scanners suffered from a range of problems, later designs have brought about needed improvements. Today, those who produce recut piano rolls use a roll scanning system to create MIDI files of the roll data to operate a MIDI-controlled perforator. Stahnke and others have developed software that can make corrections to the MIDI data file by aligning perforations to the correct row, or matrix position.[321] Alignment errors occur due to problems with the roll that is being scanned, or the scanning process itself.

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[319] *Mechanical Music Preservationists* (IAMPP), https://groups.yahoo.com/neo/groups/Rollscanners/info (accessed 2 July 2016).
[320] Matrix refers to the distance between perforator punch steps and can be visualised as a series of lines drawn across a piano roll to show the separation between individual punches in each track.
[321] Wayne Stahnke, *Copying Music Rolls Hole for Hole*, http://www.waterex.com.au/player/copying.html (accessed 5 July 2016).

Issues related to roll scanning

My examination of piano roll MIDI files produced with roll scanning technology has identified a range of problems, although the problems do not apply to all scanned files. A common error is misinterpretation of chain perforations, which is a long perforation with bridges between punches to give strength to the paper. In some instances, chain perforations have been interpreted as a series of repeating notes, in others, repeating notes are interpreted as a chain perforation. Other examples include MIDI files with missing expression data, note data with obvious timing errors, and extra notes caused by dark spots on the roll being interpreted as a perforation. These issues have been noted in scanned MIDI files produced by a number of enthusiasts, and also in files that are commercially available.[322]

The interpreting software needs to accurately determine the start and end times of each perforation, which can be difficult if the image is blurred or if perforations have a ragged cut. This can account for misaligned notes in the MIDI file. Although roll scanning technology has generally matured, the need for post-editing each MIDI file remains a necessity.

The accuracy of a MIDI file of roll data can be determined by comparing the recut roll and the roll used to make the MIDI file, which might be done by laying one copy over the other. A comparison, however achieved, of the recut roll and the original roll is the only form of feedback available to confirm accuracy.

Roll imaging

The use of a digital camera to capture roll data is a developing technology. In 2013, a group associated with the University of Pavia in Italy published a short description of a system they had developed that involved a special type of digital camera linked to a computerised roll transport system. Referred to as the SISAR project, the writers explain that the technology can be used to create image files and MIDI files of any form of linear media, such as piano rolls and organ books.[323] Stanford University is constructing an imaging system based on technology developed by UK software engineer Anthony Robinson.[324]

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[322] Files were obtained from http://www.spencerserolls.com/ (accessed 5 December 2016).
[323] Flavio Pedrazzini, Matteo Malosio and Niccolò Perego, *SISAR Project*, https://sites.google.com/site/wwwammilab/projects/sisar (accessed 28 April 2016).
[324] Stanford University Libraries, *About the [Player Piano] Project*, https://library.stanford.edu/projects/player-piano-project/about-project (accessed 30 October 2016).

Roll imaging that captures all aspects of a piano roll is an important part of archiving piano rolls, as the process can archive in visual form the text and drawings found on rolls such as Aeolian's Audiographic series,[325] as well as the placement of perforations. A roll scanner does not produce an image file of this type. A computerised image of the entire length of a piano roll would obviously have a large file size, but it provides a very convenient means of examining a piano roll.

The main purpose of developing roll imaging systems has been to produce MIDI files of the data stored on linear media. In principle, software detects each perforation and converts it to MIDI data, in a similar way to roll scanning software. Although my experience with roll imaging is limited, it is clear that this technology has advantages compared to roll scanning technology.

Performance data and roll data

MIDI files produced by roll scanning or imaging are of the roll data. As later explained, a performance file differs in vital respects to a roll data file, and can be obtained in various ways. A method used by Denis Condon involved a number of pneumatic push-up players playing a Disklavier that recorded the piano roll performances. Condon's method, while reliant on the adjustments and operation of the pneumatic players, produces a performance file that can be played on any standard MIDI piano. This is because the Disklavier recording system converts the dynamics of the playing to MIDI velocity codes, the notes to MIDI note codes and pedal data to MIDI control codes.

MIDI files made using a push-up player can only be an interpretation of the roll recording, as the same roll played on another pneumatic push-up player might produce different dynamics. An archival-quality performance MIDI file of a piano roll must therefore contain data representing all the roll perforations without interpretation. This type of file can be played on a MIDI-equipped original instrument, in which a reproducing piano is fitted with a number of electrically-operated valves that open and close in accordance with the applied MIDI signal, thereby operating the player mechanism as if from a roll. The MIDI data must therefore represent all the roll perforations as notes, not as control or velocity codes.

[325] Audiographic rolls are described in Chapter 1 on page 71.

Definitions

The three types of MIDI files of piano rolls that have been referred to are defined below using terminology based on general usage among those working in this field.

- Raw performance MIDI file – for playing only on a MIDI-equipped reproducing piano of the same brand as the roll. All perforations are captured as MIDI notes with durations and timings identical to those a roll would produce when played on the instrument.
- E-roll data MIDI file – in which all perforations as they appear on the roll are captured as MIDI notes, giving an electronic replica of the roll; the type of file used in roll duplication.
- Standard MIDI file – a recording of a piano performance for playing on a standard MIDI instrument.

The differences between an e-roll data file and a raw performance file can only be appreciated, as I was to find, by understanding certain aspects of player piano technology, in particular the operating characteristics of the pneumatic valves that respond to roll perforations.

Player piano technology

The motive power of a pneumatic player piano is provided by a vacuum pump, such as a vacuum cleaner. The pump in a standard player piano is foot-impelled, typically motor-driven in a reproducing piano. A device called a ‘pneumatic’ is fitted under each key of the piano. A pneumatic consists of two rectangular sections of thin timber, hinged at one end and covered with air-tight cloth to form a bellows. When the air inside the pneumatic is removed by suction, atmospheric pressure causes the pneumatic to close, thereby pushing the piano key and making the note play. When the suction source is removed, atmospheric air flows into the pneumatic, causing it to open and release the piano key. The action of connecting a pneumatic to either suction or atmosphere is achieved with a pneumatic valve which is operated by piano roll perforations.

Figures 3.1 and 3.2 show the operating principle of a player piano. The drawings show that the main parts are a tracker bar,[326] a valve and a pneumatic, with interconnecting tubes. The applied suction creates a partial vacuum (or low pressure) in the areas shaded light blue. In Figure 3.1, the roll is covering the note hole in the tracker bar, the valve is closed, the pneumatic is open because it is connected to atmosphere, and the piano key is at rest.

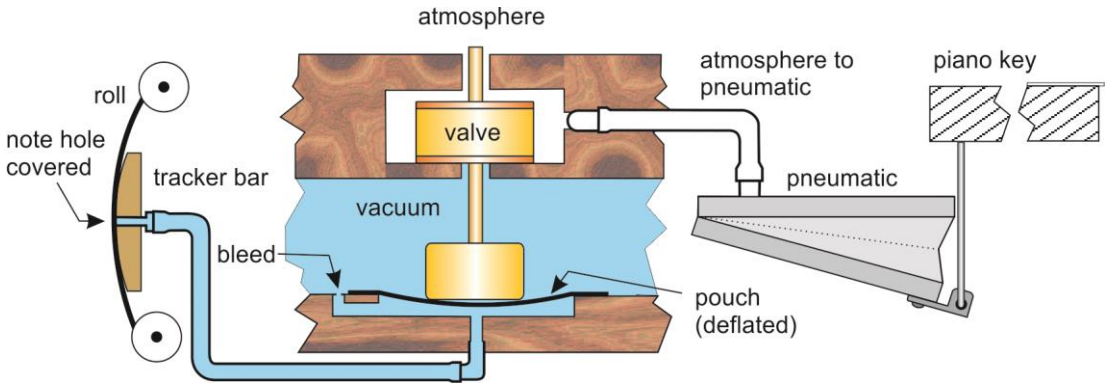

Figure 3.1 *Basic components in a player piano, shown when the note is at rest*

The valve is closed in Figure 3.1 because of the small hole called a 'bleed' that links both sides of the pouch,[327] which is usually made of thin leather or an airtight product called zephyr skin. Because the roll paper is covering the hole in the tracker bar, the vacuum present in the chamber exists equally on both sides of the pouch. Therefore the pouch is deflated and the valve is placed to allow atmosphere into the pneumatic.

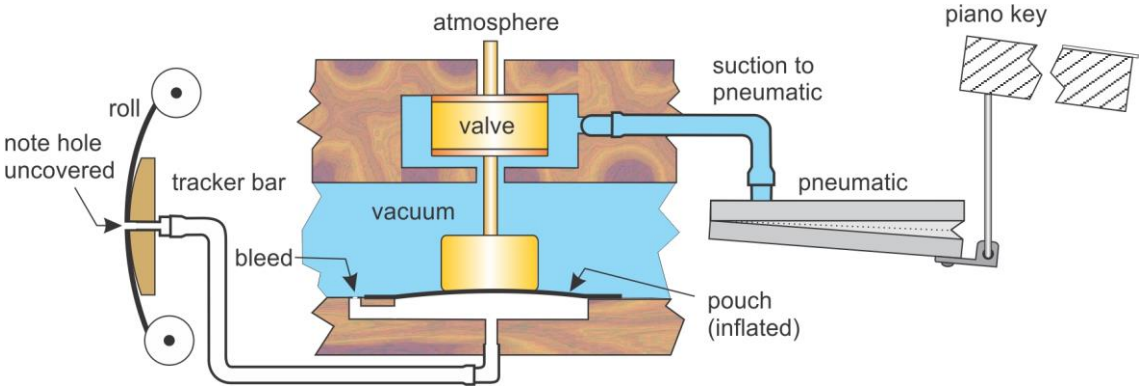

Figure 3.2 *The pressure difference either side of the pouch causes it to lift and allow suction through to the pneumatic*

[326] Definition of a tracker bar is given on page 12.
[327] The term 'pouch' is used in lieu of the term 'diaphragm' when discussing player piano valves.

As shown in Figure 3.2, when a perforation uncovers the tracker bar hole, atmosphere is admitted to the underside of the pouch. The suction on the top of the pouch causes it to inflate, which lifts the valve and connects the pneumatic to the suction source, causing the pneumatic to close, making the note sound.

Pneumatic valve characteristics

The operation of a pneumatic valve is seemingly quite simple, but it was found to be more complex when a number of experimental models were analysed by way of various tests.[328] One test was aimed at measuring the time a valve was operated when a single punch perforation was passed over a tracker bar at a predetermined speed. Another test sought to examine the behaviour of a pneumatic valve under different operating conditions, such as roll paper speed and applied suction level. The findings show that the time a valve is open (pouch inflated) depends on the:

1. applied suction
2. speed at which a tracker bar hole is opened
3. size of the bleed (including the porosity of the pouch material)
4. weight of the valve.

In a reproducing piano, the suction level varies over a wide range and is determined by the expression coding on the roll. It was found that increasing the suction level caused the valve to turn on sooner and turn off later compared to a lower suction level, giving a longer on-time. It was also found that, at low suction levels, the speed at which a tracker bar hole is uncovered affects the on-time of the valve. A slow paper speed when compared to a faster speed required a greater amount of the tracker bar hole to be uncovered before the valve would operate, giving a shorter on-time.

Factors 3 and 4 are part of the design of the valve. The size of the bleed hole is critical to the operation of the valve. The smaller the bleed hole, the smaller the amount of the tracker bar hole that must be uncovered before the valve operates. If the bleed size is too small, the valve will remain operated after a perforation has passed. A large bleed size requires more of the tracker bar hole to be uncovered before the valve operates, and causes the valve to turn off well before the perforation has passed, giving a short on-time. If the pouch material is slightly porous, the effective size of the bleed is increased and under conditions of low suction, the valve may fail to operate.

[328] Tests carried out using equipment described further on in this chapter.

The variables associated with a pneumatic valve are not typically accounted for in piano rolls, as the timing differences that occur are generally not musically obvious. The important fact is that a pneumatic valve is held on for a time that exceeds the apparent length of a perforation. This effect is shown in Figure 3.3, which compares a photo of a test roll and a MIDI file of the pneumatic signals caused when playing the roll at its designated tempo. Despite the appearance of the roll, the signal to the note pneumatic will cause it to be opened and closed for equal times.

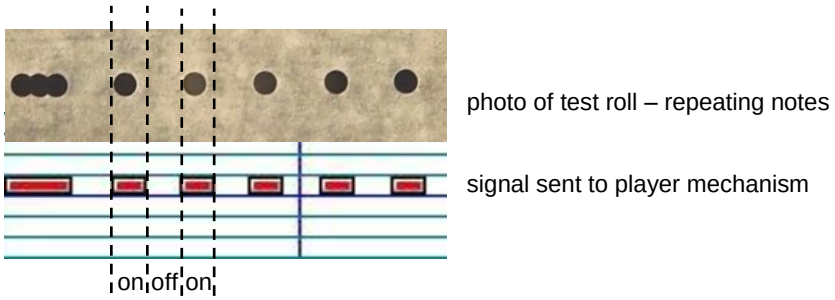

Figure 3.3 *The perforations on the roll cause the notes to have equal on and off times*

Tracker bar design

Another difference between a data file and a performance file is that caused by the design of the tracker bars used by the companies. The Duo-Art tracker bar is the most complex of the three systems being examined. The bass side of the bar is illustrated in Figure 3.4, showing that the expression holes are offset from the note holes, and that holes have differing dimensions.

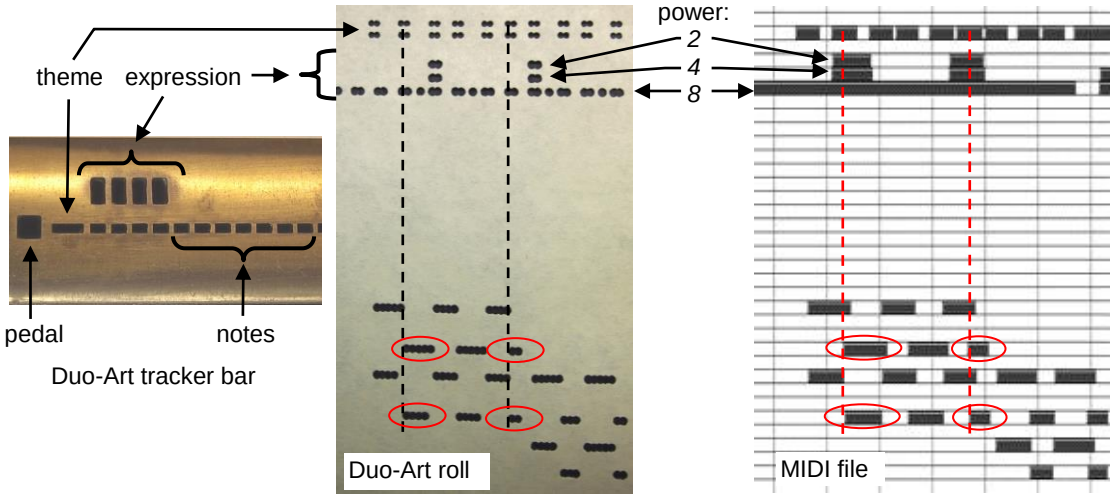

Figure 3.4 *Duo-Art tracker bar, roll, and MIDI file of signal sent to player mechanism*

Because the expression holes in the bar are offset from the note holes, expression signals occur before note signals. The dashed lines in Figure 3.4 show the difference between the roll data and performance data. Looking at the roll suggests that the circled notes will play at power 8, but as the MIDI file shows, they play at power 14 (the combination of powers 2, 4 and 8), while other notes play at power 8. Because the expression holes in the bar are elongated, expression signals are on for much longer than they appear on the roll, as shown in the MIDI file.

Tracker bar holes for pedal perforations are also larger than note holes, such that a pedal perforation aligned with a note perforation operates the pedal pneumatic before the note, and holds it on longer than the note, assuming both perforations have the same length. While the larger hole size might be seen as compensating for a slow-acting pneumatic pedal actuator, it is unlikely, as the pedal actuators in instruments I have observed respond quite rapidly. Instead it is possibly for reasons of standardisation, as the tracker bars in many player pianos have oversize holes for pedal commands. The pedal perforations on Duo-Art rolls appear to take the larger hole size into account.

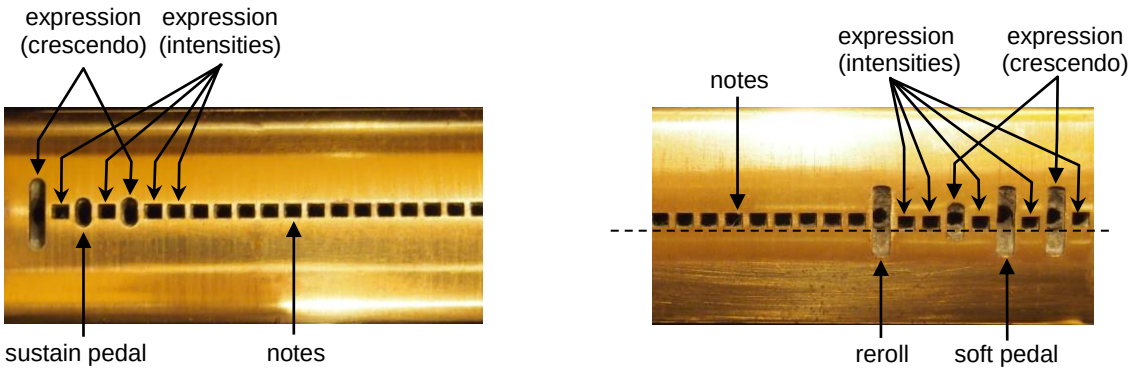

Figure 3.5 *Ampico tracker bars showing differing sizes of holes*

The tracker bars for a model A and model B Ampico are shown in Figure 3.5. Both bars have three sizes of holes, and the note holes in the model B bar are offset slightly from the expression holes, as explained in Chapter 2 (page 146). The elongated holes read perforations for pedal and crescendo actions. As in the Duo-Art, Ampico pedal data is read before note data and remains on after the notes. The amount of overlap between the pedal and note holes is less than in a Duo-Art bar, but is nonetheless present. It appears Ampico editors took the pedal hole size into account, and it is likely that the enlarged size was consistent with industry practice.

Welte Licensee *Welte-Mignon*

Figure 3.6 *Tracker bars in Welte instruments do not have offset or differing size holes*

The tracker bars for Welte instruments in Figure 3.6 show that all holes in each bar have the same dimensions. Holes in the Welte-Mignon bar are taller by 0.5 millimetres than those in the Welte Licensee bar. A critical aspect of the Welte expression system is the time that a particular expression function is turned on, which depends on the length of the perforation, the size of the tracker bar hole and the roll paper speed.

Paper acceleration

The action of pneumatic valves and tracker bar design are two factors that cause roll data to differ from performance data. Another differing factor is musical tempo and paper acceleration. An e-roll data MIDI file is obtained by advancing the roll being scanned by a fixed distance in synchronism with each scan cycle. A stepped paper advance matches the process of cutting a roll, in which paper is stepped through a perforator at a constant rate after each punch cycle.

However, when a roll is played on a reproducing piano, the paper speed accelerates. Unless compensated for during recording, the tempo of the music will also accelerate. As discussed in Chapter 2, paper acceleration was compensated for, which means playing an e-roll data MIDI file will result in the music decelerating as it plays.

Producing raw performance files of piano rolls

As previously explained, a raw performance MIDI file of a piano roll captures all perforations as MIDI notes, with durations and timings identical to those a roll would produce as pneumatic signals when played on a reproducing piano.

Raw performance files from e-roll data files

A raw performance MIDI file can be derived from an e-roll data MIDI file with computer software. The level of complexity of the software depends on the brand of roll. Welte-branded rolls are the easiest to consider, as for all three types of Welte instruments, the tracker bars have holes of the same size, and all holes are aligned.

Ampico and Duo-Art instruments have the issue of tracker bars with differing hole sizes and position, and like Welte Licensee, the rolls play at a range of paper speeds. Several software developers have written software to convert an e-roll data file produced by a roll scanner to a raw performance file for playing on a reproducing piano. I argue that such a process cannot guarantee best accuracy because of the complex processing that must be applied, and to an extent, the limitations of MIDI.

The smallest amount that a MIDI note length can be changed is by a MIDI tick, which is a time interval with a value determined by the selected tempo and number of ticks selected per beat.[329] A typical MIDI file might have a tempo of around 120 beats per minute, and a ticks-per-beat setting of 384, giving a tick time of 1.3 milliseconds. Therefore, in files with these settings, notes can only be extended by multiples of the tick time. While the resulting timing errors may be unnoticeable when listening to the music, they nonetheless exist. Accounting for different tracker bar hole sizes and positions can also introduce small but cumulative errors. Collectively, there is considerable potential for performance files produced from e-roll data files to have timing errors.

Another aspect is applying acceleration, which is achieved by software that inserts an ever-increasing tempo at regular intervals throughout the MIDI file. When acceleration and initial tempo are correctly applied, the playing time of the file should agree with the playing time of the roll. Establishing the correct initial tempo is therefore most important, as each increment is based on the start tempo. I have found the issues of

[329] Also called pulses per quarter note, or ppqn.

tempo and acceleration to be a major problem with performance files produced from software-processed e-roll data files.

A key aspect that is missing throughout the entire roll scanning or imaging process is visual and audible feedback that monitors the accuracy of the process. It is not until all processing is done that a recorded performance can be listened to and assessed.

I argue that monitoring the recording process while it is taking place is an essential part of any methodology used to transfer a piano roll recording to another medium.

Producing raw performance files directly

As already explained, when a roll is played on a pneumatic player piano, the data stored on the piano roll is read by a set of pneumatic valves that send pneumatic signals to the player mechanism that instruct the mechanism to reproduce the performance. It therefore stands to reason that if pneumatic signals could become MIDI signals, a performance file would be directly produced.

This concept is not new, and various arrangements have been constructed by enthusiasts. One simple method I observed during the 1980s involved a player piano with contacts attached to each piano key pneumatic. When a roll was played, the contacts being operated by the pneumatics caused a MIDI signal to be generated. Another method was placing contacts under the keys of a player piano, yet another was to cause note pneumatics to operate keys on a MIDI keyboard. In most cases, the developers were creating MIDI files of standard player rolls containing popular music, allowing the use of unsophisticated technologies.

A common feature of systems devised by enthusiasts to create MIDI files from piano rolls is to use parts of a player piano, typically the note pneumatics. A less cumbersome and potentially more accurate system would be to sense the operation of the pneumatic valves that trigger the note pneumatics. An improvement would be to develop a set of pneumatically-operated electronic switches designed to be more compact and stable in operation, as now explained.

First pneumatic roll reader

My first attempt at developing a method of transferring piano roll data to electronic media began in 1977, starting with experiments based on the technology associated with punched card readers of the time. These devices incorporated photo-sensitive transistors and a light source to read the holes in paper cards. At the time I had not analysed the

operation of a player piano and believed it was only necessary to capture the roll data. After spending six months trying various setups it became obvious that optical technology was not sufficiently advanced to suit the purpose.

My next approach focused on experimenting with a pneumatic reading system that involved developing a pneumatic switch which behaved in the same way as a pneumatic valve. By this time, and after restoring my model A Ampico, I was aware of the difference between piano roll data and performance data, in particular of the critical role played by the pneumatic valves in a player piano. The pneumatic switch that was eventually designed involved all the component parts of a pneumatic valve, except its output was an electrical signal.

In principle, the design incorporated an inflatable pouch (as in Figures 3.1 and 3.2), but made of an air-tight material called Perflex that had only recently come onto the market. The 'valve' was a ten-millimetre diameter thin metal disc that formed one plate of a capacitor. When raised by the inflated pouch, a high frequency signal could pass through the capacitor and activate an electronic component. This setup remained in use for ten years before the Perflex material began to fail.

The important aspects learnt from this design were the role of the bleed, the requirement for a steady and consistent value of air pressure (or suction) and the need to establish a means of measuring the performance characteristics of the pneumatic switches. At the time, correct operation of each switch was achieved by using a test roll to cause a repeating note to play with best repetition on the Ampico, while adjusting the size of the bleed hole associated with each switch. In effect, each switch was tuned using dynamic testing, which I discovered gave a more reliable test than static testing in which a switch would be operated once, not repeatedly.

Another aspect concerned the roll transport, which involved adapting a player piano spool box by fitting an electric motor to drive the take-up spool. A model B Ampico take-up spool was chosen on the basis that the spool was being driven by an electric motor, as in the model B Ampico, and the reader was designed to record only Ampico rolls. Other considerations included a means of keeping the roll aligned with the tracker bar, and maintaining correct roll paper tension.

The roll reader was commissioned in late 1979 along with an electric valve interface fitted to the Ampico, so it could play the raw electronic recordings of piano rolls that were stored on magnetic tape. Years later I became aware the Stahnke had

developed a similar system in the US. At the time, the MIDI standard had not been developed, so Stahnke and I used our own data formats to store piano roll data on magnetic tape.

During the early 1980s when personal computers became available, I developed software to connect the roll reader to an Apple II computer. The data format supported a range of compression techniques, allowing programs to be developed to play the files from a computer with only 64K of memory. By the end of the 1980s the reader was decommissioned, having by now recorded 1500 Ampico piano rolls that were stored as digital data on 5.25 inch floppy disks.

During the 1990s, the electronic files were converted to MIDI format, allowing them to be examined on a computer. This confirmed that the files did not exhibit any major differences to the rolls from which they were derived. There was no evidence of delayed or offset notes other than timing errors caused by framing,[330] in which note data was updated every twenty milliseconds. Delays due to the reading process were minimal, proving the concepts embodied in the design of the roll reading equipment.

Building on past experience

The years spent developing and using this equipment provided considerable insight into producing raw performance MIDI files of piano rolls using pneumatic roll reader technology. In particular, it highlighted the numerous issues to consider when designing a pneumatic roll reader. The importance of visual and aural feedback when recording a piano roll was also highlighted. By intently watching a roll and hearing it play while it was being recorded, a greater number of errors could be captured than by listening to a recording afterwards. A critical issue was ensuring that a perceived error was in fact an error, particularly when dealing with unfamiliar music.

With the advent of roll scanning technology, it appeared to offer another way of producing raw performance files. My research at the time showed that the technology was still developing, and as previously explained, it would rely on processing the data files with specialised software to produce performance files. An attraction was the mechanical simplicity of a roll scanner compared to a pneumatic roll reader, but my main concerns were the lack of feedback offered by the scanning process and the potential for timing and tempo errors.

[330] Each frame contained data that required a transmission time of twenty milliseconds.

In 2006, I began developing a new pneumatic roll reader, having by now dismissed the scanning option. The reader itself is only briefly described, as there are numerous ways of implementing the functions it incorporates. Instead the emphasis is on the philosophy behind its development. My aim is to present a case for this method of recording raw performance files from piano rolls. I argue that the accuracy of MIDI files produced by a pneumatic roll reader is limited only by the design of the reader. Furthermore, it is how piano rolls are read by the instruments for which they were intended.

Pneumatic roll reader design

The main parts of a pneumatic roll reader are a spool box containing the roll transport system and tracker bar, a set of pneumatic switches that respond to roll perforations, a source of suction to operate the switches, and circuitry to convert the switch signals to a MIDI signal. Prior experience had shown the importance of a modular design, in order to achieve flexibility and serviceability. Flexibility included being able to record all types of piano rolls.

An issue to consider was operator comfort. Recording piano rolls as MIDI files is a tiring process that demands considerable sensory concentration, requiring attention to the ergonomics of the equipment. An important concern, as it would be in any apparatus handling a piano roll, was minimising the potential for roll damage.

The most critical aspects were establishing the desired accuracies and the means of confirming accuracies. Therefore, before beginning the design, I established a number of standards for each main part of the reader as a set of criteria. Here follows an explanation of the various parts, the criteria that apply to each part and a brief explanation of how some of the criteria were implemented.

Spool box

All player pianos have a spool box in which a roll to be played is held such that it can unwind as the paper passes over the tracker bar and winds onto the take-up spool. Keeping the roll aligned with the holes in the tracker bar is achieved with a roll tracking mechanism. Original instruments used pneumatic power (suction) to drive the roll motor and roll tracking system, an obvious alternative is electric power. The major components in this new spool box are a roll drive motor assembly, a reroll mechanism and a tracking mechanism.

- **Criteria for roll drive motor**

A roll drive motor has to rotate the take-up spool at a constant, predetermined speed. In a typical pneumatic player piano, it also serves as a reroll motor. The criteria established for the roll drive motor assembly were:

1. A modular design incorporating an easy means of removal for servicing, modification or repair.
2. A speed variation within ± 0.5%. To achieve such a tight specification, a high-speed low-voltage electric motor driving the take-up spool through a 500:1 reduction gear box was developed. This arrangement produces a very high torque at the take-up spool, far more than would be required by the longest piano roll. Motor speed was electronically controlled.
3. Playing speed of a roll to be displayed in terms of roll tempo markings. The first reader had incorporated a display that showed a number requiring interpretation. In the new design, the motor has an in-built tacho generator that produces a signal with a frequency proportional to motor speed. Circuitry converts the frequency to a value as marked on a piano roll, such as tempo 80. Calibration was carried out with a crystal-locked digital counter to measure the time per revolution of the take-up spool.
4. Ability to operate with two sizes of take-up spools (diameters of 48.3 and 69 millimetres).
5. Ability to decelerate the motor speed as a roll was playing to achieve a constant paper speed, or to compensate for apparent musical acceleration. While experience has shown that this feature was rarely used, research at the time indicated it would be necessary. Deceleration was achieved by automatically reducing the motor speed by a pre-set amount each revolution of the take-up spool. The amount of required reduction could be calculated from the diameter of the take-up spool and its diameter after a roll had been played, along with the number of turns required to wind the roll onto the spool.

Being the largest of the proposed assemblies to be fitted to the spool box, the roll drive motor was constructed first to establish minimum sizes of the spool box.

- **Criteria for reroll mechanism**

Player piano spool boxes generally have one motor, with gearing that selects play or reroll. A separate reroll motor provides less gearing and complexity and offers the advantage of dynamic roll braking, in which a brake is applied to the roll during play to maintain a certain degree of paper tension. The following criteria were established for the reroll motor:

1. Reroll motor to serve as a dynamic braking force during play, the braking force to reduce proportionally as the roll unwinds. This required selecting a motor that did not exhibit 'cogging', which would otherwise cause variations in the braking force.
2. Motor reroll speed to be adjustable and to permit very slow speeds without stalling. A slow reroll speed is often needed to allow fragile rolls to be carefully and slowly rewound.
3. An interlock between the tracking and reroll mechanisms to prevent reroll if the tracking system was not retracted.

The initial design incorporated dynamic braking by reducing the reverse power being applied to the reroll motor as a roll was unwound. While this suited many rolls, some types of roll paper made it necessary to manually adjust the braking force. Too much tension could cause paper judder, too little could result in a poor seal between the tracker bar and the roll paper, and could also cause the paper to wind loosely onto the take-up spool. I concluded that there is no automated roll braking system that suits all types of roll, especially fragile original rolls.

- **Criteria for tracking mechanism**

Most reproducing and player pianos have some means of keeping the roll paper aligned with the tracker bar. An exception is the Welte-Mignon. The systems used are typically based on sensing the position of the edges of the roll paper, either with two 'ears' that rest against either side of the paper,[331] or with extra holes in the tracker bar. When misalignment is detected, a pneumatically-powered mechanism moves either the roll or the tracker bar to compensate. Roll damage is often caused by tracking systems, an important consideration when determining criteria for the tracking system.

[331] A tracking ear is a lightly-weighted metal tab that rests against the edge of the roll paper and forms part of a system that keeps a piano roll aligned with the tracker bar during playing.

1. Tracker system to have a single ear resting lightly under spring tension on one side of a roll. By using a single ear, rather than an ear each side of the roll, there would be no problems caused by varying paper widths.
2. Ear to be retractable and to have an electrical interlock with the reroll motor.
3. Ear to control the speed and direction of rotation of an electric motor that would move the tracker bar to correct misalignment. While many Duo-Art instruments have a tracking system that moves the bar, the most commonly used system moves the roll, which can cause the roll paper to rub against the flanges of both spools, causing feathering and tears at the edges of the paper.
4. Alignment between roll perforations and tracker bar holes to be maintained within ± 0.25 millimetres. A larger variation does not usually cause an error as the perforations are round, passing over a rectangular hole, and only a small amount of the hole needs to be uncovered to trigger a pneumatic switch. Variations in roll paper width can cause perforations at either side of the paper to be misaligned with the tracker bar holes, while perforations in the centre are correctly aligned. Therefore, a tight alignment specification was necessary.

The arrangement used required the ear mechanism and its sensing electronics to be fitted to the tracker bar, so the mechanism would move with the bar and therefore move the ear accordingly during tracking correction. As the reader was to record all types of reproducing piano rolls, the tracking sensing mechanism had to be capable of being fitted to all types of standard-size tracker bars.

- **Criteria for spool box**

The criteria for the spool box were:

1. Modular design so it could be detached as a unit to allow different spool boxes to be connected to the rest of the reader.
2. A mounting system so the box could be positioned at any angle from horizontal to vertical.
3. Removable panels to give access to all parts installed in the box.
4. Tracker bar to be supported by roller bearings and guided by adjustable posts to maintain an exact 90-degree relationship to the roll paper. (Each type of tracker bar

was connected to a detachable manifold with flexible tubing so tracker bars could be changed to suit the brand of roll.)

5. Tracker bar height relative to the roll and take-up spools to ensure at least 80 percent of the bar area is covered by the roll paper at all times, taking into account the changing diameters of the roll and take-up spool as a roll is played.

- **Spool box implementation**

The spool box size was governed by the size of the parts to be fitted, and the need to accommodate the largest size roll, such as Ampico long-play rolls. The photo in Figure 3.7 shows my implementation of the complete spool box.

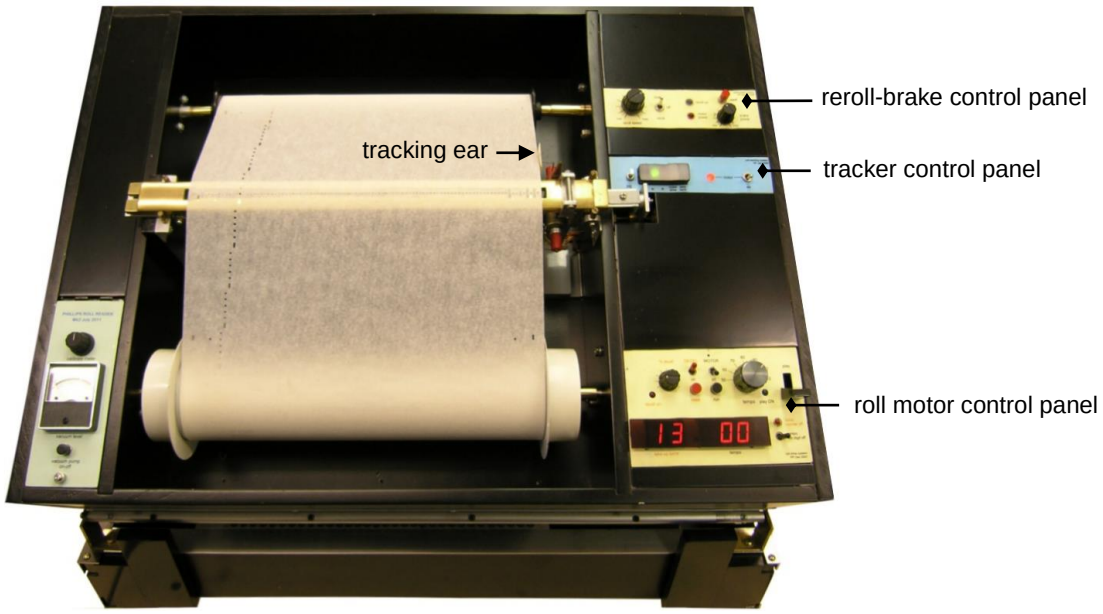

Figure 3.7 *Complete spool box with motor mechanisms on the right, displays showing roll tempo and number of turns of the take-up spool. Meter on the left displays the level of suction being applied to the pneumatic switches.*

Pneumatic switches

In the context of a roll reader, a pneumatic switch should operate in the same way as a pneumatic valve in a player piano, except it switches an electric current rather than air flow. While the principle is simple, finding a suitable implementation required testing a number of designs involving different ideas and materials. In the initial stages, I established a single criterion:

- Switches to replicate all operating characteristics of a typical pneumatic valve.

The pneumatic switch design used in the first roll reader, although satisfactory in many ways, did not allow the precise adjustments now being sought. It also required complex electronic circuitry, and the construction made it difficult to repair a failing switch. Therefore, a new approach was required.

A starting point was determining how a typical pneumatic valve responded to the start and end of a roll perforation passing over a tracker bar hole, which would depend on the factors listed on page 177, in particular the size of the bleed and the suction level. The required timing measurements were made at a number of suction levels using a pneumatic valve fitted with sensors that were connected to a digital oscilloscope. The measurements thus obtained were then used to mathematically determine a theoretical value of the on-time of a pneumatic valve when a typical size single-punch perforation was passed over a standard-size tracker bar hole at a specified speed.

An additional source of information was the note repetition test on a test roll for the model A Ampico. In this test, according to the calculations, the series of single-punch perforations were spaced on the roll to cause the pneumatic valve controlling a note pneumatic to be opened and closed for equal times, as shown in Figure 3.3 on page 178. On the basis of this deduction, I constructed a device called a ‘note repeater’; a motorised device which provides a continuous stream of pneumatic pulses such as would be produced when playing the above-mentioned note repetition test. This vital item of test equipment was used in numerous tests during the design stage of a pneumatic switch, then during the calibration stages, as later explained.

I initially considered adapting commercially-available vacuum switches or vacuum sensors. However, research showed that adapting existing devices to a roll reader application would be difficult, and possibly unsuccessful, making it necessary to develop a new design. The four criteria established as a starting point were:

1. Switch to operate on the same principle as a pneumatic valve and to incorporate only airtight materials.

A pneumatic valve in a player piano was typically built into a timber framework sealed with varnish or shellac, with chemically-sealed leather to form a pouch. Welte and Hupfeld used a range of other materials, such as aluminium or Bakelite for the valve body, and air-tight zephyr skin as the pouch material. In all cases, when new, the valves would have had an almost airtight construction, although over time some of the

materials would become porous. A concern was to achieve an airtight construction that would not deteriorate over time, leading to selecting PVC plastic to make the valve body, and neoprene rubber as the pouch or diaphragm material. An important aim was to ensure that the only passage of air between either sides of the diaphragm would be through the bleed hole (as in Figures 3.1 and 3.2).

2. Operating characteristics of each switch to have a maximum variation of ± 2%.

An important consideration was selecting the type of component to act as an electronic switch in response to an inflated diaphragm. I had previously experimented with photo-sensitive devices, in which an inflated diaphragm lifted a vane to interrupt a light beam, thereby triggering a light-sensitive solid-state switch. Yamaha uses optical technology in its Disklavier recording system that involves a multiplexed array of optical fibres arranged so the passage of light is interrupted by vanes attached to piano keys. This arrangement requires a high level of engineering to achieve the required tolerances. The idea of using optical switches was finally abandoned, as it was impossible to adjust each experimental model to obtain identical operating characteristics. Nonetheless, the concept could well prove satisfactory if a high level of engineering is applied.

Experiments were then made using a component called a Hall-effect sensor,[332] a solid-state electronic device that responds to a magnetic field. The first type to be tested was a proximity Hall effect switch, which switches on in the presence of a magnetic field, and switches off when the field is removed. However, the travel distance of the magnet to reliably switch the device on and off exceeded the travel distance of a typical pneumatic valve, and consistency between all experimental models was not achievable.

Another type is the bipolar Hall-effect switch which switches on in the presence of a magnetic field, and turns off in the presence of a magnetic field of the opposite polarity. Test showed that it responded reliably to the magnetic field produced by a flexible magnet (fridge magnet material), in which the alternate north and south poles embedded in the flexible substrate would operate the bipolar device over a diaphragm travel distance consistent with that of a pneumatic valve. The bipolar configuration meant all switches could be adjusted to operate with the same characteristics, due to the precise spacing of the magnetic poles in the flexible magnet material.

[332] Hall-effect sensors are used in motor vehicles and many forms of machinery, they are miniature in size and have three connections.

Subsequent testing with various models proved that this design conformed to the above criteria, allowing additional criteria to be determined:

3. Switches to be grouped into modules that could be easily removed.

Prior experience had shown the importance of being able to easily replace a faulty pneumatic switch with a spare unit. I chose a module size of four pneumatic switches.

4. All parts of each switch to be serviceable.

To achieve total serviceability meant using glues and construction that would allow a module to be disassembled so a neoprene rubber diaphragm could be replaced, on the assumption this would be the most likely cause of failure.

Switch calibration

To calibrate each electro-pneumatic switch required establishing a series of tests that involved two different pulse rates from the note repeater, at three values of air pressure (equivalent to suction). The setup, shown in Figure 3.8, involved a means of applying the pneumatic pulses from the note repeater to an individual pneumatic switch, electronics to power the Hall-effect component, and a digital storage oscilloscope to display the operation of the switch.

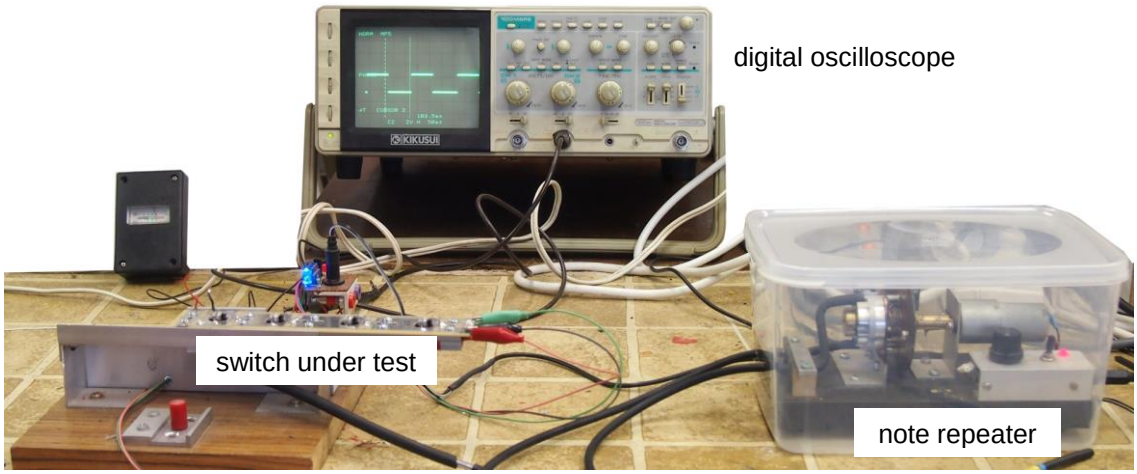

Figure 3.8 *Setup to calibrate each electro-pneumatic switch, in which the position of each Hall-effect component was adjusted to achieve a predetermined display on the oscilloscope in response to the pneumatic signal produced by the note repeater*

The oscilloscope display in Figure 3.8 shows the response of a switch to a test at the typical level of air pressure (suction) that would be applied.[333] Like all pneumatic valves, the on-time of these pneumatic switches depends on the level of the applied pressure (or suction). Therefore, each switch was required to respond in the same way at each level of pressure and at two different pulse rates. Adjustment was achieved by positioning the Hall-effect device horizontally and vertically in relation to the small section of magnetic material attached to an aluminium support which was attached to, and therefore lifted by the diaphragm.

The tests that were applied were more severe than the switches would experience under normal use. If a switch could not meet the specifications, it was rebuilt or the Hall-effect component was replaced, a situation that occurred in only a few cases. An important test was stability of operation over time, and part of the on-going checks involved removing a switch module from the reader and running the various tests. The design proved to be very stable, requiring only minor adjustments in a few cases.

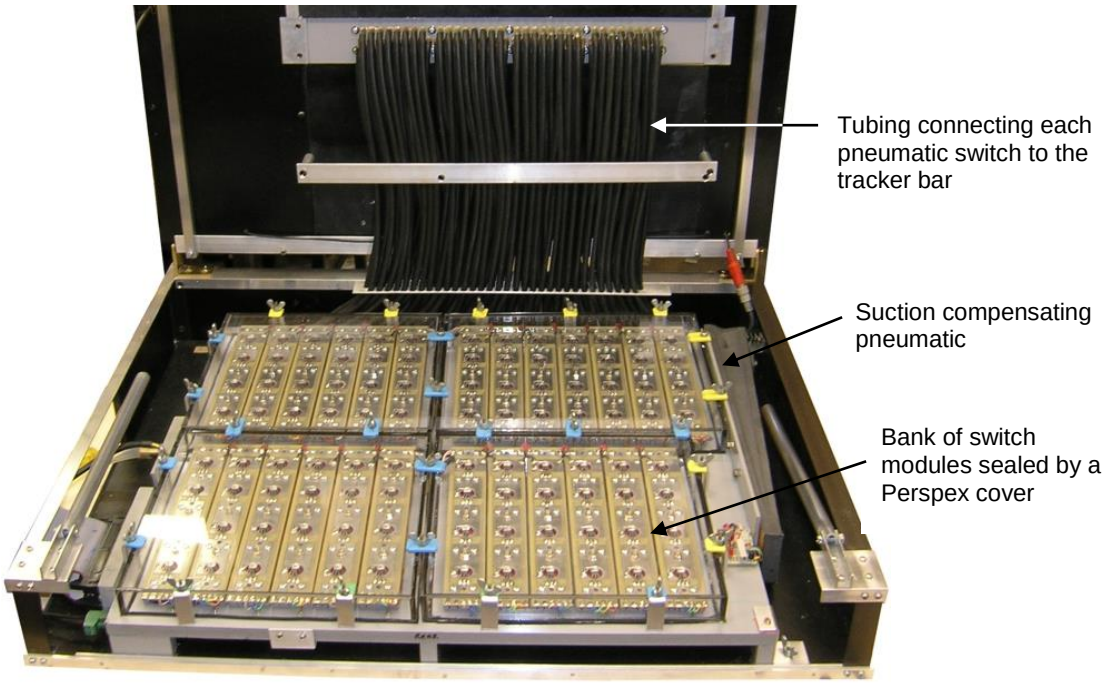

Figure 3.9 *Showing the 100 pneumatic switches after installation in the roll reader. The Perspex box covers are sealed to allow suction to exist within a box, and each cover is easily removed by undoing a series of wing nuts.*

[333] Air pressure and suction are analogous to positive and negative voltages, in which the only difference is the direction of air (or electrical current) flow.

The photo in Figure 3.9 shows the 100 pneumatic switches installed on a PVC base behind the spool box, with neoprene rubber tubing connecting them to the tracker bar via a manifold. Groups of switch modules are covered by a Perspex box that is sealed against the PVC base, allowing suction to exist within each box. This gives ready access to each switch module, and each module can be easily removed for testing or repair.

The operation and accuracy of the pneumatic switches were tested regularly by using the repetition tests on different brands of test rolls. A typical test causes each switch to operate briefly five times, and any differences between the resulting MIDI file to that previously established would identify inaccurate operation of a switch. The modular construction of the switches facilitated their easy removal for recalibration where necessary, which rarely occurred. Instead, a switch was more likely to fail completely than go out of calibration, a situation that was readily identified.

Suction pump

Experiments showed that a suction level ranging from 1.5 to 3 inches of water gauge (WG) was required to operate the pneumatic switches. Water gauge (WG) is a unit of measurement for a vacuum, and refers to the inches of water that would be drawn into a tube sitting upright in a pool of water when suction is applied to the open end of the tube. It is the standard way of expressing levels of suction in a reproducing piano.

Similar values of suction were used in the previous roll reader, and it had been found that altering the suction level was sometimes needed to obtain best repetition with badly perforated recut rolls. The criteria established for the suction pump were:

1. Pump suction level to be adjustable over the range of 1.5 to 3 inches WG.
2. Suction level to drop by no more than 5% under all operating conditions. Ampico rolls can require up to 35 switches to be operated simultaneously.
3. Pump to be silent in operation. The implementation resulted in a pump with pneumatic ‘lungs’ rather than a turbine pump, as used in a vacuum cleaner.

The suction pump design incorporated pneumatic and electronic regulation, in which any change from the set point would be quickly restored by changing the speed of the motor driving the pump. Further regulation was provided in the form of a spring-tensioned compensating pneumatic, which is shown in Figure 3.9. The suction level was monitored electronically by a meter fitted to the spool box as shown in Figure 3.7. The pump was driven by a twelve-volt direct current electric motor.

MIDI electronics

There are various commercial products that produce a MIDI output signal in response to a number of inputs. The criteria for the selection of a suitable MIDI product were:

1. Running status as the native operation.

If running status is not used, when a key is played on a MIDI piano, three data bytes are generated in which the first byte refers to the status of the event, in this case a note event. Typically the next event will also be a note event, so manufacturers have introduced the concept of not sending the status byte unless the status has changed, for example if a controller event (pedal operation) has occurred. Running status reduces the transmission time of a note event by a third. Because the MIDI signal from the roll reader would always be note events, running status therefore gives the least amount of data that must be transmitted, and the least time delay between successive notes.

2. Minimal or no contact bounce detection.

Some MIDI products incorporate a delay to overcome the effects of contact bounce, in which metal contacts on closure tend to make an erratic connection that lasts for around 30 milliseconds. Because solid-state switches are used in the reader, there is no contact bounce. The contact bounce detection software sometimes used in MIDI products could cause timing errors, so a product was sought that did not incorporate the software.

Other considerations

The final construction of the reader needed to take into account two criteria:

1. Ergonomics.

As already mentioned, ergonomics was an important consideration and involved mounting the reader at a convenient height, with the spool box able to be held at any desired angle for best viewing and access from a seated position. It also required designing a cabinet to support the reader and hold the peripheral components such as the vacuum pump and MIDI electronics. In particular, it required a means of having a computer in close proximity such that the screen was clearly visible so the MIDI signal being recorded could be easily monitored.

2. Portability.

In the final construction, the reader was designed to fold into a compact size for transport purposes. It also required attention to any aspect that prolonged travel could affect, such as parts becoming loose due to vibration.

Error sources when recording piano rolls

The reader was commissioned in late 2011, initially to record Duo-Art rolls that would be monitored by a Duo-Art reproducing piano that I had recently restored and to which a set of commercially available MIDI-controlled valves had been fitted.[334] As expected, when commissioning such a complex device, the reader required attention to a number of issues which were resolved by early 2012. During that year, around 600 Duo-Art rolls from local collections were recorded, which illustrated the specific problems associated with Duo-Art rolls. In 2013, I began recording rolls from the Condon collection, resulting in MIDI recordings of over 4000 Duo-Art, Ampico and Welte rolls.

While the recording process was generally error-free, the types of errors that could, and sometimes did occur became increasingly obvious over the process of recording such a large number of rolls. All methods of obtaining a MIDI file of a piano roll have error sources, which can be grouped as issues associated with the equipment, piano roll imperfections, and issues with MIDI technology and computer systems.

- **Roll reader**

Errors attributable to roll reader technology are similar to those that occur when a roll is played on a pneumatic player piano. However, the greater precision of the roll reader minimises the errors. Issues that were found are:

- *Slight variations in playing time.* If a roll is recorded several times, the playing times of each MIDI file might differ by a small amount, depending on the length of the roll. The cause is due to how tightly the roll winds onto the take-up spool. Each pass might cause slightly different build-up diameters, causing slight differences in roll paper speed. Variations are generally insignificant, unless a roll has wound loosely onto the take-up spool.

[334] From Hunt Piano Company, VirtualRoll System, http://www.virtualroll.com/ (accessed 9 July 2016).

- *Paper judder near the end of playing a long roll*. This is caused by the change in torque due to the reduced diameter of the supply spool and the increased diameter of the take-up spool. That is, a higher torque is required to unwind the roll when it nears the end of the paper, and judder will occur if the paper does not wind tightly onto the take-up spool, or if the roll itself is loosely wound and the roll tension is too high. Where noted, rolls exhibiting paper judder could be corrected by several play-rewind cycles to improve the pliability of the paper.
- *Timing errors affecting the start time and length of recorded notes*. The pneumatic switches in the roll reader were adjusted to give a maximum timing difference between each switch of two milliseconds. But if the characteristics of a pneumatic switch changed, the timing errors would be greater. This was a fundamental reason for the previously described method of using a test roll to regularly test the timing characteristics of all switches.

It is generally agreed that a time interval of ten milliseconds between two notes is not discernible, as explained by Brad Robinson when discussing audio processing and the Windows operating system.[335] Therefore, a timing difference of two milliseconds between switches is arguably an acceptable standard.

- **MIDI and computer issues**

Any process that involves converting a piano roll to a MIDI signal will be subject to the limitations of the MIDI standard, and also the random problems caused by computers. The main limitation of MIDI is that data is sent serially. For example, a ten-note chord sent as a MIDI signal will have, at best, a time difference of nearly seven milliseconds between the first and last notes to be transmitted. Due to its design, a pneumatic player piano would read all these notes simultaneously.

Regarding computer issues, in a few cases a software glitch would cause a break in a MIDI file, an issue that was difficult to detect at the time, as there was usually no audible interruption to the music. It would however be noticed when reviewing the file. Some types of MIDI adaptors (device connecting the roll reader to a computer) could introduce errors such as missing or wrong notes. Selection of the best quality device was essential.

[335] Brad Robinson, *Glitch Free - An In-depth Guide to Tuning Windows for Reliable Real-time Audio Performance*, PDF document available at

- **Roll imperfections**

Piano roll imperfections include paper damage and deterioration, or production errors, such as ragged perforations due to blunt perforator punches. A roll scanning or imaging system would respond to paper damage and deterioration in a different way to that of a roll reader; both systems would have unique issues. The roll reader setup involved a computer screen showing a piano roll view of the MIDI file being recorded; the screen positioned so that it and the roll being recorded were in the same view. This arrangement facilitated identifying roll imperfections and whether an imperfection caused erroneous data to be recorded by the MIDI file. Audible feedback was via a mechanical player piano suited to the brand of roll. While recording each roll, errors and related MIDI file bar numbers were noted in writing for subsequent post-editing of the file. The most common imperfections and their effects are:

- Damaged edges that caused incorrect MIDI data to be recorded. The majority of rolls with damaged or feathered edges were most affected on the treble side, the minority had damage on both sides or only the bass side of the roll. This is probably because the bass side flange can be moved away from the paper during reroll, where the treble side flange in all piano rolls is not moveable. Erroneous MIDI data was visually obvious on the computer screen, as it was generally confined to the outside tracks of the roll and therefore affected only the top and bottom notes being recorded as MIDI data. In some cases, it was necessary to make repairs to a roll to reduce or prevent erroneous data being recorded. Because Duo-Art rolls have the soft pedal perforation at the extreme treble edge, the pneumatic switch sensing this perforation was desensitised to prevent erroneous soft pedal data.
- Holes or tears in the roll paper, causing additional notes. This type of error was generally easy to detect, both visually from the roll and by hearing obviously incorrect notes. (A roll scanner or imaging camera would detect black spots on the paper, and the software would interpret them as notes.)
- Non-pliable paper, or paper with an irregular surface that caused notes to remain on for longer than they should, due to an imperfect seal between the roll paper and the tracker bar. Paper pliability or surface issues tended to affect closely-spaced repeating notes, which might sound as an extended note. The additional note length caused by non-pliable paper was generally no more than twelve milliseconds. The problem occurred mainly with Duo-Art rolls.

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https://www.cantabilesoftware.com/glitchfree/?utm_source=mailinglist&utm_medium=email&utm_campaign=glitchfree1 (accessed 26 May 2016), 8.

- Broken perforations and breaks in the paper between perforations, causing bleed notes, which are notes a semitone away from the correct note, usually of short duration. Bleed notes were generally audibly and visually obvious, and were the most common problem to be encountered, typically with Ampico rolls.
- Paper width too wide or too narrow. Width variations are caused by changes in moisture content and paper chemistry, and occurred with numerous recut rolls, occasionally with original rolls. Original rolls from the US were more likely to have width problems than rolls in Australia, perhaps due to differences in climatic conditions. In the majority of cases, the paper width had stretched rather than shrunk. In extreme cases, two adjacent perforations might be read by the same tracker bar hole, although this rarely occurred. The effect was generally confined to notes at the sides of the roll, including notes representing expression perforations. Errors were quite obvious, noted by observing the roll and the MIDI file display on the computer screen.
- Rolls that exhibited poor tracking, thereby causing a loose build-up of paper on the take-up spool, due to the paper wandering from side to side. It is caused by one side of the paper having stretched as a result of poor rewinding, bad storage conditions, age and other factors. Some rolls needed to be played and rewound several times before the roll would track correctly and wind tightly onto the take-up spool without spreading. Otherwise, a loose wind on the take-up spool would cause the paper speed to accelerate and increase the tempo of the music.
- Considerable damage that required repairs to the roll and post-editing of the MIDI file, with reference to the roll, such as the damage shown in Figure 3.10 (a). Post-editing of this type was often time-consuming but ultimately edits to the MIDI file could result in excellent accuracy, providing the roll was always referred to, and care taken to align notes in the MIDI file as per the roll.
- Badly perforated rolls. Errors included missing punches that caused a held note to repeat, as shown in Figure 3.10 (b) and gaps between punches caused by paper slip during perforating that are ambiguous as to whether the note should or should not repeat. These problems were particularly prevalent in recut rolls.

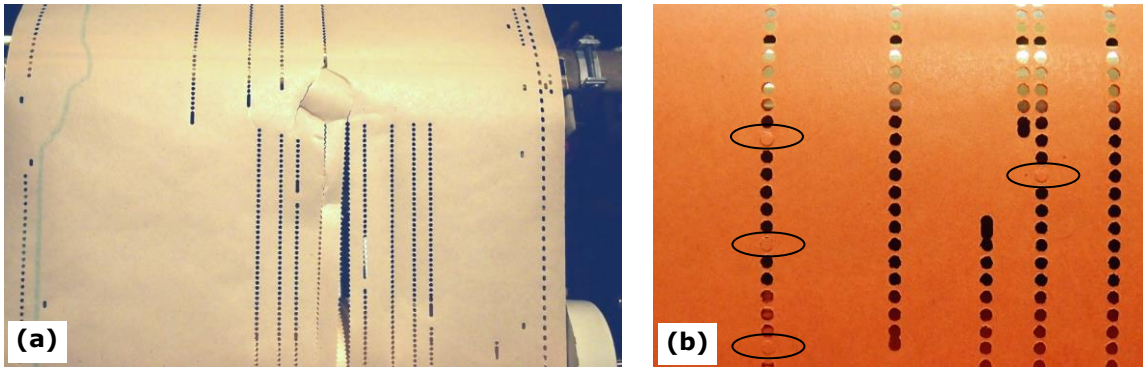

Figure 3.10 *Examples of roll imperfections.* ***(a)*** *Ampico roll with broken chain perforations and paper break,* ***(b)*** *Welte-Mignon roll with missing punches*

Each brand of roll presented its own problems, in addition to those already described. In the following descriptions only original rolls are referred to, as recut rolls are a category described later.

- **Duo-Art rolls**

The majority of Duo-Art rolls that were recorded with the reader were in good to excellent condition and gave no problems. A unique issue was an expression perforation (typically power 2) being held on for longer than the MIDI settings allowed.[336] A solution was to briefly interrupt the generation of the MIDI signal before the time-out period by routinely blocking the pneumatic signal. MIDI time-outs also occurred with soft pedal perforations, in which the pedal might be held on for the length of a roll, a characteristic found mainly with Duo-Art rolls, but also with other brands of rolls.

A particular problem with Duo-Art rolls was the quality of roll paper. Some papers had limited pliability, some had an irregular surface and in many cases, the paper was particularly fragile. To minimise the problems caused by paper quality, a lightly weighted two-wheel roller was fitted to the spool box that sat on the roll paper between the supply spool and the tracker bar. It not only provided visual feedback of paper tension, it helped maintain the necessary seal between the paper and the tracker bar.

A vexing issue was selecting the size of the roll reader's take-up spool for Duo-Art rolls. As explained in Chapter 2 (page 162), the evidence presented by Rex Lawson suggests this should be the same size as the spool in a Duo-Art reproducing piano, and based on this evidence, the roll motor assembly was designed to accommodate a Duo-

[336] I used the PC program *Cakewalk* version 9, in which for a tick time of 384 at tempo 100 a note timeout would occur after just over one minute and 43 seconds.

Art or a model B Ampico take-up spool. But it soon became obvious when using the Duo-Art spool that the music was accelerating. Evidence included repeating notes being unable to play at the end of a long roll and fast passages being played at an unmusical tempo.

When using the model B Ampico take-up spool to record Duo-Art rolls, musical acceleration was no longer noticed, which might be explained because of the use of an electric roll drive motor. A Duo-Art air motor does not always have sufficient torque to maintain a constant speed, particularly towards the end of a roll when the load on the motor is increased. Another factor that Aeolian would have considered when selecting the size of the Duo-Art take-up spool is compatibility with the spool size in the company's range of Pianolas. The spool size in most standard player pianos is similar to that used by Aeolian.

Poor production quality was also a factor with Duo-Art rolls. For example, rolls with missing theme perforations, rolls with repeating notes so closely spaced they could not possibly repeat, regardless of the roll paper speed. A few rolls had a paper speed that was too slow to give a clean repetition of trill and repeating notes.

- **Ampico rolls**

As explained in Chapter 2 (page 140), many Ampico rolls have extended perforations to achieve Stoddard's 'singing tone'. The photo in Figure 3.10 (a) shows an example of extended perforations falling apart, often leading to other paper damage. This problem was commonly encountered with Ampico rolls, in a few cases with Duo-Art rolls. The extended perforations often meant a substantial number of notes being held down at the same time. The effect on playback on a MIDI instrument will depend on its polyphony.[337]

The question of musical acceleration and Ampico rolls is discussed in Chapter 2 (see page 130). Research at the time suggested the need for a means of applying deceleration to the roll drive motor in the roll reader, but it was found to be rarely necessary. When it was applied on a few occasions, the amount of deceleration was relatively small, certainly not enough to warrant special efforts to maintain a constant paper speed as argued by Stahnke.

[337] MIDI instrument polyphony refers to the number of notes the instrument can play simultaneously, either 16 notes, 32 notes, 64 notes or full keyboard.

- **Welte rolls**

Like the Ampico and Duo-Art instruments, Welte Licensee and Welte Green instruments were designed to play standard size rolls. Therefore, Licensee and Green rolls were recorded using the spool box previously described and shown in Figure 3.7 on page 189. The only change between roll brands was the tracker bar.

To record Welte-Mignon rolls required a different spool box, which was achieved by adapting the spool box from a decommissioned upright Welte-Mignon instrument. It included a metal T-100 tracker bar and an aluminium take-up spool,[338] thereby providing all necessary parts. An electric motor was fitted in lieu of the original air motor, along with a means of displaying roll paper speed, which in general would be the same for all Mignon rolls. Checks involving the tempo test on a Welte-Mignon test roll showed that the motor shaft should run at 120 RPM.

Welte-Mignon instruments do not have a tracking mechanism, although there are adjustments to align a roll to the tracker bar before playing. Modification were made to the available adjustments to allow manual tracking, which was necessary for the minority of rolls. Because Welte-Mignon rolls use a lock-and-cancel system instead of extended perforations for expression and pedals, there is less tendency for rolls to become fragile. As well, those that were recorded were in generally good condition.

Green Welte rolls have continuous perforations for pedals and expression information, requiring awareness of the MIDI time-out problem. Most of the rolls that were recorded were in good to almost pristine condition and exhibited few problems. Some Welte rolls have a playing time of up to 15 minutes, and because the paper used for Green rolls is not as pliable or as thin as that used for Mignon rolls, several play-rewind cycles were sometimes needed to achieve a tight wind on the take-up spool.

Rolls for the Welte Licensee, as explained on page 123, were made by M. Welte and Sons in the US, and later by the De Luxe recording company. Those made by M. Welte and Sons at Poughkeepsie include the Purple Series, some of which were found to be badly perforated. Poughkeepsie rolls were all marked as Tempo 80 to 90, in which I chose Tempo 80. De Luxe rolls were generally well produced and gave few problems, although their quality did not match that of Welte-Mignon or Green Welte rolls.

[338] Early instruments had a timber tracker bar and timber take-up spool.

- **Recut rolls**

Recut rolls began appearing in the 1960s, when Gordon Iles, using perforators from the Aeolian factory, began producing Duo-Art rolls from Duo-Art masters from which production rolls had never been published.[339] Issued under the Artona label, these rolls were generally satisfactory, although some had variable quality and thick roll paper. In the US, also during the 1960s, Larry Givens produced a number of previously unissued Ampico rolls from newly-discovered masters, using perforators from the American Piano Company. Rolls produced by Givens are characterised by the use of Kraft paper,[340] a thin glassine paper with a tendency to crinkle.

Also in the US, during the early 1970s Klavier Music Rolls under the management of Harold Powell began issuing recut rolls made from Ampico masters using Ampico perforators. Powell later sold the business and equipment to Keystone Music Rolls.[341] Another entrant at this time was Play-Rite, a now defunct company that produced recut Ampico rolls from production rolls.[342] Recut rolls produced by Keystone and in particular Play-Rite had extremely variable quality.

Issues included paper that was too wide, incorrect tempo markings, and badly cut chain perforations causing repeating notes. Perforations controlling the damper pedal were often so poorly cut that the damper pedal would remain on, because the spacing between perforations was too close to allow the pedal pneumatic to respond. Recut Duo-Art rolls often had the wrong punch size for the theme 'snake-bite' perforations. A common error was a missing note due to a perforator fault, in which no occurrences of the note would occur throughout a roll.

During the early 1980s, recut rolls for the Welte Licensee instrument began appearing, made by Custom Music rolls, managed by Richard Tonnesen. These recut rolls were among the first to be produced using a MIDI file produced from a roll reading system, the file controlling a purpose-built perforator.[343] Using this technology and converting the MIDI data of a Green Welte or Welte-Mignon roll allowed Tonnesen to produce rolls for the Welte Licensee instrument that had previously never been

[339] Davis Smith, *Duo-Art Piano Music*, 247.
[340] Kraft paper is used as insulation in large power transformers, and is often called 'transformer paper.'
[341] Keystone Music Roll Company, http://www.player-care.com/keystone.html (accessed 5 December 2016).
[342] Douglas Henderson, *Play-Rite Music Rolls Business for Sale*, https://www.mmdigest.com/Archives/Digests/200411/2004.11.23.10.html (accessed 5 December 2016).

issued. In general, Tonnesen's rolls were well produced, although I have noted several instances of additional and obviously incorrect notes on some of the rolls.

During the 21st century, a number of people have established a means of producing recut rolls using scanning technology and MIDI-controlled perforators. The quality of recut rolls produced this way is often significantly better than those produced using original perforating equipment. In a few cases, the Gryphon brand of Welte Licensee recut rolls omit a tempo marking, otherwise Gryphon rolls were well produced.

The majority of recut rolls are of popular music, although a substantial number of recut rolls of art music have been issued. While some recut rolls are accurately perforated and produced, there are many that are not. New rolls produced from original masters that were previously never issued are all that we have available, and in general these rolls are of acceptable, even excellent quality.

Chapter summary

An archival version of a piano roll can be a physical copy of the roll, or for greater convenience and accessibility, a computer file of various types. An image file preserves everything visual about a roll, and an e-roll data MIDI file can be derived with suitable software from the image. Roll scanning technology can also produce an e-roll data MIDI file. Both techniques preserve a piano roll in some form, but do not preserve the performance recorded on the roll.

Creating an archival version of the recorded performance as a raw MIDI file can be achieved with complex processing of an e-roll data file, or directly with a pneumatic roll reader. Either way requires dealing with fragile and sometimes damaged piano rolls. Advantages of pneumatic roll reader technology are being able to monitor the recording process audibly and visually, and that performance files are produced without the need for further computer processing that can potentially introduce errors.

A raw performance MIDI file can be played on a MIDI-equipped reproducing piano for that brand of roll. The advantages include a potentially large library of raw MIDI files, and the ability to hear roll recordings this way without fear of damage to a roll. Critical issues are a well-restored and adjusted reproducing piano fitted with a set of

[343] Richard Tonnesen, *Music Roll Reader and Perforator*, http://www.mmdigest.com/Pictures/tonnesen.html (accessed 9 July 2016).

well-engineered, MIDI-controlled electric valves.[344] MIDI valve systems for reproducing pianos have been marketed in limited numbers and are currently available from at least one source.[345]

Chapter conclusion

Having recorded over 6,500 piano rolls using the roll reader described in this chapter, it is clear that the methodology is efficient and generally error-free. On average, it took around fifteen minutes to document and record a typical three-minute reproducing piano roll. Errors due to the roll, or occasionally to the roll reader were generally easily detected and remedied. Even so, later examinations of the MIDI files have shown that despite the available feedback, a few errors remained that were not identified at the time. Examples are broken notes that don't sound, as the break is too short and a few instances of an extra but harmonious note, later traced to being present on some recut rolls, or to a tear on an original roll.

When compared to any other method of producing a performance MIDI file of a piano roll, pneumatic roll reader technology, although mechanically more complex than other technologies, is potentially the most accurate way of producing this type of file. Each roll is read in the way it would be when being played on a reproducing piano, and accuracy is determined by the design of the reader.

The design of the roll reader described in this chapter has not been detailed, instead the criteria, or standards that were applied are presented. There are numerous ways to implement these criteria, which will depend on the engineering facilities that are available. The most critical components are the electro-pneumatic switches, which must have identical characteristics and long-term stability. The switch design outlined in this chapter has met these demands.

[344] The use of electrically-operated valves in reproducing pianos was practiced in the 1920s, to accommodate instruments with a remotely positioned spool box.
[345] Hunt Piano Company, *VirtualRoll System*, http://www.virtualroll.com/ (accessed 9 July 2016).

Chapter 4 – Piano roll MIDI files and contemporary instruments

Introduction

A raw performance MIDI file of a piano roll, derived as described in the previous chapter, has a number of potential uses. For example, files of this type can be used to analyse a performance in terms of pitches and timings, because notes in the file will have the correct duration (assuming notes have not been extended, as in some Ampico rolls). Analysing e-roll MIDI data can only show pitches and note start times. More information can be gleaned from a raw file if the viewer understands piano roll expression coding and pedal perforations. In Chapter 3 it was explained that a raw performance MIDI file can only be played on a MIDI-equipped reproducing piano of the correct brand. Playing it on a standard MIDI instrument will cause MIDI information that represents expression data to play as spurious notes, giving a cacophony of sound.

The conversion of a raw performance MIDI file to compatibility with contemporary instruments is achieved by converting expression coding to MIDI velocity values and the pedal information to MIDI control codes. This process is generally called 'emulation', although a more accurate term is 'decoding', as it better describes what is done to the file. The term 'emulation' is used in this chapter because of its general acceptance, but only when referring to files that have both the expression and pedalling information converted to standard MIDI codes.

Background

The first commercial application of emulated piano roll MIDI files belongs to Artis Wodehouse, who in 1992 worked with a number of people to produce a CD of Gershwin's Duo-Art piano roll recordings.[346] The liner notes explain that Richard Tonnesen converted the rolls to raw performance MIDI files, and that US software engineer Richard Brandle wrote a "computer simulation of the reproducing pianos which translated the computer files into MIDI representing the notes, their duration and position in time and relative loudness as executed by the old reproducing pianos."[347] The recordings were made by playing the resulting MIDI files on a Disklavier.

[346] *Gershwin Plays Gershwin, The Piano Rolls*, Elektra Nonesuch 9 79287-2, issued November 5, 1993, http://www.nonesuch.com/albums/gershwin-plays-gershwin-the-piano-rolls (accessed 12 July 2016).
[347] Artis Wodehouse, liner notes to *Gershwin Plays Gershwin, The Piano Rolls*, http://albumlinernotes.com/The_Piano_Rolls.html (accessed 12 July 2016).

In 1998, Brandle wrote a program called *WindPlay*, primarily for a device called the *PowerRoll*, a commercially-available MIDI valve interface that clipped onto the tracker bar of a reproducing piano.[348] Although of no use to the *PowerRoll*, Brandle added the functionality of converting raw MIDI files to emulated files for playing on a standard MIDI piano. Unfortunately, the program only recognised a file format designed by Wayne Stahnke, known as bar/ann files.[349]

When *WindPlay* and a companion program called *Wind* (also written by Brandle) became available, I used *Wind* to convert raw MIDI files of Ampico rolls to bar/ann format, and *WindPlay* to play the files through its Ampico emulator. The MIDI output from *WindPlay* was recorded on another computer. Using the default settings in *WindPlay* produced MIDI velocity levels that gave excessively loud playing, requiring the settings to be changed to suit the dynamic range of a MIDI mechanical piano, which at the time was a Yamaha G5 grand piano fitted with a PianoDisc system.

In 2001, at an AMICA convention held in Melbourne I used a Disklavier to demonstrate the emulated MIDI files produced using *WindPlay*,[350] and received a warm response, including offers to market the files on my behalf. As pointed out in the Introduction (page 5), in 2007 I was invited by the Vienna-based piano manufacturer Bösendorfer to make recordings of the files on the company's new CEUS-equipped Imperial grand piano.[351] The general acceptance of the emulated MIDI files by collectors and musicians supports the notion that Brandle's Ampico expression decoding software produced convincing results.

When roll scanning became an established technology, software developers in the US, including Warren Trachtman and Spencer Chase,[352] wrote emulation programs and distributed or marketed emulated MIDI files of piano rolls. Stahnke also wrote software to emulate Ampico rolls, which he describes as a "computer program that contains within it a mathematical model of the pneumatic mechanism."[353]

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[348] Michael Waters, *Player Piano – Power Roll* (2000), http://www.waterex.com.au/player/poweroll.html (accessed 12 July 2016).
[349] The bar/ann format has two files, a bar file (for tracker bar) that contains MIDI data, and an associated ann file (for annotation) that contains information about the bar file, such as title, pianist, composer etc.
[350] AMICA (Automatic Musical Instrument Collectors' Association) is a US-based group of collectors of mechanical musical instruments.
[351] *CEUS Project* series of 12 CDs, eleced label, available from http://www.naxosmusiclibrary.com (accessed 12 July 2016).
[352] Warren Trachtman, *Saving The Old Piano Roll Music*, http://www.trachtman.org/rollscans, Spencer Chase, *Spencer's E-Rolls*, http://www.spencerserolls.com/index.html (both sites accessed 12 July 2016).
[353] Stahnke, liner notes to *A Window in Time*, 6.

In 2011, a group of researchers from the Universidad Central de Venezuela published a study that they had conducted concerning computational modelling of reproducing piano rolls.[354] To achieve an emulated MIDI file of an Ampico roll, the authors developed a computer program they called *RollToMidi* that processed a raw MIDI file produced by Stahnke. The accuracy of the dynamics in the emulated MIDI file was tested using MATLAB software by comparing the sound waveforms of a recording made of the roll played on a reproducing piano, and the sound waveform created by the emulated MIDI file.[355] The authors point out that this comparison was only a first step to validate the computer model and conclude that their software produced a result "close to the direct execution of a roll by a reproducing piano."[356]

Interestingly, software to convert piano roll expression to MIDI velocity values has been largely focused on rolls for the Ampico or Duo-Art, although in 1997 Stahnke marketed a limited number of emulated MIDI files derived from Welte Licensee rolls, presumably using his own emulating software. Brandle included a Welte expression decoder in his *WindPlay*, but I found the results were entirely unsatisfactory. Using a test roll to check the operation of the decoding software showed it did not conform to any of the tests.

In 2013, I was faced with the need to provide a monitor instrument for Welte-branded rolls, as these were due to be recorded using the roll reader. As discussed in Chapter 2, there are three types of Welte reproducing pianos. It may have been possible to adapt any one of the three types to act as a monitor, but a search to purchase a suitable Welte instrument was unsuccessful.

Another solution was to develop a means of producing an emulated MIDI file of a Welte roll as it was being recorded on the reader, so the recording could be monitored on a Disklavier. Emulation programs work only with a stored MIDI file, not one that is being fed into the computer from an external source. That is, an in-line Welte emulator was required, the development of which is now explained.

[354] G. Colmenares, R. Escalante, J. Sans and R. Surós, "Computational Modeling of Reproducing-Piano Rolls," *Computer Music Journal* 35, no. 1 (2011).
[355] Colmenares et al, 70.
[356] Colmenares et al, 72.

Welte expression decoder

Mention has been made of 'modelling the expression system'. The assumption often made today is that modelling of any sort is done with computer software, however there are various reasons, later explained, that deterred me from this approach. My aim throughout has been to introduce minimal errors in any process involving piano roll data. On the basis that it would offer best accuracy, I began by designing an analogue electronic circuit to model the Welte expression regulator. The design would belong to the class of circuitry used in analogue computing systems.

Welte expression regulator

The obvious starting point in developing a model of the Welte expression regulator was to fully understand its operation. My familiarity with Welte instruments was limited to working on those owned by others, which provided experience with all three types of instruments. I also had a general understanding of the expression system, which further evolved through discussions with Welte-Mignon owners and repairers, and reading descriptions of the instrument in available literature, in particular factory-produced handbooks and manuals for the Welte-Mignon. As these manuals point out, the Welte expression regulator is based on simple principles, and is illustrated in Figure 4.1.

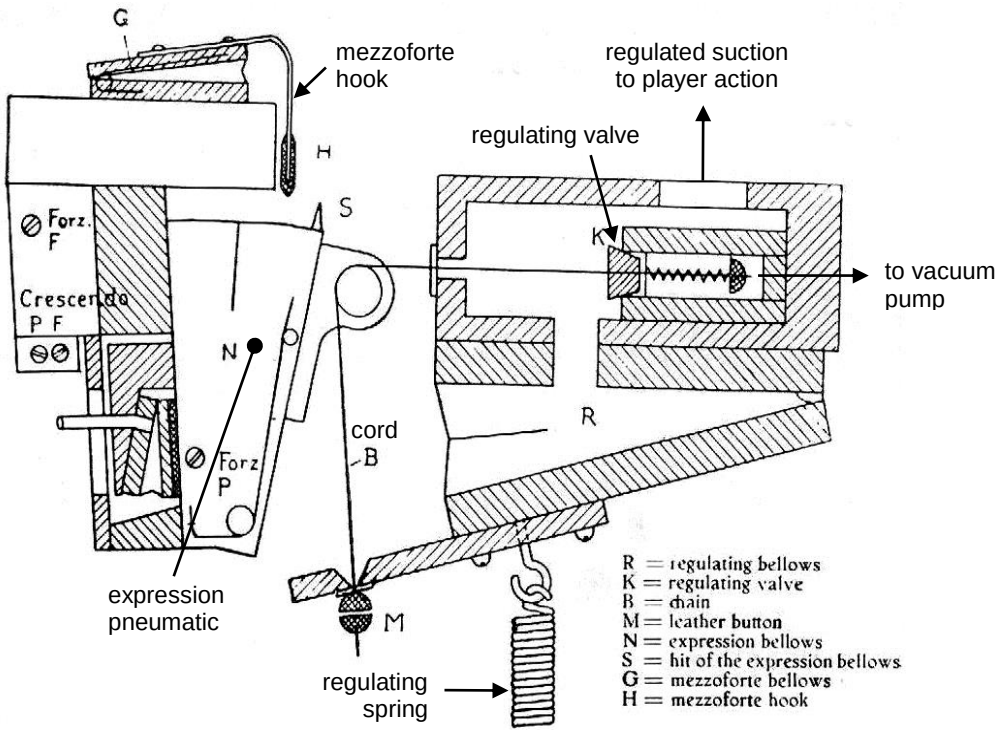


Figure 4.1 *Welte-Mignon expression system, from a Welte handbook*

The principle behind all reproducing pianos is that the loudness of a note depends on the level of suction applied to the pneumatic operating that note. This principle was patented by Welte, regardless of how the suction level might be regulated. In all such regulators, a restriction is placed between the vacuum pump and the player piano action, to allow more or less air to flow through the restriction. In Figure 4.1, the restriction is accomplished by regulating valve K.

If valve K is moved away from the opening, more suction is allowed into regulating bellows R and to the player action, causing notes to play more loudly, and regulator R to partially close against the opposing force of the regulating spring. The action of moving valve K is accomplished by the expression pneumatic N, which is a fundamental component of the system.

If pneumatic N attempts to close, the tension applied to the cord connected between the valve and the regulating bellows will open the valve and allow more suction into the regulating bellows, which will tend to close. The effect is that the valve opens by a small amount, and the much larger shift in the position of the regulating bellows supplies the cord to allow the expression pneumatic to move by a similar amount. In principle, the position of expression pneumatic N determines the level of suction supplied by the regulator to the player action.[357] This important concept forms the basis of how the expression regulator is controlled by piano roll perforations.

- **Action of expression pneumatic N**

At any one time, expression pneumatic N can do one of three things: open or close slowly, open or close quickly, or remain stationary. There are four stationary positions; fully open, fully closed and two others yet to be explained. There are four adjustments that determine how quickly the expression pneumatic moves:

1. Slow closing speed, adjustment noted in Figure 4.1 as Crescendo F; produces a slow crescendo by slowly increasing the suction level as the expression pneumatic closes.
2. Slow opening speed, adjustment Crescendo P, produces effect of a slow decrescendo.
3. Fast closing speed, adjustment Forz F, causes suction level to increase quickly, produces a fast crescendo.

[357] There are two expression regulators, one each for the bass and treble sides of the player action.

4. Fast opening speed, adjustment Forz P, causes suction level to drop quickly, producing a fast decrescendo.

To achieve a slow closing speed, the expression pneumatic is connected to a regulated suction source (vacuum pump, regulated at the pump) via a restriction in the form of a small aperture of adjustable size, also called an adjustable bleed. The size of the aperture determines how quickly air will be evacuated from the pneumatic. A fast closing speed is provided by connecting the pneumatic to the suction source via a large size aperture, also adjustable. The opening speed of the pneumatic is similarly controlled, except the pneumatic is now connected to atmosphere via either the smaller or larger aperture.

Connection to either suction or atmosphere is achieved with pneumatic valves similar to that described in Chapter 3, Figures 3.1 and 3.2 on page 176. In practice, the expression pneumatic is always connected to atmosphere via the adjustable aperture Crescendo P in Figure 4.1. As a result, in the absence of other expression data, the pneumatic will always open slowly until it reaches a stationary point, typically when it is fully open. At this point, the suction level applied to the player action is at its lowest, giving the softest playing.

It is not always convenient to have the expression pneumatic reaching its fully open position if the playing has dynamics well above the softest playing. Therefore, the Welte expression system has a separate pneumatic (shown as G in Figure 4.1) that can interrupt the travel of the expression pneumatic. When pneumatic G is closed, the metal tab S on the top of the expression pneumatic will engage with tab H, which is now lowered into position. The effect is to either prevent the expression pneumatic from fully opening or fully closing, depending on the side by which tab S is engaged. Tab H is called the ‘mezzoforte hook’, and pneumatic G the ‘mezzoforte pneumatic’, because the playing level at the point of engagement is around mezzo forte level.

A fourth stationary position for the expression pneumatic is the point it reaches when instructed to close slowly (slow crescendo). The relatively small size of the aperture allowing the pneumatic to be exhausted prevents it from fully closing due to external forces on the pneumatic. This position is not referred to in Welte instructions, but can be observed on an original instrument.

Summary of Welte expression system

The system is based solely on the crescendo principle, in which the expression pneumatic moves either slowly or quickly to produce corresponding changes in suction and playing dynamics. By interrupting the travel of the expression pneumatic, a stationary position representing mezzo forte level is introduced, which might be the maximum or minimum playing level. Other fixed positions are the softest playing level, called the zero level, which is adjustable with button M in Figure 4.1, and the maximum playing level, also adjustable, but not shown in Figure 4.1.[358]

In operation, the expression pneumatic is connected to either suction or atmosphere through adjustable apertures that determine the opening or closing speed of the pneumatic. The position of the expression pneumatic determines the suction level applied to the player action, and expression perforations on the roll operate pneumatic valves to cause the expression pneumatic to move in the required direction at either of the two speeds.

While the principle of operation is relatively straightforward, there were two critical aspects that had to be considered in developing a model of the system: the travel times of the expression pneumatic under all four conditions, and the dynamic playing level at the four stationary positions of the pneumatic.

Developing a model of the Welte expression regulator

The expression system in Welte instruments is adjusted with the aid of a test roll. Each type of instrument has its own test roll, although the same set of tests are applied. The various tests require observation of the expression pneumatic, which should behave in a specified way for each test. One particular test causes the expression pneumatic to close slowly from rest, in which it should just reach the mezzoforte hook by the time a note is sounded.

Determining a value for this time interval was achieved by taking measurements from MIDI files of Welte test rolls. This revealed that the time interval differed between test rolls for the Mignon, Licensee and Green Welte instruments. Other measurements taken from the test roll MIDI files gave more timing information, although there were time intervals that could not be resolved, such as the times taken for the expression pneumatic to fully open or to fully close at the fast speed settings.

[358] The maximum playing level is set by an adjustment at the vacuum pump.

By this stage, there was enough information to start designing the circuit that would model the regulator. Its output signal would be a variable DC voltage analogous to suction level, and the circuit would change the voltage in response to the applied expression information, thereby mimicking the behaviour of a Welte expression regulator.

Suction level and MIDI velocity

The values of suction at the dynamic extremes of a reproducing piano depend on factors that include owner preferences, regulation of the piano action and design of the player action. A typical 'zero' level is between four and six inches WG, while a maximum level might be fourteen inches WG, or more typically 25 to 30 inches WG. A range of five to 29 inches WG was chosen as a basis with which to begin.

To establish the MIDI velocity values that would apply, it was necessary to determine the relationship between suction (in inches WG) and MIDI velocity levels. A mechanism modelled on a typical pneumatic player piano was constructed, in which a pneumatic was positioned to operate a wooden 'finger' that would play a piano key. The apparatus is shown in Figure 4.2 sitting before a Disklavier, in which each key strike could be recorded as MIDI data to show the velocity of each strike. Accuracy was therefore determined by the Disklavier's recording system.

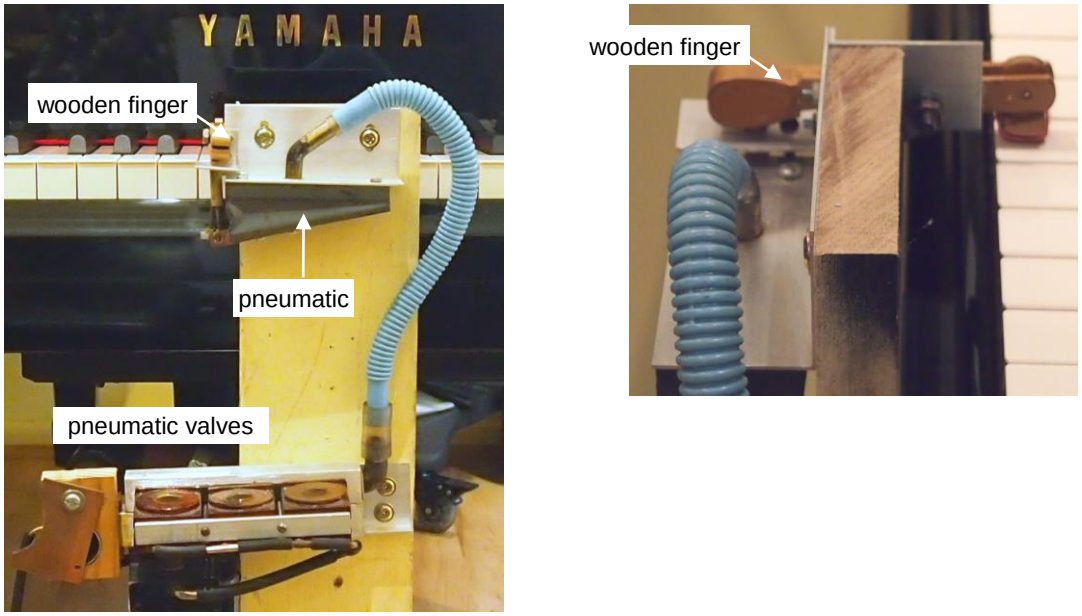


Figure 4.2 *Apparatus used to establish the relationship between suction and MIDI velocity levels, in which a wooden finger playing a key on a Disklavier is operated by a pneumatic supplied with various levels of regulated suction*

To cater for variations that might occur with pneumatics of differing shapes, two pneumatics of equal surface area were constructed, with one pneumatic 40 percent longer and correspondingly thinner than the other. The shorter pneumatic was based on the dimensions of pneumatics typically used by Ampico, the longer pneumatic was based on the shape used in the Welte-Mignon. It is well understood that the larger the surface area of a key-striking pneumatic, the greater the force it can apply, so both test pneumatics differed only in dimensions, not surface area. The aim was to determine if the geometry of a pneumatic was a factor in determining playing dynamics.

Another variable to consider was the playing weight of different piano actions, so tests were conducted on two Disklaviers with differently weighted piano actions. A significant variable present in all piano actions is the variation across the keyboard in the size and weight of the hammers. To determine the effect that hammer weight might have, tests were carried out on five different notes, ranging from bottom C (C2) to note C8, with a reference of middle C (C5). Other notes forming part of the tests were C3 and F6.[359]

Each test involved accurately adjusting the applied suction level in one inch increments, by taking measurements with a single-tube vertical manometer, chosen because of its higher resolution compared to a U-tube manometer.[360] The lowest suction level that could cause the pneumatic to play a note was recorded, but in general it was found that levels below five inches WG produced erratic velocity values. All tests were conducted by operating the pneumatic five times at each of the 25 suction levels that ranged from five inches to 29 inches WG. Each test was conducted at least twice, occasionally three times and more often if inconclusive results were obtained.

Several tests were made in which the pneumatic was caused to repeat rapidly at a tempo often found in piano works involving trills or repeating triplets. The aim was to determine if repetition rate affected the playing dynamics. This test was done with both pneumatics on note E5. Apart from action weight tests using a Disklavier in a C7 piano, all tests were done on a new Disklavier Pro Mark 4, in a C5 piano.

[359] Note numbering is not standardised, and throughout this chapter I use a reference of middle C as being C5. In MIDI terms, middle C is note number 60.

[360] A U-tube manometer has water in two tubes in which the suction level is the difference between the water levels in both tubes. A single-tube manometer registers suction by the height of the column of water in the tube, allowing graduations to be one inch apart, not half an inch apart as in the U-tube device.

Findings and results

There were minor differences in the velocities produced by both pneumatics which could be ignored, as they averaged less than two MIDI velocity steps. The geometry of a pneumatic therefore has little impact on velocity levels although the longer pneumatic was able to play some notes more reliably at low suction levels.

The tests revealed that a lightly-weighted piano action gave slightly higher MIDI velocity values than a heavier action. Tests were carried out on the same note (middle C) on two Disklaviers, which showed a consistent difference in the velocity levels across the dynamic range. The difference averaged three MIDI velocity steps, showing that the heavier the piano action, the slower the closing speed of a note-playing pneumatic. This conclusion is further supported by the graphs shown in Figure 4.3, which were developed from the measured values obtained during the tests.

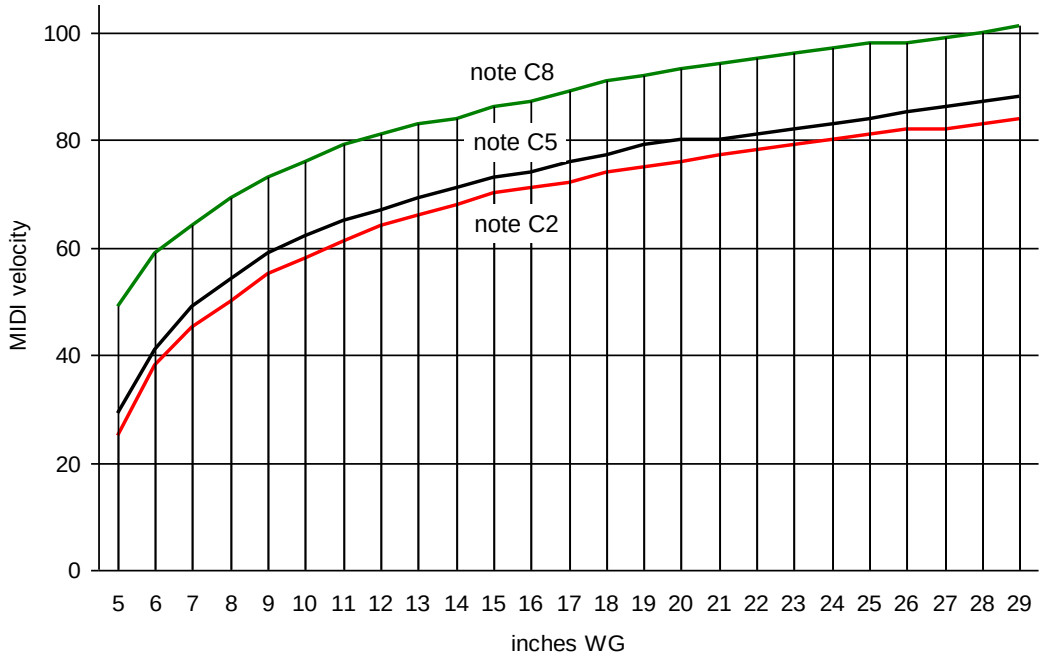


Figure 4.3 *Graphs of suction and MIDI velocity at three different points on a piano keyboard*

While tests were conducted on five notes, the graphs in Figure 4.3 show the velocity readings of three notes: C2, middle C (C5) and C8. It can be seen that the lightest note (C8) recorded higher values of MIDI velocities than the other notes. The average difference in MIDI velocities between C8 and the heaviest note (C2) is a substantial seventeen steps, with around twelve steps between C8 and C5. C2 is around three steps lower in velocity than C5. This shows the effect of hammer weight on the closing speed of a note-playing pneumatic.

When the velocity figures obtained with F6 and C3 are also considered, it is clear that there is a relationship between hammer weight and velocity for a given level of suction. It also appears that the relationship is linear, although this has not been confirmed by measuring the weight of the hammers used in the tests, only by examining the size of each hammer.

An important finding is that when comparing the ten graphs that were developed from the tests, the shapes of the velocity graphs are almost identical. The graphs show that the relationship between suction and MIDI velocity is essentially logarithmic, in which a small change in suction at the low end of the graphs gives a much greater change in MIDI velocity level compared to a similar suction change at the high end.

The stepped nature of the MIDI velocity graphs is due to the relatively few available MIDI velocity values of 1 to 127. For example, a MIDI velocity value of 80 was registered by C5 for suction levels of 21 and 22 inches WG. The stepped effect is not so noticeable with lower suction levels, where the graph has a smoother appearance. High definition MIDI, as used in high-end mechanical instruments, would give a greater range of velocity values and therefore smoother graphs.

The graphs in Figure 4.3 show that, for a given value of suction, the recorded MIDI velocity depends on the weight of each hammer. Because the mass of a hammer, in conjunction with its velocity determines how loudly a note is played, the lower the mass of the hammer, the lower the volume for a given velocity. Therefore, although the MIDI velocity increases as hammer weight reduces, the perceived volume level remains essentially unchanged. [361]

MIDI and WG value range used in the model

A pneumatic piano can play over a wide dynamic range, although at very low suction levels, playing is not reliable. For example, the lightly weighted treble notes could be played at a suction level of four inches WG, but working progressively down the keyboard showed that notes responded spasmodically or not at all. Rather, suction levels of five inches WG and higher were necessary for consistent behaviour. At this value of suction, middle C played at MIDI level 30, which is about as soft as can be reliably achieved by many solenoid mechanical pianos.

[361] Zenph refers to this relationship as ‘context-awareness’ in the user guide for the company’s *RePerform* MIDI editing software package.

The maximum playing levels of the lightest notes were found to exceed MIDI 100 at 29 inches WG, while at this level, middle C registered MIDI 88. In my experience, most MIDI mechanical pianos have an upper limit of around MIDI 85 to 90. Goebl and Bresin reached a similar conclusion in their study of the performance characteristics of a Mark 2 Disklavier.[362] The authors recognise that later models of Disklavier might give improved figures.

I therefore determined, as a starting point, to use a value of 35 as the minimum MIDI velocity, and 85 as the maximum. The DC voltages generated by the analogue decoder circuitry would be converted to an 8-bit digital value ranging up to 255, giving an acceptable resolution. The voltage range was set to around one volt for MIDI 35 and ten volts for MIDI 85.

[362] Werner Goebland and Roberto Bresin, "Are Computer-controlled Pianos a Reliable Tool in Music Performance Research? Recording and Reproduction Precision of a Yamaha Disklavier Grand Piano." *Austrian Research Institute for Artificial Intelligence (OFAI) (*November 2001), http://www.ofai.at/cgi-bin/tr-online?number+2001-27 (accessed 28 July 2016), 6.

Prototype Welte expression decoder

It is not necessary to explain how the model worked, but it is useful to outline its operation to show why an analogue expression decoder was chosen as a starting point. The block diagram in Figure 4.4 summarises the operation, in which the Welte expression regulators are modelled by two identical, analogue electronic circuits. Welte expression data is applied as electronic signals to each circuit, and the output of each circuit is a DC voltage analogous to suction level. The dashed lines point to the equivalent parts in the analogue model, in which the bass regulator circuitry is underneath the circuit board pointed to on the right.

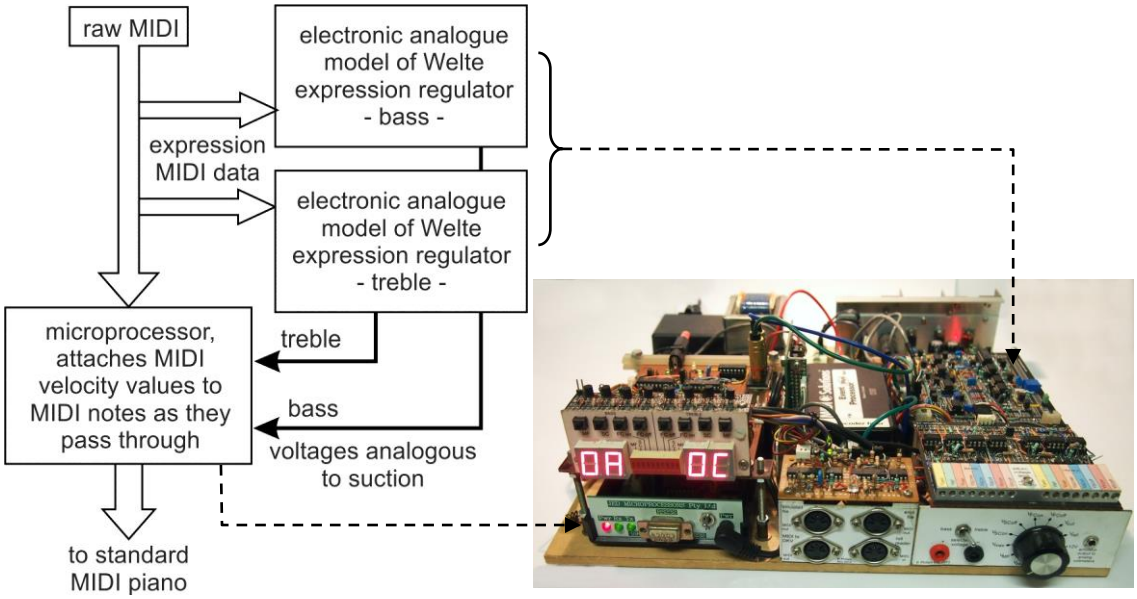
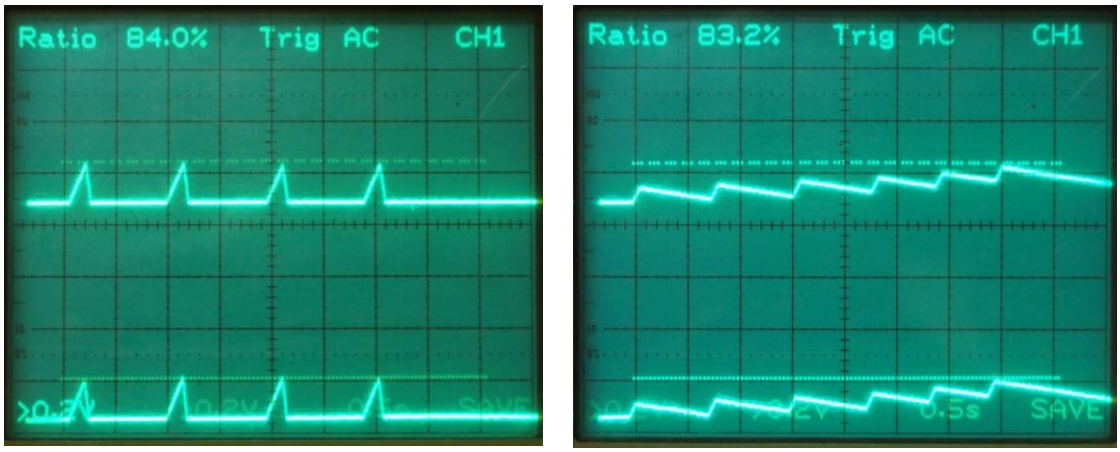


Figure 4.4 *Block diagram of Welte expression decoder and the prototype model*

In operation, the raw MIDI data passes through a microprocessor that reads the two DC voltages representing suction, and attaches the related MIDI velocity codes to the MIDI notes passing through at the time. There is virtually no delay in the process. The analogue circuits work independently, so the only processing time is that required by a few lines of code to read the analogue voltages, fetch the related MIDI velocity codes from a table stored in the microprocessor, and attach these to the MIDI note data. That is, the timing errors that might occur in a computer program running under an operating system are entirely removed.

Because the expression values are varying DC voltages, they can be observed on an oscilloscope. This was particularly important, as it gave the same visual representation as in an original instrument, for which observing the behaviour of the expression pneumatic is essential when making adjustments to the regulators. The photos in Figure 4.5 are of the expression dynamics as shown on a digital storage oscilloscope. The dashed horizontal lines show the position of the mezzoforte hook, the higher display shows the treble dynamic behaviour, the lower display shows the bass dynamic behaviour.



***(a)** test 4* ***(b)** test 6*

***Figure 4.5** Oscilloscope displays of expression behaviour from Welte Mignon test roll*

The traces shown in Figure 4.5 (a) are the results from test 4 on the Welte-Mignon test roll, for which the instructions state that "the expression bellows must move exactly as high up as the position of the mezzoforte hook, and must return every time to its original position by forzando piano [fast decrescendo]."[363] Test 4 triggers the slow and fast speeds of the expression pneumatic, in both directions of travel. Prior to running this test, the slow speed (slow crescendo) is adjusted with test 3, so test 4 is used to adjust the fast crescendo speed.

The photo in Figure 4.5 (b) shows traces from test 6, for which "the expression bellows must move during these short forzando [fast crescendo] movements from pianissimo [zero] position until its pin touches the mezzoforte hook with the last hit."[364] This is a critical test of the fast closing speed of the expression pneumatic.

[363] Descriptions of the tests on the Welte Mignon Test Roll T-100, handbook held by the author, 4.
[364] Descriptions - Welte Mignon Test Roll, 6.

Another critical test is the adjustment of the fast opening speed of the expression pneumatic, which is covered by test 5. The display for this test is shown in Figure 4.6.

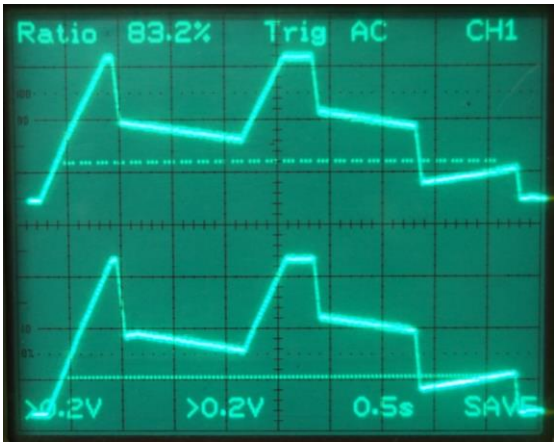


Figure 4.6 *Oscilloscope display for Welte-Mignon expression test number 5*

In test 5, "the first note must strike in fortissimo, 2nd, 3rd and 4th in pianissimo, the 2nd slightly louder than the 3rd and 4th."[365] The traces shown in Figure 4.6 achieve the objectives of the test without needing to judge the relative loudness of each note. In practice the adjustment is critical, as it has to cause the expression level to reach the zero level by the end of the test, not beforehand. In general, I found it easier to adjust the model than to adjust a Welte-Mignon instrument, as the oscilloscope display showed the operation of the system very clearly.

An adjustment that must be done by ear is setting the minimum playing levels of the bass and treble regulators, in which "the chord of the bass should be a trifle softer than the chord of the treble."[366] For the purposes of gathering timing data, it was only necessary to set the treble regulator's zero and mezzo forte levels slightly higher than for the bass regulator. Judgement of the meaning of the term "trifle" could wait.

Once the model was adjusted according to the test roll, it was possible to make accurate timing measurements of all movements associated with the expression pneumatic. Measurements were achieved by using the oscilloscope's in-built cursors to measure the times taken for each type of excursion, whether to the maximum level or to the mezzoforte hook. The measured timing values for a Welte-Mignon expression regulator are shown in Table 4.1.

[365] Descriptions - Welte Mignon Test Roll, 5.
[366] Descriptions - Welte Mignon Test Roll, 3.

Table 4.1 *Timing values of Welte-Mignon expression pneumatic*

Adjustment	***Bass regulator***	***Treble regulator***
Slow crescendo, travel from zero to mezzoforte hook	2.38 seconds	2.38 seconds
Slow decrescendo, travel from mezzoforte hook to zero	2.38 seconds	2.38 seconds
Fast crescendo, travel from zero to maximum	700 milliseconds	700 milliseconds
Fast decrescendo, travel from maximum to zero	150 milliseconds	156 milliseconds

The test rolls had shown that the slow crescendo and decrescendo times differed between each type of Welte instrument. To establish all the timing values for the Green and Licensee instruments required reconfiguring the model and adjusting it using the MIDI file of the relevant test roll. Tables 4.2 and 4.3 show the timing values that were established for the Green and Licensee instruments.

Table 4.2 *Timing values of Green Welte expression pneumatic*

Adjustment	***Bass regulator***	***Treble regulator***
Slow crescendo, travel from zero to mezzoforte hook	2.49 seconds	2.43 seconds
Slow decrescendo, travel from mezzoforte hook to zero	2.49 seconds	2.34 seconds
Fast crescendo, travel from zero to maximum	870 milliseconds	850 milliseconds
Fast decrescendo, travel from maximum to zero	190 milliseconds	180 milliseconds

Table 4.3 *Timing values of Welte Licensee expression pneumatic*

Adjustment	***Bass regulator***	***Treble regulator***
Slow crescendo, travel from zero to mezzoforte hook	2.45 seconds	2.48 seconds
Slow decrescendo, travel from mezzoforte hook to zero	2.73 seconds	2.86 seconds
Fast crescendo, travel from zero to maximum	560 milliseconds	580 milliseconds
Fast decrescendo, travel from maximum to zero	150 milliseconds	156 milliseconds

As the tables show, the timings vary between instruments. The greatest differences are associated with the fast movements, in which the Licensee instrument has a considerably faster operating speed for the fast crescendo function, compared to that for

the Green Welte. Owners of Welte Licensee or Green instruments often adapt the instrument to play either type of roll, but the dynamics of the added version will be different to those when the roll is played on its own instrument. In all cases, the times for the slow crescendo and decrescendo were measured from the MIDI file of the relevant test roll. Although the measurements were obtained from original test rolls, production rolls vary, and it may be that other test rolls would give slightly different timing values.

The performance of the Welte-Mignon expression model yielded interesting results when the oscilloscope display was compared with the expression lines marked on a Welte-Mignon roll. I concluded in Chapter 2 that the expression lines were produced by a tracing pen attached to pneumatics connected to the bass and treble suction regulators. This conclusion was based on the oscilloscope displays that were observed when using the model while recording Welte-Mignon rolls. The photos in Figure 4.7 compare the dynamic lines on a roll and the oscilloscope display for that part of the roll when the raw MIDI file is played into the analogue model.

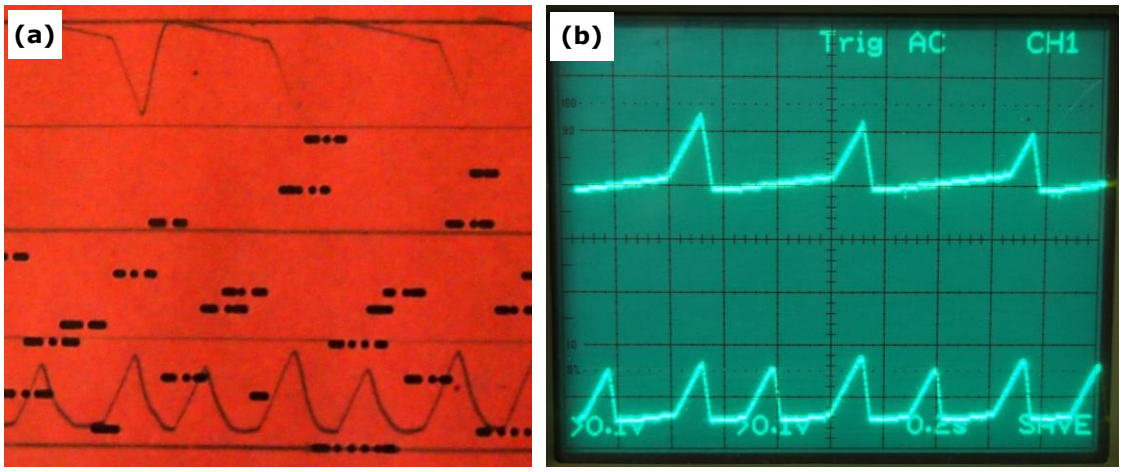


Figure 4.7 **(a)** *Dynamic lines on a Welte-Mignon roll* ***(b)*** *dynamics produced by the model*

The centre line on the roll in Figure 4.7 (a) indicates the maximum level of both dynamic lines, therefore the treble (higher) dynamic line on the roll is upside down compared to the oscilloscope display. Even so, it can be seen that there is considerable similarity between both sets of dynamic lines.

Microprocessor-based Welte expression decoder

The analogue model served for some time as the means of using a Disklavier to monitor roll reader recordings of Welte rolls. It required an additional electronic module to convert piano roll pedal data to MIDI control codes, achieved with a commercially available device.[367] Using the model in a practical application provided considerable insight into those settings of the Welte expression regulators that are not explained. Settings include the position of the mezzoforte hook, and the dynamic level that the expression pneumatic reaches under slow crescendo action.

The model embodied all the adjustments found on a Welte-Mignon. A particular issue in an original instruments is the interaction between the adjustments of the slow crescendo and decrescendo settings, which were overcome in the model by making both adjustments independent.

In an original instrument, if the zero or mezzoforte hook levels are changed, the slow and fast crescendo and decrescendo times must all be readjusted, using a test roll. Correct adjustments are achieved by observing the expression pneumatic and listening to the loudness of notes, making it a tedious process.

In the model, the various actions such as fast and slow crescendo or decrescendo could be invoked with pushbuttons, and all adjustments were made by observing the signal displayed on an oscilloscope. Readjusting the settings when changing to a different type of Welte roll was time consuming, requiring many settings to be readjusted. It also involved reprogramming the event processor unit handling the lock-and-cancel expression coding for Mignon and Licensee rolls, as opposed to the single perforation coding for Green rolls.

The analogue model used a microprocessor as part of its function. If advancements were to be made, it seemed logical to incorporate the entire model into a microprocessor. A microprocessor model, although entirely software-based, does not have the timing issues associated with software running under a computer operating system. Windows or Apple iOS operating systems offer multi-tasking, in which programs are updated at regular intervals, typically every ten milliseconds. Because the Welte fast decrescendo action must occur in around 150 milliseconds, a ten-millisecond delay is obviously a problem.

[367] MIDI Solutions Event Processor Plus, from MIDI Solutions Inc at www.midisolutions.com.

While there are ways around delays that could occur in a computer operating system, it is ideal to model the Welte crescendo action as a free-standing operation, as in the analogue model, so it is not affected by other actions going on around it. The selected microprocessor (Atmel Atmega32) incorporates free-running timers that can be programmed to act in the same way as their equivalent in the analogue circuit, with the exception that a varying digital value is produced instead of a varying analogue voltage.

The analogue model had highlighted the difficulties associated with changing to a different type of Welte roll, or if any of the fixed points such as the zero or mezzoforte levels were changed. In all cases, the timings of the fast and slow crescendo and decrescendo actions had to be re-adjusted and checked with the relevant test roll MIDI file. The microprocessor version could simplify the adjustments by allowing levels to be changed while automatically maintaining the time values listed in Tables 4.1 to 4.3.

At first it seemed best to incorporate into the microprocessor model a bank of eight rotary controls to allow adjustment of the four fixed points in each regulator. This idea was abandoned for a number of reasons, and instead, adjustment was provided with a set of lookup tables to be stored in the microprocessor's memory, one set each for the treble and bass regulators for the three types of Welte instruments. Each set would have eight tables specifying all timing values and dynamic levels. Changing a setting could be achieved by selecting a different table with a pushbutton, and tables could be established to suit different instruments or listening conditions.

Much of the actual programming of the microprocessor was carried out by colleague and software engineer David Gosden, who implemented the flow chart that I developed. The program included the ability to output the bass and treble expression values as varying DC voltages, allowing both voltages to be observed on an oscilloscope, as with the analogue model.

The photo in Figure 4.8 shows the final device.[368] Because it also converts pedal data to MIDI control codes, the output of the decoder is an emulated MIDI file that is compatible with a standard MIDI instrument. The input is a raw MIDI file from the roll reader or a computer playing a raw MIDI file of a Welte roll. A single pushbutton selects the type of Welte roll, and two buttons select one of the eight expression tables for that type of roll.

[368] Welte expression decoder designed and built by the author, programming by David Gosden.

Figure 4.8 *Microprocessor-based expression decoder for all types of Welte rolls*

Assumptions

The operation of the microprocessor model was compared with the analogue model by comparing signals on an oscilloscope, proving that the two behaved in an identical way to the tests on Welte test rolls. However, I have made two assumptions about the Welte expression regulator that could mean it behaves slightly differently to the models.

The first assumption is that the suction level is exactly related to the position of the expression pneumatic. The assumption is supported by measurements taken from original instruments, although such readings are not exact and some non-linearity may apply, particularly at the extremes of travel of the pneumatic. For example, slight movement from the fully open (zero) position may create a greater change in suction than the same movement a few millimetres of travel later. It may also be that when the expression pneumatic is approaching its fully-closed position, the change in suction level over the last few millimetres of travel is relatively small.

The second assumption is that the expression pneumatic moves at a constant speed over its full stroke for both slow and fast actions. In theory, a pneumatic that is being exhausted through a fixed aperture by a fixed level of suction will close at a constant rate, because the air inside the pneumatic is being withdrawn at a constant rate. However, this assumes the external forces working against the pneumatic remain constant. Changes in external forces are likely to occur at the positional extremities of the pneumatic, where they would have the greatest effect.

In both assumptions, the dynamics at the positional extremes are potentially affected. The most audible effect, should it exist, will be heard in the soft playing. The shape of the dynamic lines on the Welte roll in Figure 4.7 on page 222 differ slightly to those generated by the models. The dynamic lines on the roll are rounded at the bottom

of each excursion, while those generated by the models are not rounded. This assumes that the apparatus used to produce the dynamic lines on the roll accurately followed the changes in suction, and the curvature was not caused by the apparatus.

The difference is that the softest playing level (zero level) is reached slightly later by the pneumatic regulator compared to how the models behave. However, as Figure 4.7 also shows, once past the zero position, the dynamic lines on the roll are relatively straight, particularly when moving in a positive direction. Determining the MIDI velocity levels that would occur if the expression pneumatic behaved according to the dynamic lines in Figure 4.7(a) showed an indiscernible difference of one or two steps.

Determining the relationship between the position of the expression pneumatic and level of suction is difficult. On the basis that there might be non-linearity at low suction levels, where it would be most noticeable, the decoder in Figure 4.8 has two look-up tables of MIDI velocity values, selected by a pushbutton. The default table contains the measured values as shown in the graph of Figure 4.3, the secondary table contains values in which low velocity MIDI values increment more rapidly to mimic the type of non-linearity that could exist in the regulator.

Comparing the playing dynamics produced by both look-up tables to determine if a non-linearity exists has proven inconclusive. That is, one table does not produce a better set of dynamics than the other, instead both sound convincing to my ears. I have concluded that if a non-linearity exists in the Welte expression regulator, for either of the two reasons given, it would not have been taken into account during production of piano rolls, as the effects are minor. Taking measurements from an original Welte instrument might give greater insight, although the instrument would need to be as close to new condition as possible for best accuracy.

Fine adjustments

An important setting with Welte instruments is the difference in playing level of the bass and treble sides of the keyboard, described as differing by a "trifle." In audio engineering terms, a change in dynamic level of three decibels (3dB) is regarded as being just discernible.[369] In his *WindPlay* program, Brandle lists MIDI velocity levels and decibels that show a dynamic change of 3dB requires a change of twelve velocity steps. My experiments tend to confirm this figure, particularly at low volume levels.

Another critical setting in a Welte-Mignon is the position of the mezzoforte hooks, in which the treble hook is positioned so that the treble expression pneumatic travels slightly further than the bass expression pneumatic. Therefore, the suction level at the mezzoforte hook position is slightly higher for the treble side than the bass side. Another consideration is the side of the hook by which the expression pneumatic is engaged. Measurements from an original instrument show a difference of 0.5 inches WG, due to the thickness of the metal tab.

Establishing these settings in the model required judgement, as Welte literature gives no information. As a guide, I listened to recordings of well-adjusted original instruments particularly to assess the loudness of thematic notes compared to accompaniment notes, the overall loudness of the playing and the dynamic range. I subsequently developed values for each of the expression tables in the model so that for the three types of Welte instrument, each table had different values for the four stationary positions of the expression pneumatic. Tables for the treble expression had higher values than those for the bass by varying amounts. The times associated with the fast and slow crescendo or decrescendo actions were the same in all tables, as the timing values were determined from test rolls and could therefore be assumed to be correct.

Tables could be selected while a MIDI file was playing, facilitating comparisons between settings. While most of the settings in the expression decoder were derived from measurements, those that required judgement were eventually arrived at by listening, in the same way a technician might go about it when adjusting a Welte-Mignon. The dynamics produced by each table were not significantly different, requiring numerous MIDI files of Welte rolls to be played to arrive at the final settings.

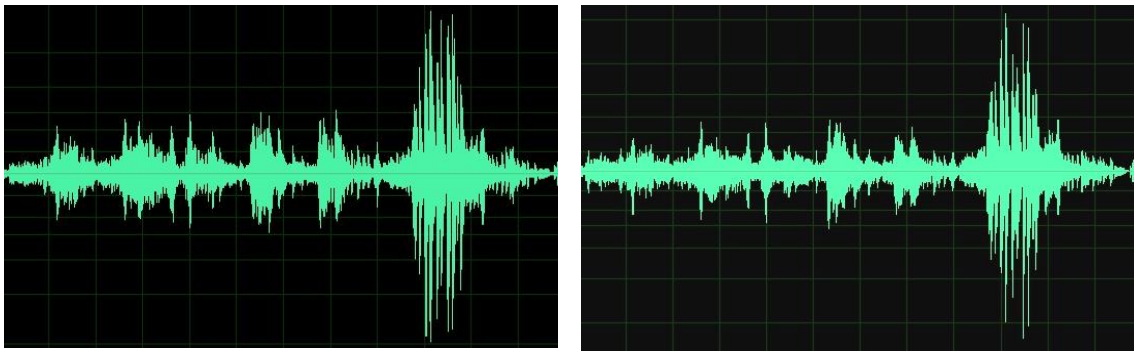
Validating Welte expression decoder

To validate their expression decoding software, the Universidad Central de Venezuela team compared the sound waveforms of an emulated MIDI file produced by their software to a recording of the actual roll when played on an Ampico reproducing piano. This method of comparison, the authors admit, has its limitations. The tonal differences of the instruments used to create the sound waveforms are a factor in how the waveforms are shaped, and a valid comparison relies on the performing accuracy of the

[369] For example, the bandwidth of an audio amplifier is taken as the frequency range between the lower and upper points at which the output of the amplifier drops by 3dB.

reproducing piano used as a reference. Nonetheless, if both factors are satisfied, a comparison using sound waveforms is informative.

A number of recordings have been made of a Welte-Mignon playing piano rolls, including commercial recordings and those available on the internet or through collectors. The recordings I chose as a reference were made by Denis Hall in 2006 of his 1921-22 Welte-Mignon Steinway model O grand piano (180 cm in length).[370] The emulated MIDI files were played on a Yamaha Disklavier Pro in a C5 grand piano (200 cm in length). The waveforms of the two recordings are shown in Figure 4.9.



(a) *Emulated MIDI file* ***(b)*** *Welte-Mignon reproducing piano*

Figure 4.9 *Waveforms of Granados playing the first 24 bars of his Danza Española No. 5 from Welte-Mignon roll number 2780*

The waveforms in Figure 4.9 are undoubtedly similar, and their differences, such as the fatter bursts of sound in (a) compared to (b), can be attributed to tonal differences, in which the piano used in (a) has a slightly more substantial bass. The spikes in each burst of sound are thematic notes, surrounded by accompaniment notes. Both waveforms have a similar dynamic difference between accompaniment and thematic notes. In the model, the minimum playing level of the treble expression is around twelve MIDI steps higher than the bass expression, which the waveforms show agrees with the settings of Hall's Welte-Mignon.

Comparing the softest and loudest sounds in both waveforms shows a similar dynamic range. A Disklavier Pro can play more softly than any standard MIDI mechanical or pneumatic reproducing piano, so its volume control was set to 100, where it has no effect on MIDI velocity values.

[370] This instrument, in my opinion, provides an accurate reproduction of a Welte-Mignon piano roll.

Computer program – the next step

A reality with MIDI mechanical pianos and virtual pianos is that the dynamic response will differ between instruments. This occurs with different brands of MIDI mechanical pianos and in particular with electronic and virtual pianos, as there is no standard that specifies the sound pressure level for each MIDI velocity level. Therefore, an emulated MIDI file might sound dynamically compressed or expanded on one brand of MIDI instrument compared to another. That is, it is not possible to have MIDI velocity settings for a piano roll expression decoding system that suit all MIDI instruments.

The listening environment is a factor that can determine the desired dynamic range of a MIDI instrument. For example, during the 1920s, piano roll companies promoted their reproducing pianos through public concerts. It was usually necessary to increase the suction level well above the normal level to suit the location, such as a concert hall, giving a higher maximum playing level without increasing the minimum playing level. That is, the dynamic range was increased, not the overall volume. Similarly, lowering the maximum playing level by reducing the maximum level of suction reduces the dynamic range, but not the softest playing level.

Another factor is listener opinion. A complaint among owners of reproducing pianos is that they often play too loudly, others feel their instruments should offer more volume. Both opinions point towards an expression decoding system in which settings can be easily adjusted to suit the listener's requirements. This is difficult to achieve with an original instrument and the previously described analogue and microprocessor-based Welte expression decoders. An obvious solution is computer software, where all relevant settings (zero, mezzoforte, maximum etc) are shown on-screen and are able to be adjusted to suit. I am presently working with Gosden in developing Windows-based software that will provide the necessary functionality.

Summary

I have detailed the process used to develop a method of decoding Welte expression data because there is no information known to me on this topic. If piano rolls are to be made accessible through MIDI files, the science of converting the expression coding on rolls to MIDI velocity values is important. The approach that I adopted was based on the concept of analogous modelling; another approach might be through mathematical routines. In my opinion, modelling is a more reliable way, as the mathematics associated with expression regulators are unlikely to be straightforward.

The Welte expression regulator, while apparently simple, must be finely adjusted in accordance with a test roll. Critical settings are those controlling the fast crescendo and decrescendo actions, as both functions are operated by precisely timed, short-duration perforations, typically to control the playing volume of individual notes. An example is shown in Figure 4.7, where the bass expression uses only the fast actions. This highlights the importance of accurate time durations of the notes representing expression perforations in the raw MIDI data of a Welte piano roll.

The analogue model was based on the physics of a Welte expression regulator, by incorporating an electronic circuit with a behaviour analogous to the movement of the expression pneumatic. Timings were determined from MIDI files of test rolls, and from oscilloscope displays produced by the model under certain test roll conditions. The analogue decoding circuits operated in real time, so the whole decoding process was virtually instant. While impractical in some ways, I propose that an analogue model potentially provides the most accurate analogy of any type of pneumatic expression regulator.

The microprocessor model incorporated a software equivalent of the analogue model and an output signal so the dynamics could be monitored on an oscilloscope, as with the analogue model. Monitoring via an oscilloscope allowed easy comparisons and confirmation of the accuracy of the software model. Both models have laid the groundwork for future computer software.

Validating the accuracy of any system that converts piano roll expression to MIDI velocity values is always going to be difficult. Comparison of sound waveforms produced by both roll and MIDI file provides insight, but assumes the reference instrument is playing at its best. Ultimately, the human ear is the final arbiter when fine tuning the dynamics of a Welte instrument or Welte expression decoder. However, getting the settings as close as possible using known data ensures that later, only fine adjustments will be required.

Ampico expression decoder

The Ampico expression system is discussed in Chapter 2 (see page 145), and in summary, involves eight intensity levels in combination with a fast or slow moving crescendo pneumatic. While apparently complex, I found that the system was easily modelled as an analogue circuit. As previously discussed, Brandle and others have successfully developed software to decode Ampico expression to MIDI velocity values.

It had become necessary to build an in-line Ampico expression decoder so the Disklavier, rather than my failing model A Ampico could be used as a monitoring instrument. As well, this decoder could incorporate a means of decoding model A and model B Ampico expression data.

The behaviour of an Ampico expression regulator can be expressed mathematically,[371] but my approach was to follow a similar process to that used when developing the in-line Welte expression decoder. That is, beginning with an analysis of the Ampico expression system, followed by constructing an analogue model of the system. The operating principles of the expression regulator do not need further explanation, but it is important to describe the process of determining the values for each setting in the model.

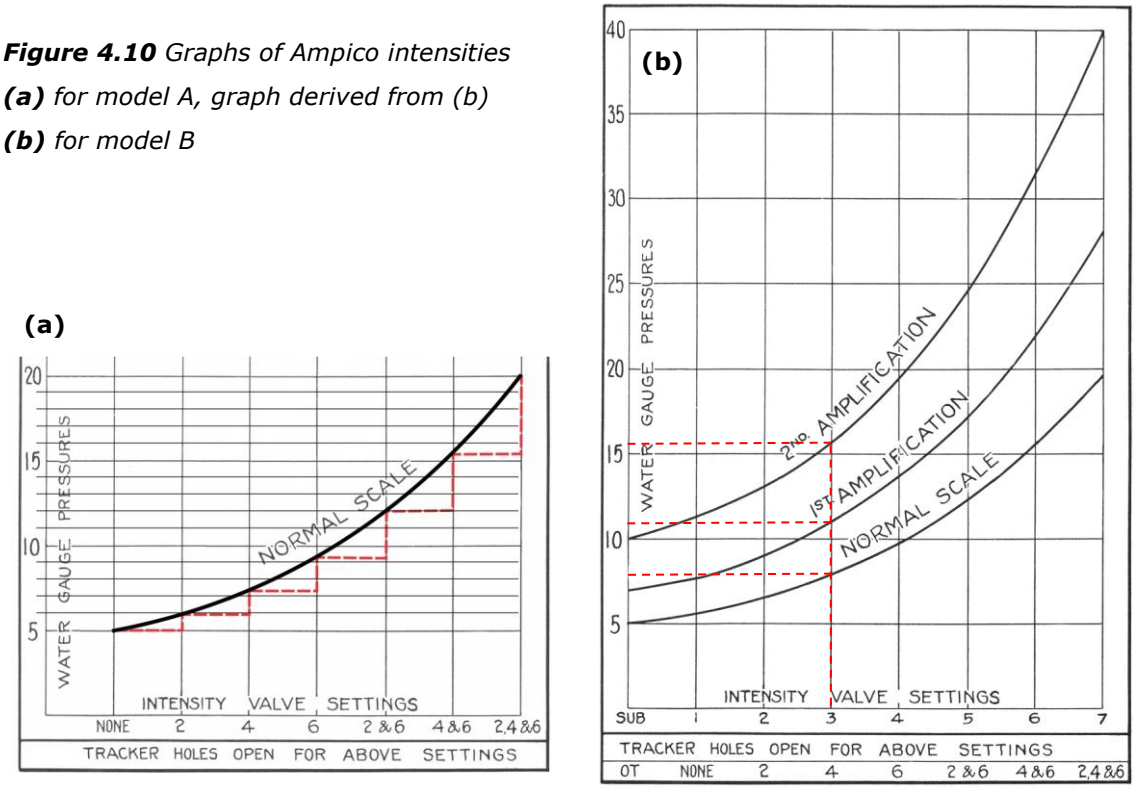
Ampico expression values

Settings for the model A Ampico expression system are explained by Larry Givens.[372] Of all the reproducing piano expression systems, the model A system is arguably the simplest to adjust and the most reliable in long term operation. Unlike Welte or Aeolian, Ampico technical publications provided suction values, such as a minimum suction level of five inches WG for a model A Ampico.[373]

[371] Stahnke refers to a mathematical model for decoding Ampico expression, as previously mentioned.
[372] Larry Givens, *Rebuilding the Player Piano* (New York: Vestal Press, 1963), 68-71.
[373] Ampico, Corporation, *Inspector's Reference Book* (New York: post 1920), 10.

More information is given in the model B Ampico Service Manual, including a set of graphs referred to as 'intensity scales' which are reproduced in Figure 4.10 (b).[374] The 'normal scale' graph gives values of suction that generally agree with measurements taken from a model A Ampico. This is predictable, as the values of intensities in both models of Ampico would need to be similar for compatibility with both types of rolls. A graph depicting model A Ampico intensities is shown in Figure 4.10 (a), which have been derived from the 'normal scale' graph in Figure 4.10 (b). The dashed red line in (a) shows the actual effect on suction of the three intensities, as intensities can only produce step changes.

Figure 4.10 *Graphs of Ampico intensities*
(a) *for model A, graph derived from (b)*
(b) *for model B*



The graphs in Figure 4.10 do not show all possible intensity combinations, as the intensity level when tracker bar holes 2 and 4 are open is omitted. The model A Ampico therefore has eight intensity levels. As explained in Chapter 2 (page 145), the model B Ampico added a fourth intensity, called the 'sub-zero' which was used to "obtain extreme pianissimo effects."[375] Therefore, the minimum playing level in a model B Ampico occurs only when the sub-zero intensity is operated, which causes the suction

[374] Ampico, Corporation. *The Ampico Service Manual 1929* (New York: 1929), 20.
[375] *Ampico Service Manual 1929*, 11.

level to fall to five inches WG, the specified minimum playing level of a model A Ampico. The sub-zero intensity is used on its own, not in combination with the others, so in effect, the model B Ampico also has eight levels of intensity, with a ninth intensity to produce softest playing.

The 1st and 2nd amplification graphs in Figure 4.10 (b) show the intensity levels that occur when the crescendo pneumatic is in either of two fixed positions, thereby raising the intensity levels proportionally, giving three times the number of available levels. For example, as shown by the dashed lines in (b), at intensity 3, the normal suction level is around eight inches WG, rising to eleven inches at first amplification and to slightly less than sixteen inches at second amplification. Unlike the model A Ampico, the crescendo pneumatic in a model B Ampico could be locked at either of the two required positions. However, a similar effect could be created in a model A Ampico using its crescendo pneumatics, because of its slow operating speed.

The operating speed of the crescendo pneumatic in a model A Ampico is not defined. Givens explains that by using a particular test roll, the speed of the crescendo can be observed but not adjusted.[376] He does not give opening and closing times for either the slow or fast speeds. The model B Ampico Service Manual gives a slow crescendo time of four seconds, and a fast crescendo time of about half a second.[377] Both times differ from those measured in a model A Ampico, where a slow crescendo takes around nine seconds, and a fast crescendo about two seconds. It is assumed by some technicians that the times given by Ampico for the model B were for half the travel distance of the crescendo pneumatic.

Model B Ampico crescendo operation

The model B Ampico was fitted with one crescendo unit, the model A with two, as pointed out in Chapter 2, page 145. In order that model B rolls could be played on a model A Ampico, crescendo perforations were added to both sides of the roll, even though the model B instrument would only read the treble-side perforation. The use of a single crescendo in the model B instrument was probably done to simplify manufacturing. It is arguably a limiting feature, as it means a crescendo will always occur over the entire keyboard, unlike the Welte or Duo-Art pneumatic regulating systems that maintain complete independence between both regulators.

[376] Givens, *Rebuilding the Player Piano*, 71.

Controlling the mechanisms needed to hold the model B crescendo pneumatic at the 1st and 2nd amplification positions required an extra perforation on the extreme bass side of the roll. Perforations were either short or long, depending on the action that was required, such as bringing the crescendo pneumatic back to the 1st amplification position from the 2nd amplification position, or resetting its position back to zero (fully opened).

Implementing these actions in an analogue model would be difficult. Because all B-coded rolls have coding for model A crescendos, it also seemed unnecessary.

Most B-coded Ampico rolls were made in the 1930s, the majority of which contain popular music. As pointed out on page 149, B-coded rolls of art music rarely used the 1st and 2nd amplification settings. For example, I found only one instance of such use in Rachmaninoff's B-coded Ampico roll recording of Rubinstein's Barcarolle Op. 93 No. 7,[378] with other rolls recorded by notable artists revealing an equally limited use. Therefore, the model B crescendo action was not included in the analogue expression model.

Final Ampico expression decoder

The sub-zero intensity was to be part of the model, as it was used sufficiently to warrant its inclusion. Concerning dynamic levels, the graphs in Figure 4.10 (b) show that on the normal scale, at intensity 3 (tracker bar hole 4 open) and intensity 4 (tracker bar hole 6 open) the suction levels are 8.0 and 9.8 inches WG respectively. When tracker bar holes 4 and 6 are both open (intensity 6), the suction is around 15.6 inches WG, but if tracker bar hole 2 is also opened (intensity 7), the suction level increases substantially to nearly 20 inches WG. Therefore, because the intensity combinations are not mathematically related, the model would need individual adjustments for each of the eight intensity levels.

A particular setting on a model A Ampico is the maximum suction level when its three-position volume control switch is at 'medium', which is specified as twenty inches WG. On suggestions from other Ampico owners, I had found that a setting of eighteen inches WG gave improved dynamics with a reduced tendency to being too loud. In the decoder, the required value would be achieved by setting the combination of all intensities to the equivalent of eighteen, rather than twenty inches WG.

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[377] *Ampico Service Manual 1929*, 18.
[378] Ampico roll number 69893, recorded February 1, 1929, dates from records held by the author.

Using these figures meant that there would be differences between the dynamics produced by the analogue decoder to those produced by Brandle's *WindPlay* software. The graphs in Figure 4.11 are generated by a computer program called *Veloset*.[379] The program shows the distribution of MIDI velocity levels of notes in a MIDI file, as either single lines, where the length of a line indicates the number of notes with that velocity level, or the smoothed view as shown. The images were generated from MIDI files of the Ampico roll of Tina Lerner playing Chopin's *Andante Spianato et Grande Polonaise Brillante* Op. 22, which has a playing time of over nine minutes.

The differences are subtle, in which the graph in (b) has a slightly wider dynamic range of 27 velocity steps between the two peaks, compared to 23 in (a). There are also fewer notes in (b) playing above level 75. As expected from the settings used, the overall volume is slightly reduced and, in my opinion, the expression has more subtlety.

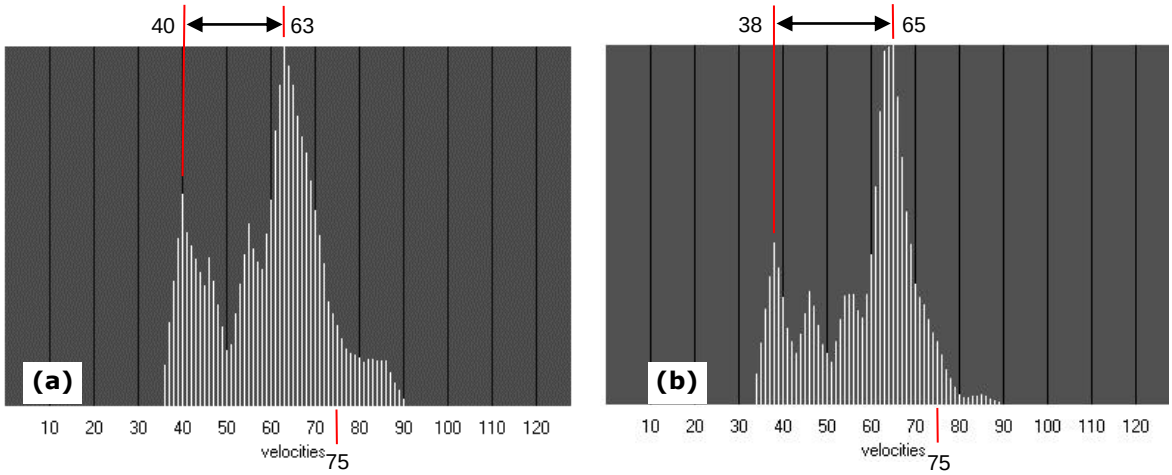

Figure 4.11 *MIDI levels as produced by* ***(a)*** *WindPlay* ***(b)*** *analogue model*

The Ampico expression analogue model is shown in Figure 4.12. Although the expression decoder circuitry was entirely analogue, as in the Welte model, a higher level of digital logic was needed to sort out the expression data as read from the roll into a form that could be presented to the analogue decoders. Like the Welte-Mignon, the Ampico uses a lock-and-cancel arrangement to control some aspects of the expression. However, unlike Welte in which the cancel command always follows the command that needs cancelling, Ampico coding often has both commands occurring at the same time. The resulting effect depends on which command is the last to turn off, requiring extra digital circuitry to resolve this unusual arrangement.

[379] Program for a PC written in 1998 by Anthony Robinson.

Another complexity is multiplexed expression coding to control the slow and fast crescendo and decrescendo actions, in which two perforations control four different functions. Although the digital circuitry needed to present Ampico expression data to the analogue decoding circuit was relatively straightforward, it shows the level of complexity inherent in the design of the Ampico expression system.

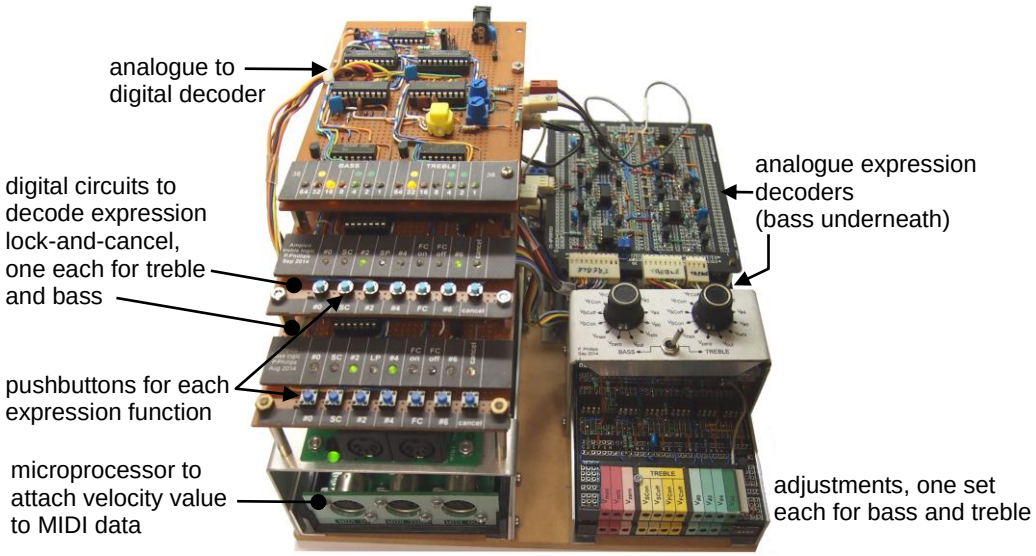

Figure 4.12 *Analogue model of Ampico expression regulators*

Summary

Despite its apparent complexity, the Ampico expression regulator system was relatively easy to model as an analogue circuit. The analogue expression decoding circuit was implemented with seven, 8-pin integrated circuits and various passive components, all of which are readily available. The intensities were set according to the graph in Figure 4.10 (b), except for the value caused by the combination of all three intensities, as previously explained, which was set to the equivalent of eighteen inches WG, not twenty. The sub-zero intensity associated with the model B Ampico was adjusted so it reduced the MIDI velocity by a just discernible amount, with the aim of maintaining a minimum playing level equivalent to 5.0 inches WG for A-coded Ampico rolls.

Developing the Ampico expression analogue model has provided insight and data that can be used when developing a software model. It was not necessary to reconfigure the analogue model into a microprocessor-equivalent, as the hardware version has proved satisfactory. Instead, it remains to develop computer software that incorporates on-screen adjustments, as proposed previously for Welte expression decoding software.

Duo-Art expression regulator

Although I have not needed to develop an in-line Duo-Art expression decoder, I have studied the operation of the Duo-Art's expression regulators for various reasons, including to validate the results being achieved with Brandle's *WindPlay* Duo-Art emulation software. It is generally agreed that the behaviour of a Duo-Art suction regulator is difficult to model, a factor worth explaining.

My introduction to Duo-Art expression came somewhat dramatically in 1977 during the development of the Duo-Art vorsetzer mentioned in Chapter 2 on page 139. The suction regulator design being used in the vorsetzer was based on a model B Ampico regulator, which features a membrane that responds almost instantly to external control signals. Each regulator was fitted with sixteen electrically-operated valves which were operated in accordance with Duo-Art expression coding. The regulators therefore produced sixteen levels of loudness, in which each level was adjustable. Graphs were used to record particular settings, or to achieve new settings.

Over time, it became clear that despite its innovative design, the regulator was not achieving the full expression of which a Duo-Art reproducing piano was capable. At the time I could not understand why, as the membrane regulator was producing the same number of dynamic levels as a Duo-Art regulator. The only difference was the response time of the two regulators. That is how I saw it then, but as pointed out in Chapter 2, and now further explained, there are several aspects to its operation that collectively complicate the behaviour of a Duo-Art expression regulator.

Analysis – Duo-Art expression regulator

The basic operation of the Duo-Art expression system is explained in Chapter 2 (see page 153). In summary, a Duo-Art regulator is controlled by an accordion pneumatic that has sixteen positions, giving in effect, sixteen dynamic levels. The two expression regulators, called 'accompaniment' and 'theme' are directed by theme (snakebite) perforations to control the dynamics of the bass and treble sides of the player action. In the absence of any theme perforations, the accompaniment regulator controls the dynamics of both sides of the player action, as depicted in Figure 4.13.

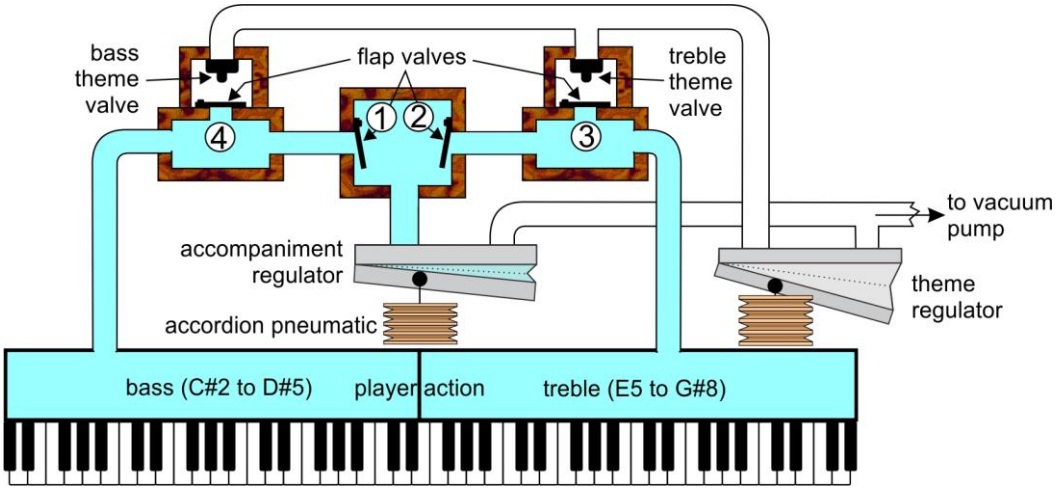

Figure 4.13 *Duo-Art dynamic control in the absence of theme perforations*

The regulator switching system uses four flap valves to direct which regulator controls which side of the player action.[380] The flap valves are strips of flexible leather covering a hole, in which a leather flap moves towards the highest level of suction. In Figure 4.13, because the bass and treble theme valves are shut (as there are no theme perforations), the suction developed by the accompaniment regulator causes flap valves 1 and 2 to open, and 3 and 4 to close. Therefore, air flow is directed such that the accompaniment regulator controls the dynamics on both sides of the player action.

[380] Aeolian Company, *The Duo-Art Reproducing Piano – Service Manual No.3* (New York: 1927), 15-21.

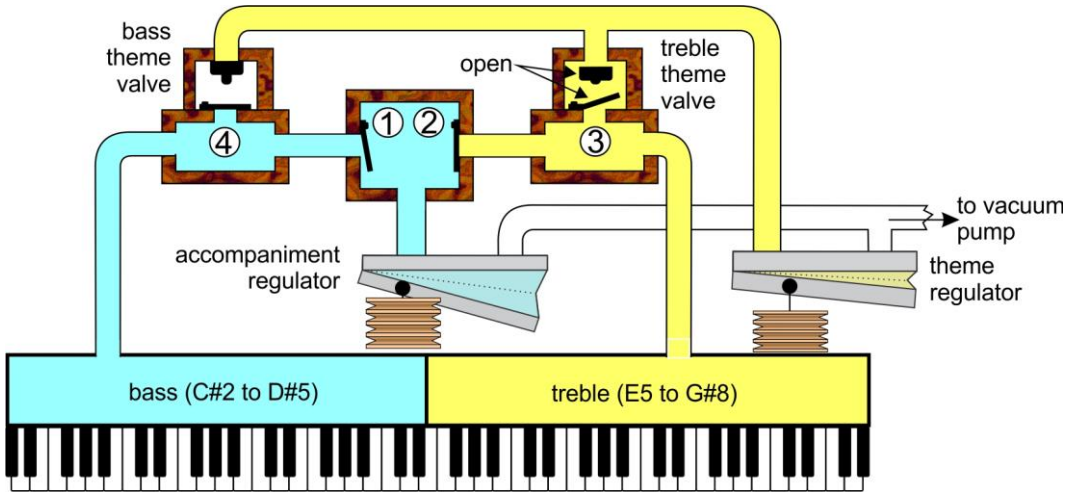

Figure 4.14 *Duo-Art dynamic control when a treble theme perforation occurs*

Figure 4.14 shows the effect when a treble theme perforation occurs. Under this condition, the treble theme valve is opened, allowing suction from the theme regulator to enter the chamber via flap valve 3. This occurs because the theme suction level is higher than the accompaniment suction level, causing flap valve 3 to open and flap valve 2 to close. Therefore, the treble side of the player action is now dynamically controlled by the theme regulator and the bass side is controlled by the accompaniment regulator. A similar situation occurs when a bass-side theme perforation occurs, except the bass side of the player action is now connected to the theme regulator, and the treble side to the accompaniment regulator.

The condition shown in Figure 4.14 lasts for the brief duration of a theme perforation. When the theme perforation has passed, the treble theme valve closes, in effect trapping the partial vacuum that was established in the player action. That is, even though the treble theme valve is now shut, the suction level in the treble side of the player action is still relatively high, and above the accompaniment level. This happens because the sealed system can only evacuate air when a key-striking pneumatic is operated. The effect is that the suction level created by the momentary action of the treble theme valve will remain until it is exhausted by treble notes being played.

A consequence is that notes following a thematic note could play at unintended dynamic levels. The problem was recognised by Aeolian, and some Duo-Art expression boxes have a small bleed hole that exhausts the theme chamber to atmosphere. The extent of the effect depends on the seal quality between the player action parts. Player

actions after restoration are generally almost air-tight, as they would have been when new. If the player action is leaky, trapped suction will decay rapidly, negating any expressive effects that editors may have added that exploit the usual slow decay.

A similar situation occurs with the accompaniment regulator, in which the time taken to change to a lower level of suction is determined by how rapidly the player action is exhausted. Because the accompaniment regulator is often controlling the entire keyboard, a sufficient number of notes are usually being played to keep the delay relatively short.

The time taken for a Duo-Art regulator to *increase* the suction level is generally consistent, but is quite long compared to other expression regulators. As shown in Chapter 2, Figure 2.11 (see page 166), this effect was also exploited by editors. Therefore, unlike the Ampico system in which an intensity change is regarded as happening instantly, an intensity change in a Duo-Art occurs relatively slowly, with some dependency on how many notes are playing at the time.

Aeolian did not document the suction level that should occur at each of the sixteen positions of the accordion pneumatics. Measurements on my Duo-Art suggest a linear relationship between suction and accordion position. However, static measurements can be misleading, and I recall that the graphs developed with the Duo-Art vorsetzer were curved, not a straight line.

In summary, there are a number of variables that must be considered when modelling a Duo-Art expression regulator. The two most complex are the response times of the regulator, in particular the delay when changing to a lower suction level, which is greatly affected by the number of notes being played. A third consideration is determining a suitable difference between the regulator outputs, which according to Aeolian should differ in dynamic level by ‘one degree’ which probably compares to ‘a trifle,’ as specified by Welte. The individual dynamic levels for each of the sixteen steps must also be established.

WindPlay Duo-Art emulation software

Because I could monitor rolls during recording on a recently-restored Duo-Art instrument, there was no need to develop a means of monitoring each recording on a Disklavier. Instead, emulation software, such as Brandle’s *WindPlay* could be used to

produce emulated versions of the raw performance files for subsequent playing on the Disklavier.

The process of producing these files, as explained previously, required the raw MIDI files to be converted to bar/ann files, then playing the bar/ann files from *WindPlay* on one computer into another computer that was running MIDI editing software. Each file was therefore converted from the raw to the emulated version in real time, allowing the process to be monitored.

It was usually necessary to post-edit each emulated file to correct velocity levels outside the two extreme settings. For example, *WindPlay* always caused notes playing at the Duo-Art's zero level to have an excessively low velocity level. In a few cases, the program generated velocity levels above the maximum setting. Both errors could be corrected using MIDI editing software. The range of velocity levels produced by the program were excessively loud, requiring subsequent adjustment so the dynamics ranged over my preferred values of MIDI velocity 35 to 85. I also later discovered that *WindPlay* caused MIDI pedal data to be delayed by 77 milliseconds which was remedied by post-processing each emulated file with suitable software.

Validating the effectiveness of *WindPlay's* Duo-Art emulation software involved checking for dynamic levels that should be slowly decaying after a thematic note. This effect was certainly present in the emulated files, and the rate of decay seemed to vary with the number of notes played after the accented note. The software also took into account the time taken for a regulator to change in a positive direction.

After comparing numerous raw MIDI files played on the Duo-Art to the emulated version played on a Disklavier, I concluded that the dynamics sounded much the same, although such comparisons assume the Duo-Art is playing to perfection. There is no doubt that *WindPlay* models most or all aspects of the Duo-Art expression system.

Summary

The inherent vagaries of the Duo-Art expression system pose a challenge when developing a hardware or software model of the system. If the effect of the slow response times of the regulators is not included in the model, dynamic nuances are lost, as was found with the fast-acting regulators used in the previously-mentioned Duo-Art vorsetzer. Brandle's *WindPlay* software is one solution to achieving acceptably accurate emulated Duo-Art MIDI files, although additional processing is required.

Conclusion – piano roll emulations

Converting piano roll expression perforations to MIDI velocity values is an immature but essential science if historical piano roll recordings are to be made more accessible. While there are difficulties, such as the dynamic response differences in MIDI playback instruments, they can be overcome. When developing the two expression models described in this chapter, I was able to accurately relate suction and MIDI velocity values for the instrument on which the files would be played. The instrument is a Disklavier Pro, and given its level of engineering, there is close conformity in terms of response to MIDI velocity values between it and other Pro-equipped pianos. Therefore, reproduction of the dynamic levels on these instruments will generally be consistent, with differences occurring mainly in tonal quality.

The expression regulators in each brand of reproducing piano are different, even those in the three Welte instruments, although they all achieve the same dynamic effects. My approach in developing the models was to relate suction and MIDI velocity values, and to base all values on actual measurements. The aim was to reduce the amount of musical judgement that ultimately could not be entirely avoided.

In presenting my research and findings, I have, at the very least, added to the scant body of knowledge that presently exists. Although the research only examines Welte, Ampico and Duo-Art rolls, the principles presented can be applied to developing models of the expression systems in other brands of instruments, such as the Hupfeld reproducing pianos (DEA and Triphonola) and the Duca reproducing piano.

Correcting emulated piano roll MIDI files

A significant advantage of emulated piano roll MIDI files is being able to edit the files to make the recordings more accurate to the original performances, which can be achieved by correcting some of the errors caused by the limitations of piano roll technology. I have found many instances in which corrections can be made that are based on existing data within the MIDI file. Corrections include changing dynamics, note data and pedal data. Other forms of evidence can also be gathered, such as disc recordings made by the pianists and written descriptions of their performing characteristics. Editing based on evidence has the potential to realise more fully the original performances.

Editing MIDI velocity levels

A limitation of all reproducing pianos is the inability of pneumatic player systems to control the dynamic level of individual notes. Even if notes were recorded with individual dynamics, the roll expression coding must suit the 'split-stack' design of a pneumatic player piano, in which there can only ever be two dynamic levels at any one time; the treble side dynamic and the bass side dynamic. A problem arises therefore if thematic and accompaniment notes share the same part of the keyboard.

The split-stack limitation is highlighted in a Duo-Art roll recording by Guiomar Novaes of Gottschalk's *Grand Triumphal Fantasia on the Brazilian National Anthem* Op. 69.[381] This work, described by Schonberg as a "horrendously bad piece of music,"[382] has a trill lasting nearly two minutes between bass notes C#4 and D4, during which a melodic line is played on surrounding notes. When played on a Duo-Art, the musical effect is a nonsensical jumble of notes due to the limitations of the instrument.

[381] Duo-Art roll number 6442.
[382] Schonberg, *Great Pianists,* 409.

A section of the score is given in Figure 4.15, other sections will show that the melody is often a single note in close proximity to the trill notes.

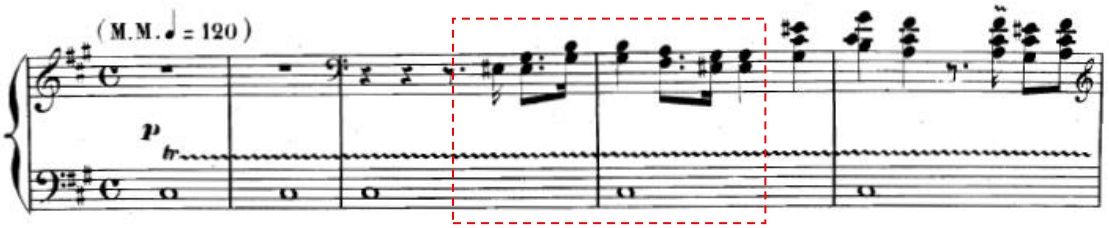

Figure 4.15 *Start of a two minute trill, from the score of Gottschalk's* Grand Triumphal Fantasia on the Brazilian National Anthem *Op. 69*

A section of the raw MIDI file of this recording is in Figure 4.16 (a), which shows the first set of notes played after the start of the trill (enclosed notes in Figure 4.15). The dashed lines at the start of each theme perforation show that the perforations are aligned to cause thematic notes to play at a higher volume, but the trill notes (circled) that are aligned with the thematic notes will also play at this volume. The edited emulated MIDI file is shown in Figure 4.16 (b), in which the MIDI velocity of each trill note has been reduced to match that of its neighbours, leaving a clearly identified melodic line.

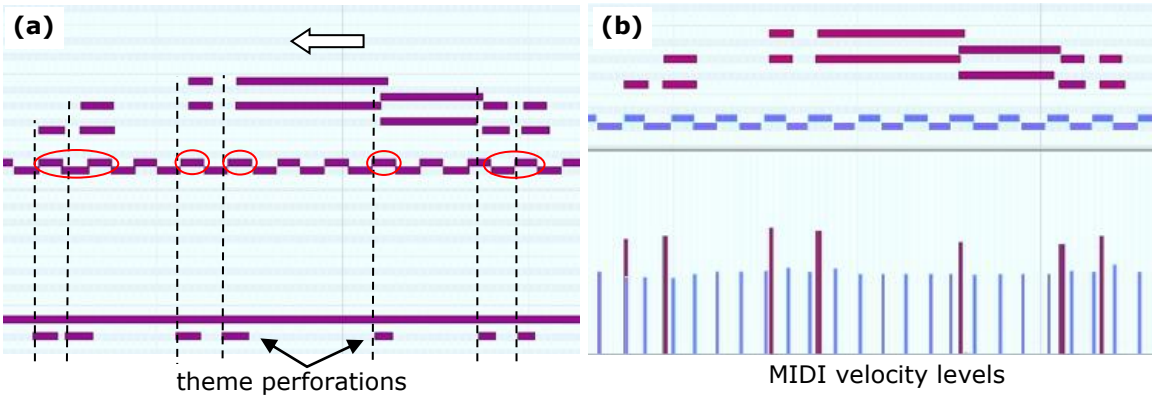

Figure 4.16 *(**a**) Raw MIDI file in which notes that occur prior to the dashed lines will play at theme volume, (**b**) emulated MIDI file with trill notes restored to the correct volume*

Changing the dynamic levels as shown in Figure 4.16 does not enhance a recording, rather it takes advantage of MIDI technology to improve its accuracy. There are many other examples where trill notes are incorrectly accented in piano roll recordings, especially trills in the treble side of the keyboard. The musical effect can be quite disturbing, as the accented trill note might not be harmonically related to the thematic note. As well, if the accented trill notes are higher in pitch than the thematic notes, the melodic line is broken.

Accompaniment and thematic notes can also become confused when a chord intended to be played louder than accompaniment level has notes occurring in both sides of the keyboard. An example, of which there are many instances, is shown in Figure 4.17, which is of an extract from an Ampico roll of Liszt's *Hungarian Rhapsody* No. 2, S.244/2 played by Alfred Cortot.[383] The extract from the score is shown in (b), and the MIDI file of that extract is shown in (a), where the vertical lines indicate MIDI velocity, blue shaded notes are played softly and red shaded notes play more loudly.

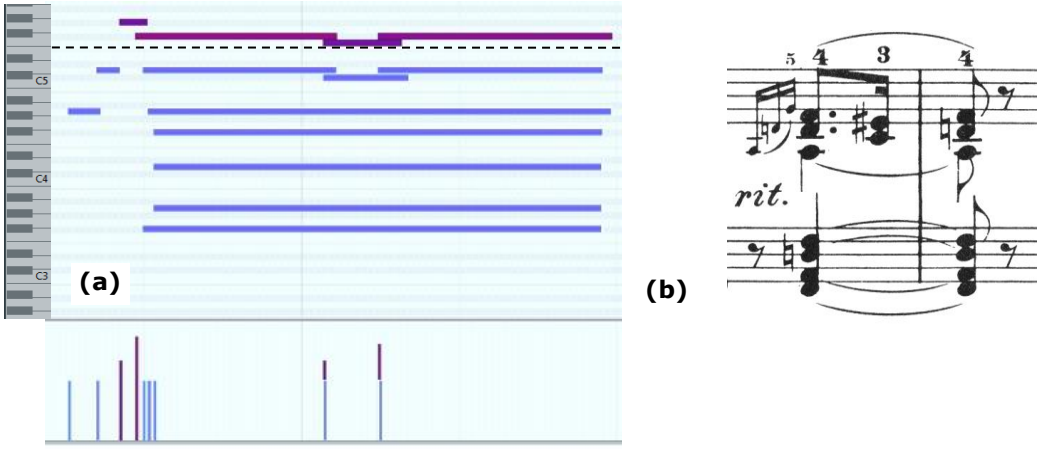

Figure 4.17 (a) *Emulated MIDI file in which notes below the dashed line all play at accompaniment level,* ***(b)*** *relevant part of the score*

The only accented notes in the piano roll are the top notes of the chords, because all other notes are below note F5 (the dashed line), and therefore fall into the accompaniment side of the keyboard.[384] Obviously, accenting the bottom notes in the chords would cause the accompaniment notes also to play more loudly, so Ampico's editors appear to have chosen the simpler path of accenting only notes in the treble side of the keyboard. The effect is not so noticeable, as the melody remains intact. It is unlikely that Cortot would have played the work with only the top notes in the chords at a higher velocity than the other chord notes. Instead, the limitations of the technology explain these dynamics. Increasing the velocity level of other notes associated with the melody is therefore very likely to improve the accuracy of the recording.

[383] Ampico roll number 59263, from a Hupfeld roll recording.
[384] The Ampico player action is divided at notes E5 and F5 (middle C is note C5).

Another example is given in Figure 4.18, which is an excerpt from a Duo-Art roll recording of Liszt's *St. François d'Assise: La prédication aux oiseaux* S.175/1, played by Arthur Friedheim.[385] It is obvious that both octave notes played by the left hand would have the same or similar dynamic. However, in this recording, when the top note of an octave is higher than note Eb5 (above the dashed line), it has the same dynamic as the repeating notes played by the right hand. It is therefore obvious that the error can be removed by matching the MIDI velocity of the affected notes to their bass counterpart.

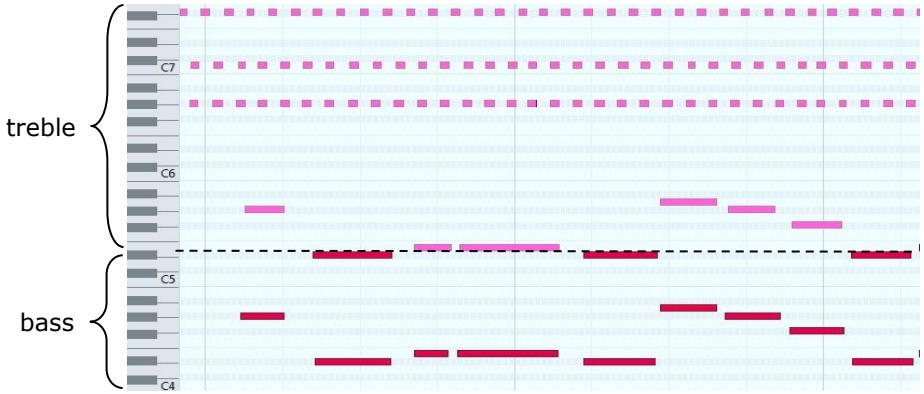

Figure 4.18 *Emulated MIDI file in which notes below the dashed line all play at theme level, while some top notes of the octaves play at accompaniment level*

[385] Duo-Art roll number 5718.

There are also examples where it is obvious that note dynamics are incorrect, but with conflicting evidence as to the correct dynamics. The MIDI file image in Figure 4.19 shows a section of Pachmann's Welte-Mignon roll recording of Liszt's *La Leggierezza* S.144.[386] The score, as Pachmann played it, is shown in Figure 4.20.

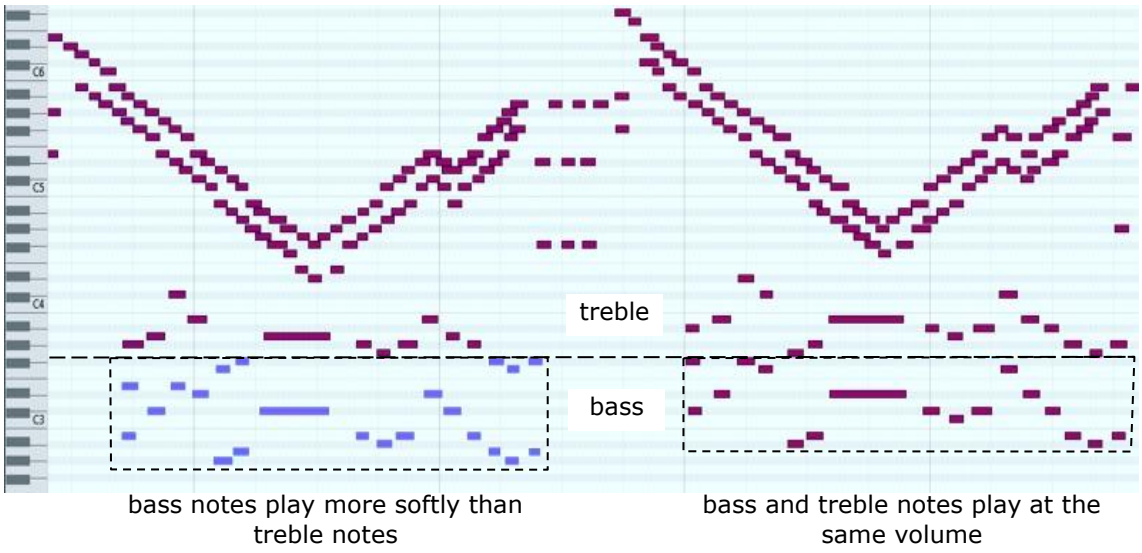

Figure 4.19 *Example in which some dynamics are clearly wrong, but with insufficient evidence to be sure of the required corrections*

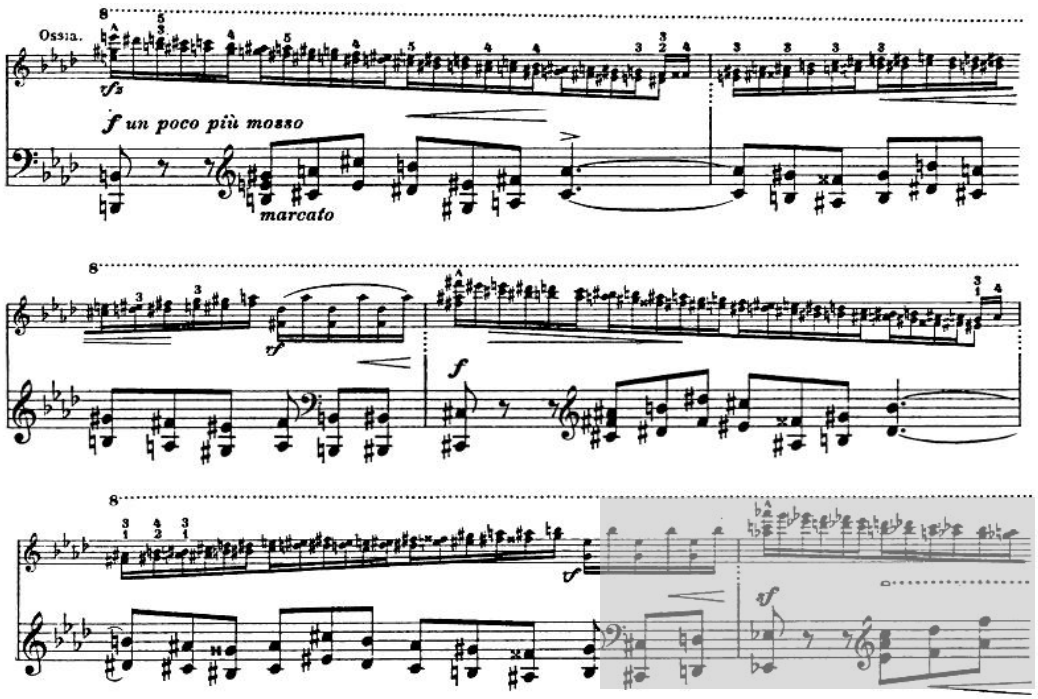

Figure 4.20 *Score of Liszt's* La Leggierezza *S.144 as played by Pachmann on the Welte-Mignon roll recording shown in Figure 4.19*

[386] Welte-Mignon roll number 1216.

The emulated MIDI file of the roll recording in Figure 4.19 shows that during the first passage, notes in the bass side of the keyboard are played far more softly than treble-side notes (those above the dashed line). The dilemma is whether this is an error associated with expression coding on the roll, or whether the other notes associated with the soft notes were also played softly. It would seem reasonable that Pachmann played all left-hand notes quite softly, but in the next similar passage, they are all played at the same volume as those in the right hand. Whatever the answer, it is unlikely that Pachmann played the left-hand notes in the first two bars shown in the score in Figure 4.20 with the dynamics as reproduced from the roll.

Incorrect dynamics can occur due to roll production errors. There are instances in original rolls, and more often in recut rolls where expression perforations have been erroneously omitted or wrongly placed during production. Such an omission is more likely to occur on Duo-Art rolls, in which a theme perforation might be delayed, missed altogether or held on for too long. As a result, notes can be incorrectly accented, or not accented at all.

Ampico rolls can sometimes have a missing cancel perforation, causing the expression to remain unchanged until the next cancel perforation occurs. Welte-Mignon and Welte Licensee rolls both have similar expression coding in which some perforations have an exact, but relatively short length. If these expression perforations are cut with an incorrect length, note dynamics will be affected. Additionally, like Ampico, part of the expression uses a lock-and-cancel arrangement, which means the absence of a cancel perforation can leave the expression locked in an incorrect setting.

While such problems are rare and generally confined to recut rolls, the question of whether to make corrections to individual note dynamics can arise. For example, it may be obvious that there are production errors associated with the expression perforations on a particular roll, requiring musical judgement to correct the resulting dynamics. In some cases, the error will be obvious, such as a misplaced theme perforation on a Duo-Art roll, requiring only that accenting be applied to the affected thematic note.

Editing soft pedal data

Soft pedal perforations on piano rolls were often added by editors to achieve dynamic effects. There are numerous instances, particularly with Duo-Art rolls, of the soft pedal being held on during a phrase, then briefly released to allow a single note to play more loudly, before being re-engaged. An example is shown in Figure 4.21, in which all notes except the enclosed notes play with the soft pedal on. In this example, the soft pedal is operated more often than the damper pedal.[387]

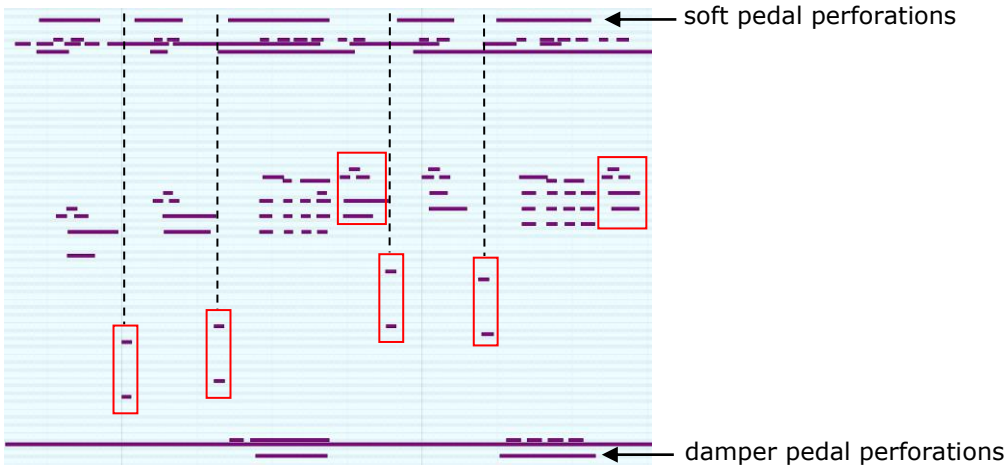

Figure 4.21 *Showing use of the soft pedal to create dynamic accenting of a few notes*

As previously explained, the soft pedal mechanism in most reproducing pianos is of the half-blow type, in which the hammers are moved towards the strings. A half-blow mechanism can operate quickly, while the *una corda* (or side-shift) mechanism in a grand piano is not so adroit, which means some of the dynamic subtleties could be lost when a piano roll file is played on a grand piano with an *una corda* mechanism. A solution is to edit the soft pedal so it stays on, but to increase the MIDI velocity of the few notes that should be played without a soft pedal.

In regard to all types of Welte rolls, if the soft pedal is on for an extended time it is turned off, then on during a time when notes are held on, thereby having no musical effect. The reason is unclear, as the soft pedal is controlled by lock-and-cancel operation in Mignon and Licensee rolls, not by single, long perforations as used in Green Welte, Ampico and Duo-Art rolls. In these rolls, extended soft pedal perforations weaken the paper and are therefore interrupted to give strength to the paper, causing unnecessary soft pedal cycling.

[387] From Duo-Art roll number 0363, part 3 of *Enigma Variations* by Elgar, played by duo-pianists Cuthbert Whitemore and Dorothy Manley (dates unknown).

There are many cases in Duo-Art and Ampico rolls in which the soft pedal is operated for a brief time to reduce the volume of a single note. While this works in a pneumatic piano with a half-blow soft pedal actuator, the effect may be lost with an *una corda* mechanism. Omitting the soft pedal command and reducing the MIDI velocity of the particular notes is therefore an option to regain the effect.

An issue associated with some MIDI mechanical grand pianos is that operation of the soft pedal while notes are being played can sometimes cause notes to be held on, due to the piano action sliding over a raised solenoid, thereby preventing it from falling to its rest position.[388] Editing the soft pedal data so the pedal does not operate unnecessarily reduces the held note problem and also noises caused by an *una corda* action.

Editing damper pedal data

A piano roll has only basic control of the damper pedal, a limitation that prevents certain pedal effects from being recorded. However, there are occasions when the available pedal data gives a clue as to how the pianist operated the damper pedal, which could allow some of the lost effects to be recreated. The variables associated with damper pedal MIDI data that can be edited are: height to which the dampers are raised, depth to which the dampers fall on release, and speed of travel. Some MIDI instruments do not have the functionality to respond to such data, although most Disklaviers have this capability.

The damper pedal in many piano roll recordings is operated, on average, about every second. The pedal is typically held on for around three-quarters of a second, and is off for a quarter of a second. Pedalling that follows this cycle is likely to be as the pianist played, in which pedal excursion is over the full travel. In some passages, the pedal is operated more rapidly, such as four or more times a second, in which the dampers are raised for a short time, then lowered. An example is shown in Figure 4.22, in which the damper pedal is held on for about a tenth of a second each time, and is operated six times over two seconds.[389]

[388] The Disklavier soft pedal action in all grand pianos operates the *una corda* mechanism.
[389] From Welte-Mignon roll number 3188, *Études d'exécution transcendante d'après Paganini* No. 4, S.141 by Liszt, played by Maria Carreras.

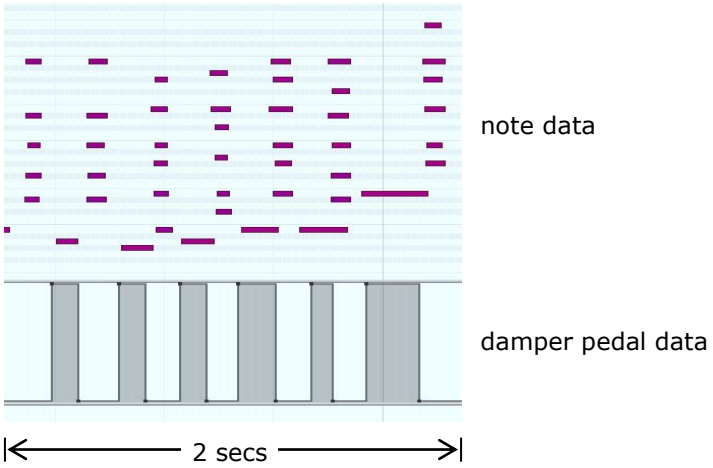

Figure 4.22 *Section of a Welte-Mignon piano roll MIDI file showing damper pedal operation over a two second interval. The greyed sections show when the pedal is on.*

When pedalling rapidly, pianists do not typically operate the damper pedal through its full stroke.[390] Unfortunately, the simplified roll data causes full-stroke operation, regardless. The pedal actuator in well-adjusted mechanical pianos can operate rapidly, but not instantaneously. Making it travel over its full distance could mean the dampers are lifted for less time than the pianist actually played. Reducing the travel height of the dampers and also the drop distance of the pedal actuator reduces the travel time, and allows the dampers to be lifted for a longer period. While the effect is minor, it is illustrative of other examples, in which it could be argued that the pianist's intention was to create half-pedalling effects.

In many cases other forms of evidence are required if changes to pedal data are to be made. Musicologist Nigel Nettheim used a combination of MIDI files of piano roll and gramophone recordings to produce a "reconstitution" of Pachmann's gramophone recording of Chopin's Nocturne in E minor Op. 72 No. 1.[391] To produce the reconstituted audio file, Nettheim developed a MIDI file based on note data from the piano roll MIDI file, and derived the dynamic level of each note and the operation of both pedals from a gramophone recording. The final audio file was produced by rendering the resulting MIDI file with virtual piano software.

[390] As observed from MIDI file recordings made by professional pianists on a Disklavier.
[391] Nigel Nettheim, "The Reconstitution of Historical Piano Recordings: Vladimir de Pachmann plays Chopin's Nocturne in E minor," *MPR, Music Performance Research* vol. 6, 97-125, 2013. http://mpr-online.net/Issues/Volume%206%20%5b2013%5d/MPR0074.pdf (accessed 19 November 2016).

In Nettheim's case, pedalling information was derived from gramophone recordings, and the MIDI values controlling the pedals and note dynamics were chosen by ear to suit the virtual piano being used. In 2009, John Q. Walker filed a US patent titled: "Methods, systems and computer program products for regenerating audio performances."[392] Walker had previously established a company called Zenph that used his patented technologies to produce MIDI files derived from disc recordings of pianists such as Glenn Gould (1932–1982), Rachmaninoff and other historically interesting pianists. Once perfected, the MIDI files were played on a high-end MIDI piano such as a Yamaha Disklavier Pro to make new audio recordings that Zenph describes as a "re-performance."[393]

Walker and Nettheim both sought to produce audio recordings via MIDI files, in which Nettheim used a virtual piano and Walker chose a mechanical piano. Deriving pedal data from gramophone recordings is practical, if time consuming. It is therefore clearly possible to modify the pedal data in the MIDI file of a piano roll to give the effect noted on the recording. Such editing could also be informed by written documentation describing the pedalling techniques of a particular pianist.

[392] John Q. Walker, Ii, Raleigh NC, *US patent number 20090282966*, http://www.patentsencyclopedia.com/inventor/walker-ii-us-5/ (accessed 11 October 2015).
[393] *New Technology Recaptures Pianists of the Past*, http://www.npr.org/templates/story/story.php?storyId=10439850 (accessed 11 October 2015).

Editing note data

A limitation with reproducing piano roll recordings is the reduced note compass, as summarised in Table 4.4. Although the Green Welte reproducing piano could play all 88 notes, because the rolls for the instrument were produced from Mignon masters, the recorded compass was restricted to 80 notes.

Table 4.4 *Compass and playing notes*

Roll type	***Number of playing notes***	****Compass***
Ampico	83	B1 to A8
Duo-Art	80	C#2 to G#8
Welte-Mignon and Licensee	80	C2 to G8
Welte Green (T-98)	88	full (actually uses 80)

* note numbers based on a scale where middle C is note C5

There are numerous instances in piano roll recordings in which extreme bass or treble notes were necessarily omitted. Adding known missing notes is therefore making a recording more accurate to the original performance. The limitations of reduced compass in the treble side of the keyboard were editorially dealt with in various ways. An example is the opening notes of Grieg's Piano Concerto, where note A8 forms part of the first two chords. This note is available on an Ampico reproducing piano, however the most famous recording of the concerto is by Percy Grainger, who recorded it for the Duo-Art, which lacks note A8. Figure 4.23 shows the relevant part of the score and section of the MIDI file of Grainger's roll recording of the first movement.[394]

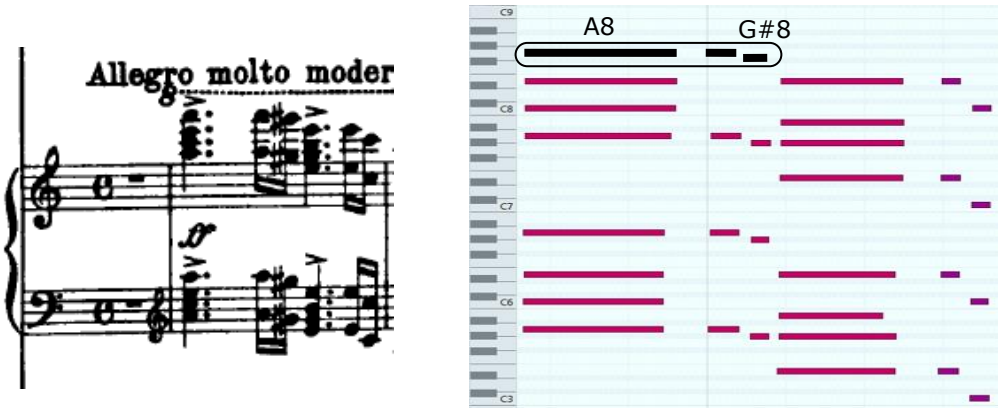

Figure 4.23 *Opening notes of Grieg's Piano Concerto and Grainger's Duo-Art roll recording. The circled lines are notes omitted from the roll.*

[394] Duo-Art roll number 6475.

Although the omission of note A8 is predictable on a Duo-Art roll, that does not explain the absence of note G#8. Instead, editors may have deleted this note to better balance the sound, due to the lack of note A8. Olga Samaroff recorded the first movement of this concerto for the Welte-Mignon,[395] and because its compass only extends to note G8, notes A8 and G#8 are not on the roll recording.

The evidence of missing notes is typically derived from a piano score, although there are roll recordings in which the pianist played extra notes, such as octave notes in the bass that extend below the available compass. An example is an Ampico recording by Nyiregyházi playing the third work in a set titled *Turquie* Op. 18, composed by Emile-Robert Blanchet (1877–1943).[396] Relevant sections of the MIDI file and score are shown in Figure 4.24.

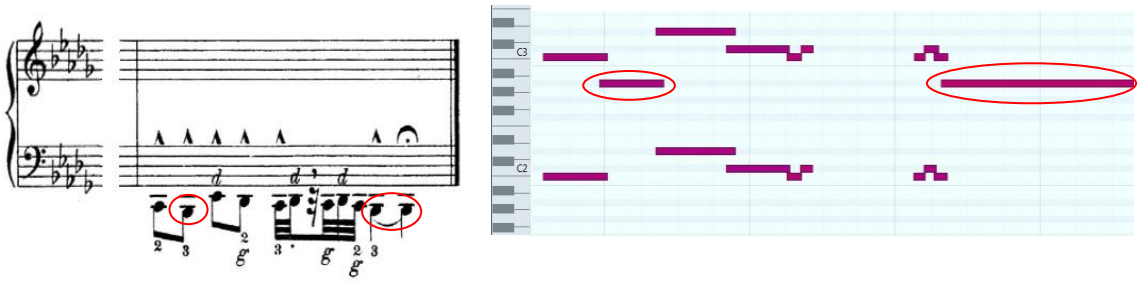

Figure 4.24 *Last bar of* Turquie*, and MIDI file of Nyiregyházi's recording of the work, circled notes are missing the octave note of Bb1*

The score does not have the octave notes that Nyiregyházi added, but it is a reasonable assumption that during the recording he would have played octave notes with the circled notes in Figure 4.24. The lowest note on an Ampico is note B1, while the missing octave notes in the MIDI file are note Bb1. Adding the missing notes is therefore appropriate, even though they do not appear in the score. As well, the score has a tremolo during bars 19-21 that requires bottom A. Adding this note to the MIDI file restores the character of the work.

[395] Welte-Mignon roll number 1478.
[396] Ampico roll number 67583, titled *In the Garden of the Old Harem* (*Au jardin de vieux Serail*).

An interesting example of a composer-pianist adapting a score to deal with the reduced compass of the Duo-Art occurs in Busoni's recording of the Bach-Busoni Chaconne (based on the Chaconne from the Violin Partita in D minor BWV 1004).[397] At bar 76, the last note in the treble stave is a B flat (Bb8), as shown in Figure 4.25. However, this note is outside the Duo-Art compass, so Busoni changes the sequence of eight notes to a run of seven notes, ending instead in A flat (Ab8) and leaving out note A8. This works harmonically with the following sequence of notes, which constitute a G diminished harmony, whereas ending on note A8 would be musically inappropriate.

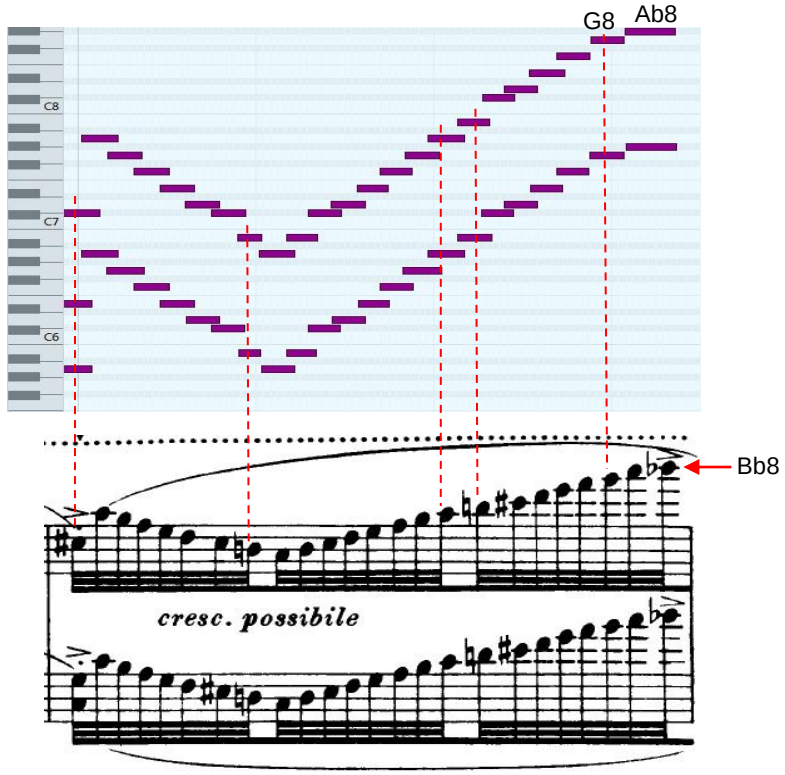

Figure 4.25 *Showing Busoni's alteration to the score of his* Chaconne *to accommodate the missing Bb8 in the Duo-Art*

There are several instances in the score of this work where bass notes lie outside the compass of the Duo-Art, which Busoni partially accommodated by changes to the score. Figure 4.26 shows part of the fourth-last bar and the complete third-last bar, in which circled notes in the score are not played. Although note D2 is within the compass of the Duo-Art, it is not played, note A1 in the score is replaced with note A2, and note G2 is coupled with note G3. In two of the chords, notes are different to those in the score.

[397] Duo-Art roll number 6928.

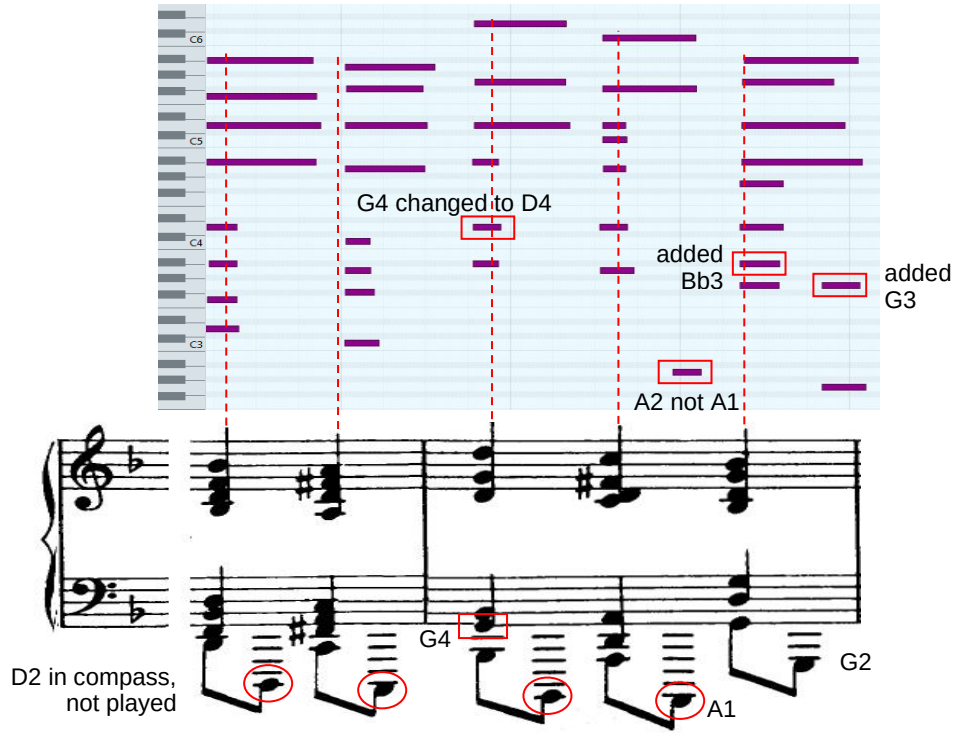

Figure 4.26 *Showing variations from the score of Busoni's* Chaconne, *circled notes in the score could not be recorded as they are outside the compass of the Duo-Art*

There are other changes to the score found in this recording, and some are not related to the reduced compass of the Duo-Art. It could be argued that it is valid to add notes to a recording that lie outside the compass of the reproducing piano, while other changes may be those of the pianist that are best left unaltered.

There are instances of incorrect notes on reproducing piano rolls. As pointed out in Chapter 2, page 118, Leikin found three wrong notes in the Welte-Mignon recording of Scriabin playing his Poem Op. 32 No. 1 on roll 2068.[398] Colleague Glenn Amer observed a wrong note in Friedheim's Duo-Art recording of Liszt's *Les jeux d'eaux à la Villa d'Este* S.163, in which an F sharp was punched as F in the first chord after the key change from E Major to D Major, as shown in Figure 4.27. This error is present in all the original and recut rolls of this recording that I have encountered.[399]

[398] Leikin, *The Performing Style of Alexander Scriabin*, 70.
[399] Duo-Art roll number 5724.

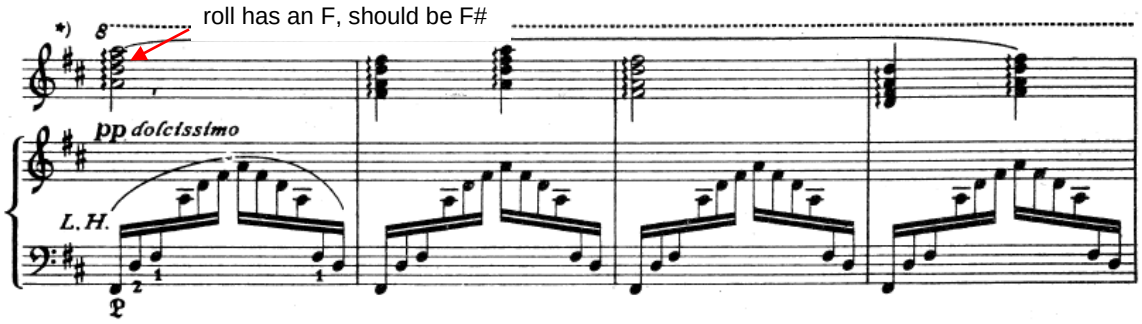

Figure 4.27 *Wrong note in the Duo-Art recording by Friedheim of Liszt's* Les jeux d'eaux à la Villa d'Este *S.163 giving a D minor chord in the treble against a D Major sequence in the bass, clear evidence of a wrong note*

Editing note length

The main reason to modify the length of a note is to ensure a following note of the same pitch can repeat. In my experience, there are two reasons that make changing the length of a note necessary: roll production errors, and attempts by roll editors to reduce the effect of accompaniment notes playing at the same dynamic level as thematic notes. In the latter case, by keeping a short distance between the end of a note and the start of a repeating note, a piano hammer does not always have time to fall back to its rest position. This tends to make the repeating note play more softly, or in some cases the note cannot repeat at all. In this case, altering the length of a note to effect better repetition was done in conjunction with editing the dynamics of the relevant notes. An example is shown in Figure 4.28.[400]

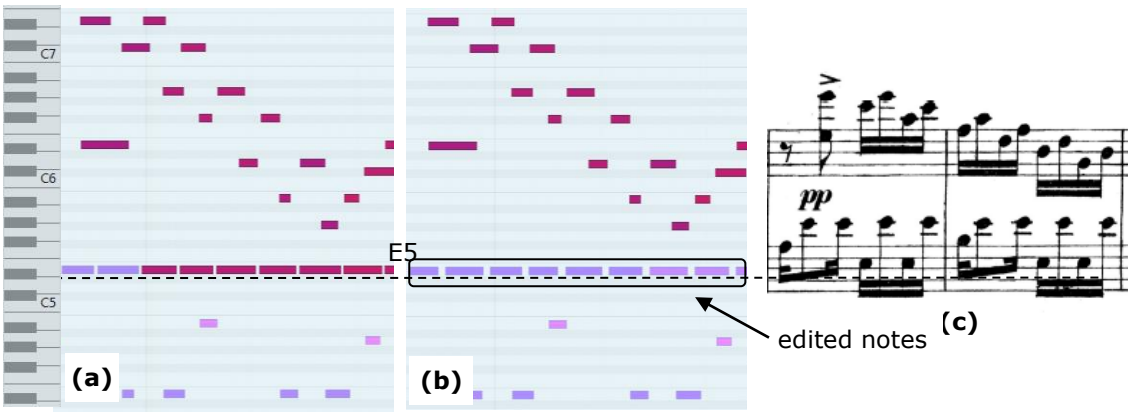

Figure 4.28 (a) *Prior to editing note length and dynamics,* ***(b)*** *after the changes* ***(c)*** *score*

[400] Duo-Art roll number 66560, Brazilian Dance (*Galhofeira*) Op. 13 No. 4 by Alberto Nepomuceno (1864-1920), played by Maria Carreras.

As the score in Figure 4.28 (c) shows, note E5 is clearly part of the accompaniment. This note is just within the treble side of the keyboard (above the dashed line), and therefore each repeat of the note has similar dynamics to the thematic notes. The short gap between each repetition is most probably an editor's attempt to prevent the note sounding too loudly. Increasing the time between each repetition ensures the note will play correctly, which in Figure 4.28 (b) has been done in conjunction with matching its dynamic value to other notes in the accompaniment. Because Carreras may have held these notes, their length is only reduced to ensure clean repetition.

Trill notes on piano rolls were often edited to obtain best effect, although production errors and the quantising that occurs when a roll is perforated can create slight variations. However, Welte-Mignon rolls, as discussed in Chapter 2 were not edited to the same extent as Ampico or Duo-Art rolls. Figure 4.29 shows an example of a trill played by Busoni in his recording of Liszt's *Grandes études de Paganini* No. 3, S.141, known as "La campanella." Busoni recorded this work for both the Welte-Mignon and the Duo-Art.[401]

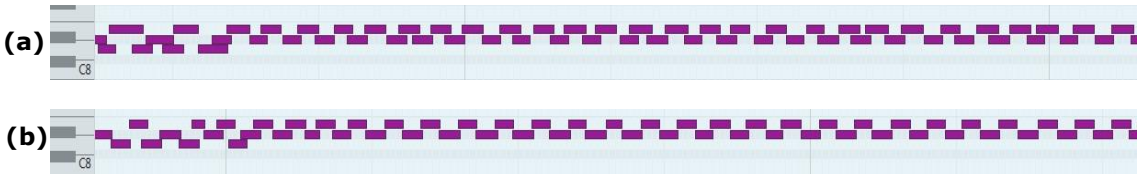

Figure 4.29 (a) *Welte-Mignon roll recording,* ***(b)*** *Duo-Art roll recording*

The trill notes in the Duo-Art recording (b) are far more regular compared to those in the Welte-Mignon recording shown in (a). It is unlikely Busoni played the trill with such irregularities, and tidying the trills in the MIDI file to give a clean sounding trill is therefore appropriate. In most case, notes are shortened slightly, although sometimes it is necessary to realign a trill note altogether.

As detailed in Chapter 2 (page 140), many Ampico rolls have extended note perforations to create a "singing tone." Notes that are extended by the duration of a damper pedal command can obviously be shortened without changing the musical effect. This might be done for visual reasons, in which more than ten notes are held

[401] Duo-Art roll number 5698, issued November 1915, and Welte-Mignon roll number 444, recorded 10 June 1905.

down simultaneously, giving a false impression when observing the keyboard of an Ampico reproducing piano. Notes that extend beyond damper pedal operation are likely to be an editorial change, unless the pianist used the *sostenuto* pedal. In this case, one must make a judgement. Extended notes are generally only found on Ampico rolls; Figure 4.30 shows an example.[402]

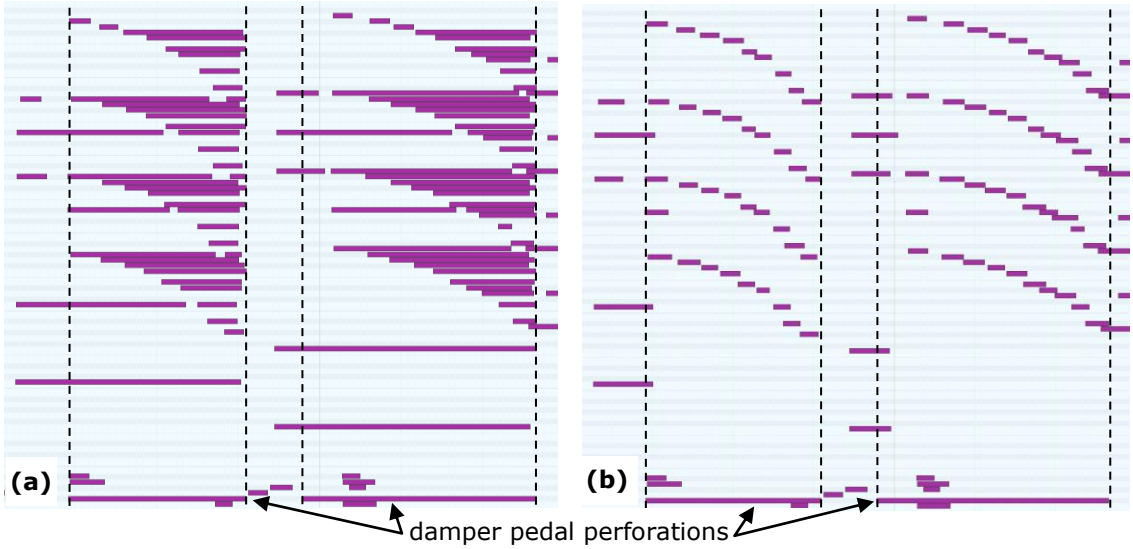

Figure 4.30 (a) *Extended notes matching the duration of the damper pedal,* ***(b)*** *notes shortened to show more accurately the actual playing*

The images in Figure 4.30 are of the raw MIDI file, which in this case can be edited in the same manner as the emulated version. The dashed lines show the operation of the damper pedal and (b) illustrates that shortening the duration of the notes has no musical effect and gives a more accurate account of how the pianist played the work.

Editing tempo

Chapter 2 (page 160) presents examples of variations between the playing time of the same performance issued on different Duo-Art roll recordings. Tempo differences from the original recording also apply to Licensee issues of Welte-Mignon rolls, as discussed on page 123. There is no obvious way of determining the correct playing speed of a piano roll, unlike a gramophone recording, in which the playing speed can often be determined from the pitch of the notes, taking into account the pitch standards existing at the time of the recording.

[402] Ampico roll number 52514, Mazurka Op. 103 by Benjamin Godard, played by Marguerite Volavy.

In the case of Welte-branded rolls, it is more likely that rolls for the Mignon have the correct tempo, as they all play at the same paper speed of three metres per minute. Even then there is the possibility that the recording equipment was not operating correctly, perhaps explaining why Roy Howat felt some parts of the Welte-Mignon recordings of Debussy playing his *Children's Corner Suite* to be too fast.[403] The tempo of the Welte Licensee issues of the same recording were obviously changed, causing Howat to regard other parts of the recording as "suspiciously slow."[404]

Howat also refers to issues with recordings made on original instruments having considerable variations in playing times. When noting the playing time of Friedheim's Welte-Mignon recording of Liszt's Ballade No. 2 in B minor, S.171,[405] Condon noted the following playing times and dates on the roll: 12:48 (1979), 13:49 (1983), 14.36 (1984), 12:42 (2005). When recording this roll using the roll reader described in Chapter 3, the playing time was 12:03.[406]

While accurately recorded MIDI files of piano rolls solves the issue of variations in playing time caused by original instruments, there is still the dilemma of whether the marked roll speed is correct. As this is an issue that is not easily resolved, it becomes a matter for musical judgement. In some cases, it is clear the speed is too fast, judged by impossibly fast playing. Matching the tempo of a roll recording to a pianist's disc recording of the same work does not always solve the problem, given the time constraints of early gramophone recordings. Musical tempo of piano rolls therefore remains an unknown; however, I have found that the majority of piano rolls appear to have the correct playing speed.

Playback technologies

A significant reason to produce emulated MIDI files of reproducing piano rolls is to make the recorded performance accessible through modern instruments. Reference is made in Chapter 2 (page 105) to high-end MIDI solenoid player pianos such as Yamaha's Disklavier Pro series, and Bösendorfer's CEUS-equipped series as potentially offering the most accurate reproduction. It has been my experience that most MIDI solenoid player pianos, such as a PianoDisc or standard Disklavier can give acceptable reproduction of emulated MIDI files, in which the brand, type and size of the

[403] Howat, *The Art of French Piano Music*, 317.
[404] Howat, *The Art of French Piano Music*, 318.
[405] Welte-Mignon roll 214, recorded 1905.

piano determines the tonal qualities. It is worth noting that reproducing player mechanisms were fitted to a wide range of pianos, including expensive brands such as Steinway and Mason & Hamlin, as well as numerous cheaper brands. That is, the rolls themselves were not recorded for playback only on a particular quality of instrument.

While a mechanical player piano will potentially deliver the best sound quality, depending on the piano, a MIDI file has a wider range of options for playback than a piano roll. Contemporary digital pianos now offer sounds that are sampled from mechanical pianos, rather than electronically generated tones. For example, in its range of digital pianos, Yamaha uses samples derived from the company's CFX grand piano and Bösendorfer's model 280 grand piano.[407] An advantage of a digital piano is the complete lack of mechanical operation, which means issues affecting playback such as action regulation and tuning are bypassed.

Virtual piano technology

Although a mechanical MIDI piano might be a preferred way of hearing a piano roll MIDI file, it is only possible if there is access to such an instrument. If piano roll recordings are to be made more accessible, this is surely through audio recordings. I have experimented with creating audio files of piano roll performances using a range of virtual pianos. There are two basic types of virtual pianos; software that uses samples of actual pianos, and software that generates piano tones from mathematical routines. An example of the latter is software known as *Pianoteq* produced by the Modartt Company.[408]

Unlike sampled piano software, *Pianoteq* software offers a wide range of sounds that include early instruments and modern concert grands.[409] Nettheim used *Pianoteq* software to produce the afore-mentioned reconstitutions of Pachmann's gramophone recording of Chopin's Nocturne in E minor Op. 72 No. 1.[410] This type of software therefore suits applications in which a particular sound is required, such as matching the sound to an early recording, as in Nettheim's case.

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[406] Playing time as noted when roll was recorded using the equipment described in Chapter 3.
[407] *Digital Pianos*, http://usa.yamaha.com/products/musical-instruments/keyboards/digitalpianos/ (accessed 9 November 2016).
[408] *Pianoteq*, https://www.pianoteq.com/home (accessed 9 November 2016).
[409] *Pianoteq Instruments*, https://www.pianoteq.com/instrument_list (accessed 9 November 2016).
[410] Nettheim, "The Reconstitution of Historical Piano Recordings," 101.

I have experimented with three virtual piano software packages that use samples of an actual piano, although there are many more packages currently available. The first, now discontinued, was produced by Garritan Corp in 2009 under licence from Steinway and Sons, using samples of a Steinway model D piano. In 2014, Garritan released a software package based on Yamaha's CFX concert grand,[411] which offers a higher number of samples than the Steinway sample set. A third virtual instrument is the "Vintage D", a sample set of a 1920 Steinway model D owned by German recording company Bauer Studios.[412] This instrument has the significance of being potentially tonally similar to pianos played by piano roll artists.

Creating a sound file using any virtual piano package requires modifying the velocity range of the MIDI files that otherwise suit a mechanical piano. This can be achieved either directly with the MIDI file or by adjustments within the virtual piano software. The sound quality produced by a virtual piano depends on how the samples were recorded, and how many samples were taken. The CFX virtual piano has the greatest number of samples of the three instruments, but for authentic tone, the Vintage D virtual piano may be a preferred choice, despite its fewer number of samples.

In summary, virtual piano software is a developing technology that offers high quality renditions of emulated MIDI files of piano rolls for a modest price and minimal effort.[413] It potentially offers a ready means of making piano roll recordings widely accessible through the medium of audio recordings.

[411] *CFX Concert Grand*, https://www.garritan.com/products/cfx-concert-grand-virtual-piano/ (accessed 9 November 2016).
[412] *Vintage D*, http://www.galaxy-instruments.com/vintage-d.html (accessed 25 June 2017).
[413] At the time of writing, the Garritan CFX virtual piano software is priced at US $200.

Chapter summary and conclusion

Reproducing piano rolls can only be played on original instruments, while the options for listening to an emulated MIDI file of a piano roll recording include contemporary mechanical pianos, high-end digital pianos and virtual piano software. The sound quality of recordings made with virtual piano software is equalled only by professional-quality studio recordings. Any of these play-back methods make piano roll recordings accessible, providing emulated MIDI files of piano rolls embody the correct dynamics, pedalling and timings of the original rolls.

A key aspect to accessibility is surely through virtual piano software. Today's musicologists are usually familiar with this technology, which requires only a computer and relevant software. Examining MIDI files and creating sound files from MIDI files using a digital audio workstation (DAW) is therefore a routine operation for these researchers. The cost of a suitable setup is also relatively small, compared to the cost of a MIDI mechanical piano. Even so, numerous musical institutions have such instruments, while few will have a working, MIDI-equipped original reproducing piano.

Correcting aspects of a piano roll recording that are caused by the limitations of the technology is only possible with their emulated MIDI counterpart. In some cases, corrections can be made by simply examining the MIDI data; otherwise reference to a score is required. It may not be possible to bring back every aspect of the original playing, but many opportunities exist in restoring a recording that cannot be achieved when working with the original technology.

Thesis conclusion

The narrative began in 1904, when an "80-ton" mechanical player piano, now recognised to be a prototype of the Welte-Mignon reproducing piano was first demonstrated. From that time to the 1930s, a world-wide industry employing thousands of people produced many thousands of reproducing piano roll recordings. In Chapter 1, I took advantage of having recorded as MIDI files about two thirds of the art music on piano roll for the four types of instruments discussed in this thesis to answer questions that had long concerned me. In particular, I sought to determine the make-up of the art music catalogues, and therefore to determine their musical value. The numbers alone are mind boggling: around 760 pianists recorded works by at least 850 composers, with a total playing time of around 500 hours. Virtually all the famous pianists of the times made piano roll recordings and at least 100 of them have their birth date prior to 1870, offering the best musical link we have to nineteenth-century performing practices. The large number of now forgotten works on piano roll provides a unique resource for pianists wishing to expand their repertoire.

A library of recorded music only has value if the recordings actually captured the art of the pianists. In Chapter 2 I established factual data to determine the accuracy of reproducing piano roll recordings. There is little doubt that Welte-Mignon rolls are as faithful to the artist as the technology could allow, while Ampico and Duo-Art recordings, though sometimes edited, were often presented to a musical public alongside performances by the artists themselves. The limitations of piano roll recordings are not as restrictive as is sometimes suggested, and in many cases the perceived issues are due to the quality and condition of the playback instrument.

Establishing the musical accuracy of reproducing piano rolls is important, as archiving and making these recordings accessible through other formats would otherwise be pointless. Chapter 3 presents a methodology that I have used for recording piano rolls as raw MIDI files, and thereby provides base-line data that other researchers can refer to. My philosophy was to read piano roll perforations in the same manner as they are read by the instruments that play them.

The most important aspect covered in this thesis is making piano roll recordings accessible to all, the topic of the final chapter. This under-researched area has attracted only a few enthusiasts and even fewer academic researchers. By presenting the approach and philosophy that I have followed to produce MIDI files of piano rolls that

are playable on contemporary instruments, I have again established base-line data that can form a starting point, perhaps even a reference for other researchers. While accessibility was the goal, a secondary and exciting aspect is being able to make a range of valid corrections to the original roll recordings.

When the performances recorded on reproducing piano rolls are made into standard MIDI files, they become accessible through contemporary technology that includes mechanical and virtual MIDI pianos. This surely places piano roll recordings into the 21st century, over 110 years since Alfred Grünfeld made the first Welte-Mignon recordings at Leipzig on January 19, 1905.

Bibliography

Articles published on some websites and by the trade publications *Music Trade Review* and *Presto* do not always identify the author. These references are therefore listed by the title of the article. *Music Trade Review* and *Presto* publications are available at http://mtr.arcade-museum.com/

Aeolian Company. *The Duo-Art Reproducing Piano – Service Manual No. 3*. New York, 1927.

"Aeolian Hall Gleanings." *Music Trade Review*, vol. 58 no. 11, Mar 14, 1914, 38.

Ampico, Corporation. *The Ampico Service Manual 1929*. New York, 1929.

_____. *Inspector's Reference Book*. New York, post 1920.

_____. *Sales Manual*. New York, post 1925.

"Ampico Recital at Biltmore." *Music Trade Review*, vol. 64 no. 11, March 17, 1917, 36.

"Ampico Reproducing Piano Featured as Soloist, The." *Music Trade Review*, vol. 70 no. 19, May 8, 1920, 36.

"Auto De Luxe Player Action at the Show." *Presto*, no. 1750, February 5, 1920, 11.

Bazzana, Kevin. *Lost Genius: the Curious and Tragic Story of an Extraordinary Musical Prodigy*. New York: Carroll & Graf, 2007.

Bird, John. *Percy Grainger*. new ed. New York: Oxford University Press, 1999.

Blanks, Fred. "Relentless Ghost at the Keyboard." *Sydney Morning Herald*, June 15, 1978, (page number not known).

Bowers, Q. David. *Encyclopedia of Automatic Musical Instruments*. New York: Vestal Press, 1972.

Broyles, Michael and Von Glahn, Denise. *Leo Ornstein: Modernist Dilemmas, Personal Choices*. Bloomington: Indiana University Press, 2007.

"Buy Electrelle Co. Player." *Music Trade Review*, vol. 50 no. 17, April 23, 1910, 29.

CEUS Project. *eleced* label. http://www.naxosmusiclibrary.com (accessed 12 July 2016).

CEUS Reproducing System. http://www.boesendorfer.com/en/ceus-reproducing-system (accessed 4 December 2016).

CFX Concert Grand. https://www.garritan.com/products/cfx-concert-grand-virtual-piano/ (accessed 9 November 2016).

Chase, Spencer. *Spencer's E-Rolls.* http://www.spencerserolls.com/index.html (accessed 12 July 2016).

Colmenares, Gustavo, and Escalante, René, and Sans, Juan, and Surós, Rina. "Computational Modeling of Reproducing-Piano Rolls." *Computer Music Journal* 35, no. 1 (2011), 58-75.

"Controls the Aeolian-Weber Destiny." *Music Trade Review*, vol. 37 no. 6, Aug 8, 1903, 15.

Cook, Nicholas, and Leech-Wilkinson, Daniel. *A Musicologist's Guide to Sonic Visualiser.* http://www.charm.rhul.ac.uk/analysing/p9_1.html (accessed 15 October 2016).

Dangel, Gerhard and Schmitz, Hans W. *Welte-mignon klavierrollen: Gesamkatalog der europäischen aufnahmen 1904-1932 für das welte-mignon reproduktionspiano*, 2 parts. Stuttgart: Rombach Druck, 2006.

Dangel, Gerhard. "A History of M. Welte & Sons: The Family and the Company." *The Pianola Journal*, no. 18 (2007), 31, 39, 40-41, 42, 46.

De Luxe Roll Corporation. *Library of De Luxe Welte-Mignon (Licensee) Music Records*. USA, 1924.

"De Luxe Welte-Mignon (Licensee) Recording Roll Laboratories in New York." *Music Trade Review*, vol. 76 no. 5, February 3, 1923, 47.

Denis Condon Collection, The. http://efemera-ephemera.org/CondonCollection/indexx.html (accessed 17 March 2016).

Digital pianos. http://usa.yamaha.com/products/musical-instruments/keyboards/digitalpianos/ (accessed 9 November 2016).

Dubal, David. *The Art of the Piano Its Performers, Literature and Recordings*. New Jersey USA and Swavesey UK: Amadeus Press, 2004.

"Duo-Art and Detroit Symphony Orchestra Concert." *Music Trade Review*, vol. 70 no. 7, February 14, 1920, 18.

Elste, Martin. "You Had to be Able to Play the Piano." in *Famous Pianists at the Hupfeld Recording Salon*, edited by Eszter Fontana, 9-17. Germany: Verlag Stekovics, Halle / Saale, 2000. English translation.

"Echoes of the Duo-Art Recital." *Music Trade Review*, vol. 65 no. 22, December 1, 1917, 42.

"Effective Demonstration in Pittsburgh Store." *Presto*, no. 1942, October 13, 1923, 12.

Evans, Allen. *Ignaz Friedman - Romantic Master Pianist*. Bloomington: Indiana University Press, 2009.

Fontana, Mark Andrew. *Preservation and MIDI Translation of the Pianocorder Music Library*. http://pianocorder.info/pdf/mark_fontana_thesis.pdf (accessed 21 October 2015).

"Ganz Appears in Dual Role at Duo-Art Concert." *Music Trade Review*, vol. 70 no. 4, January 24, 1920, 79.

Ganz, Esther. "Letter to Mr. Elfers, Editor." June 1970. *AMICA Bulletin* vol. 7 no. 7, July 1970, 1.

Gershwin Plays Gershwin, The Piano Rolls. Elektra Nonesuch 9 79287-2, issued November 5, 1993. http://www.nonesuch.com/albums/gershwin-plays-gershwin-the-piano-rolls (accessed 12 July 2016).

Givens, Larry. *Rebuilding the Player Piano*. New York: Vestal Press, 1963.

_____. *Re-Enacting the Artist.* New York: Vestal Press, 1970.

Goebland, Werner, and Bresin, Roberto. "Are Computer-controlled Pianos a Reliable Tool in Music Performance Research? Recording and Reproduction Precision of a Yamaha Disklavier Grand Piano." *Austrian Research Institute for Artificial Intelligence (OFAI)*, November 2001. http://www.ofai.at/cgi-bin/tr-online?number+2001-27 (accessed 28 July 2016).

"Great Ampico Concert Reproduced in Washington." *Music Trade Review*, vol. 70 no. 10, March 6, 1920, 23.

Hall, Denis. "How Do You Like Your Debussy." *The Pianola Journal*, no. 23 (2013), 35.

Hall, Denis. "Piano Roll Speeds." *The Pianola Journal*, no. 22 (2012), 3.

Handscombe, Patrick and Broadbent, Terry. *The London Duo-Art Pianists*. London: Player Piano Group, 2014.

Henderson, Douglas. *Play-Rite Music Rolls Business for Sale.* https://www.mmdigest.com/Archives/Digests/200411/2004.11.23.10.html (accessed 5 December 2016).

History of the Pianola - An Overview. http://www.pianola.org/history/history.cfm (accessed 30 April 2015).

History of the Pianola – Inventors. http://www.pianola.org/history/history_inventors.cfm (accessed 10 March 2016).

Ho, Jocelyn. "Debussy and Late-Romantic Performing Practices: An Investigation of Debussy's Piano Rolls of 1912." Masters diss., University of Sydney, 2012.

Hofmann, Josef. *Recorder for Musical Dynamics*. http://www.google.com/patents/US1614984 (accessed 13 March 2016).

Howat, Roy. *The Art of French Piano Music. Debussy, Ravel, Fauré, Chabrier*. New Haven: Yale University Press, 2009.

Howe, Richard, ed. *The AMPICO Reproducing Piano*. St Paul, Minnesota: Musical Box Society International, 1987.

Howe, Richard, and Morgan, Jeffrey. *The Evolution of the Ampico.* (1991). http://www.amica.org/Live/Publications/Past-Bulletin-Articles/EvolutionOfTheAmpico.pdf (accessed 23 January 2016).

Hunt Piano Company. *VirtualRoll System*. http://www.virtualroll.com/ (accessed 9 July 2016).

Husarik, Stephen. "Problems of Transcription, Fingering and Performance Practices in Vladimir Horowitz's Duo-Art Piano Roll Performance of *Carmen* Variations." *ESCOM Proceedings 2005*. http://www.escom.org/proceedings/ESCOM2005_Proceedings_Performance_Matters/html/pdf/StephenHusarik.pdf (accessed 13 September 2015).

Keystone Music Roll Company. http://www.player-care.com/keystone.html (accessed 5 December 2016).

Lawson, Rex. "Duo-Art Roll Speeds and Recording Methods." *AMICA Bulletin*, vol. 33 no. 6, November-December 1996, 299.

_____. "Joseph Hunter Dickinson and the Origins of the Duo-Art." *The Pianola Journal*, no. 24 (2014), 13.

_____. "On The Right Track: The Recording of Dynamics for the Reproducing Piano - Part One." *The Pianola Journal*, no. 20 (2009), 4.

Leikin, Anatole. "Piano Roll Recordings of Enrique Granados: A Study of a Transcription of the Composer's Performance." *Journal of Musicological Research*, vol. 21 nos. 1-2 (2002), 3-19.

_____. *The Performing Style of Alexander Scriabin*. UK: Ashgate Publishing Limited, 2011.

"Letter from Richard Simonton to Larry Givens of 15 August 1963." *AMICA Bulletin*, vol. 37 no. 2, March-April 2000), 84.

Litterst, George F. *Anatomy of a Disklavier*. http://yamahaden.com/anatomy-of-a-disklavier (accessed 19 April 2016).

Lyle, Wilson. *A Dictionary of Pianists*. London: Robert Hale, 1985.

Macleod, Beth Abelson. *Fannie Bloomfield-Zeisler*: *The Life and Times of a Piano Virtuoso*. Chicago: University of Illinois Press, 2015.

Manildi, Donald. "Sound Recording Reviews: "Welte-Mignon Piano Rolls, Volumes 1, 2, and 3"." *ARSC Journal* 36, no. 2 (2005), 290-293.

Mechanical Music Preservationists, (IAMPP). https://groups.yahoo.com/neo/groups/Rollscanners/info (accessed 2 July 2016).

Method of Recording Music. http://www.google.com/patents/US1367634 (accessed 21 March 2016).

Mitchell, Mark. *Vladimir De Pachmann*: *A Piano Virtuoso's Life and Art*. Bloomington: Indiana University Press, 2002.

Modest Altschuler. https://en.wikipedia.org/wiki/Modest_Altschuler (accessed 24 February 2016).

"Moiseiwitsch Appears with Ampico in London." *Presto-Times*, no. 2120, March 19, 1927, 9.

Morrey, Grace Hamilton. https://beta.worldcat.org/archivegrid/collection/data/5862015 (accessed 24 September 2015).

Nettheim, Nigel. "The Reconstitution of Historical Piano Recordings: Vladimir de Pachmann plays Chopin's Nocturne in E minor." *MPR, Music Performance Research* vol. 6, 97-125, 2013, http://mpr-online.net/Issues/Volume%206%20%5b2013%5d/MPR0074.pdf (accessed 19 November 2016).

"New De Luxe Reproducing Rolls Well Received." *Presto*, no. 1780, September 4, 1920, 8.

"New De Luxe Roll Catalog." *Presto*, no. 1932, August 4, 1923, 17.

New Technology Recaptures Pianists of the Past. http://www.npr.org/templates/story/story.php?storyId=10439850 (accessed 11 October 2015).

"Notable Presentation of a Notable Instrument, A." *New York Tribune*, November 25, 1917, 6. http://chroniclingamerica.loc.gov/lccn/sn83030214/1917-11-25/ed-1/seq-6.pdf (accessed 16 November 2016).

Obenchain, Elaine. *The Complete Catalog of Ampico Reproducing Piano Rolls*. New York: William H. Edgerton, 1977, PDF electronic version 2009.

"Orders Coming at Lively Rate." *Music Trade Review*, vol. 53 no. 12, September 23, 1911, 37.

Pedrazzini, Flavio, and Malosio, Matteo, and Perego, Niccolò. *SISAR Project*. https://sites.google.com/site/wwwammilab/projects/sisar (accessed 28 April 2016).

Peres Da Costa, Neal. *Off the Record: Performing Practices in Romantic Piano Playing*. New York: Oxford University Press, 2012.

Permut, Steven. "Recordings." in *Encyclopedia of the Piano*, edited by Robert Palmieri, 312-13. New York and London: Garland Publishing Inc, 1996.

Pianoteq Instruments. https://www.pianoteq.com/instrument_list (accessed 9 November 2016).

Pianoteq. https://www.pianoteq.com/home (accessed 9 November 2016).

"Player Convention Aftermath." *Music Trade Review*, vol. 47 no. 25, December 19, 1908, 10.

Reblitz, Arthur A. and Bowers, Q. David. *Treasures of Mechanical Music*. New York: Vestal Press, 1981.

Reproducing Piano, The – Ampico. http://www.pianola.org/reproducing/reproducing_ampico.cfm (accessed 18 March 2016).

Reproducing Piano, The - Artrio-Angelus. http://www.pianola.org/reproducing/reproducing_artrio.cfm (accessed 25 March 2016).

Reproducing Piano, The - Duo-Art. http://www.pianola.org/reproducing/reproducing_duo-art.cfm (accessed 24 February 2016).

Reproducing Piano, The - Philipps Duca. http://www.pianola.org/reproducing/reproducing_duca.cfm (accessed 25 March 2016).

Reproducing Piano, The - Welte-Mignon. http://www.pianola.org/reproducing/reproducing_welte.cfm (accessed 29 January 2016).

Reinhart, Mark. "The Welte-Mignon Recording Process in Germany." *The Pianola Journal*, no. 16 (2005), 10, 11.

Reynolds, Reginald. "A Note on the Technique of Recording." *The Gramophone*, (February 1924), reprinted in *The Pianola Journal*, no. 7 (1994), 36.

Robinson, Brad. *Glitch Free - An In-depth Guide to Tuning Windows for Reliable Real-time Audio Performance*. PDF document available at https://www.cantabilesoftware.com/glitchfree/?utm_source=mailinglist&utm_medium=email&utm_campaign=glitchfree1 (accessed 26 May 2016).

Rumsey, David. *Welte's Instruments, Rolls, Recording, Digital Editing*. http://www.davidrumsey.ch/OVERVIEW1.pdf (accessed 29 January 2016).

Schmitz, Hans W. "Music Roll Production at Ludwig Hupfeld AG, Leipzig." in *Famous Pianists at the Hupfeld Recording Salon*, edited by Eszter Fontana, 19-22. Germany: Verlag Stekovics, Halle / Saale, 2000. English translation, 2000.

Scholes, Percy A and Ward, John Owen, eds. *The Oxford Companion to Music*. Tenth Edition. London: Oxford University Press, 1977.

Schonberg, Harold C. *The Great Pianists*. New York: Simon and Schuster, 1963, paperback edition 2006.

_____. "Romantic Pianists Display Mastery on Piano Roll Disks." *The New York Times*, July 28, 1985. http://www.nytimes.com/1985/07/28/arts/romantic-pianists-display-mastery-on-piano-roll-disks.html (accessed 15 November 2016).

Sitsky, Larry. *The Classical Reproducing Piano Roll: A Catalogue-index*. New York: Greenwood Press, 1990.

Slonimsky, Nicolas. *Baker's Biographical Dictionary of Musicians*. New York: Schirmer Books, 1997.

Smith, Charles Davis. *Duo-Art Piano Music: A Complete Classified Catalog of Music Recorded for the Duo-Art Reproducing Piano*. Monrovia, California: The Player Shop, 1987.

Smith, Charles Davis and Howe, Richard James. *The Welte-Mignon: Its Music and Musicians*. New York: Vestal Press, 1994.

"Special Artigraph Music Rolls." *Music Trade Review*, vol. 53 no. 11, September 16, 1911, 33.

Stahnke, Wayne. *Live Performance*. http://www.live-performance.com/about.html (accessed 28 January 2016).

_____. *Copying Music Rolls Hole for Hole*. http://www.waterex.com.au/player/copying.html (accessed 5 July 2016).

_____. Liner notes to *A Window in Time, Sergei Rachmaninoff.* Telarc CD-80491, 1998.

_____. *Prototype Rolls and Pattern Rolls.* http://www.mmdigest.com/Archives/Digests/199708/1997.08.27.17.html (accessed 22 October 2015).

Stanford University Libraries. *About the [Player Piano] Project*. https://library.stanford.edu/projects/player-piano-project/about-project (accessed 30 October 2016).

"Steinway Pianola Piano, The." *Music Trade Review*, vol. 50 no. 8, Feb 19, 1910, 26.

"Takes Over Welte Business." *Music Trade Review*, vol. 66 no. 26, June 29, 1918, 31.

"To Feature Rythmodik Rolls." *Music Trade Review*, vol. 54 no. 10, March 9, 1912, 37.

Tonnesen, Richard. *Music Roll Reader and Perforator*. http://www.mmdigest.com/Pictures/tonnesen.html (accessed 9 July 2016).

Trachtman, Warren. *Saving The Old Piano Roll Music.* http://www.trachtman.org/index.htm (accessed 12 July 2016).

"Twelve Million Dollar Combination, A." *Music Trade Review*, vol. 46 no. 24, June 13, 1908, 7.

Van Riper, Joseph D. "The Reproducing Piano: A Portrait of the Artist." DMA diss., Illinois State University, 2012.

Vintage D, http://www.galaxy-instruments.com/vintage-d.html (accessed 25 June, 2017).

Walker, John Q. Ii, Raleigh NC, *US patent number 20090282966*. http://www.patentsencyclopedia.com/inventor/walker-ii-us-5/ (accessed 11 October 2015).

Waters, Michael. *Player Piano – Power Roll* (2000). http://www.waterex.com.au/player/poweroll.html (accessed 12 July 2016).

Wodehouse, Artis. Liner notes to *Gershwin Plays Gershwin, The Piano Rolls*. http://albumlinernotes.com/The_Piano_Rolls.html (accessed 12 July 2016).

Woods, Creary, W. "Interview." *High Fidelity*, (July 1967), reprinted in *AMICA Bulletin*, vol. 36 no. 1, January-February (1999), 14.

_____. "Regarding the Art of Reproducing." *Music Trade Review*, vol. 71 no. 24, December 11, 1920, 57.