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Cylinder Record Materials

Although record collecting may be traced back to the turn of the century, there has been little in the way of serious study devoted to the problems of preservation. The 1959 Pickett and Lemcoe study for the Library of Congress[1] identified some of the problems of shellac and vinyl records but ignored completely those of cylinders and most other vertical-cut recordings. As far as I know, an unpublished paper that I delivered before the New York Chapter of the Music Library Association in 1978 was unique in raising questions; it was greeted with an almost audible "ho hum".[2] Since the date of that paper, more years have lapsed and further degradation of stored cylinders has undoubtedly taken place. The notes to follow are offered in the hope that, by examining the historical evidence, steps may be taken to redress past omissions.

Tinfoil Recordings

The most difficult period to document in terms of surviving recordings is the first – the tinfoil period. In many cases, the tinfoil was attached to the phonograph mandrel by means of shellac. The removal of a foil that had been so affixed was virtually certain to assure its destruction.

A later form of phonograph developed by Edison used a clamping bar to temporarily secure the foil in an axial slot in the mandrel. While this bar held the foil securely, it also caused a dead spot in the recording and added the difficulty of groove alignment, should one wish to reattach a previously recorded foil.

Few tinfoil recordings have survived and I know of none that have been successfully reproduced. One tinfoil, in the Smithsonian Archives, may contain the voice of Joseph Henry (American physicist, President of the National Academy of Sciences and first Secretary and Director of the Smithsonian Institution). Another foil, also supposedly recorded during Edison's visit to Washington, DC, in April 1878, was at the Franklin Institute in Philadelphia, during the 1970s. It is reputedly a recording of Carl Schurz, soldier and political leader, one of the most famous U.S. citizens of German birth. For this recording, Schurz spoke in his native German so as to assure the integrity of his speech. A third tinfoil of uncertain content and provenance was offered to the Science Museum in London, England in the late 1970s.

The Smithsonian unsuccessfully attempted to reproduce the "Henry" foil using a laser. Other efforts to "read" recordings by noncontact methods employing laser technology have been reported.[3]

Other Very Early Recordings

The granddaddy of the Berliner Gramophone - Léon Scott's Phonautograph of 1857 - presents the tantalizing possibility of recovering even earlier nineteenth-century sounds. The stylus of Scott's apparatus traced patterns of sound vibrations on lamp-black-coated sheets of paper (wrapped around a revolving cylinder). The paper tracings were removable and could be permanently "fixed". Surviving examples could be converted into electrotypes, using the method described in Emile Berliner's first Gramophone patent, or could perhaps be read optically.

The discovery of Frank Lambert's "talking clock phonograph"[4] provides a sample of speech from "around 1879," engraved on a solid lead cylinder. This is currently the world's oldest recording to have been successfully played. Lambert may have made earlier recordings, because he claimed to have been working since 1871!

Bell-Tainter Cylinders

The limitations of the original tinfoil phonograph led Alexander Graham Bell and his Volta Laboratory associates, Chichester Bell and Charles Sumner Tainter, to modify an Edison tinfoil machine in 1881. They first embedded wax into deepened grooves on the surface of the metal mandrel. Because of the softness of the wax, they devised an air-jet method for reproducing the sound.[5]

The Volta group later experimented with wax-covered glass discs and wax-coated paper tubes. While the disc format was not used commercially by the original promoters of the Graphophone, the coated paper tubes were; they came to be known as Bell-Tainter cylinders. Their coating of ozocerite mineral wax was quite thin, so the tubes could be used only once. They were also subject to the unequal expansion coefficients of the wax and the paper, which often caused the coating to crack and flake off. In addition, they were vulnerable to heat - so much so that James Lyons, Berliner's patent attorney, testified in 1901 that it was common knowledge that "the Bell and Tainter wax record [must] be preserved in a refrigerator during hot weather".[6] Though never very successful, these were the first removable and portable records used in commerce.

White Wax

When Edison resumed serious work on the phonograph in 1887, he pursued various animal, vegetable and mineral waxes for use in making removable and reusable cylinder blanks. Late that year he described composite blanks having a thick layer of wax over a core of cheaper supporting material. Over the next several years, other constructions were tried, to improve ruggedness, such as wax reinforced with embedded cotton string, tape, or a mesh cloth backing. Jonas W. Aylsworth provided much of the chemical technology for the Edison cylinder products, throughout their long development and decades of manufacture. His work started at this time and he and Edison eventually settled on a solid-wax blank, with the earliest ones being white in color.

John C. English, who had been General Manager of the Edison Phonograph Works early in 1889, later testified that these first Edison cylinders consisted "principally of white wax, containing a small percentage of commercial carnauba wax".[7] The white wax material proved too soft to be practical and soon led to a search for a more suitable substance.

Metallic Soaps

Edison and his chemists needed a material soft enough to take a faithful recording, yet stable and durable enough to permit repeated playback. They found that a class of compounds known as "metallic soaps" afford optimal properties for such a recordable and shavable cylinder blank. These salts of a fatty acid combined with one or more metals yield amorphous materials with a waxy feel, insoluble in cold water. Though chemically quite different from the true waxes occurring in nature, the metallic soaps used in the cylinder record industry continued to be referred to as "wax" because of their wax-like feel and mouldability.

Depending on their exact formulation, process temperatures, and the amount of recycled content, the metallic soaps used for recordable phonograph blanks ranged in color from a light cream to a dark chocolate brown. The material later came to be broadly known as "brown wax"; contemporary industry jargon included "the soap blanks". John English further testified:

The word soap is used in this connection not that the blank is a soap in the general sense of the word, because washing soaps are stearates, containing a percentage of water from 30 to possibly 50 percent, while the Edison blank is a double stearate of soda and another metal, made from the purest and best material which is essential and is anhydrous, that is, without water. A stearate of this description, if properly made, is not affected by moisture, and is a definite chemical compound, very hard and brittle, and like most chemical salts, very different in character and appearance from the individual elements themselves ...[8]

The preparation or compound was one of stearic acid and caustic soda, and acetate of aluminum, to which a very small percentage of white ozocerite was added, which I afterward found as a result of my experience, was rather more to bind this extremely dry and brittle material together than for any other practical purpose.[9]

Metallic soaps quickly supplanted white wax at the Edison Phonograph Works and became the most widely used class of materials in the cylinder record industry, until celluloid finally took hold in the years after 1909. English, testifying in 1898, said that the blanks in use in 1898 were essentially the same [as those of 1889] except that, because of chemical difficulties, the acetate of aluminum had been abandoned.[10]

John English was a key contributor to the Graphophone developments of the 1890s. He left Edison's employ in 1890 and worked as Superintendent for the New York Phonograph Company, experimenting on his own on the side. Because of his previous connection with Edison, English was approached by James O. Clephane of the American Graphophone Company in the early summer of 1893.[11] Clephane asked whether English could supply the Edison "wax" formula, "for which he said the Graphophone Company would pay a very large sum". "He [Clephane] said that the machines they were then putting out were made to use the Edison cylinder, but that they depended for their supply of blanks upon purchasing them through the Columbia Phonograph Company, or upon remelting such broken Edison cylinders as they could get."[12] As a result of the interview, English met Thomas H. Macdonald, manager of the American Graphophone Company factory.

In 1894, English resumed experimenting and produced results which concluded his deal with Macdonald. "In furnishing Mr. Macdonald this formula, while the results were extremely satisfactory, it seems he had trouble in manufacturing cylinders" and English was led to believe that Macdonald did not use enough acetate of aluminum "and in consequence he had troubles such as the Edison Phonograph Works have experienced at a later date, in that the surface molded, or in other words there was a thin film formed upon the surface which has been claimed to cause records to reproduce more scratchy than when this film did not form".[13]

At one period during the 1890s, Columbia's brown-wax cylinders were nicknamed "blue cylinders" by the trade, because of a blue film that formed on them. This film had the appearance of a fungal mold, but was actually an "efflorescence" of hygroscopic compounds (within the metallic soap itself) which worked outward to the surface under the influence of atmospheric moisture. The American Graphophone Company once insisted on paying the United States Phonograph Company partially with blank cylinders in settlement of a bill for prerecorded cylinders. U.S. Phonograph deemed the blanks unusable on account of the blue film and demanded a credit. Thomas Macdonald later determined that stearates and acetates of lead were particularly prone to these hygroscopic compounds and found that aluminum was a better metal to use in the saponification of the fatty acid.[14]

Brown Wax Formula

In *Thomas Edison, Chemist,* Byron M. Vanderbilt, without citing sources, gave the Edison "wax" formula of 1896 as:

Stearic Acid	48.0%
Sodium Stearate	20.2%
Aluminum Stearate	11.3%
Ceresin	20.5%

> The blend was prepared in approximately 900-pound batches. The best grade of stearic acid was melted in a lead-lined iron kettle and filtered through canvas into a copper kettle lined with silver. Crystalline sodium carbonate, $Na_2CO_3 \cdot 10\ H_2O$, was added at 260°F and the temperature allowed to reach 280°F. When foaming had subsided, aluminum stearate and ceresin were added. The mass was heated to 440°-480°F until all foaming ceased. The temperature was then lowered to about 308°F and the molten wax was strained through three thicknesses of finely woven muslin and poured into pans to cool. The congealing point was to be about 260°F. If lower than this, the proportion of soda was increased in the subsequent batch and decreased if it was above 260°.[15]

Before the Graphophone group was able to duplicate the Edison formula, they evidently tried several different materials in production. A sample cylinder was analyzed and reported on in one of the surviving notebooks at the Edison National Historic Site.[16] The notebook, with an initial entry dated August 1, 1893, was devoted to several subjects. The entry concerning the sample cylinder provides a detailed chemical analysis, but offers no further judgment regarding the Graphophone blank, made of "hard, black, brittle wax". By now the majority of Graphophones had been adapted to take the Edison-style blank.[17]

Moulded Duplicates

Throughout the 1890s, most entertainment cylinders were mechanically duplicated from master records by pantographing onto brown-wax blanks. This process was relatively costly because of the limited life of the master records and it yielded variable results as the masters wore out.

Edison had envisioned various means of mass-duplicating records since the tinfoil days. He experimented with moulding processes for cylinder duplication as early as 1889, with help from Dr. F. Schulze-Berge and Charles N. Wurth (both members of the Edison staff). Still, it wasn't until 1898 that suitable materials were compounded for practical and economical moulding of cylinder records. (Among other demanding requirements, the hot "wax" material had to contract at a precise rate upon cooling, and in a specific manner, to allow the moulded duplicate to shrink away from the grooved wall of the metal matrix and be withdrawn without damage.)

In the Gold-Moulding process, a master metal mould was produced by electroplating copper onto the wax master record, made conductive with a thin layer of vacuum-deposited gold. The original wax master was destroyed in some variations of the process, but many submaster waxes could be made from the master metal mould. Each submaster wax in turn then produced a working mould for use in factory production.

At first (1898), the Gold-Moulding process was used solely to make hard duplicate "master" records for in-house pantographing onto brown-wax blanks. Moulded-wax entertainment records were first sold at retail in 1902, by Edison beginning in January and by Columbia in March.

With the advent of the moulded wax process, cylinders were being produced for three end uses:

1. **the taking of dictation** (business blanks, still based on soft metallic soaps),

2. **the taking of masters** ("master wax" blanks, based on very soft metallic soaps), and

3. **moulded duplicates** (Gold-Moulded Records, non-recordable, using hard metallic soaps).

Each required its own specific formula, to produce materials with properties appropriate to the application.

Edison Master Wax Formula

Tremendous research efforts were expended to develop the ideal material for master recording blanks. The exact constituents and preparation of "master wax" were closely-guarded trade secrets that usually remained unpatented.

In 1932, Martin André Rosanoff prepared a fascinating account titled "Edison in His Laboratory".[18] Rosanoff's duty (in 1903) had been to search for an improved master wax to produce masters for the Edison Gold-Moulding process. The long search provides a rare view of Edison's methods.

By 1921, Thomas Edison had to ask for the well-protected formula used in his own mastering process. On December 24, Edison dropped a short note to Walter H.

Miller, in charge of the Edison Recording Studios in New York City and formerly in charge of the wax-making operations at the Silver Lake (New Jersey) plant: "Please leave the formula of present wax master wax & just how it is made - want to try some experiments at Laboratory. Leave it with Meadowcroft in sealed envelope *marked personal*". Walter Miller responded with:

Wax Formula (Dec. 24, 1921)[19]

Caustic Soda	4580 gm
Sheet Aluminum	1750 gm
Sal Soda	225 lbs
Water	36 gals

Boil above in steam-jacketed kettle, 2 to 2-1/2 hours until metal is dissolved. Filter and add, little by little, this solution to 1000 lbs stearic acid melted and held at 390°. Will take from 2 to 2-1/2 hours, then raise heat to 420°F and hold there for 30 minutes. Then add 75 lbs F.T.F. [?] oil and raise heat to 450° and hold there for 30 minutes.

Congeal point is set at 265°. If too high, bring down by adding stearic acid-takes about 1% of stearic to [for each] 5° too high.

Formula for Moulded Master Records

In 1905, the following formula was provided to the Edison plant in Brussels, Belgium, for moulding master records from mother moulds:

Stearic Acid	100 lbs
Ebonite	64 lbs
Recrystallized Sal Soda	22.13 lbs
Caustic Soda	468.5 gm
Copper Powder	113.47 gm
Aluminum	181.28 gm

Note that no ceresin is used in this formula and that Ebonite has been substituted for carnauba wax.[20]

Black Wax Formula for Edison Gold-Moulded Records

By 1903, this formula was in use for the new, harder metallic-soap Edison records:

Sodium Carbonate	12.9%
Sodium Hydroxide	0.6%
Aluminum	0.2%
Stearic Acid	60.1%
Carnauba	12.8%
Lampblack	0.5%
Ceresin	12.8%

Recrystallized sodium carbonate ($Na_2CO_3 \cdot 10\ H_2O$) was melted in an iron vessel with water and 98% pure sodium hydroxide (NaOH). Upon liquefaction pieces of 20/1000 sheet aluminum were added, and the hot solution filtered through canvas. Stearic acid, with a melting point of 136°F, was brought to a temperature of 240°F; at which point the previous solution was added as rapidly as possible without boiling over. At a temperature of 360°, purified #3 Sierra carnauba wax and the best grade lampblack were added; the temperature raised to 450°F and held till foaming subsided, at which time the ceresin (145°F melting point) was added. The wax mixture was brought to a congealing point at 290°F with the addition of stearic acid.[21]

Hard-Wax Formula for Edison Amberol Records

An even harder material was needed to mould the four-minute Edison Amberol Records, with their doubly-fine 200-TPI groove pitch. Jonas Aylsworth developed such a compound with the following ingredients:

Stearic Acid	100 lbs
Ebonite	41.9 lbs
Ceresin	7.377 lbs
Sal Soda	22.6 lbs
Caustic Soda	474.74 gm
Aluminum	183.72 gm

Aylsworth fully described the preparation of this compound in his U.S. Patent 880,707.[22] He explains that the demand for carnauba wax [previously used in the Edison Gold-Moulded Records] had become so great in the cylinder industry that the price was driven "objectionably high". Aylsworth here substituted Ebonite for the carnauba. His patent gives an alternate formulation calling for Montan wax. Ebonite and Montan were both less-costly mineral waxes, extracted from coal.

After the introduction of the Blue Amberol celluloid cylinder, Edison used "wax" only for business blanks and for the in-house master cylinders and discs.

Celluloid

Celluloid is considered by many to be the first synthetic plastic. John Wesley Hyatt mixed camphor with cellulose nitrate to create the mouldable thermoplastic material he called Celluloid in 1869. Henri Lioret moulded cylinder records from celluloid in France in 1893 and The Lambert Company produced a series of celluloid cylinders in Chicago from 1900 through 1905.

Thomas A. Edison, Inc. announced the Edison Blue Amberol Record in October 1912 - their first non-"wax" cylinder record. Edison purchased raw celluloid in tube form and stretched it to the proper diameter for various types of cylinder records. To impart the distinctive color for Blue Amberols, the stretched tubing was then dipped in an aniline-based dye solution. After "seasoning" for fourteen to eighteen days, the celluloid was then "ready to be manufactured into a printed [moulded] record".[23]

Formula for Bluing Amberols[24]

Denatured Alcohol	60 parts
Water	40 parts
Acetone	10 parts
Methyl Blue BB (Heller & Merz)	2 parts

Bring up to 140°F and stir well, then cool down all night in cold place - 60°, about. Then filter through fine-grain Swedish filter paper, two thicknesses.

Deep blue:	20 minutes
Proper blue:	10 minutes
Light blue:	15 seconds

Time to Dip

Some of the problems encountered in the celluloid cylinder operations at the Edison plants may be seen in one of a series of interviews conducted by Mary Childs Nerney in 1928 and 1929.

Reminiscing on his days as foreman, Ernest Lippelgoose told of dyeing the celluloid for cylinder records:

"Unless the weather was just right, the dye would run."

"How," the interviewer asked "could you tell?" "Had you no thermometer, no barometer?"

"No" was the reply, in some disgust: "I just knew".

"Often I would lie in bed - look at the stars and say to the wife 'The time has come to dip'.

"It might be two in the morning but up I would get, and walk from Bloomfield where I lived, to West Orange. There were no automobiles in them days.

"On the way I would wake up two or three workmen and take them along. We'd dip all night and on through the rest of the day - as long as the weather was right or until we had a lot ahead".

"Did Mr. Edison ever know about this?" asked the interviewer.

"Mr. Edison," *disgust visibly deepened; "Mr. Edison should worry about production. That was* my *job".*[25]

Preservation

The experience of Mr. Lippelgoose highlights the problems faced by those interested in preservation. Much of the earlier cylinder period represented a catch-as-catch-can approach to manufacturing and marketing. In this atmosphere, formulas changed often, adding to the difficulties facing the conservator today.

Preservation should take into account that the end products of the "wax" formulas have had at least eighty years since the last commercial examples were manufactured to dry, embrittle and otherwise deteriorate. One example may shed some light on the changes caused by the aging of materials. During the disc period, the Edison staff did not make up wax masters until they were needed. In the early 1920s, as a cost saving measure, many master "waxes" recorded earlier were finally processed for issue and used to pad out the monthly issues. The aria "Ah! non credea mirarti" from *La Sonnambula* as sung by Lucrezia Bori was one of these older masters; most copies of Diamond Disc 82289 that I have encountered seem to show the effects of wax granulation. (Incidentally, many early original Edison wax disc masters are *still* stored at the Henry Ford Museum in Dearborn, Michigan.)

With celluloid cylinders, there is the possibility that some of the celluloid tubes were made by butt-joining celluloid (rolled from sheet form) and that aging may be allowing the joints to separate.

But at least a knowledge of some of the materials and manufacturing processes employed may allow conservators to arrive at preservation techniques other than solely the requirement of keeping the original artifacts in a climate-controlled environment.

Raymond R. Wile *is a noted researcher and collector. He has authored numerous articles and presented many conference papers on the history of sound recording. He has been a regular contributor to the* ARSC Journal. *His book,* Edison Disc Recordings, *was published in 1978.*

Endnotes

1. A. G. Pickett and M. M. Lemcoe, *Preservation and Storage of Sound Recordings* (Washington, DC: Library of Congress, 1959).

2. The paper was presented on February 11, 1978.

3. Tom Hedberg, "Rescuing the Voices of the Dead - A Laser-Read Sound Reproduction System," *Antique Phonograph Monthly*, 1978;5(8):7-8. Hedberg's *proposed* laser system was roughly sketched in this brief article. During the mid-1980s, Bill Storm and Ken Whistler developed a laser- and fiber-optic system to play cylinders at the Belfer Audio Laboratory and Archive at Syracuse University, in Syracuse, New York.

4. Aaron Cramer, "The World's Oldest Recording: Frank Lambert's Amazing Time Machine," *Antique Phonograph Monthly*, 1992;10(3)/Issue 87:1,3-8.

5. Most photographs of this modified phonograph do not properly show the added support for the air jet nozzle.

6. Testimony of James Lyons in *American Graphophone Co. vs. National Gramophone Co. and Frank Seaman* (U.S. Circuit Court for the Southern District of New York. In Equity No. 7063). NN-NARC.

7. Testimony of John C. English, September 30, 1898 in *American Graphophone Co. vs. United States Phonograph Co., et al.* (U.S. Circuit Court for the District of New Jersey. In Equity No. 4004 on Patents Nos. 341,214 and 341,288). NN-NARC. Answer to Question 6.

8. Ibid., Q7.

9. Ibid.

10. Ibid., Q8.

11. Ibid., Q13.

12. See exhibit letters attached to the Testimony of John C. English. Clephane to English, May 29, 1893; Macdonald to English, June 10, 1893; Macdonald to English, June 23, 1893; Agreement, English and Clephane, June 30, 1893; Clephane to English, June 30, 1893. The letters were also introduced into other suits that had been brought by the American Graphophone Co. NN-NARC.

13. Testimony of John C. English, Q14.

14. U.S. Patent 606,725: "Manufacture of Graphophone-Tablets," granted to Thomas H. Macdonald, July 5, 1898, application filed November 27, 1896.

15. Byron M. Vanderbilt, *Thomas Edison, Chemist* (Washington, DC: American Chemical Society, 1971), p. 122.

16. The analysis is contained in Laboratory Notebook N93-08-01. ENHS.

17. This is frequently pointed out in the various court cases.

18. Martin André Rosanoff, "Edison in His Laboratory," *Harper's Monthly Magazine* (September 1932), pp. 402-417. Reprinted in: Martin André Rosanoff, *Collected Works* (Brooklyn, NY: Galois Institute of Mathematics of Long Island University, [no date]).

19. Edison to Walter Miller and response, Miller to Edison, December 24, 1921. ENHS.

20. D. A. Dodd to E. Riehl, October 19, 1904 and June 20, 1905. At the time I photocopied this, it was Legal Paper No. 283 at the Edison National Historic Site. The order of these papers was changed and the papers subsequently refiled.

21. Leah S. Burt, "Chemical Technology in the Edison Recording Industry," *Journal of the Audio Engineering Society*, 1977;25(10/11)October-November:714. The materials and chemical process are described in more detail in: U.S. Patent 782,375: "Composition for Making Duplicate Phonograph-Records," granted to Jonas W. Aylsworth, February 14, 1905, application filed November 3, 1903.

22. U.S. Patent 880,707: "Composition for Making Duplicate Phonograph-Records," granted to Jonas W. Aylsworth, March 3, 1908, application filed February 5, 1906. Later patents disclose other materials intended for improved 200-TPI cylinder records, but the March 3, 1908 Grant Date is specifically cited on many Edison Amberol Record box labels.

23. Burt, "Chemical Technology," p. 715.

24. The formula is contained in Laboratory Notebook N11-06-07. ENHS.

25. Interview with Ernest Lippelgoose appears in Notebook N29-09-12. ENHS.