

Typology guide

Lacquer discs collection of
Radio-Lausanne and Radio-Genève



Rebecca Rochat



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Cover page: Cracked Pyral ersatz disc.

Coverage of the football match Servette - Lausanne Sport on 27 May 1945 by Squibbs (Radio-Lausanne, accession number 12953).

Back cover: VisualAudio negative of one Pyral ersatz disc

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Abstract

Between 1930 and 1960, radio contents were mainly recorded on lacquer transcription discs, consisting of a thin layer of lacquer applied on aluminium, PVC, paper or glass substrates. Due to their composite structure and lack of standardisation in manufacturing, these carriers have proved to be very unstable and deteriorate rapidly.

Radio Télévision Suisse's collection of 85,000 lacquer discs is of substantial significance for local communities in Switzerland, in addition to historical and political values with the coverage of international events. The collection also holds technological importance and includes a wide range of international manufacturers used in broadcasting services, namely Presto, Audiodiscs, Pyral, MSS, Simplat and Thorens.

Initiated by FONSART in 2012, the digitisation project aims to ensure the preservation and permanent accessibility of RTS lacquer discs, and raise awareness of this sensitive sound heritage. A typological research studied the different types of instantaneous discs in the collection as well as patents on manufacturing technologies. Chemical analyses revealed that the collection contains more than 90% cellulose nitrate discs, a safety hazardous material that decomposes and requires specific implications in the collection management. Microscopical characterisation provided high-resolution images of the grooves to tangibly visualise sound characteristics. Additionally, historical research in the BBC archives revealed the Second World War conditions and their consequences on discs manufacturing.

This typology guide collects the main results of this several-year long research and highlights the important heterogeneity of the international manufacturers and its impact on the collection preservation. The typological classification toolkit enables the origin of a disc to be identified by visual observation, supported by identification and characterisation criteria for each manufacturer. It is supplemented by a visual notebook of the degradations and digitisation specificities. This typological research finally aims to highlight audiovisual contents that form an integral part of Switzerland's collective memory.

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Introduction

Until the widespread adoption of magnetic tapes, radio services mainly used lacquer discs between 1930 and 1960 to record and broadcast their content. A part of the 20th century's world heritage, testimonies of historical events, but also popular traditions are recorded on these analogue carriers. The discs are often unique, amplifying their historical, cultural and political significance. Radio Télévision Suisse's collection of 85,000 discs, recorded between 1935 and 1958 by Radio-Lausanne and Radio-Genève, is of substantial significance for local communities in Switzerland comprising a rich traditional and folk heritage. Historical and political values are equally important, especially with the coverage of Swiss and international events. The collection features the last General Assembly of the League of Nations in April 1946, the general mobilisation on 2 September 1939, numerous choirs from Swiss villages, interviews with Edith Piaf or William Wyler, radio plays by William Aguet, along with Churchill's visit to Lausanne in 1946, to name but a few.

Heritage collections include lacquer discs for professional use from multiple countries (Table 1), with differences in manufacturing quality, wear and tear resistance, and degradations. The chemical manufacture of the discs requires a compromise between the ease of recording and the quality of the final result. The disc consists of a rigid core, usually metallic but occasionally also made of glass, coated with cellulosic polymer sufficiently malleable to record the sound but with sufficient hardness to withstand repeated playback without deforming the groove. Problematic for long-term conservation due to their layered structure, these formats are the least stable of the phonographic disc family, with alterations that can lead to the delamination of the recorded surface.

Table 1 Main discs manufacturers for professional use, by country of production (not exhaustive)

Country of production	Manufacturers
United States	Presto, Audio Devices (Audi discs), Wilcox-Gay, Advance, Allied, Sonic, Reeves Sound Studios, Muzak, Muzikon
France	Pyral
United Kingdom	MSS, EMI, V.G. Manufacturing Company (Simplat)
Switzerland	Thorens
Germany	Deutsche Celluloid-Fabrik (Decelith)
Netherlands	N.V. Ramie Union (Simplex), Cellodisc
Belgium	Gevaert (Gevaphone)
Australia	Audex Disc
Italy	DEA, SteaVox

The objective of any conservation intervention aims to ensure the preservation of the primary information recorded but also the physical preservation of the disc. In 2012, Radio Télévision Suisse (RTS), along with its preservation and promotion foundation FONSART, set up a mass digitisation project for 78 rpm lacquer discs. Launched in partnership with the digitisation company Gecko, this project has enabled the safeguarding of more than 30,000 records.

One of the most critical aspects of the collection is the important heterogeneity of international manufacturers, leading to conservation problems and specific treatment choices. The digitisation of a materially sensitive collection also creates conservation conditions that are sometimes difficult to identify, such as the removal of a micro-climate requiring rapid intervention. The ideas to implement a visual typology of the discs emerged. The methodology revolves around three concepts: the study of surface appearances (manufacturing methods, microscopical characterisation), the coating compositions (historical research, chemical analyses) and the alterations.

This document is a toolkit to assist in the identification of the disc. The first part focuses on the basic concepts of instantaneous discs, supported by historical research in patents and archives at RTS and BBC. It is complemented by microscopic and chemical studies of the coating compositions. The second part is a visual notebook that identifies the alterations and provides digitisation specificities. Finally, the third part presents the current findings of the collection and an inventory of the 78 rpm recordings held by RTS. The typological classification identifies the origin of a disc by visual observation and formulates hypotheses. A restricted group of trade names was selected, either for their representativeness in the RTS collection or their historical importance in the radio broadcasting services: Audiodiscs, Decelith, Gevaphone, MSS, Presto, Pyral, Simplat/Simplex and Thorens. Using identification and characterisation criteria, diagnostic tools are specified for each manufacturer and may potentially explain the material and sound characteristics of the disc.



CREDIT: Jean-Jacques Lagrange

Figure 1 Radio technician in a control room of Radio-Genève



CREDIT Freddy Bertrand

Figure 2 "The discobolus is going wild", 12 April 1952

Part I: Historical and chemical studies



The substrate

Collections contain multiple substrates used for direct-to-disc recording. The structure of the disc was either uniform or composite, the latter may consist of a coating applied to cardboard, metal, glass, papier mâché or wood substrate by baking, and sometimes followed by hardening and polishing with chemical solutions¹.

For uniform discs with the same material, experiments were performed on multiple materials:

- pure aluminium,
- aluminium alloy,
- tin,
- zinc,
- Bakelite,
- gelatin,
- aldehyde resins,
- shellac,
- waxes,
- cellulosic esters such as cellulose acetate or cellulose nitrate.

The rigid core had to meet several criteria: be solid, inflexible and lightweight. Metallic bases were the most widely used, notably aluminium.

The predominance of aluminium

Aluminium core is favoured over other metals for its lightness, rigidity and surface finish². This material has proven to be the most satisfactory, practical and durable. The ideal metallic base has a mirror-finish surface, free of imperfections, and with a tolerance of thickness of $\pm 0.005''$ (0.127 mm)³. Finally, the aluminium base is thick to keep the disc flat and reduce friction that can produce a noisy surface⁴.

Aluminium cores dominated the disc market used by radio broadcasters, but with difficulties of supply during the Second World War. Unable to get sufficient aluminium, manufacturers intensified their efforts to find alternatives. In England, the substitute base for aluminium was zinc⁵, with the use of litho-zinc first mentioned in February 1941⁶. Too thin and rarely flat, zinc was quickly proven inadequate by professionals⁷. Zinc records had significant sound distortions and flexibility, complicating the reproduction of the disc on the turntable⁸.

Aluminium was therefore preferred to zinc for the following main reasons⁹:

- Lightness: for the same format, it is half the weight of the zinc base. Zinc has also logistical repercussions such as transport costs, labour and weight of the shelves.
- Rigidity: a zinc substrate is flexible and deforms more easily than aluminium, resulting in recording and broadcasting difficulties.
- Surface: the aluminium mirror-finish surface cannot be reproduced with zinc. The latter presents imperfections and irregularities that will be reproduced at the surface of the coating and increase surface noise.

The surface finishes of aluminium discs had to be very smooth and polished to improve surface adhesion. Each manufacturer had its own way of processing aluminium to optimise its characteristics. Most of the manufacturers calendered the blanks. Capitol favoured lapping machines to refine flatness and regularity of the discs by eliminating small irregularities and surface impurities and to smooth the surface¹⁰. It was followed by a bathing of the blanks, treated using 6 different chemical solutions (Figure 3)¹¹. The French manufacturer Pyral chemically modified the aluminium surface to improve the adhesion of the coating to the metallic substrate. The surface of the metal was also degreased by wet abrasion¹². Quality controls were also undertaken by companies to verify that the aluminium surface finish was flawless (Figure 4)¹³.

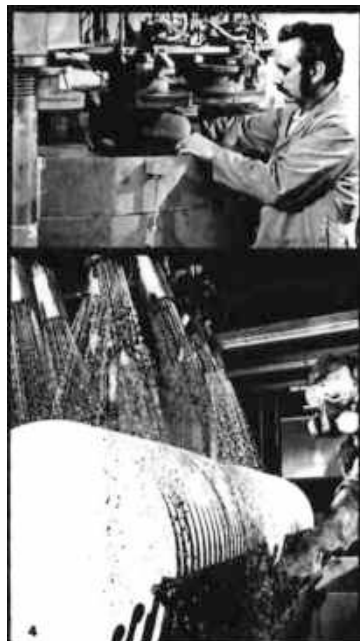


Figure 3 Aluminium blanks treatment, Capitol, c. 1975. Lapping (up) and bathing (down)



Figure 4 Inspection of aluminium substrates at Capitol, c. 1975

CREDIT Recording Engineer Producer, 1975

The closest substitute to aluminium was glass. The introduction of glass bases in 1935 was probably the result of the difficulty of achieving a perfectly flat and smooth surface with metallic cores¹⁴. Glass, despite its physical vulnerability, had all the mechanical qualities of aluminium and produced an extremely high-quality disc¹⁵. The surface noise was low as a result of the glass smoothness¹⁶. Despite these sound qualities, glass was not preferred for logistical and handling reasons. For instance, the BBC avoided as much as possible the use of glass bases as they were extremely fragile and as heavy as zinc¹⁷. The collections also include plastic cores. Plastic was not a recommended substrate by the broadcasters. It deformed and warped easily¹⁸ and had significant background noise. In addition, the material, too thin and flexible, was already deforming in 1938 during the playback on a turntable¹⁹.

Notes

- 1 Aldous, 9 October 1936, p. 388
- 2 BBC Written Archives Centre R57/49/2, 27 August 1945
- 3 BBC Written Archives Centre R57/49/1, 25 February 1941
- 4 BBC Written Archives Centre R57/194/7, 27 July 1938
- 5 BBC Written Archives Centre R57/194/7, 4 September 1940
- 6 BBC Written Archives Centre R57/49/1, 13 February 1941
- 7 Barrett and Davies, 1938, p. 7; BBC Written Archives Centre R57/49/2, 27 August 1945
- 8 Barrett and Davies, 1938, p. 7; BBC Written Archives Centre R57/49/2, 27 August 1945
- 9 BBC Written Archives Centre R57/49/2, 27 August 1945
- 10 Yentis, 1975, p. 19
- 11 Capitol 1975, p. 2
- 12 Ramel, 1996, p. 6-7; Yentis, 1975, p. 19
- 13 Yentis, 1975, p. 21; LeBel, July 1947, p. 4
- 14 Harley, 1960, p. 21
- 15 Barrett and Davies, 1938, p. 7; Graves, 2015
- 16 Barrett and Davies, 1938, p. 7
- 17 BBC Written Archives Centre R57/46/1, 24 February 1941
- 18 Fink, May 1941, p. 21
- 19 Barrett and Davies, 1938, p. 9

The coating

The term direct-to-disc recording refers to discs that can be reproduced immediately after the cutting without being damaged. A significant part of a successful recording is thus based on the choice of the coating¹, as it must meet mechanical properties for ideal cutting². The coating layer should be flexible enough to be cut while still being hard enough to support several reproductions without further treatment³. Coatings come in various forms of organic and inorganic mixtures polymerized by heat or hardening solutions. Many materials were used, including cellulose nitrate, cellulose acetate, gelatin, and radiographic films⁴.

Requirements

Radio broadcasters and records manufacturers had very specific requirements as to the improvement of the coating. Combining, for instance, the requirements of the BBC⁵ and the parameters sought by the American manufacturer Audio Devices⁶, 12 criteria emerge:

- low and uniform surface noise,
- easy cutting,
- good ageing qualities to avoid the increase of surface noise (cut/uncut discs),
- a flat surface,
- electrostatic properties that prevent electrostatic charging,
- few impurities in the coating and cellulose,
- good adhesion to the substrate,
- a suitable response to high frequencies,
- a long playback life,
- stability of recording properties under all climatic conditions,
- suitable processing characteristics,
- grease resistance.

Considering these criteria, each manufacturer strove to find the ideal formula by conducting multiple laboratory tests, where each ingredient was carefully tested and controlled. Advertisements from many firms highlighted this quest for the ideal coating (Figure 5-Figure 6). The pre-selection of every ingredient played a decisive role in the final quality of the disc. The slightest microscopic impurity could significantly alter the performance of the disc, resulting in quality controls of the raw materials⁷.

Manufacturers often used additives incorporated in the material for economic reasons and to ensure the coating had the required characteristics⁸. These additive materials, such as fillers, plasticisers, diluents, stabilisers, and dyes, have greater variations in quality than the

core material⁹. The quantities of these ingredients varied and were dependent on the desired viscosity to facilitate the coating of discs¹⁰.

Components

An article published in Audio Record magazine, edited by the disc manufacturer Audio Devices and written by C.J. LeBel, one of the founders of the Audio Engineering Society (AES), provided detailed information on the coating components¹¹:

- The polymeric material is the core ingredient of the coating. The entire formula revolves around it.
- Solvents transform all the ingredients into a soluble, smooth and homogeneous solution for the coating operation. Low boiling, medium and high boiled solvents could be use.
- The addition of a resin improves adhesion to the substrate, strengthens the coating and facilitates drying. The most commonly used are the dammar resins, copal, mastic, and shellac.
- Diluents, such as benzene, toluene, naphtha, are often added to the solution to dissolve the resin or change the evaporation properties of the solvent.
- Considered the most important additive, the plasticiser, a non-volatile substance, provides the plasticity and elasticity of the coating following evaporation of the solvent and gives the coating the necessary flexibility required for cutting. Additionally, it reduces the flammability of cellulose nitrate.
- A black dye is added to the coating to simplify inspection when cutting the groove. For instance, lampblack was initially used by the manufacturer Pyral before being replaced by a blue dye known as *purple pencil*¹².

4,632 Little Bottles

SILENT SENTINELS OF CONTINUOUS RESEARCH

These bottles are but a small portion of the 4,632 which have passed through our laboratory. Each represents a part of a continuous series of chemical research experiments for scientific and technical progress in the world of audiodiscs.

For the leadership of Audiodiscs is the result of extensive experimental work plus the most exacting quality controls known in the coating industry.

Recently we will still further to our research facilities, we greatly improved our laboratory. Today our research program is continuously exploring new materials and methods, in order to further improve recording fidelity and broaden the field of sound reproduction.

... they speak for themselves

audiodiscs

Audiodiscs are manufactured at the U.S.A. under exclusive license from La Societe des Grammes-Phonogrammes.

AUDIO DEVICES, INC., 444 Madison Ave., New York 22, N.Y.

Testing-1, 2, 3

Testing-1, 2, 3

Testing-1, 2, 3

Here's how continual testing assures consistent, uniform, and lasting quality in every audiodisc

All incoming lacquer materials are tested for:

1. Chemical purity
2. Uniformity
3. Physical properties

Each lacquer mix is found before going into production:

1. For solids
2. For viscosity
3. A test coating is made and checked for frequency response, wax, dust, noise, wear, and discoloration

Coating process checks throughout the day by plant chemists:

1. Temperature control
2. Humidity control
3. Evaporation rate and balance

Final inspection of finished discs:

1. Visual grading by trained inspectors
2. Spot checking by chief inspector
3. Production discs tested for surface noise, wear and break behavior at regular intervals

In addition, sample discs of each day's production are filed in serial manner, with the complete history of detail record and laboratory notes recorded on discs. This practice, which has been followed for the past 10 years, has helped in making many refinements and improvements in lacquer formulae and control.

If you want to be SURE of flawless recording quality—ask your dealer for AUDIODISCS.

Audiodiscs are manufactured in the U.S.A. under exclusive license from PYRAL, S.A.S., Paris.

Audio Devices, Inc., 444 Madison Ave., N.Y. C.
East 107th Street, New York 22, N.Y.

audiodiscs *they speak for themselves*

Figure 5 Audiodiscs manufacturer's ads, 1947 and 1948

portrait of an engineer...

Engineers are a happy lot, until faced with a moment like this:
 A recording is completed. The disc is put on the playback table . . .
 but it's full of "pops," "ticks" and "hisses".

This can easily happen in the life of any engineer, if he has not been
 discriminating in his selection of recording discs.

If this picture fits you . . . you are ready for a change in brand. And the
 wisest change is to PRESTO Green Label discs . . . because this label is your
 assurance of the smoothest lacquer surface available and
 top performance every time.

PRESTO
 RECORDING CORPORATION
 PARAMUS, NEW JERSEY

EXPORT DIVISION: 25 Warren Street, New York 7, N. Y.
 CANADIAN DIVISION: Walter P. Downs, Ltd., Dominion Square Bldg., Montreal

WORLD'S LARGEST MANUFACTURER
 OF PRECISION
 RECORDING EQUIPMENT AND DISCS

Manufacture of a lacquer-coated disc is one of the most *exacting* of all industrial processes. It has taken PRESTO many years of chemical research and constant improvement in every phase of manufacture to produce the famous *Green Label* disc. Even after manufacture, many hundreds of discs are rejected before those are chosen to bear the respected insignia . . . PRESTO Green Label.

CREDIT Museum of Magnetic Sound Recording

Figure 6 Presto manufacturer's ad, 1953

Historical study of coating compositions

The various formulas developed for direct-to-disc recording are complex due to the wide variety of ingredients used. The manufacturer Audio Devices referred to a lacquer that contains more than 30 ingredients, some of which do not exceed 0.05%. Presto reported 51 compounds¹³. Since recipes differ from one manufacturer to another for reasons of cost or product quality¹⁴, the precise coating mixture is difficult to identify. As a result of commercial secrecy, patent specifications research remains one of the only ways to approximate the ingredients used.

Example of a typical coating formulation in a patent filed by George Sutheim of Audio Devices, manufacturer of Audiodiscs (US2607699, 1948):

- 33.3% ½ dry cellulose nitrate
 - 18.0% alcohol
 - 28.2% ethyl acetate
 - 10.0% dibutyl phthalate
 - 10.0% castor oil
 - 0.5% dye
-

Main component

The chemical composition of the discs has changed considerably over time: the wax of the early discs was replaced by ethyl cellulose, then cellulose acetate and lastly by cellulose nitrate. A review of 65 patents¹⁵, published between 1888 and 1953, established a pattern of the different ingredients used in the coating composition (Graph 1). Cellulose nitrate derivatives are the most cited components, followed by shellac, cellulose acetate, gelatin, and wax. Cellulose nitrate was widely adopted by professionals because, in its new state, it had low background noise. This lacquer is frequently referred to as "acetate"¹⁶ in literature and oral histories. This misleading name originated from the short period of use of cellulose acetate as a coating pre-1934. Since that year, lacquer discs were mainly coated with a solution of cellulose nitrate¹⁷.

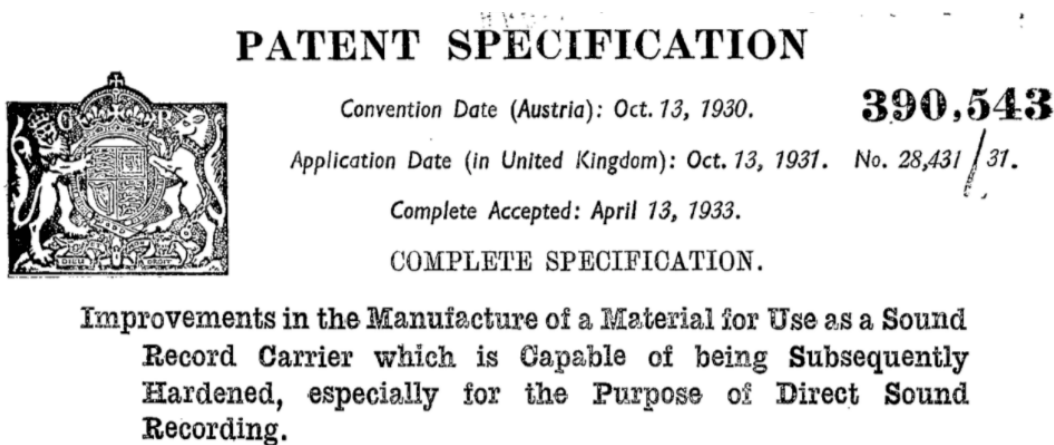
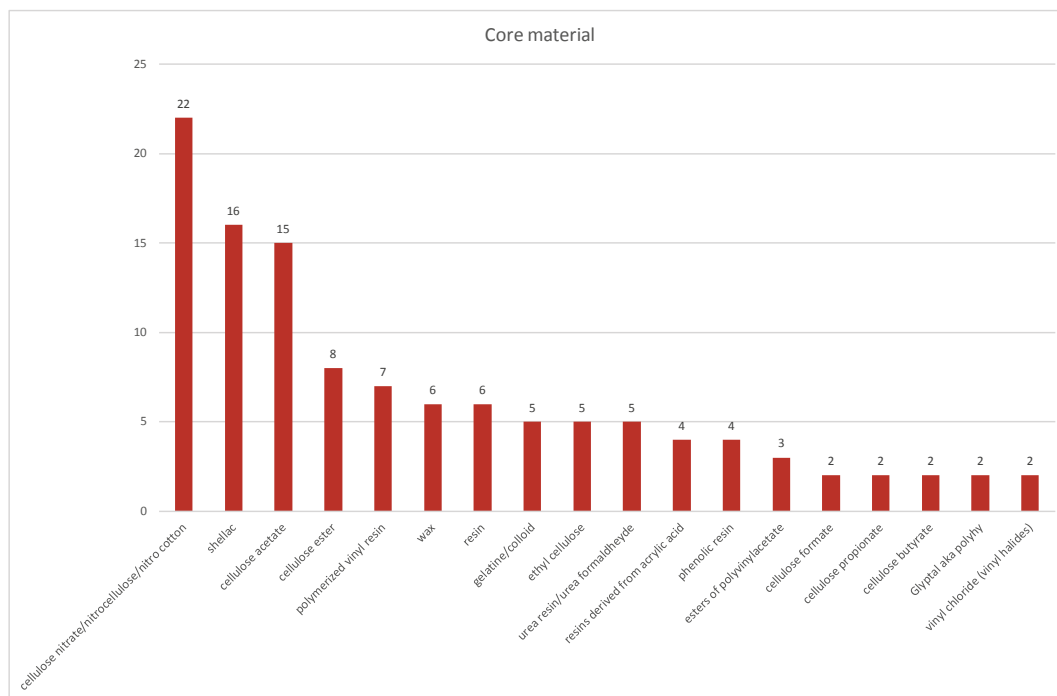


Figure 7 Patent specification GB 390,543, filed by Robert Pollack Rudin

Additional advantages of cellulose nitrate are its ease of application, optical qualities, and adhesive properties, beneficial to use despite the concern for flammability and instability of the product¹⁸. Finally, cellulose esters, organic compounds such as cellulose nitrate and acetate, were preferred, for example, to wax, as they required a smaller amount of ingredients to produce a disc of the same size and were cheaper¹⁹.



Graph 1 Main coating material distribution (based on 65 patents)

Few patents have been granted on the manufacture of lacquer discs as all system requirements are based on previous techniques²⁰. The first development of the nitrate cellulose formulation for professional use in lacquer discs is subject to debate. Several firms have developed coating formulas at the same time, making it difficult to establish precise authorship.

Since 1929, the French company Pyrolac had been producing discs with a fireproof coating called Pyrolac. This disc, lightweight and less fragile than wax, was replayable immediately after being recorded. Subsequently, the subsidiary Pyral was created to produce the coated discs - *Pyr* to reuse the original Pyrolac and *al* for aluminium²¹. A Pyrolac patent, filed in 1933, indicated that the coating consisted notably of cellulose, oil, and silica²². As early as 1934, the American manufacturer Presto developed a coating to record high-quality instantaneous discs. Similar experiments were undertaken by Cecil Watts, director of the British company Marguerite Sound Studios (MSS)²³. Watts corresponded with the British Broadcasting Corporation (BBC) in late 1933 intended to be selected by the broadcaster as the official supplier of disc records²⁴. The BBC investigated with Reddie + Grose, a patent law firm, to determine whether Watts had violated three previous British patents: GB319,038 (1928, John Edward Thornton), GB388,421 (1933, British Celanese Limited) and GB390,543 (1933, Robert Pollak Rudin, Figure 7). Watts argued that he did not infringe by referring to differences in the viscosity of cellulose nitrate²⁵.

Although cellulose nitrate had remained the market leader, niche products were emerging. The English firm V.G. Manufacturing Company patented in 1935 the Simplat disc on which a thin layer of gelatin was applied to a glass substrate (GB438,029A)²⁶. With a uniform coating and minor defects, this disc was highly suitable for direct recording²⁷. In Germany, Deutsche Celluloid-Fabrik developed from 1935 flexible discs called Decelith, made of three layers of PVC²⁸.

Plasticiser

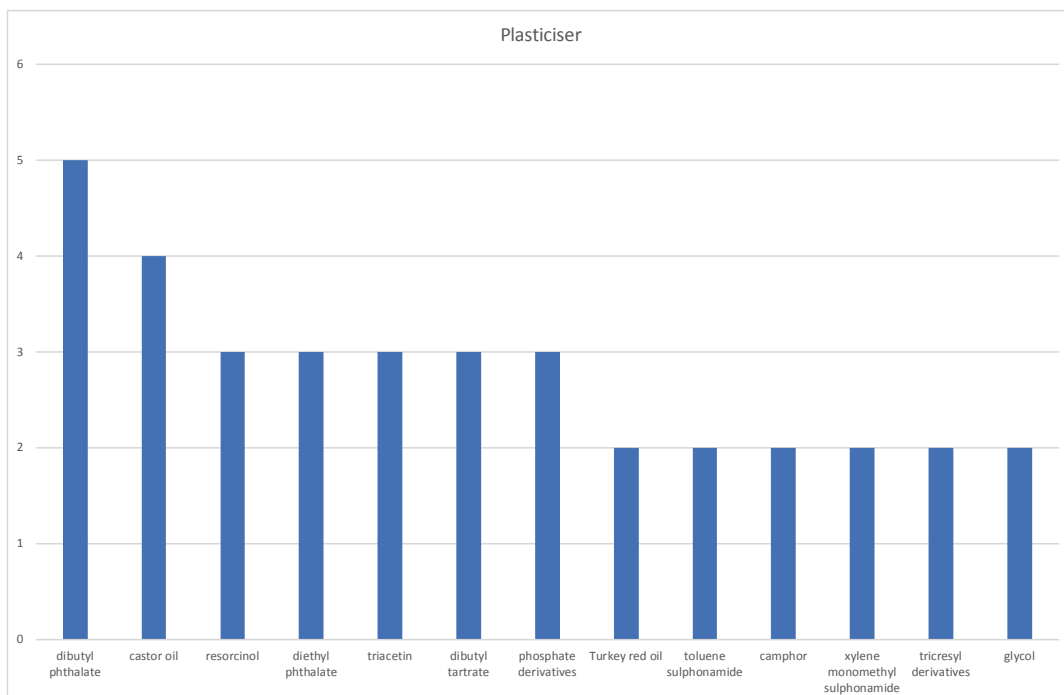
Cellulose nitrate, too hard, brittle and flammable in its raw state for direct recording, required the addition of a plasticiser. There are two types of plasticisers: solvent type - dibutyl phthalate, dioctyl phthalate, triacetin - and non-solvent type, an external plasticiser, the most common being castor oil. As the external plasticiser tends to exude in wet conditions, a combination of both types of plasticisers was recommended²⁹. This claim is reinforced by the specifications of Audio Devices' patent (US2,607,699, filed in August 1948), which mentions both dibutyl phthalate and castor oil³⁰.

Two types of philosophy dominated in the 1930s for the selection of the plasticiser: the American recipe and the French formulation. Between 1934 and 1938, the American formula used only a small amount of plasticiser, preferring to use a large quantity of solvent to soften the material. The French formula, elaborated by Société des Vernis Pyrolac between 1929 and 1935, was the result of the finding that flexible coatings can be produced using appropriate proportions of plasticisers. When the manufacturer Audio Devices exchanged expertise with Pyrolac in 1938, the American practice gradually changed from 1941 onwards³¹.

Furthermore, C.J. LeBel, co-founder of Audio Devices, argued that any coating formula can be used, but specified that recipes can be softened, and surface noise reduced using a higher percentage of plasticisers³².

The most common plasticisers mentioned in patents are dibutyl phthalate, castor oil, resorcinol and camphor (Graph 2). Castor oil is a recurring plasticiser found in historical sources (Pyrac manufacturer, 1959 Library of Congress Lemcoe and Pickett report)³³.

The most common plasticisers mentioned in patents are dibutyl phthalate, castor oil, resorcinol and camphor. Manufacturers would not hesitate to add the plasticiser in large quantities to the plastic mass to obtain a sufficiently flexible coating and to reduce surface noise.



Graph 2 Plasticiser distribution (based on 65 patents)

Chemical study of coating compositions

Molecular analyses using Fourier-transform infrared spectroscopy (FTIR) were carried out to determine the components of the disc coatings from the collections of Radio-Lausanne and Radio-Genève. These analyses aim to confirm historical data sources and to develop preventive conservation strategies, including the identification of cellulose nitrate that requires specific storage conditions. The selected discs include a wide range of international manufacturers, although with a focus on the Swiss Thorens discs to demonstrate the effects of the ersatz lacquers produced in Sainte-Croix during the Second World War.

Table 2 The 11 samples collected from 7 different types of coating

Manufacturer	Year*	Accession number (Sample number)	Results	Conservation state
MSS (452 lacquer?) (UK)	1949	DD4906-4 (1)	Cellulose nitrate	Good condition
Presto (Orange Seal Label?) (USA)	1948	DU4852 (2)	Cellulose nitrate	Good condition
Simplat (UK) or Simplex (NL)	1936	P4506 (3)	Collagen	Peeling
Pyral ersatz (FR)	1944	13674, A (6)	Cellulose nitrate	Cracked (parallel and perpendicular)
Pyral, zinc-based (FR)	1946	DN4639 (9)	Cellulose nitrate	Peeling
Thorens 2 nd generation (CH)	1942	7399 (12)	Cellulose nitrate Polyacrylic acid	Cracked (parallel and perpendicular)
Thorens 3 rd generation (CH)	1945 1946	16819 (14) DX4624-1 (15) DN4626 (17) DW4624-2 (19) DW4621 (21)	Cellulose nitrate	Peeling Flaking Good condition (19)
*recording year				

Data acquisition

Analyses were performed³⁴ in ATR (Germanium) mode using Micro-FTIR Thermo Scientific device, Nicolet iN10 MX model equipped with an MCT (Mercury Cadmium Telluride) detector. It analyses a spectral region between 4000 and 600 cm⁻¹, with a spectral resolution of 4 cm⁻¹ and an average interferogram. The penetration of the measurement was 5 microns. The spectra were analysed and interpreted with the Thermo Scientific™ Omnic™ Picta software³⁵. The analysed sample was identified by comparison with a reference spectrum.

Results

Historical sources mainly indicate the use of cellulose nitrate as the main polymer. Cellulose nitrate is identified by the characteristic infrared peaks of the nitrate group, observed as asymmetric and symmetric around $1660\text{-}1625\text{ cm}^{-1}$ (1632 cm^{-1}) and $1285\text{-}1270\text{ cm}^{-1}$ (1272 cm^{-1}), and by the functional group N-O at $890\text{-}800\text{ cm}^{-1}$ (824 cm^{-1}) (Spectrum 1)³⁶. Apart from the Simplat/Simplex sample which, as expected, presents the characteristics of animal collagen (Spectrum 4), all samples are made of cellulose nitrate³⁷.

Except for the Simplat/Simplex gelatinous sample, all samples are composed of cellulose nitrate.

The characteristic infrared bands of cellulose nitrate for each sample are highlighted in Table 3. The spectra are very similar (Spectra 1-3), regardless of the period of production (1942, 1944, 1945, 1946, 1948, 1949) or the manufacturers.

Lower peak intensity is observed at $\sim 1720\text{ cm}^{-1}$ for the samples containing cellulose nitrate. It refers to the carbonyl group typically associated with a plasticiser. The historical study highlighted that cellulose nitrate discs were mainly plasticised with phthalates and/or castor oil. Dibutyl phthalate and castor oil have a characteristic carbonyl peak at 1720 cm^{-1} and $\sim 1740\text{ cm}^{-1}$, located respectively with a slightly higher energy than the nitrate group peak at $\sim 1656\text{ cm}^{-1}$ ³⁸. Gas Chromatography-Mass Spectrometry (GC-MS) could identify the type of plasticiser used.

Table 3 Verification of cellulose nitrate peaks from the samples

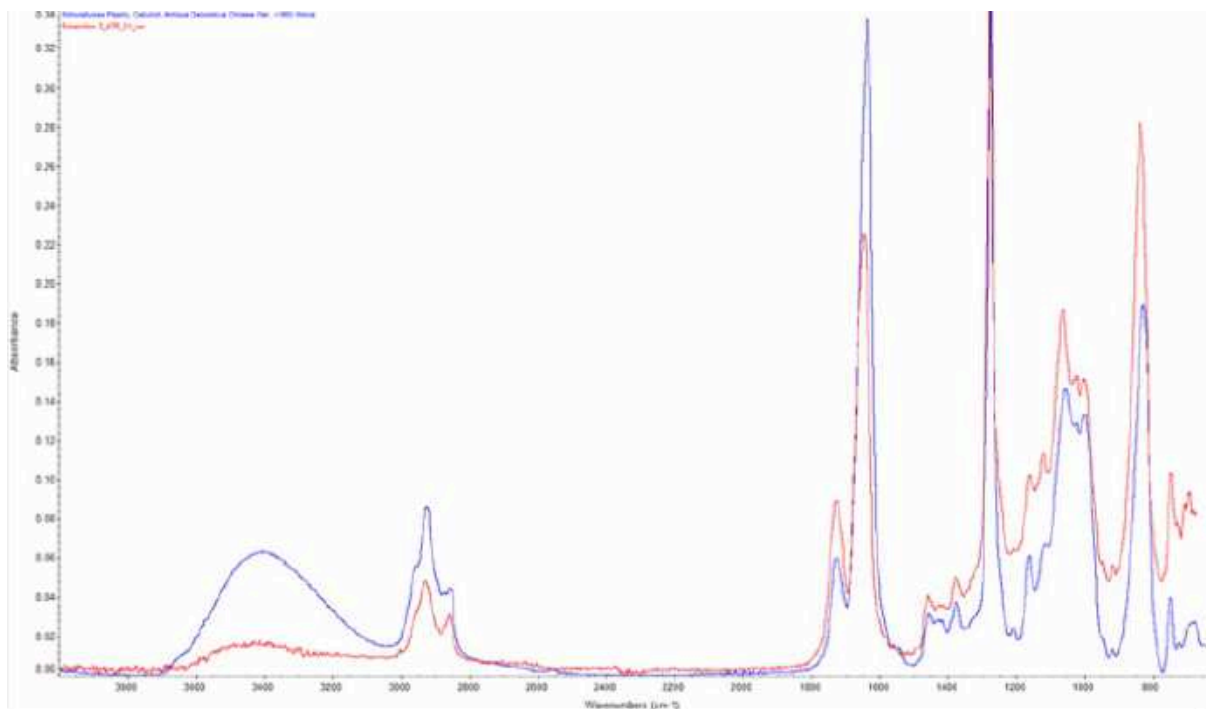
Core material	Region (cm^{-1})	Sample control peaks (cm^{-1})
Cellulose nitrate	1660–1625 cm^{-1} Functional group NO_2 Strong nitrogen dioxide stretching band close to 1650 cm^{-1} ⁴⁴	1632 (sample Pyral 9) 1639 (sample Pyral 6) 1642 (sample Thorens 14) 1643 (samples Pyral 6, 9, Thorens 12, 15, 17, 20) 1644 (samples Presto 2, Thorens 14, 19, 20) 1645 (sample MSS 1)
	1285–1270 cm^{-1} Functional group NO_2	1274 (sample Pyral 6) 1275 (samples Pyral 6, 9, Thorens 14, 15, 17, 19, 20) 1276 (samples MSS 1, Presto 2, Pyral 9, Thorens 12, 14, 17, 20)
	890–800 cm^{-1} Functional group N-O	822 (sample Pyral 9) 825, (sample Pyral 6) 829 (sample Thorens 17) 832 (sample Thorens 14, 17) 833 (samples MSS 1, Pyral 6, 9, Thorens 14, 15, 19, 20) 834 (samples Thorens 12, 20) 836 (sample Presto 2)

Cellulose nitrate

Cellulose nitrate is produced by nitration processes, mixing nitrified cellulose with a mixture of nitric acid and sulphuric acid. During the nitric acid treatment with a sulfuric acid catalyst and water, hydroxyl groups are replaced by nitrate groups (NO_2). As most nitrocellulose compounds are dinitrates containing between 10.5% and 13.5% nitrogen, this percentage is equivalent to the nitration level that determines the solubility and flammability of the final product. The reaction between the cellulose and nitric acid is an esterification. Different degrees of esterification (DE) are obtained based on the number of hydroxyl groups substituted by the nitrate group. Industrial cellulose nitrates have a degree of substitution (DS) between 1.9 and 2.7⁴⁵. This degree refers to the number of hydroxyl groups replaced by nitrate groups, with the highest value set at 3⁴⁶.

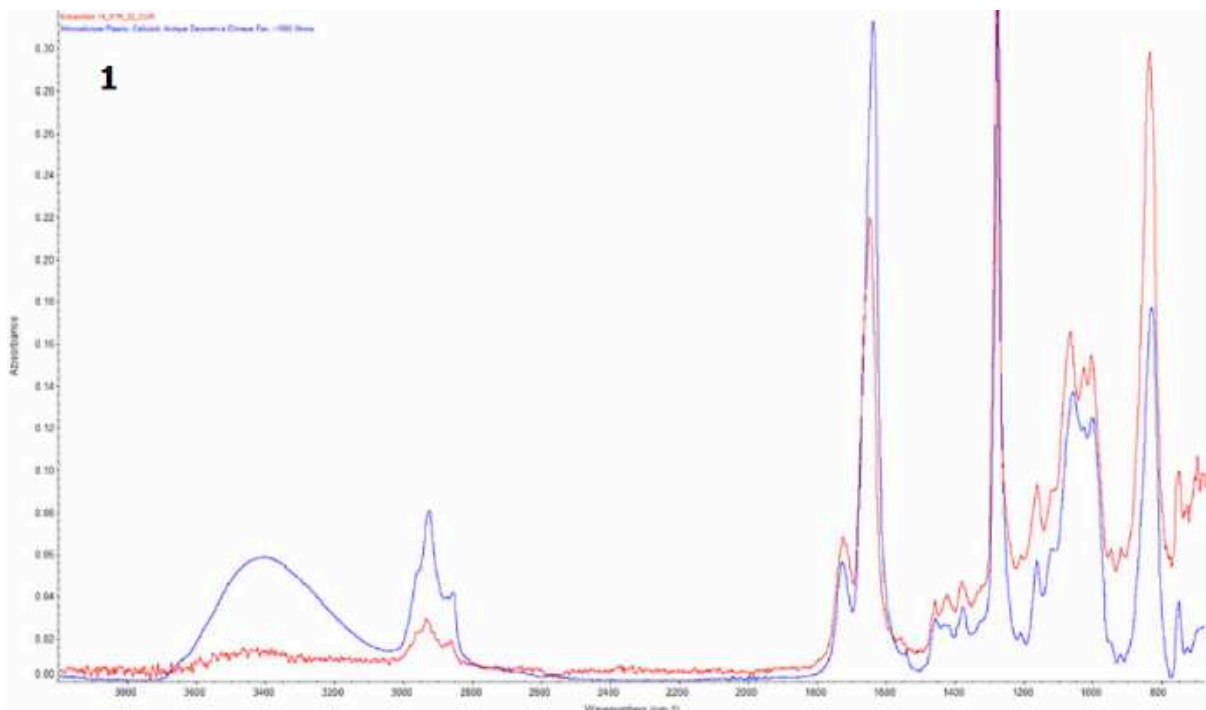
The stability of cellulose nitrate is determined by nitrogen concentration (or degree of nitration): the higher the percentage, the less stable the substance is. Films and coatings have a nitration degree between 10.7 and 12.3%. For comparison, explosives, such as gun cotton, have a nitration percentage of more than 12.4%⁴⁷.

For most samples, the stretch band of the hydroxyl group at $3650\text{-}3200\text{ cm}^{-1}$ is low in comparison to the reference spectrum. This result still has no definitive answers. There are different reference spectra of cellulose nitrate, some with very intense O-H bands, others with lower O-H bands³⁹. The band of the hydroxyl group in the spectra of cellulose nitrate can be very diffuse and have a broad band in the spectral region $3650\text{-}3200\text{ cm}^{-1}$ for several reasons. Its outline varies significantly depending on nitration conditions, even for cellulose nitrate with the same degree of substitution⁴⁰. The same spectral region is also associated with the presence of water. This specific structure of the hydroxyl group bands could be the result of a loss of substituted hydroxyl or exclusion of humidity⁴¹.



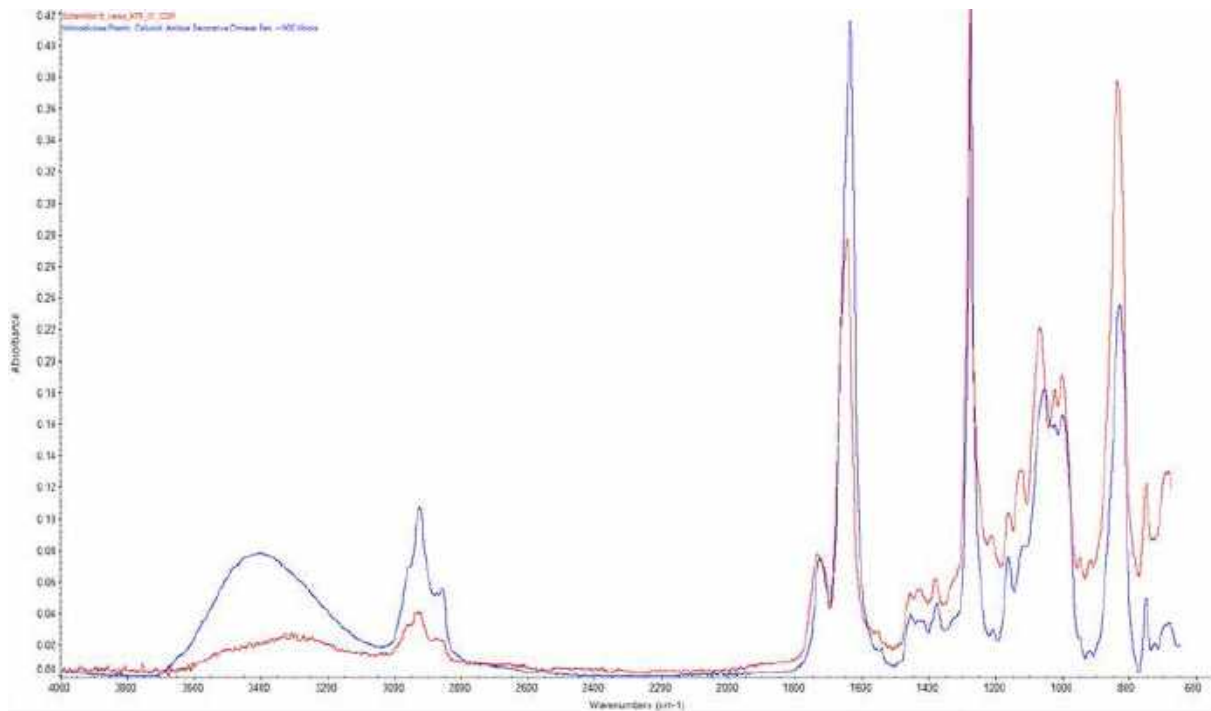
CREDIT Haute Ecole Arc, Laura Brambilla

Spectrum 1 Spectrum ATR-FTIR of a 1948 Presto coating (sample 2, accession number DU4852).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 2.



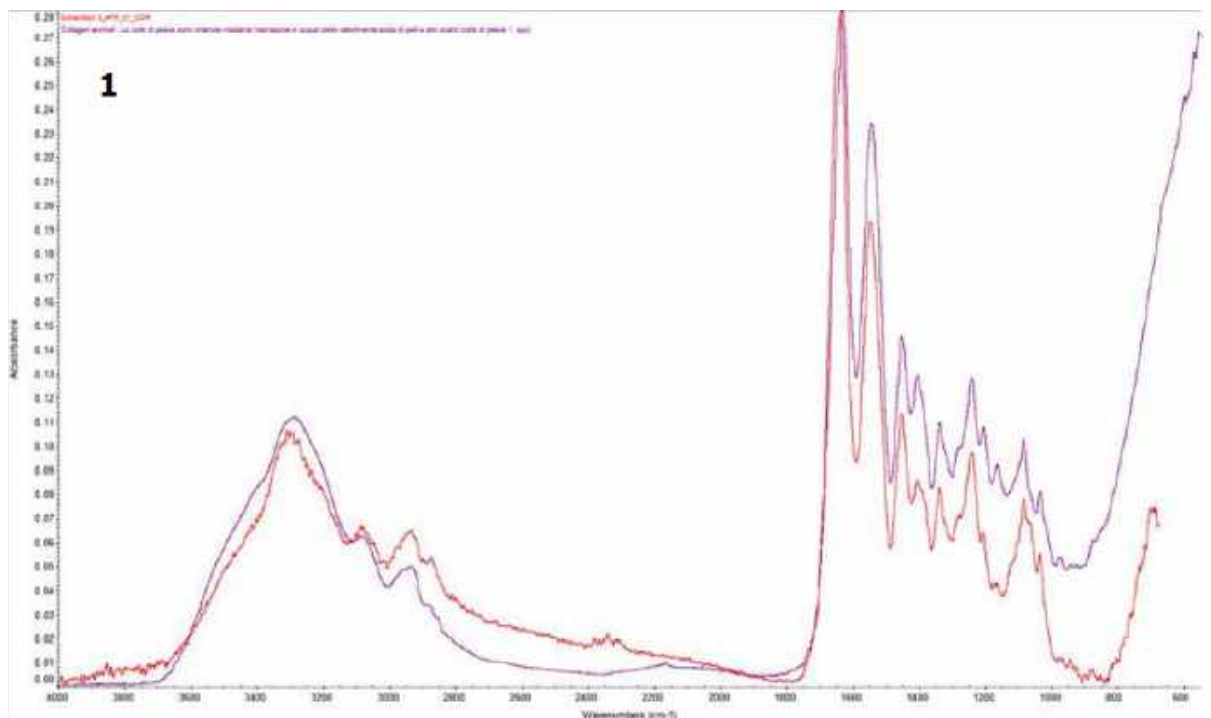
CREDIT Haute Ecole Arc, Laura Brambilla

Spectrum 2 ATR-FTIR spectrum of a 1945 Thorens coating sample 14-1
(accession number 16819, *Parce qu'on en parle, Fantaisie parisienne*, 27.09.1945).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 14-1, groove side.



CREDIT Haute Ecole Arc, Laura Brambilla

Spectrum 3 Spectrum ATR-FTIR of a 1944 Pyral coating, sample 6 (accession number 13674, Hugues Cuénod, *The campbells are coming*, Scottish song, 16.11.1944).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 6, reverse.



CREDIT Haute Ecole Arc, Laura Brambilla

Spectrum 4 ATR-FTIR spectrum of a 1936 Simplat/Simplex coating, sample 3-1 (accession number P4506, *Les chevaliers du Roy - II. Une poule sur un mur*, 23.02.1945).
Purple spectrum: reference spectrum of animal collagen; red spectrum: Simplat/Simplex sample 3-1, groove side.

Spectrum reconstruction

Some interesting research leads were identified for the coatings of 2nd and 3rd generation Thorens discs (see Thorens Typology, p. 160) as a result of the FTIR results. Repeated analyses on both sides of the samples revealed differences between the spectra of the Thorens 2nd generation disc (recorded in 1942) and Thorens 3rd generation disc (recorded in 1946). If a sample is a mixture of different compounds, Thermo Scientific™ Omnic™ Spectra software enables multi-component research and deconstructs the composite spectrum to extract each component.

Thorens 2nd generation disc

The software identified the combined presence of polyacrylic acid and cellulose nitrate for the sample of the 2nd generation Thorens disc⁴² (Spectrum 5). Referring to the same patents from the historical study, there are seven references to acrylic acid. A German patent (Deutsche Celluloid-Fabrik, GB497,429, filed in June 1937) describes the use of acrylic acid butyl ester as the first layer of the coating to coat an intermediate layer of cellulose nitrate:

Thorens is thought to have applied a first layer containing polyacrylic acid to facilitate the adhesion of cellulose nitrate to the metal substrate. The results are not as conclusive for the 3rd generation Thorens disc, where the lack of an adhesive layer could partly explain the defective adhesion of the coating to the metal.

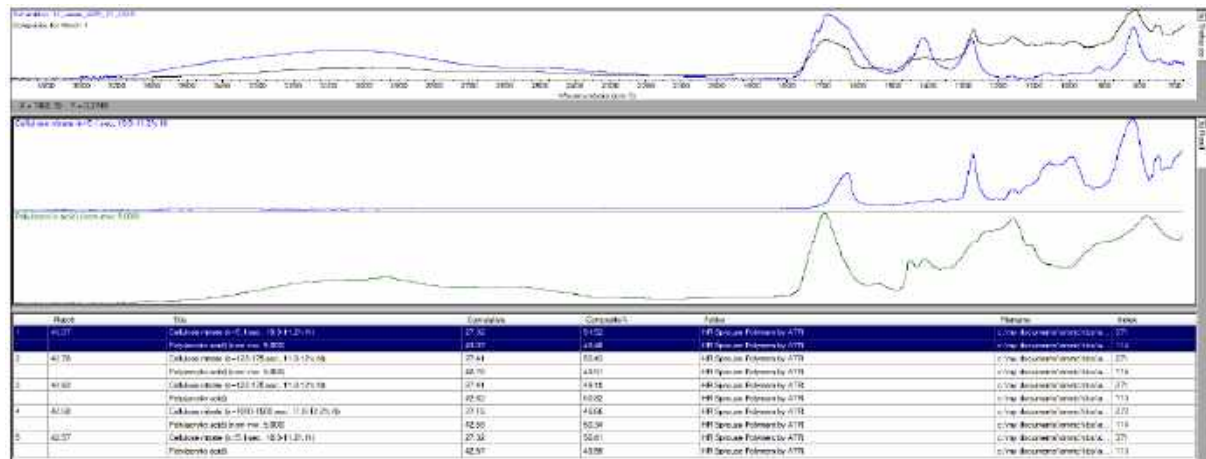
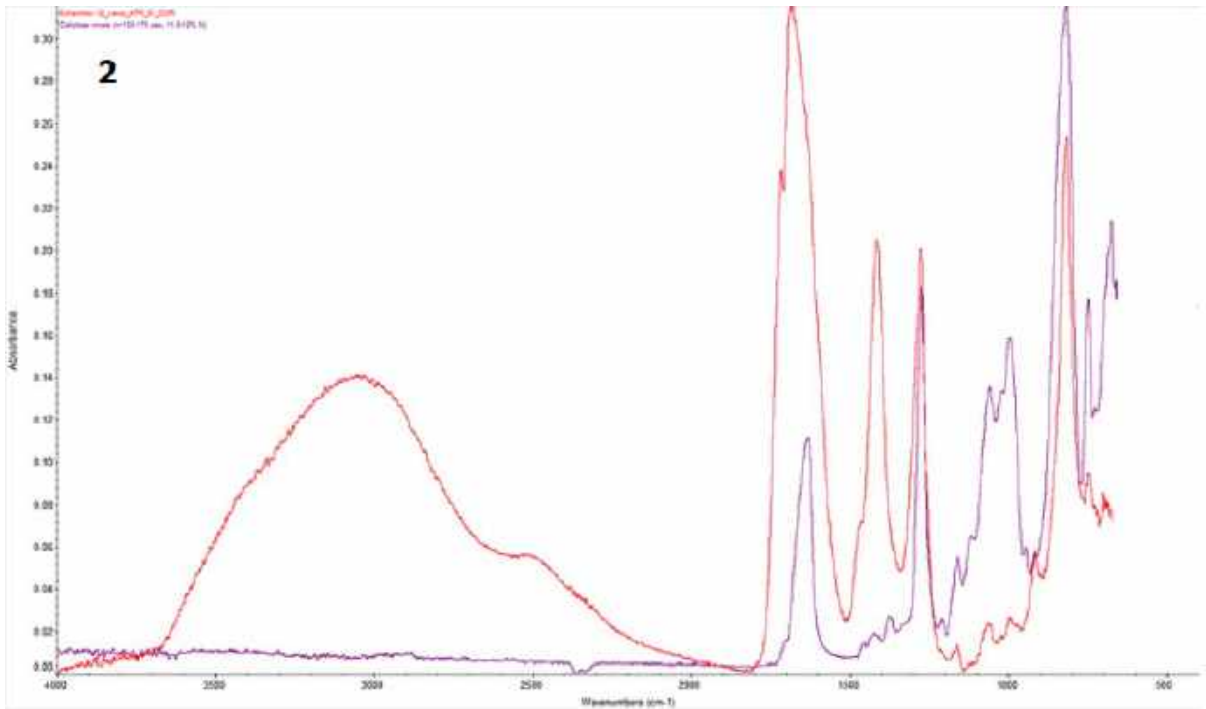
"For making gramophone records the basis of which consists of a sheet of polyvinyl chloride containing 1-2 per cent. of phthalic acid dibutyl ester as a softening agent and the surface layer of which consists of nitrocellulose of low viscosity, the procedure is as follows: The basis is first lightly sprayed with a solution of 10 per cent. strength of a mixed polymerisate from styrene and acrylic acid butyl ester (80:20) in a mixture of toluene, ethyl acetate and methylene chloride (2:1:1). There is then applied an intermediate layer of nitrocellulose and the aforesaid mixed polymerisate and on this is finally applied the actual nitrocellulose surface layer on which the soundtrack is to be cut [...]."

Based on this extract, one of the suggested hypotheses is that Thorens applied a first preparation layer containing polyacrylic acid to facilitate the adhesion of cellulose nitrate to the metal.

Thorens 3rd generation disc

A broad curve is observed in the spectral region 2800-3600 cm⁻¹ of the sample of the 3rd generation Thorens disc (manufactured between 1945 and 1947) (Spectrum 6). The spectral reconstruction is a mixture of different cellulose nitrates. One theory suggests that this sample is composed of degraded cellulose nitrate⁴³.

The hypothesis of an adhesive layer is also ascertainable regarding alterations. Interestingly, the coating of the 2nd generation Thorens discs' cracks but remains attached to the metallic substrate. Conversely, the peeling of the lacquer is very common for 3rd generation Thorens discs. The lack of an adhesive layer may explain these different states of conservation (see Thorens Typology, p. 183).



Spectrum 5 ATR-FTIR spectrum of a 1942 Thorens coating, sample 12-2, reverse (accession number 7399, *Bon dimanche*, radio play, 19.02.1942). Purple spectrum: cellulose nitrate reference spectrum; red spectrum: sample 12-2, reverse side; reconstructed spectrum with Thermo Scientific™ Omnic™ Specta.

Notes

- 1 The terms coating, lacquer, varnish are synonyms. They refer to the layer in which the groove is cut.
- 2 Copeland, 2008, p. 51
- 3 BBC Written Archives Centre R57/50, 1 December 1954; R57/352/1, undated
- 4 Brock-Nannestad, 2012, p. 17, 22
- 5 Davies and Terry, 1939; BBC Written Archives Centre R57/49/2, 27 August 1945
- 6 LeBel, May 1947, p. 4
- 7 LeBel, May 1947, p. 2, 4; Pickett and Lemcoe, 1959; BBC WAC R57/46/4, 24 August 1946
- 8 Pickett and Lemcoe, 1959, p. 10, 15
- 9 Pickett and Lemcoe, 1959, p. 5-6
- 10 US2,607,699, patent filed in August 1948, Audio Devices
- 11 LeBel, May 1947, p. 3-4; Yentis, 1975, p. 19
- 12 Ramel, 1996, p. 7
- 13 LeBel, May 1947, p. 4; Presto Recording Corporation, 1940
- 14 Pickett and Lemcoe, 1959, p. 5
- 15 Complete list of patents consulted, see p. 198-199
- 16 Copeland, 2008, p. 51
- 17 The Audio Archive, 2018
- 18 Selwitz, 1988, p. 49
- 19 Brock-Nannestad, 2012, p. 25-26, 22
- 20 Biel, July 1979, p. 8
- 21 Yentis, 1975, p. 17
- 22 FR 778,700, patent filed in December 1933, Pyrolac
- 23 Biel, July 1979, p. 6; Street, 2006
- 24 BBC Written Archives Centre, R57/194/1, 24 October 1933, 18 December 1933
- 25 BBC Written Archives Centre, R57/194/1, 29 May 1934, 30 May 1934
- 26 GB438,029A, patent filed in March 1934 and accepted in November 1935, V.G. Manufacturing; Brock-Nannestad, 2012, p. 23
- 27 BBC Written Archives Centre R57/49/1, 17 March 1944
- 28 Bretz, 2013
- 29 LeBel, May 1947, p. 3
- 30 US2,607,699, patent filed in August 1948, Audio Devices
- 31 LeBel, May 1947, p. 3
- 32 Brock-Nannestad, 2012, p. 24; LeBel, September 1940, p. 80; LeBel, May 1947, p. 4
- 33 Pickett and Lemcoe, 1959, p. 10, 15
- 34 Analyses conducted by Dr Laura Brambilla, Doctor in Chemistry and Scientific Associate, Applied Research and Development (R&D) at the Haute Ecole Arc, conservation-restauration
- 35 Brambilla, 2018, p. 2
- 36 Derrick, Stulik and Landry, 1999, p. 190; Walsh, 1995, p. 81; Zhbankov, 1966, p. 94; Noake, 2017
- 37 Brambilla, 2018, p. 3
- 38 Noake, 2017, 5:3
- 39 Email from Laura Brambilla, 25 June 2018
- 40 Kovalenko, 1994, p. 544
- 41 Céline et al., 2014, p. 87; Zhbankov, 1966, p. 96, 104; Edge, 1990, p. 627
- 42 Email from Laura Brambilla, 3 July 2018
- 43 Email from Laura Brambilla, 17 July 2018
- 44 Stuart, 2007, p. 124
- 45 Brydson, 1999, p. 616-617; Shashoua, 2008, p. 41
- 46 Fernandez de la Ossa, Torre and García-Ruiz, 2012, p. 202
- 47 Scott Williams, 2017, p. 1

The manufacture of discs

Disc standardisation

Setting a standard for the ideal disc based solely on surface inspection is complex. The discs had to meet very specific manufacturing criteria. This degree of precision was the result of the specifications requested by broadcasters. For instance, the BBC standards detailed each disc parameter down to the tenth of a millimetre (table 4). Ideally, the disc presented manufacturing uniformity: the flatness of the surface (a 0.020" gauge cannot be inserted between the disc and the turntable), the evenness of the disc dimensions and the coating thickness¹. Furthermore, the coating should be exempt from blemishes or any foreign material that could damage the cutting stylus². Other contractual conditions for direct-to-disc recording were required by the BBC, such as being recordable on both sides, and a low background noise level³. The correlation between the hardness of the coating and surface noise was also crucial: a hard disc would generate more surface noise than soft discs but provided greater resistance to wear⁴.

Table 4 BBC lacquer discs specifications

BBC lacquer discs specifications				
	inch (")	mm	Tolerance (inch)	Tolerance (mm)
Minimum coating thickness	0.006	0.1524		
Coating thickness (1945)	0.012	0.3	0.003 (1944)	0.0762
Disc diameter	17	431.8	1/32 (1944)	0.794
	13	330.2		
	12	304.8	1/16 (1946)	1.5875
Substrate thickness	0.040 (1944, zinc)	1.016	0.0015	0.0381
	0.064 (1945)	1.6256	0.005 (1941, alu)	0.127
Disc thickness (1945)	0.088	2.235		
Central hole diameter (1946)	0.286	7.26	0.001	0.0254
Driving hole diameter (1946)	0.25	6.35	0.005	0.127
<small>Source: BBC WAC R57/49/1, 25 February 1941; BBC WAC R57/49/1, undated, c. March 1944; BBC WAC R57/46/3, 17th October 1945; BBC WAC R57/46/4, 1st April 1946; BBC WAC R194/8, 5th June 1946</small>				

Manufacturing techniques

By examining patents filed between 1888 and 1953 (Figure 10), the manufacturing process of stratified discs did not evolve significantly. It was a substrate on which a coating was applied, as described in the patents filed by

- C.S. Tainter in 1888 (US385,887),
- Thomas Edison in 1914 (US1,111,999),
- J.E. Symonds in 1934 (US1,946,596),
- B.C. Bren in 1936 (US2,030,568),
- Deutsche Celluloid-Fabrik in 1937 (GB469,249),
- V.G. Manufacturing Company Limited in 1935 (GB438,029A).

Some surprising concepts were also proposed, such as a rollable disc (J.W. Aylsworth, 1915, US1,146,387). The methods used to apply the coating to the metal substrate are numerous: by dipping, spraying, pouring, extruding, wiping or spreading⁵. Press machining methods were also indicated from 1907 onwards (T.H. MacDonald, 1907, US862,407), where the coating spread from the centre to the exterior.

For professional and radio records, the manufacturing processes differed according to the period and country of production. The first British and American discs used by radio stations were hand-sprayed⁶. In France, the use of a belt conveyor system was attested by the manufacturer Pyrolac in 1933⁷. In 1942 and 1943, the English company EMI, one of the main suppliers to the BBC, manufactured double-sided discs by dipping, where the metal base was immersed in a bath containing the coating⁸. Another British firm, Marguerite Sound Studios (MSS), stated that the manufacture of a disc required at least four layers of coating per side. Each layer should be applied before the previous one has dried⁹.

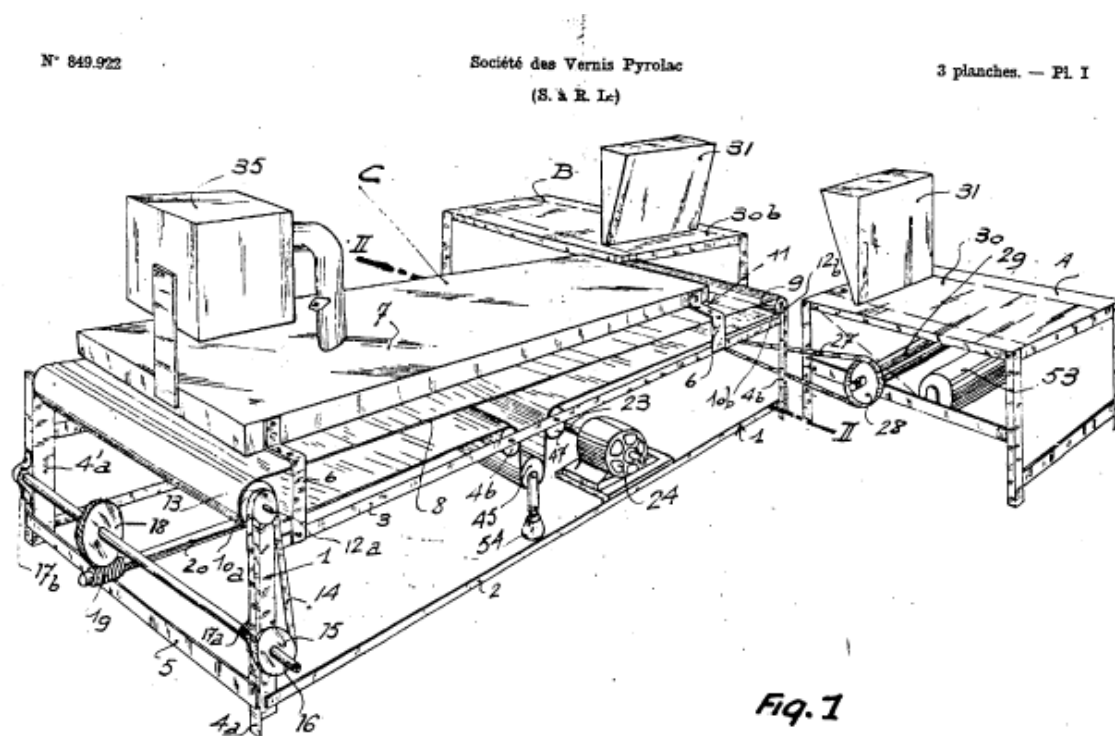


Figure 8 Perspective drawing of the apparatus for manufacturing phonographic discs. Pyrolac patent FR 849,922 (1938).

The patents filed by the French manufacturer Pyrolac are the few historical evidences of the industrial manufacturing of transcription discs (Figure 8). A 1939 patent described the conveyor as a machine where *“the discs, blanks or plates to be coated are driven on a conveyor belt passing under a dispensing device formed by a tank filled with varnish or lacquer; the height of the lacquer dispenser orifice with respect to the surface of the flanks to be coated is adjustable so that the thickness of the coating layer can be varied as required”*¹⁰. The excess of varnish is scraped off and the thickness is precisely adjusted using a scaled screw system.

Another patent of the company specified that the most crucial production process for industrial mass production is a fast drying of the coated discs. Pyrolac added a dust-free air-drying tunnel to the conveyor to achieve such results¹¹. Audio Devices, which was using a similar automatic coating machine, dispatched the disc after drying in a controlled temperature cycle. The manufacturer emphasised that this step reduced surface noise and improved high-frequency response¹². In 1946, Pyrolac, through its subsidiary Pyral, made major modifications to and automatised its system by eliminating manual intervention to transfer the discs from the coating machine to the pre-drying machine. This new device prevented dust deposits¹³.

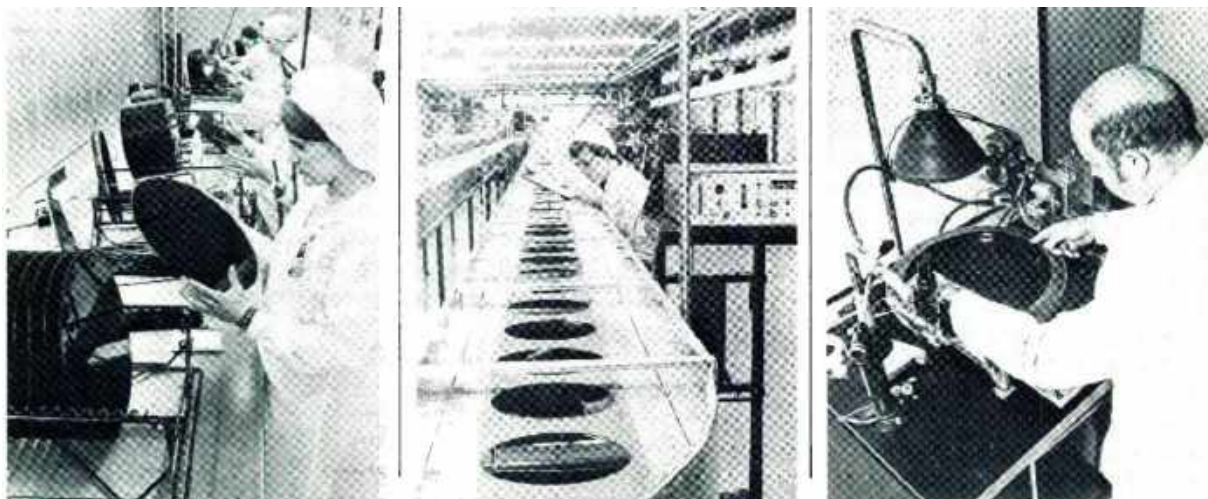


Figure 9 Late photograph illustrating the process at Capitol's quality control, c. 1975.

Throughout the manufacturing process, necessary precautions were also taken to exclude dust and impurities. Filtration was recommended before dipping or spraying the discs¹⁴. Poor filtration resulted in impurities in the coating, such as metal particles from the filters¹⁵. Disc manufacturers were reliant on raw material suppliers. A negative effect on the final quality of the disc was anticipated if the material delivered was of inferior quality¹⁶.

The discs were inspected by plant staff to guarantee the highest quality during the following process stages¹⁷ (Figure 9):

- aluminium circles before coating,
- discs after coating,
- discs leaving the drying tunnel,
- finished discs.

Even with optimal materials and manufacturing processes, the final quality of the disc could not be known until the solvents had evaporated and the disc had dried¹⁸. The discs were also visually inspected and periodically tested to verify their cutting properties¹⁹.

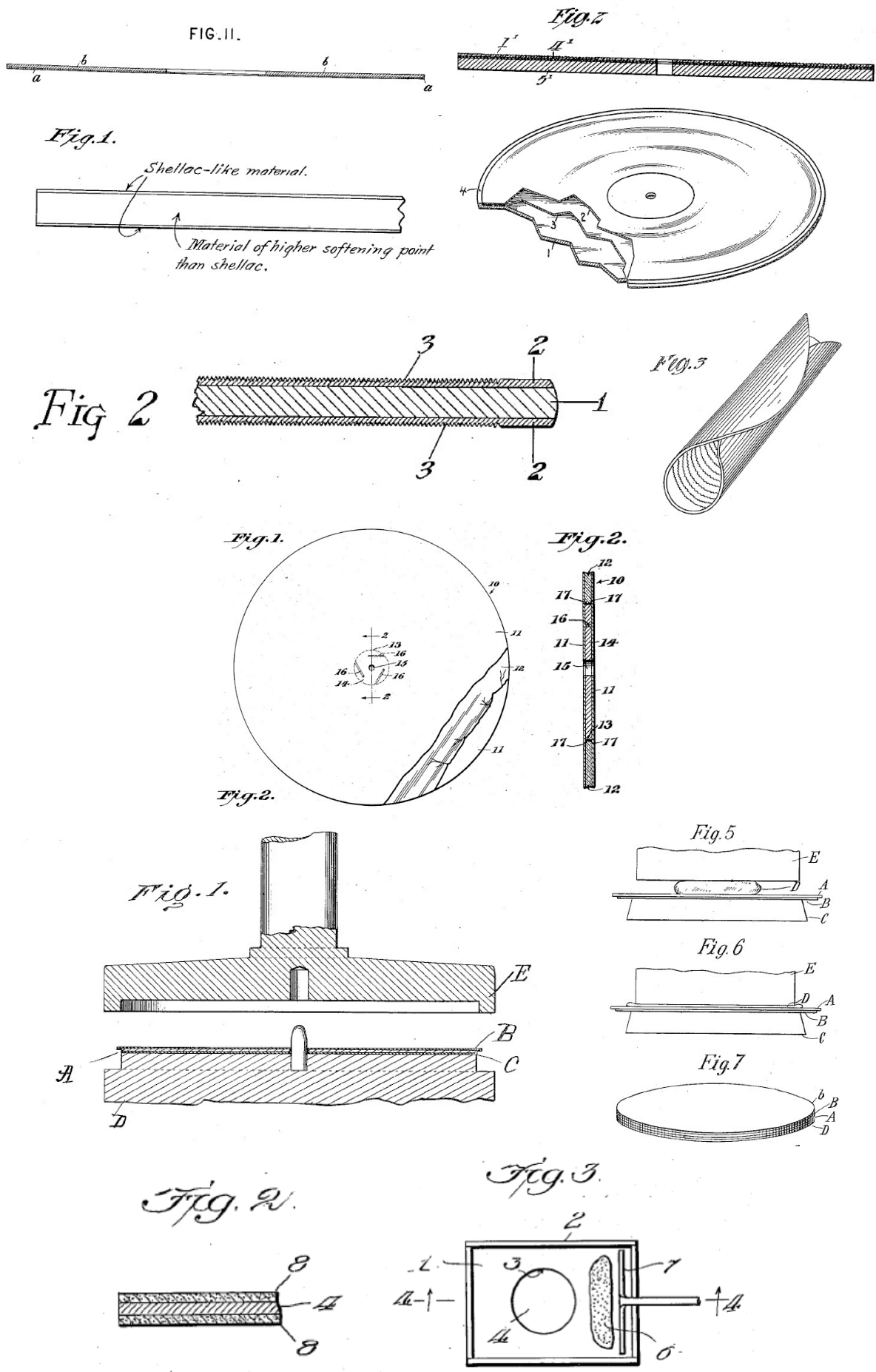



Figure 10 Patent details. Top, then left to right: E.A. Wideman (1921), US 1,370,719; J.E. Symonds (1934), US 1,946,596; B.C. Bren (1936), US 2,030,568; J.W. Aylsworth (1915), US 1,146,387; R.S. Dech (1942), US 2,295,938; T.H. MacDonald (1907), US 862,407; V.H. Emerson (1913), US 1,050,932; F.L. Porth (1942), US 2,283,286

WITH Soundcraft -
**CLEAN CUT
 LINES REDUCE
 EXTRANEIOUS
 NOISE!**



THE FORMULA:

PROPERLY COMPOUNDED RECORDING LACQUER
 MINUS { FOREIGN MATTER IN LACQUER
 MICROSCOPIC DUST IN DRYING
 AIR
 EQUALS NEW IMPROVED QUIETNESS
 IN CUTTING

THE ANALYSIS:

Not just the usual lacquer ingredients, but also new ingredients "X".

Not just the usual big-piece-removing paper filter press, but also batteries of high pressure stone filters to remove microscopic matter small as 000001".

Not just conventional dust-stop air filters for drying air, but also batteries of electronic precipitators that even can move smoke!

PROF. SOUNDY SAYS..

Scientific Manufacturing Account for Soundcraft Discs Attaining Leadership in Only Two Years - Soundcraft has no royalty to pay, is not tied to a decade-old patented process. Every disc dollar goes into continuous improvement to make your Soundcraft disc a better recording medium.

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CREDIT Audio engineering

Figure 11 Reeves Soundcraft advertisement illustrating the manufacture of discs, June 1949

Standardisation of driving holes

The addition of locating pins in the turntable prevents the slipping of the disc²⁰. Driving holes were punched in the centre according to very precise standards to ensure a wide use of the discs on different turntables (Figure 12) :

- An American standard, namely a central hole with three additional symmetrically disposed holes²¹. These holes are angularly spaced by 120°, around the circumference of a central circle with a radius of 1" (25.4 mm). The diameter of the driving holes is 0.25" (6.35 mm), with a central hole of 0.286" (7.26 mm)²².
- A standard with two holes (a central hole and a eccentric hole) is found notably on two European manufacturers: MSS in England and Pyral in France. The MSS measurements are identical to the American values, a central hole with a diameter of 0.286" and an eccentric hole of 0.25" diameter.
- A single central hole (e. g. Thorens discs).

Following the punching of the holes, the discs were usually stamped with a batch code number.

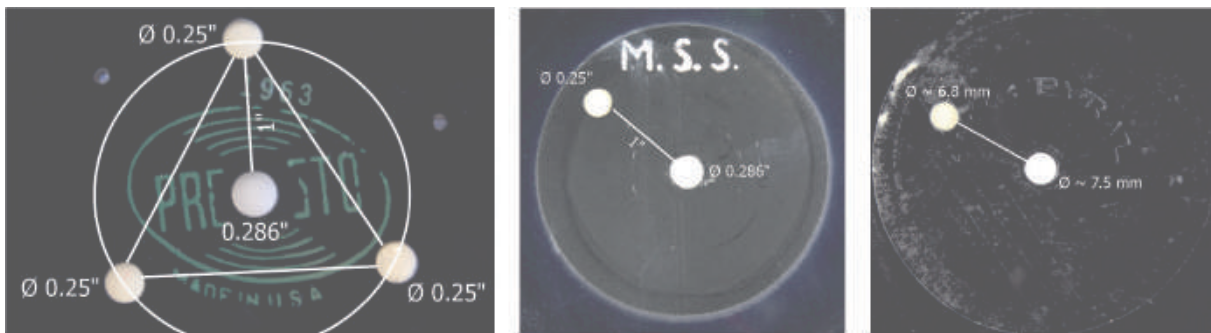


Figure 12 Driving holes, various standards

Disc transport

The finished discs were shipped in metal, wooden or cardboard containers (Figure 13-16). Packaging and transport methods from the manufacturing plants are designed to avoid imperfections on the surface of the disc and to ensure the discs reached the recording studio in satisfactory condition²³. The storage requirement is a sustainable disc, suitable for storage up to 12 months before recording while maintaining the same recording quality²⁴.

The BBC used a rating system with its supplier to classify the type of discs and coating²⁵. Each disc box was identified by a reference number indicating the date of manufacture and the condition of the batch. Variations in quality between different batches are regularly reported in the correspondence between the BBC and its supplier MSS²⁶.



Figure 13 Packing in cardboard containers of new Audiodiscs developed by Capitol, c. 1975.

CREDIT: Capitol



CREDIT Disco Patrick

Figure 14 Cardboard container used to transport Presto discs.



Figure 15 Metal container for Thorens discs held at the Bibliothèque nationale de France.



Figure 16 Pyral metal container kept at the Bibliothèque nationale de France.

Efficiency tests

Reports written by the BBC Research and Development provided an overview of the many efficiency tests conducted to assess the quality, recording properties and wear resistance of discs. One of the first reports, written in 1938 by BBC engineers Barrett and Davies, compared MSS records with Presto, Simplat, Musikon, Ericsson, Decelith and Cleen-Cut records. The tests are based on seven criteria: core rigidity, surface noise level, sound reproduction qualities, wearing properties resistance (after recording/after storage), deterioration due to storage conditions and capability for processing (Figure 17). It is the Cleen-Cut disc, produced by Allied Record Production, that satisfies all the criteria²⁷. In 1941, the BBC maintained that the American Cleen-Cut discs remained the best disc available commercially, with little deterioration, an exceptionally silent surface, and satisfactory frequency response²⁸. Their general findings concluded that the discs manufactured in the United States were more uniform, with satisfactory ageing qualities and a low electrostatic charge. A 1945 BBC report stated the broadcaster remained unsatisfied with the quality of records produced in the United Kingdom and noted large discrepancies in quality depending on the origin and the manufacturer of the material²⁹. Signal-to-noise ratio, ageing, antistatic properties, flatness and the need to lubricate the surface after recording are the main criteria that fail to satisfy the broadcaster requirements³⁰.

TABULATION OF RESULTS.

	<u>PRESTO.</u>	<u>SIMPLAT.</u>	<u>MUSIKON.</u>	<u>ERICSSON.</u>	<u>DECALITH.</u>	<u>"CLEEN-CUT".</u>
Rigidity	Good.	Very good.	Poor.	Poor.	Poor.	Good.
Surface noise	Low.	Low.	High	Fairly low.	High.	Very low.
Quality of Reproduction	Good.	Good.	Passable.	Good.	Passable.	Very good.
Wearing properties:						
(a)	Not good.	Good.	Passable.	Good.	-	Good.
(b)	Not good.	Good.	-	Satisfactory Quality inferior.	-	Good.
Deterioration after storage	Slight.	Slight.	-	Slight.	-	Negligible.
Can be processed ?	Yes.	No.	-	-	-	Yes. (Not confirmed).

AEB/CHF.

H. Kuiper

CREDIT BBC R&D

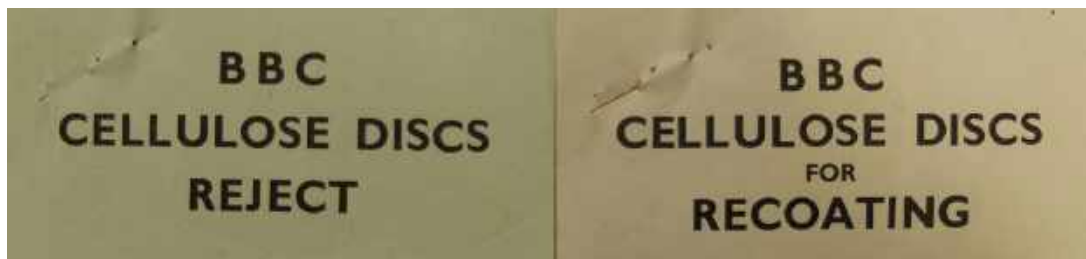
Figure 17 Summary of tests conducted by the BBC Research Unit in 1938.

In late 1946, Dutch radio Nederlandse Radio-Unie (NRU) conducted laboratory tests on several direct-to-disc recordings with noise, distortion and wear resistance as the research parameters. Simplex discs, with gelatin coating, are compared to Gevaert, Pyral, Presto, Thorens, and Audiodiscs. The mechanical resistance and signal-to-noise ratio of Simplex discs are found to be better than cellulose nitrate coating discs. Gevaert's cellulosic coating layer is deemed too soft, causing information loss during cutting and playback. A further NRU report from 1948 examined the manufacturers Presto, Soundcraft, and Gevaert. Presto was regarded as the reference, with a reliable recording³¹.

Disc recycling

Lacquer discs were expensive³². Recycling the discs (Figure 18), which consists of removing the recorded lacquer to apply a new coating, was a logistically time-consuming solution but essential during the Second World War to maintain aluminium for broadcasting purposes. For many recordings, the BBC also had a contractual obligation to use the discs for a limited period and had to prevent any possibility of reproduction when leaving the BBC³³.

The discs to be recycled were placed in a tank to dissolve the cellulosic layer. The surface of the disc was not to be scratched with scissors, although a common practice, to avoid damaging the aluminium substrate³⁴. The use of a solvent was recommended³⁵, such as a mixture of acetone (30% to 70%) and methyl acetate applied using a paintbrush³⁶. As for the gelatin-based coating, it was removed by applying enzymatic pepsin and hydrochloric acid solution³⁷.



CREDIT BBC WAC

Figure 18 BBC labels used to identify discarded discs and discs for recycling. BBC Written Archives Centre, R57/49/2, 4 October 1946. Courtesy of BBC Written Archives Centre.

Notes

- 1 BBC Written Archives Centre R57/49/1, 29 November 1943; BBC Written Archives Centre R57/49/2, 27 August 1945; BBC Written Archives Centre R57/194/8, 5 June 1946
- 2 BBC Written Archives Centre R57/46/1, 19 May 1942
- 3 BBC Written Archives Centre R57/46/1, 19 May 1942
- 4 Harris and Somerville, 1945, p. 1-2
- 5 Yentis, 1975, p. 21; US2,607,699, patent filed in August 1948, Audio Devices; GB497,429A, patent filed in June 1937, Deutsche Celluloid-Fabrik
- 6 Graves, 2015; Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984
- 7 FR778,988, filed in November 1933, Pyrolac; FR48,428E, patent filed in October 1936, Pyrolac; FR849,922A, patent filed in August 1938, Pyrolac
- 8 BBC Written Archives Centre R57/49/1, 29 September 1942; BBC Written Archives Centre R57/46/2, 30 December 1943
- 9 Brock-Nannestad, 2012, p. 22; Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984
- 10 FR50,439, patent filed in February 1939, 2nd addition to the patent FR778,988, Pyrolac
- 11 FR849,922A, patent filed in August 1938; FR50,439, patent filed in February 1939, Pyrolac
- 12 LeBel, May 1947, p. 4
- 13 FR1,001,269, patent filed in April 1946, Pyral
- 14 Harris and Somerville, 1945, p. 4
- 15 BBC Written Archives Centre R57/194/8, 23 May 1946
- 16 BBC Written Archives Centre R57/194/7, 21 March 1939
- 17 LeBel, July 1947, p. 4
- 18 Yentis, 1975, p. 21
- 19 Yentis, 1975, p. 21-22
- 20 BBC Written Archives Centre R57/46/1, 14 February 1941
- 21 BBC Written Archives Centre R57/46/1, 14 February 1941
- 22 BBC Written Archives Centre R57/46/1, 19 May 1942
- 23 BBC Written Archives Centre R57/46/1, 19 May 1942
- 24 BBC Written Archives Centre R57/46/1, 19 May 1942; R57/49/2, 27 August 1945
- 25 BBC Written Archives Centre R57/46/1, 19 May 1942; R57/194/8, 11 April 1945
- 26 BBC Written Archives Centre R57/46/2, 11 August 1944; R57/49/2, 31 March 1947
- 27 Barrett and Davies, 1938, p. 2
- 28 BBC Written Archives Centre R57/194/8, 31 July 1941
- 29 Harris and Somerville, 1945; BBC Written Archives Centre R57/49/2, 27 August 1945
- 30 BBC Written Archives Centre R57/49/2, 27 August 1945
- 31 Wolf, 2004: Rotgans, 10 December 1946; Rotgans, 26 July 1947
- 32 Brock-Nannestad, 2012, p. 23
- 33 BBC Written Archives Centre R57/194/7, 18 October 1938
- 34 BBC Written Archives Centre R57/194/5, 14 January 1936; R57/194/7, 18 October 1938
- 35 BBC Written Archives Centre R57/194/7, 23 August 1938, 18 October 1938
- 36 BBC Written Archives Centre R57/194/7, 21 September 1938
- 37 Brock-Nannestad, 2012, p. 23; Pierce, 1941, p. 243

Impacts of the Second World War

The quality and manufacturing conditions of instantaneous discs were significantly affected during the Second World War (Figure 19). Broadcasters were seeking options to record and broadcast programmes and news despite the conflict. The effects of low coating quality include high surface noise, electrostatic charging, poor adhesion¹, lack of uniformity and flatness in disc manufacturing, as well as variations between batches of discs manufactured with the same coating formula².

It was also important for manufacturers to manage supplies amid the war. English manufacturers were forced to find substitutes for aluminium, the French manufacturer Pyral developed an ersatz coating and the Swiss firm Thorens produced the discs for the Swiss broadcasters from 1940 onwards, since it was difficult to secure a sufficient supply of discs from abroad.

For the Swiss Broadcasting Corporation, the aim of the programmes during the war was notably to show civilians that the army was looking after them and, for the soldiers, to maintain a connection with civilian life (Figure 20-Figure 21). Radio broadcasts, and technically the lacquer discs, served this unifying role³.

Aluminium shortage

The effects of the war were already noticeable in October 1939, when it was mentioned that the English manufacturer MSS had considerable difficulties in obtaining aluminium circles due to a national shortage of aluminium⁴. As aluminium was requisitioned for the war effort as a strategic use⁵ for both armaments and aeronautics, a decline in the production of discs using aluminium substrates was logically observed.

An article published in *Electronics* in May 1941 reported on the impact of the war on the supply of raw materials for disc production. It is notably stated that there are no reasonable or identical substitutes for aluminium. Tests were being conducted on steel, glass, plastic, cardboard, zinc, brass and copper to find an alternative to aluminium but without satisfactory results⁶. Nevertheless, glass and zinc were used as the main substitutes. One of the advantages of glass over zinc was its superior surface finish. When using zinc bases, manufacturing standards were slightly lower than those recommended in peacetime⁷.

There are significant variations in the use of substitutes between countries. The American manufacturer Presto used glass and steel. In France, Pyral manufactured mainly zinc and aluminium-based discs. All discs produced by Thorens are on an aluminium base. Switzerland's neutrality may explain why the country was not subject to the same difficulties in the supply of this metal as its neighbours.

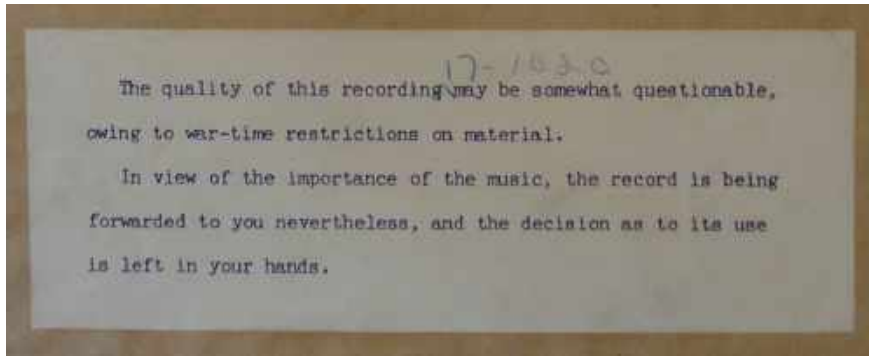


Figure 19 A label attached to the paper sleeve of a record refers to the poor recording quality. Radio-Lausanne, accession number 60GF, Radio Luxembourg Orchestra, December 1946



Ar RSR, Genève, PRGE 11:25, Photo-Hélios, Genève

Figure 20 Fred Poulin, first lieutenant, recording the program "Pour nos soldats" (For our soldiers). Observe the Radio-Genève recording car behind.



Ar RSR, Genève, PRGE 3:125, Photo-Hélios, Genève

Figure 21 The program "Pour nos soldats" (For our soldiers), with Fred Poulin, first lieutenant and reporter at Radio-Lausanne.

United Kingdom and BBC case study

The production of lacquer discs contributed to the British government's propaganda. Martin Pulling, a BBC Engineer, recalled an anecdote back when the Italians were indecisive to support the German armies. 5-inch plastic records, featuring Churchill's speeches telling the Italians the mistake of taking the German side, were scattered over Italy's territory by aircraft⁸.

Technical developments were also carried out. The BBC Research Unit developed a transportable recorder for war correspondents, supervised by mobile recording engineers. The unit improved recording techniques and developed a portable recorder to be taken directly to the front by war correspondents, recorders known as BBC Midget. This portable system, used during D-Day, has significantly changed programmes' contents, enabling to record directly on the front⁹ even under difficult situations (Figure 22-Figure 23). Furthermore, the British broadcaster needed a significant number of discs to fully achieve these missions despite the supply difficulties.



Figure 22 C.D Adamson, correspondent engineer from the BBC War Reporting Unit, using the BBC Midget portable recorder, the same type used during D-Day.

The successive changes in disc manufacture over the course of the war resulted in a loss of coating quality, a reduced workforce and a limited supply of materials (Figure 24). The Ministry of Supply, which provided the equipment, used a rating system where the BBC was not among the priorities¹⁰. The shortages of aluminium bases and difficulties in the supply of raw materials are recurring issues reported by British manufacturers. Aluminium had become "priceless"¹¹. The BBC Superintendent of Engineer Recording (SER), Martin J.L. Pulling, summarised the situation in an internal correspondence in July 1940:

"All the available supplies of aluminium in the country are being devoted to armament work, and it is now impossible to get any but the very smallest supplies for domestic purpose. The B.B.C. has a claim to certain small quantities, but nothing like sufficient to meet our needs for recording discs on a peace-time basis. It is therefore absolutely essential that the most rigid economy should be exercised in aluminium used for recording discs¹²."

In 1939, MSS placed weekly orders for aluminium bases and raw materials. Considering the emulsion manufacture, if the Government were to suddenly make requests, suppliers would either be unable to satisfy the demands or send lower quality products¹³.

In February 1940, MSS took immediate measures to find an alternative to aluminium¹⁴ and selected zinc. However, the BBC was determined to pursue aluminium for as long as possible¹⁵. Cecil E. Watts, the director of MSS, made several requests to the British Aluminium Company to acquire aluminium sheets. He also contacted the Ministry of Supply Aluminium Control, to certify that the material purchased was intended for BBC use¹⁶.

A reply from Aluminium Control to MSS stated:

"[...] in view of the very great demands for virgin aluminium, consideration can only be given to the release of material to them [BBC] provided that an equivalent weight of scrap discs are returned to the metal suppliers. [...] these discs are re-used a number of times before scrapping¹⁷."



Figure 23 Robin Duff, BBC War Correspondent, assigned to the U.S Forces, using a BBC Midget portable recorder, 26 June 1944

CREDIT BBC

MSS was taken over by the General Post Office in May 1941 as a wartime measure to provide a more substantial production of discs to the BBC¹⁸ (see Typology p. 116). MSS and EMI obtained most of their aluminium from S.D. Syndicate. The main challenge was to supply a sufficient quantity of metal sheets that complied with the standards. Only a few companies were able to laminate aluminium sheets with a surface finish appropriate for direct-to-disc recording. Besides, shortly after the war, in 1946, several ministries sought to prevent the use of aluminium for disc production as aluminium was needed for the housing programme¹⁹. A response from the BBC engineer Harold Bishop to S.D. Syndicate²⁰ is highly instructive of the essential place of lacquer discs in daily and political life:

"You will no doubt appreciate that our disc recording service is by no means used entirely for entertainment purposes. Without it we would be unable to continue the service of news and information to foreign countries, which we carry out on behalf of the Government. Great importance is placed on the maintenance of these services at the present time."

A reduced workforce, as a consequence of the staff leaving to participate in the conflict, was also a major concern for the supply of records (Figure 25). This situation revealed all the constraints associated with the long and fundamental training required to become a productive operator. Watts estimated at least five years of training:

"[...] if either of these men are called up it will be almost, if not quite impossible to maintain an adequate supply of direct recording materials. The training of both these men has taken over five years to establish the degree of perfection in disc production now obtaining²¹."

RIG

M.S.S. RECORDING CO. LTD.

Marguerite Sound System

85 THE GREEN,
KEW, SURREY.

Enquiries at the local Employment Exchange for persons for training to replace A.W.J. Bristow and H.J. Dunk have elicited the fact that there is little, if any, suitable labour to draw upon.

We have gone into the matter thoroughly and find that if either of these men are called up it will be almost, if not quite impossible to maintain an adequate supply of direct recording materials. The training of both these men has taken over five years to establish the degree of perfection in disc production now obtaining, and the existing high price of our products is to a large extent due to the wastage which even now exists as a result of manual imperfection.

The preparation of material and application of lacquer can at present only be successfully accomplished by a series of hand operations, a flaw in any one of which will ruin the finished disc; the whole process has to be scrupulously free from any form of dust or small bodies usually present in the air.

The supply of materials i.e. aluminium, nitro cotton, Butyl Acetate, alcohol, gums, resins etc. is limited to your actual requirements and to commence the training of staff with these materials would be suicidal.

The demands for our products have never been large enough to warrant the installation of mass production machinery and we do not think at this time such a change could be successfully accomplished, nor would it be justified, as continual research is being conducted with a view to the production of a substitute for aluminium, and it is at present impossible to indicate the material or modification in method of manufacture which will eventually be decided upon.

Every week brings a larger demand from Government Departments using these materials.

(Signed) C.E. WATTS

Managing Director

Figure 24 A letter from the director of MSS, C.E. Watts, relating the consequences of reduced workforce and difficulties in the supply of raw materials for the manufacture of discs.
BBC Written Archives Centre R57/194/7, undated, c. May 1940. Courtesy of BBC Written Archives Centre.

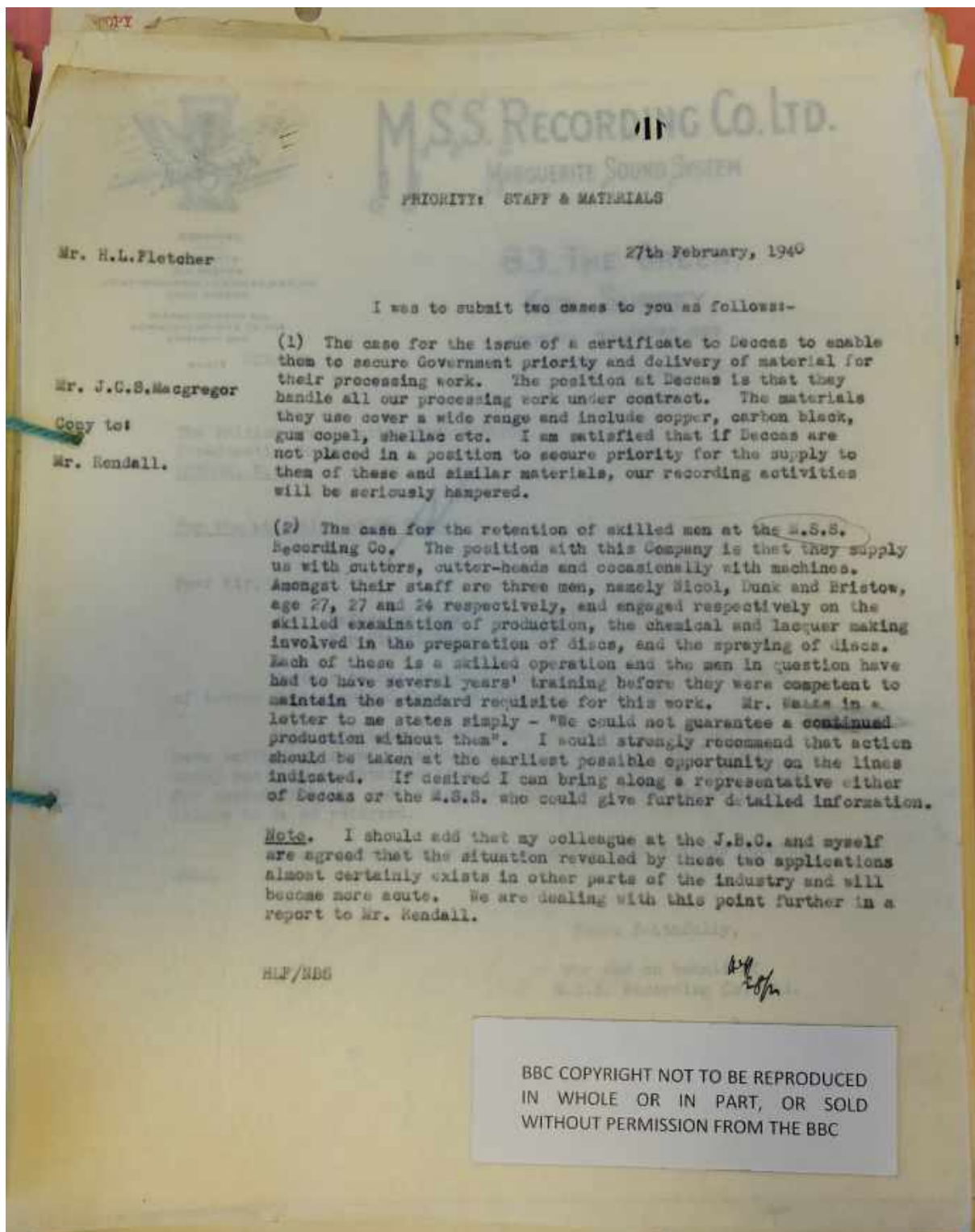


Figure 25 A correspondence from H.L. Fletcher to J.C.S. MacGregor outlining MSS' difficulties in finding qualified workers. BBC Written Archives Centre R57/194/7, 27 February 1940. Courtesy of BBC Written Archives Centre.

Notes

- 1 BBC Written Archives Centre R57/49/1, 24 January 1945; BBC WAC R57/49/1, 4th March 1946
- 2 BBC Written Archives Centre R57/49/2, 5 July 1946
- 3 Drack, 2000, 307
- 4 BBC Written Archives Centre R57/194/7, 30 October 1939
- 5 Degriigny and Schröter, 2018
- 6 Fink, May 1941, p. 21
- 7 BBC Written Archives Centre R57/49/1, 29 November 1943; BBC Written Archives Centre R57/49/2, 27 August 1945
- 8 Interview Martin Pulling, former BBC Deputy Director of Engineering, Oral history of recorded sound interview, rec. August 1984.
- 9 Interview Martin Pulling, former BBC Deputy Director of Engineering, Oral history of recorded sound interview, rec. August 1984; Interview Philip Monson, former BBC Engineer, Oral history of recorded sound, rec. June 1984.
- 10 Interview Philip Monson, former BBC Engineer, Oral history of recorded sound, rec. June 1984.
- 11 Interview Philip Monson, former BBC Engineer, Oral history of recorded sound, rec. June 1984.
- 12 BBC Written Archives Centre R57/194/7, 1 July 1940
- 13 BBC Written Archives Centre R57/194/7, 21 March 1939
- 14 BBC Written Archives Centre R57/194/7, 7 February 1940
- 15 BBC Written Archives Centre R57/194/7, 9 February 1940, 13 February 1940, 22 February 1940
- 16 BBC Written Archives Centre R57/194/7, 9 February 1940, 13 February 1940, 23 February 1940
- 17 BBC Written Archives Centre R57/49/2, 23 February 1940
- 18 BBC Written Archives Centre R57/194/8, 19 June 1941
- 19 BBC Written Archives Centre R57/49/2, 30 August 1946
- 20 BBC Written Archives Centre R57/49/2, 9 September 1946
- 21 BBC Written Archives Centre R57/194/7, undated c. May 1940

Recording procedures

The term direct-to-disc recording refers to the cutting of a soundtrack using a stylus that forms a groove. The recording parameters are a linear speed, a homogeneous cutting angle and cutting depth¹. Recording and reproducing sound characteristics depend largely on the material being cut. For instance, a difference in hardness between the discs will not produce the same result in the higher frequencies. The pressure is much higher with a hard surface, able to constrain the reproduction stylus to follow the groove at high frequencies whereas a softer disc will not².

Cutting stylus choice

There are many ways to assess the quality of a good cutting stylus: some technicians evaluate the shadow of its outline, others perform unmodulated cutting tests. Still, instantaneous discs required a different cutting stylus than wax discs. Developed in the 1930s by Frank L. Capps³ and modified in 1947 by Isabel L. Capps⁴, one of the cutting styluses used to cut lacquer discs is characterised by burnishing facets, a part of the stylus behind the cutting edge used to polish the groove walls (Figure 26-Figure 27) and reduce surface noise⁵.

The standards for the manufacture of a stylus are strict: the cutting edges of the tip are extremely sharp, free of imperfections and polished to achieve a very smooth surface. If the cutting edges are not sharp enough, the disc chip is ripped off. Rough cuts and walls cause excessive noise during the recording⁶. Additional parameters sought are a rounded tip and a radius smaller than reproduction styluses⁷.

The cheapest cutting stylus is steel-based, with very limited service life estimated at about thirty minutes⁸. Most professional styluses are made of corundum, commonly known as sapphire. The interesting properties of sapphire are its crystal structure and the ease of manufacture to obtain precise dimensions and angles while maintaining a very subtle cutting edge. The sapphire stylus, unlike the steel cutting stylus, is more efficient at recording high frequencies⁹.

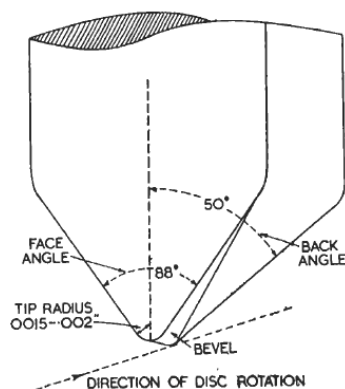


Figure 26 Sapphire stylus tip used at the BBC.

CREDIT BBC

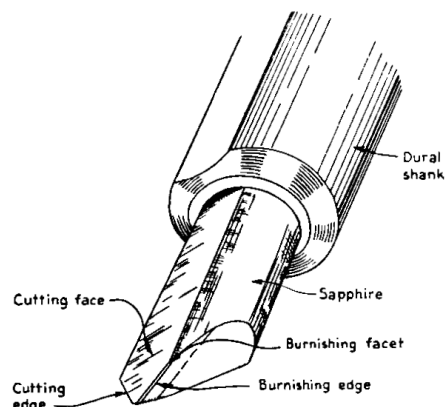


Figure 27 Perspective view of the stylus.

CREDIT Columbia Records

Angle and depth of cut

The best cutting angle is defined by trial and error experimentations¹⁰. Typically, the groove wall angle is 88 degrees +/- 5 degrees¹¹. The cutting angle depends on the type of recording-head, the material to be cut and the angle of the cutting stylus edges. An incorrect angle will increase surface noise¹². The cutting depth is determined by the width of the groove and adjusted to produce a groove/surface ratio of 2:1. This 2:1 ratio implies that the grooves must be twice as large as the remaining surface area¹³. A 50-50 cut is generally recommended, but a deeper cut and less modulation may be required in poor recording conditions such as an uneven turntable¹⁴.

Achieving a cutting depth under fixed conditions can be misleading: materials have different optimal cutting speeds, with varying angles dependent upon the quantity of material removed¹⁵. Cutting depth adjustment is also impacted by variations in material hardness, shape and the manufacturing accuracy of the stylus¹⁶. Also, irregularities in the coating will cause variations in the depth of cut¹⁷ and result in faster disc wear. The cutting depth is also influenced by the pressure on the recording head and by the climatic conditions. The effects of temperature on cellulose coating discs can be separated into two categories: either the heat softens the cellulose, or the cold hardens it¹⁸.

Table 5 BBC recording specifications

BBC recording specifications		
	inch	mm
Depth of cut (1946)	0.0025	0.0635
Groove radius (1954)	0.0015	0.0381
Pitch macrogroove (1954)	100 grooves/inch	
Tip radius (1954)	0.0025	0.0635
Width of the top of the groove (1950)	0.0056	0.1422
Spacing between unmodulated grooves (1950)	0.0028	0.0711
<small>Sources: BBC Recording Training Manual, 1950, p. 28; BBC WAC R57/46/4, 1st April 1946; BBC WAC R57/50, 1st December 1954</small>		

Cutting speed and disc diameter

The cutting speed, dependent on the rotation speed of the turntable and the diameter of the groove, is a key element to achieve accurate recording. There is a minimum cutting speed under which the recording of high frequencies is ineffective¹⁹. A major disadvantage is the loss of high-frequency response when the reproducing head approaches the centre of the disc. This loss of accuracy is the result of the groove diameter reduction and the loss of linear speed of the recorded groove²⁰.

The duration of radio broadcasts can vary from one minute for a report to over two hours for an opera. Discs of different diameters were used to meet these requirements²¹. For instance, Radio-Genève adopted discs with a diameter of 25 cm (10"), 30 cm (12") and 40 cm (16"). 30 cm diameter discs (12") have a maximum recording time of about 3.5-4.5 minutes. 17¼" disc diameter using 33 rpm speed instead of the usual 78 rpm enables to record on each side 15 minutes of programme²².

The recorder

The performance of a disc recorder relies on several parameters, with variations in cutting speeds, frequency responses, and amplitude distortions. The choice will depend on the recording conditions and the sound quality requirements. The list of professional recorders is extensive. The radio broadcasting studios were equipped with portable devices (BBC Midget specially developed during the Second World War for field recordings), massive high-fidelity recorders (BBC recording machine type D, Figure 28) not to mention models developed by Presto (e.g. Presto Model C).

Disc recording

Disc recording starts with a visual inspection of the disc to verify the flatness, the condition of the stylus and the recorder plug connections. Some machines can bring the cutting stylus to a controlled uniform temperature. A cut test is generally carried out to ensure that the surface noise is low²³. Chips or swarf, which can be seen as similar to a photo negative, are removed during the cut to prevent the stylus from being damaged. The removal of the thread is critical when considering that a 15-minute recording is equivalent to a 400-metre long thread (0.25 mile). Different swarf removers were used: brushes, pads or vacuum systems on professional recorders²⁴.

Microscopes (x10, x60) were operated to control the groove cutting, ensuring smoothness of the cut, good cutting depth and sufficient spaces between the grooves to prevent interference (Figure 30)²⁵. BBC engineers' cutting instructions were the following: under the microscope, the surface appears bright, the groove walls are dark, and a fine white line in the centre indicates the bottom of the groove²⁶. Additionally, a good chip separation is identified by a shiny surface, assimilated to low surface noise²⁷.

Various procedures were implemented to ease recording, playback and to extend the lifespan of the disc. Dust particles on the blank disc surface, which deposited during manufacture, cause a slight click during recording and defective reproduction²⁸. The particles are removed by blowing or with a soft cloth to prevent dust accumulation under the cutting stylus²⁹. Newly recorded discs were cleaned with a soft camel brush to remove chips and dust residues³⁰. Since the electrostatic charges of the disc interfered with the removal of chips, a common practice at the BBC was to apply an antistatic fluid with camel skins³¹. The disc was also oiled and lubricated after recording to increase wear resistance, reduce surface noise and facilitate reproduction³². Several solutions were used by broadcasters to lubricate the surface, such as a mixture of acetic acid and oil or medical liquid paraffin applied using a felt pad³³. The application of these different oily solutions remained problematic: the surface of the disc was not intended to be touched before cutting and cellulose absorbs oil in proportion to the porosity of the coating. Finally, oil attracts dust that inevitably scratches the tip of the reproduction stylus³⁴.



CREDIT BBC

FIG. 51. BBC DISK RECORDING EQUIPMENT, TYPE D

Figure 28 Disc recorder, Model BBC Type D.



CREDIT Ar RSR, Genève, PRGE 9.39

Figure 29 A row of disc recorders at the 1948 Olympic Games in St. Moritz.



CREDIT Radio-Actualités, 1945

Figure 30 A Radio-Genève technician monitors the work of the stylus.

Surface noise

Surface noise is the consequence of several factors: a too deep cut that reaches the metallic base, overly dry cellulose coating or the use of a worn stylus. A dry disc is recognised by chips that detach in powder and does not present a flexible, bright continuous thread³⁵.

Additionally, the recording produced a slight ridge, a horning of material at the top of each groove wall left by the cutting stylus (Figure 31)³⁶. A BBC R&D report on surface noise suggested that as the groove was subjected to internal or external pressure, the ridges deformed and increased the surface noise during reproduction. The ridges are mainly distorted by pressure during storage³⁷.

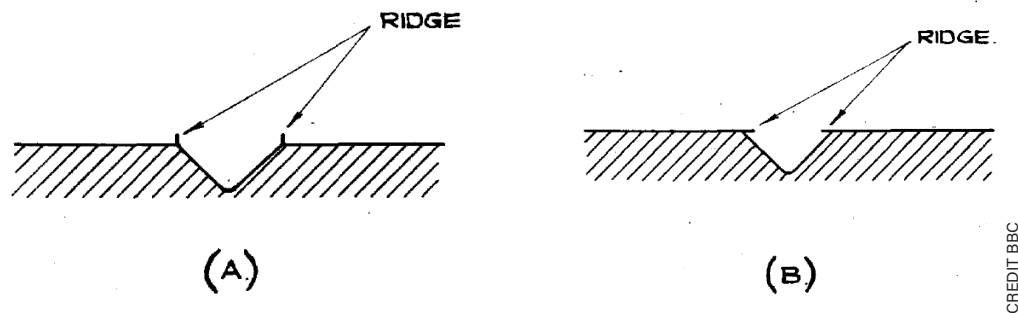


Figure 31 Ridge formed by the stylus during the cutting process. The ridges are still intact (a). The ridges were deformed and folded back into the groove (b), increasing surface noise.

Disc reproduction

The BBC used sapphire (rather than steel) styluses for disc reproduction both for technical and economic reasons. Reproduction styluses feature a radius larger than the groove to prevent touching the bottom of the groove, which could cause the groove to wobble without correctly following the modulation³⁸. From the 1930s to early 1940s, Radio Lausanne and Radio-Genève specified on their disc labels that the reproduction styluses were curved (Figure 32) as *“the wear of acetate disc is no greater than that of standard commercial discs”*³⁹.



Figure 32 Radio-Genève (1942) and Radio-Lausanne (1937) labels specifying the use of special reproduction styluses.

Microscopic groove examination

The study of the groove using microscopes enables to observe details, variations in the groove width and the sound wave. This visual method develops hypotheses as to the type and recording conditions of the cutting stylus. Research leads can be used to diagnose sound rendering and developed to assess visually the sound characteristics.

An article by Capps (1948) described the visual characteristics of the groove as shiny, with an uninterrupted line at the bottom of the groove, provided that the material is exempt from foreign particles⁴⁰. The groove shape has also evolved: from a relatively rounded U-shaped section at first, the V-shaped groove gradually became the norm from 1936 onwards⁴¹. The depth of cut, associated with the width of the groove, is set by the radius of the reproduction stylus tip and the signal level used during recording⁴².

The following observations are retrieved from a Radio Corporation of America (RCA) archive (Figure 33) illustrating grooves cut without modulation, a reliable indication of possible surface noise⁴³. Each illustration is associated with the condition of the stylus affecting the quality of the sound reproduction.

Data acquisition

The groove fragments were collected from the same discs used for the chemical study (Table 6). The samples were observed under a Scanning electron microscope (SEM)⁴⁴. SEM images provide a high-resolution visualisation of the surface texture of the disc. Visuals were taken perpendicular to the surface of the disc, the same setup as used in the 1940s and 1950s to verify the grooves condition using the microscope attached to the recorder.

Table 6 The 10 samples collected from 5 different types of coating

Manufacturer	Year*	Accession number (Sample number)	Conservation state
Simplat (UK) or Simplex (NL)	1936/1945	H28 (5), P4506 (4)	Peeling
Pyral ersatz (FR)	1944	13674 (7), 15930 (8)	Cracked (parallel and perpendicular)
Pyral, zinc-based (FR)	1946	DN4639 (10), 20378 (11)	Peeling (10), blisters
Thorens 2 nd generation (CH)	1942	7399 (13)	Cracked (parallel and perpendicular)
Thorens 3 rd generation (CH)	1945, 1946	DX4624 (16), DN4626 (18), DW4621 (21)	Peeling Flaking
*recording year			

Results

The results identify mainly technological traces, especially the type of cutting stylus used. A recurrent observation in the groove geometry is the aggregation of thin parallel cuts on the groove walls. Frequently found in the RTS collection, this characteristic was also observed at INA during the Saphir project. Hypotheses for the origin of these parallel cuts include marks left by the machining process of the cutting stylus, the coating hardening resulting in stratification, or the wear induced by mechanical reproduction⁴⁵.

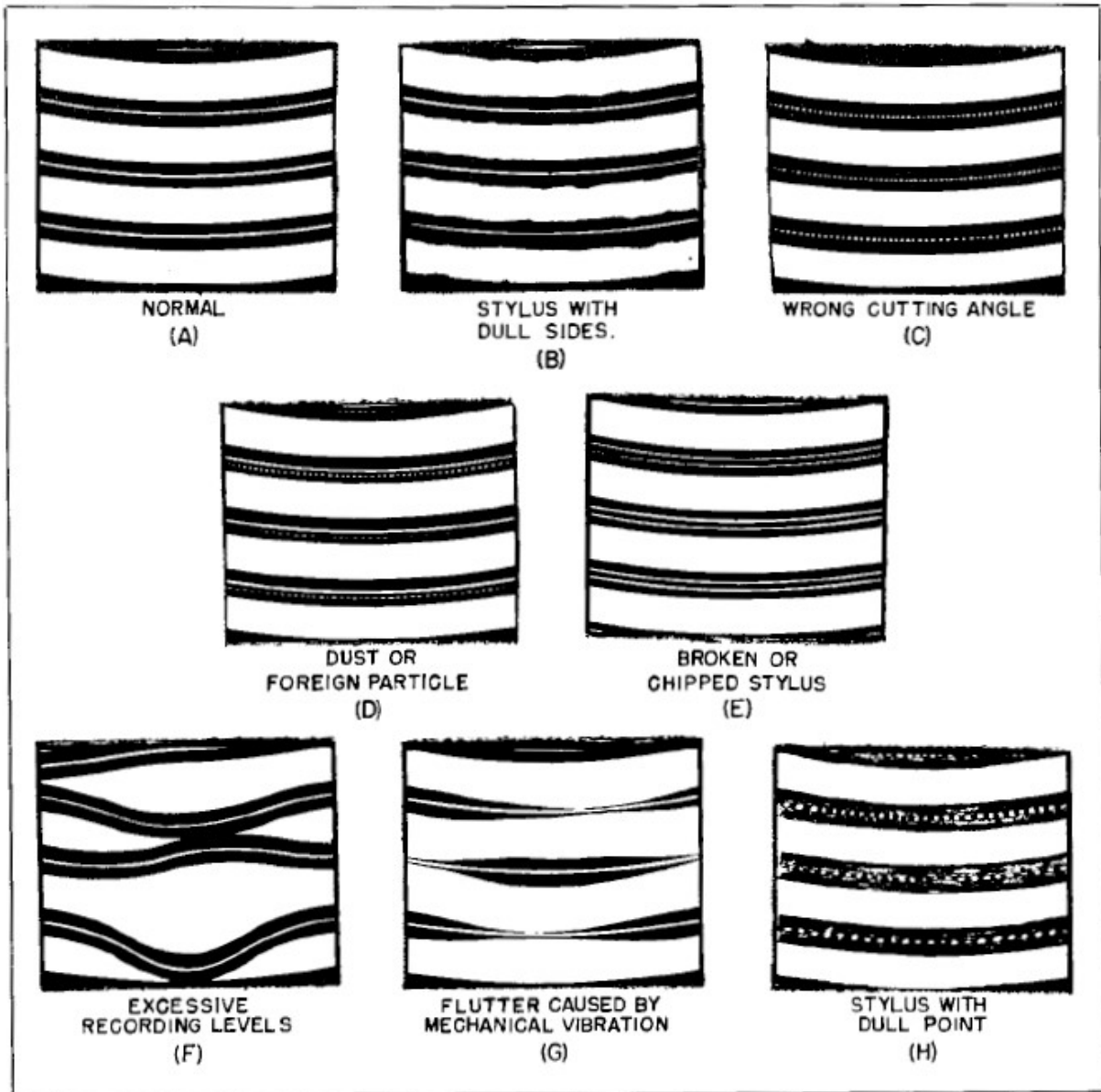


Figure 33 Characteristics of macrogrooves. All the grooves, except F, were cut without modulation.

CREDIT RCA, Read

SEM micrographs: Glass substrate, gelatin coating (Simplat or Simplex manufacturer)

The two SEM images were taken from the same Radio-Genève disc. Each side was recorded at distinct times: the A-side (accession number H28) was recorded in 1936, the B-side (accession number P4506) in 1945. Variations in recording parameters are apparent: the cutting depth is deeper in 1945. A small ridge formed by the cutting stylus on one of the edges of the groove is noticeable on the A-side micrograph, a phenomenon known as horning. Additionally, the A-side has a U-shaped profile with a wide line at the bottom of the groove.

The modulated groove on the B-side presents evidence of tearing, with the coating showing signs of irregular cutting. The cause is either the use of a steel cutting stylus or periods of high modulation at high frequency. The steel stylus is a hypothesis based on the specifications of the Simplat disc manufacturer, which stated that using a steel stylus often produced a rough, shredded edge resulting in surface noise and sound distortion⁴⁶.

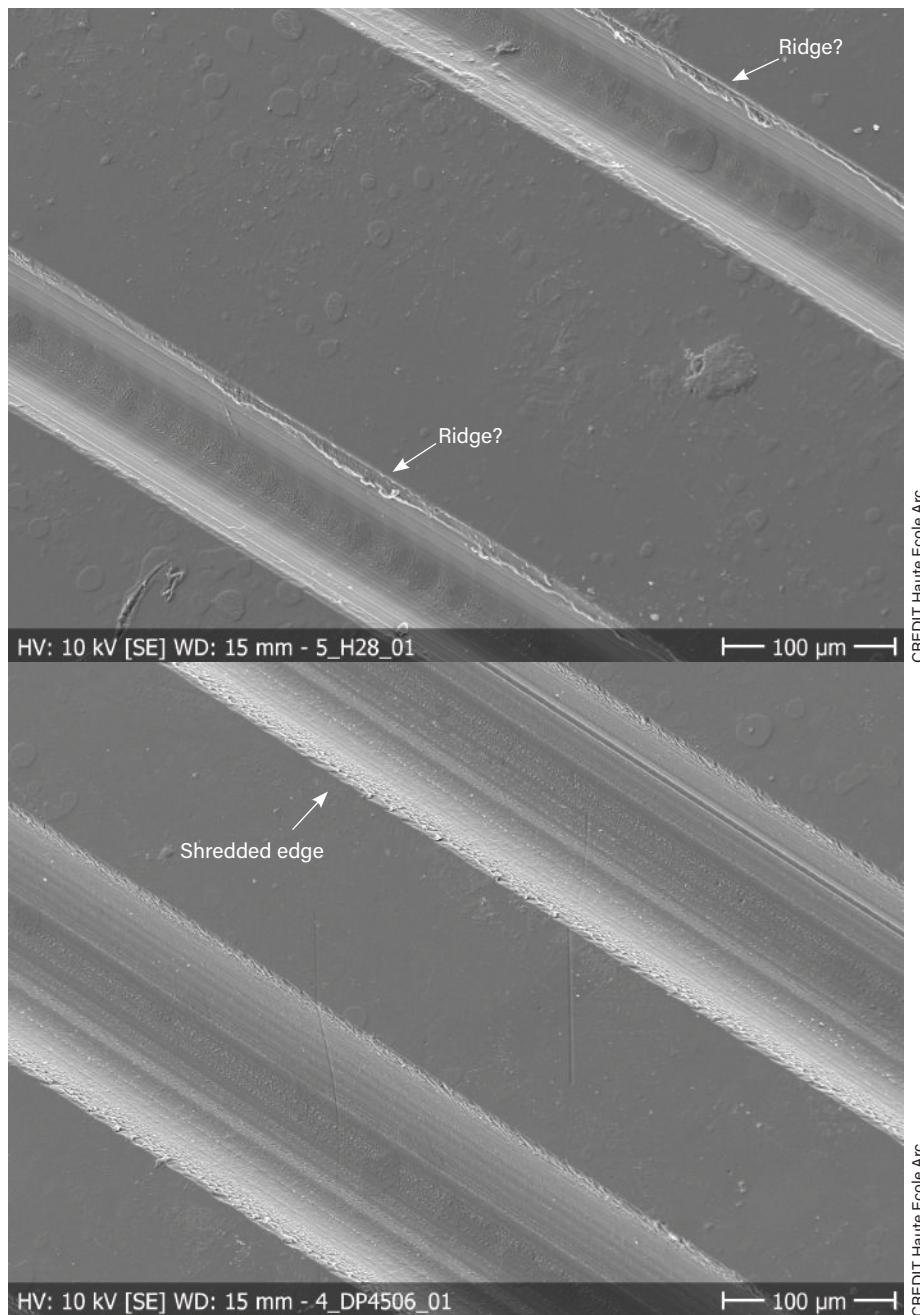


Figure 34 SEM micrographs of the same Simplat disc gelatinous coating.
A-side, accession number H28 (*Course de l'Escalade*, recorded in December 1936).
B-side, accession number P4506 (*Les chevaliers du Roy*, recorded in February 1945).
1 diffusion date

SEM micrographs: Pyral aluminium and zinc-based discs, cellulose nitrate coating

The electron micrograph of the aluminium-based Pyral coating sample (with palmitic acid) shows micro-pores caused by the exudation of the plasticiser⁴⁷. Zinc-based Pyral sample reveals a pore-free coating, without visual evidence of plasticiser loss.

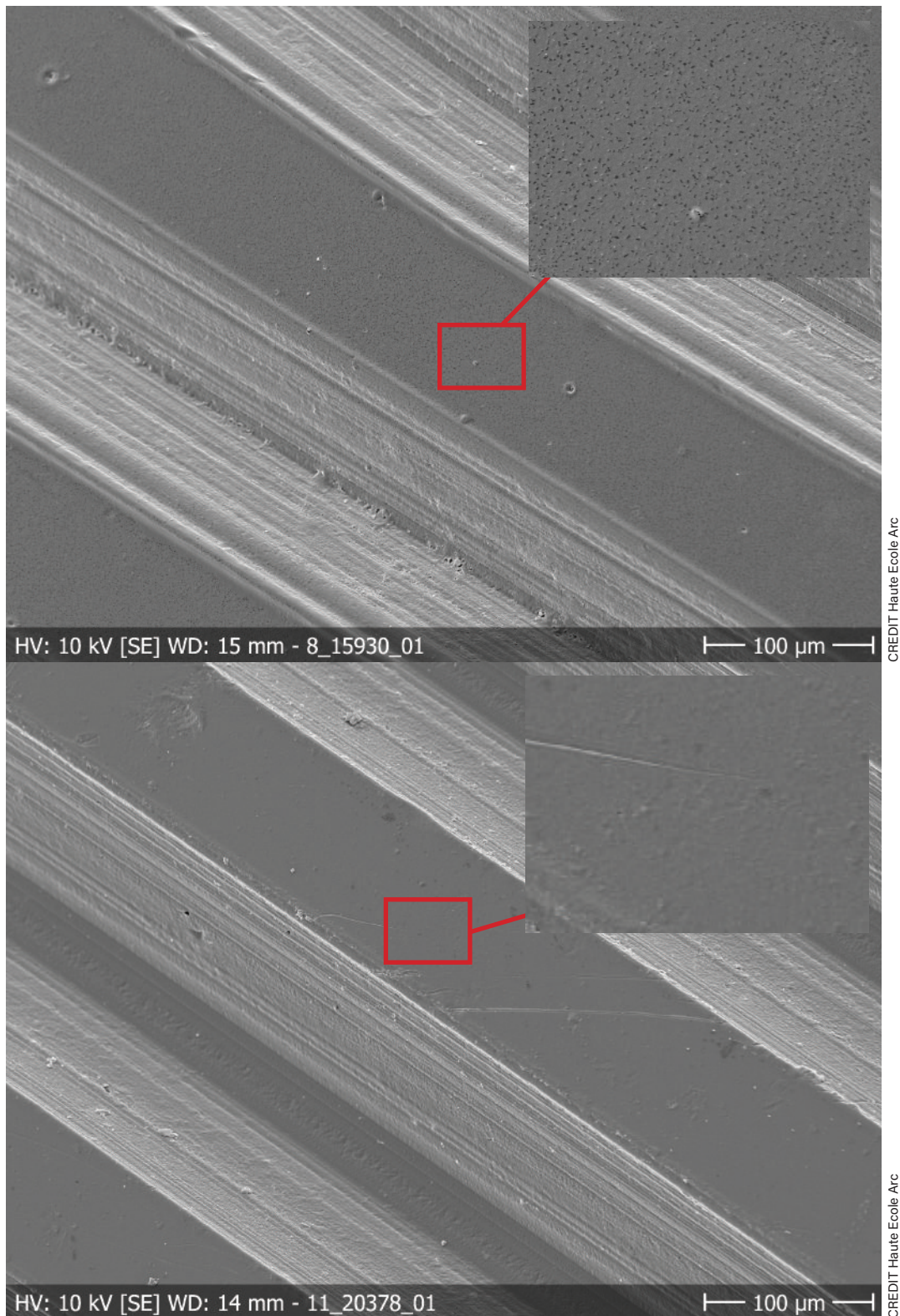


Figure 35 Up) SEM micrograph of Pyral ersatz coating, 1945. Micro-pores, dust and walls of the striated grooves. 1 diffusion date. Radio-Lausanne, accession number 15930 *Reportage sur le procès du Maréchal Pétain: impression d'audience*, Ed. Dubois, 13 August 1945. Down) SEM micrograph of Pyral zinc-based disc coating, 1946. Striated walls, pore-free. 1 diffusion date. Radio-Lausanne, accession number 20378, *Voici Paris*, no 3, 11 July 1946.

SEM micrographs: Aluminium Thorens disc, cellulose nitrate coating

SEM micrographs of the 2nd and 3rd generation coatings of Thorens discs have two distinct surface typologies: a bubbled surface (2nd generation, recorded in 1942) and a more homogeneous surface (3rd generation, recorded in 1946). In both cases, the recorded groove left technological traces, such as striated walls and presumably ridges. The groove walls of the 3rd generation disc coating presents a ripped surface.



Figure 36 SEM micrographs. Up) Thorens, 2nd generation disc, 1942. Bubbled surface. 1 diffusion date. *Radio-Lausanne*, accession number 7399, *Bon dimanche, radio theatre*, 19 February 1942. Down) Thorens, 3rd generation disc, 1946. Smooth and homogeneous surface. *Radio-Genève*, accession number DX4624. *Un quart d'heure avec Norbert Glanzberg*, 14 June 1946.

USB micrographs: recording conditions

Using a USB computer microscope (Dino-Lite Premier model) distinguishes the various recording conditions. A succession of small lines evenly spaced can be observed at the bottom of the groove on the first micrograph (gelatin coating, Figure 37). Compared to the RCA archive, the origins of this phenomenon are either a wrong cutting angle, a worn stylus tip or dust (Figure 37). Observing Figure 38, the overlap of the groove may have been caused by excessive recording levels.

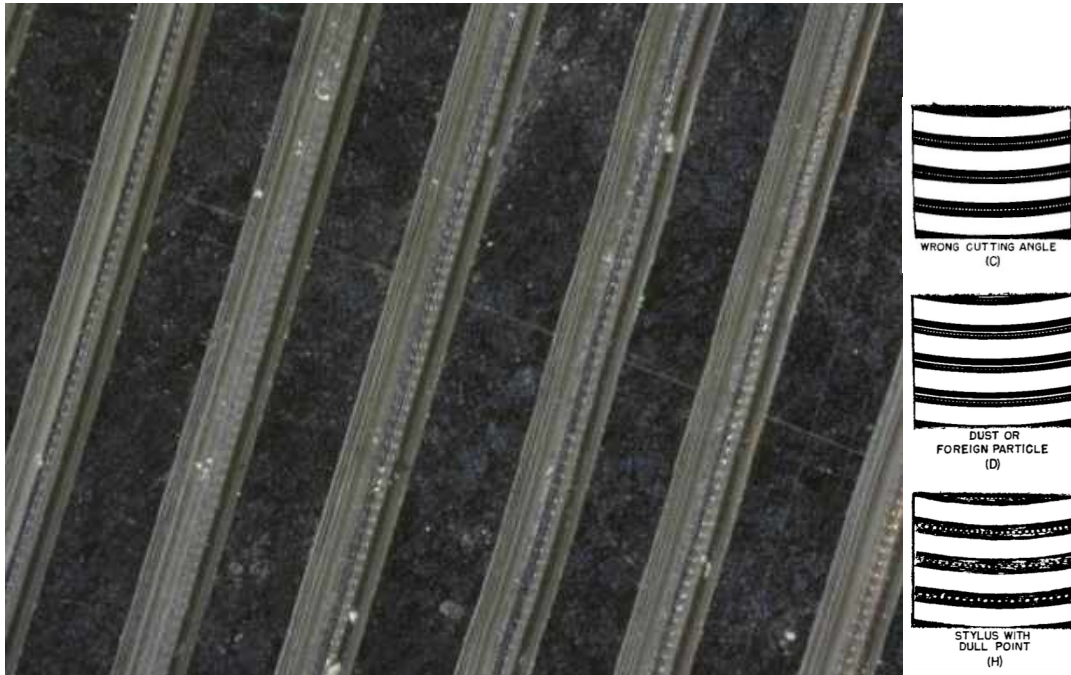


Figure 37 Gelatin coating of glass-based disc Simplat, USB micrograph, 250x.
Evenly spaced lines at the bottom of the grooves.

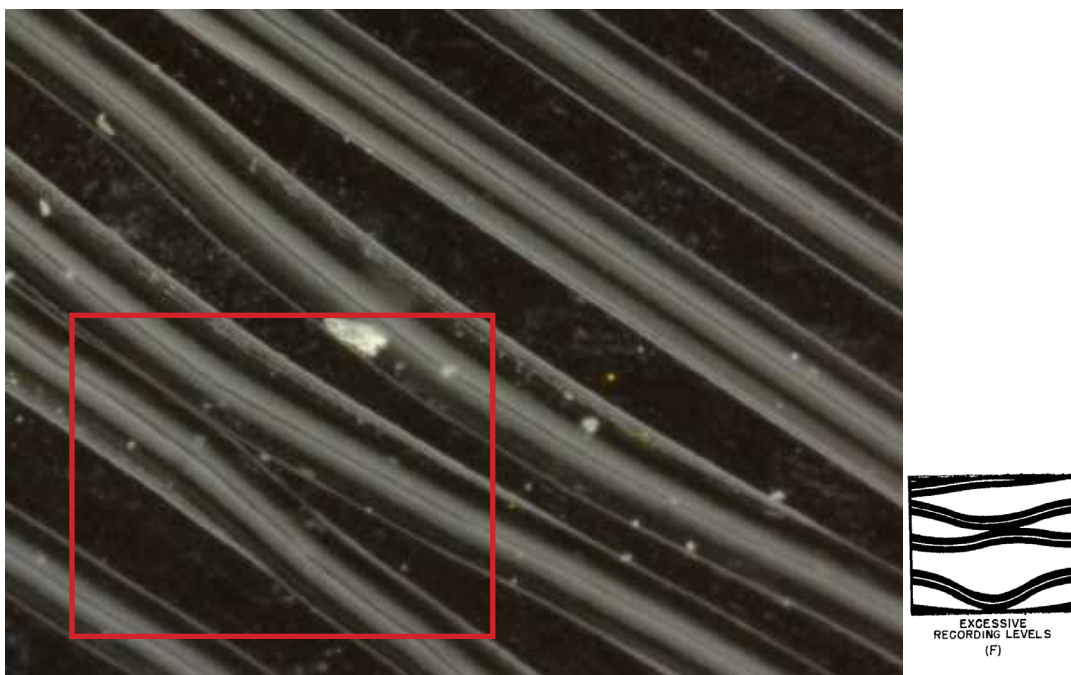


Figure 38 Cellulose nitrate coating on aluminium-based disc, USB micrograph, 250x.
Excessive recording level.

USB micrographs: cutting depth evolution

An evolution in the cutting depth is partially established for the same recording studio using the USB microscope. The discs recorded between 1940 and 1942 at Radio-Lausanne are characterised by numerous parallel striations on the walls and a substantial depth of cut, regardless of the material (cellulose nitrate or gelatin) or the manufacturer (Figures 39-44).



Figure 39 Thorens, 1st period, 4596, 1941.
USB micrograph, 250X. Radio-Lausanne, 4596, *Evocation Le fils de l'empereur: Cérémonie du baptême*, 19 March 1941.

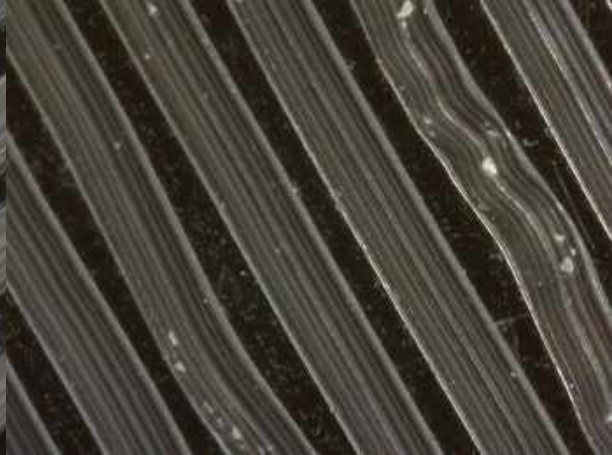


Figure 40 Pyral zinc-based, 130IX, 1940.
USB micrograph, 250X. Radio-Lausanne, 130IX. *Emission Radio-Scolaire, Complainte de la reine Berthe*, 16 February 1940.

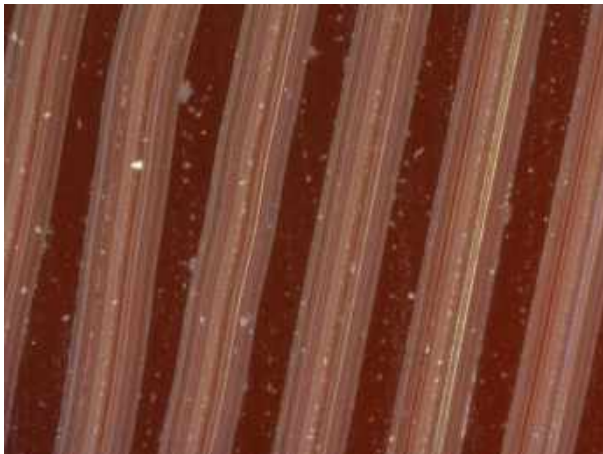


Figure 41 Gevaert, 8632, 1942. USB micrograph, 250x.
Radio-Lausanne, 8632. *Le Quart d'heure du sportif*, 18 September 1942.

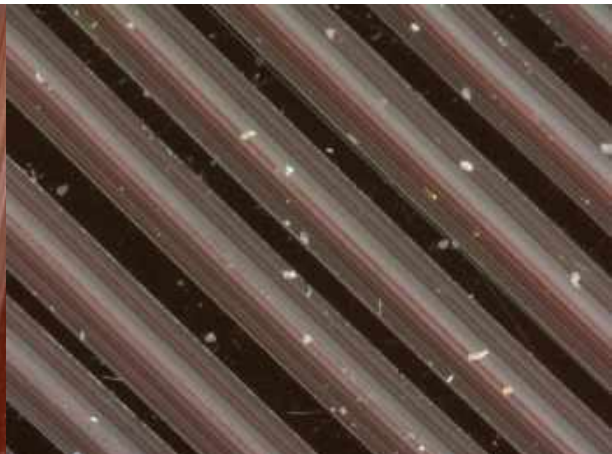


Figure 42 Pyral ersatz, 1941. USB micrograph, 250x



Figure 43 Presto lacquer Q, 606VI, 1940.
USB micrograph, 250x.
Radio-Lausanne, 606VI, *Revue « Sans fil ni ficelle » no IV*, 04 July 1940.

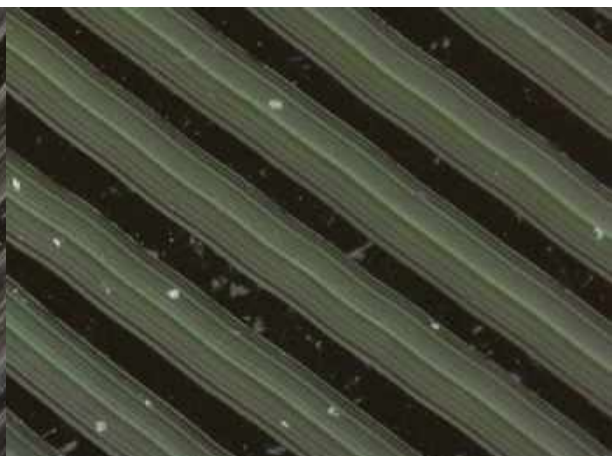


Figure 44 Audiodiscs, ATP32, 1941.
USB micrograph, 250x.
Radio-Lausanne, ATP32, *Choeur d'ensemble du IVe arrondissement*, 18 May 1941.

USB micrographs: cutting depth evolution and translucency

As early as 1945 at Radio-Lausanne, the parallel striations were not as marked on the groove walls and the depth of cut was shallower (Figure 45-Figure 50). The translucency of Thorens yellow coating (Figure 45-Figure 46) prevents a clear distinction of the groove geometry. This translucency is currently the main hypothesis to explain the inability to optically digitise Thorens discs with photo-based methods (VisualAudio), causing overexposed photographs. Green Thorens coatings (Figure 47-Figure 49) improve considerably the groove geometry outline.



Figure 45 Thorens 3rd period, yellow, 16634, 1945.
USB micrograph, 250X. Radio-Lausanne, 16634. *Cinémathèque française, Exposition: images du cinéma français, 11 September 1945.*

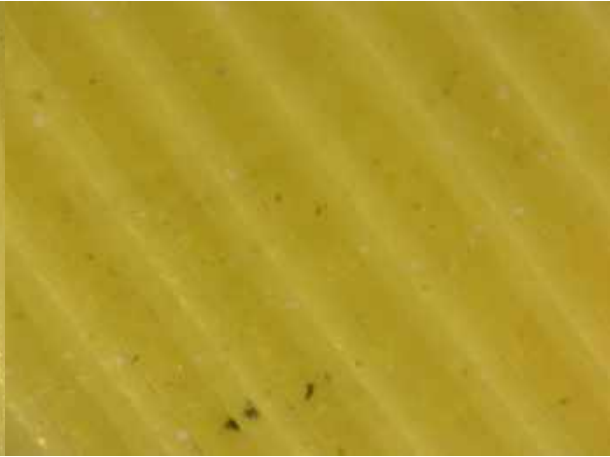


Figure 46 Thorens 3rd period, yellow, 19198, 1946.
USB micrograph, 250X. Radio-Lausanne, 19198. *Au palace de Beau-Séjour, by Albert Itten, January 1946.*

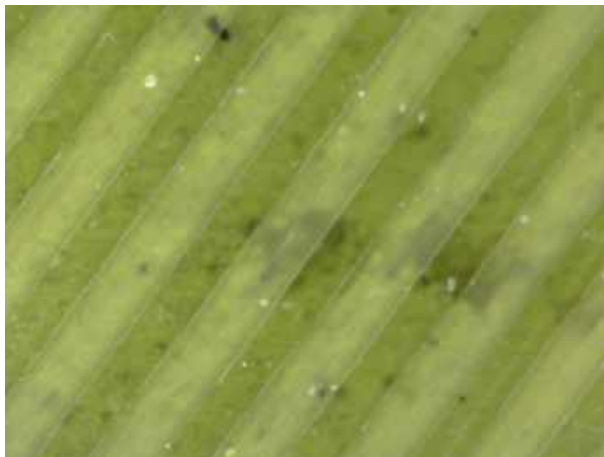


Figure 47 Thorens 3rd period, green, 23630, 1947.
USB micrograph, 250X. Radio-Lausanne, 23630.
Chorale ouvrière Le Réveil, 22 April 1947.

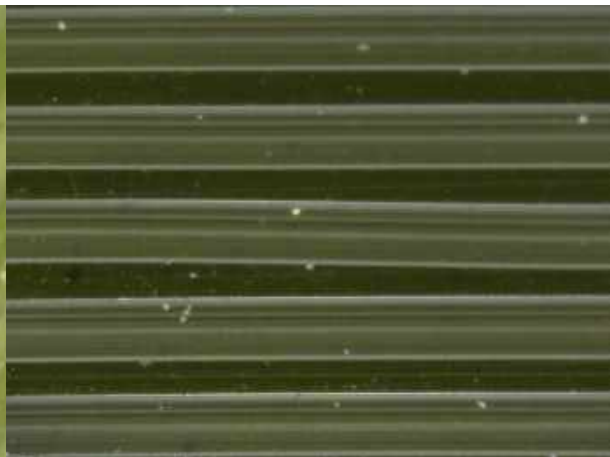


Figure 48 Thorens 3rd period, dark green, 23677, 1947.
USB micrograph, 250X. Radio-Lausanne, 23677, *Forum Radio-Lausanne: La situation des ouvriers dans le monde, 28 April 1947.*

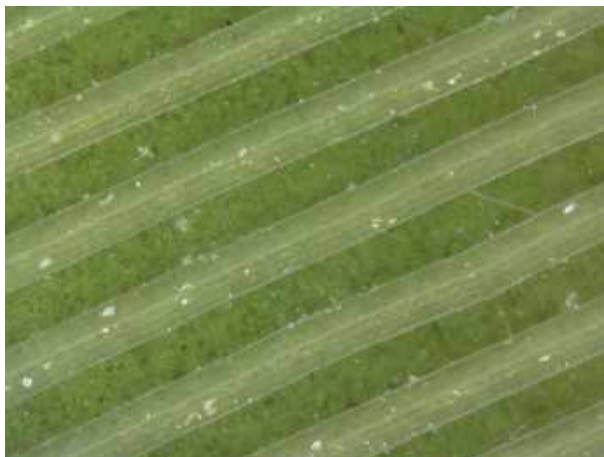


Figure 49 Thorens 3rd period, green, 41100, 1947.
USB micrograph, 250X.
Radio-Lausanne, 41100, *Folklore de l'Inde: musique musulmane, 1947.*

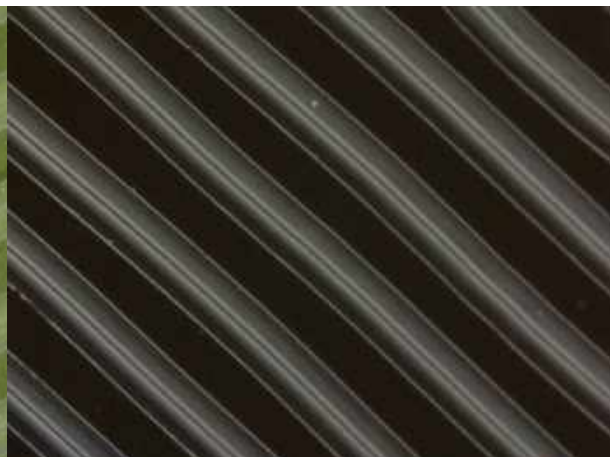


Figure 50 Presto Green Label, USB micrograph, 250X
Radio-Lausanne, R98. *Chœur des Alpes Montreux, 09 March 1949.*

USB micrographs: cutting practices

Significant differences in cutting practices by the same recording studio are apparent for the same type of coating. The following gelatin-coating examples provide an overview of a shallow and wide cutting depth on discs recorded respectively in 1938, 1940 and 1941 by Radio-Lausanne.



Figure 51 Simlat/Simplex, 88VII, 1938. USB micrograph, 250x.
Radio-Lausanne, 88VII, *Farinet ou l'or dans la montagne*, 06 September 1938.



Figure 52 Simlat/Simplex, 2865, 1940. USB micrograph, 250x.
Radio-Lausanne, 2865, *Tristan et Yseult*, radioplay, 19 October 1940.

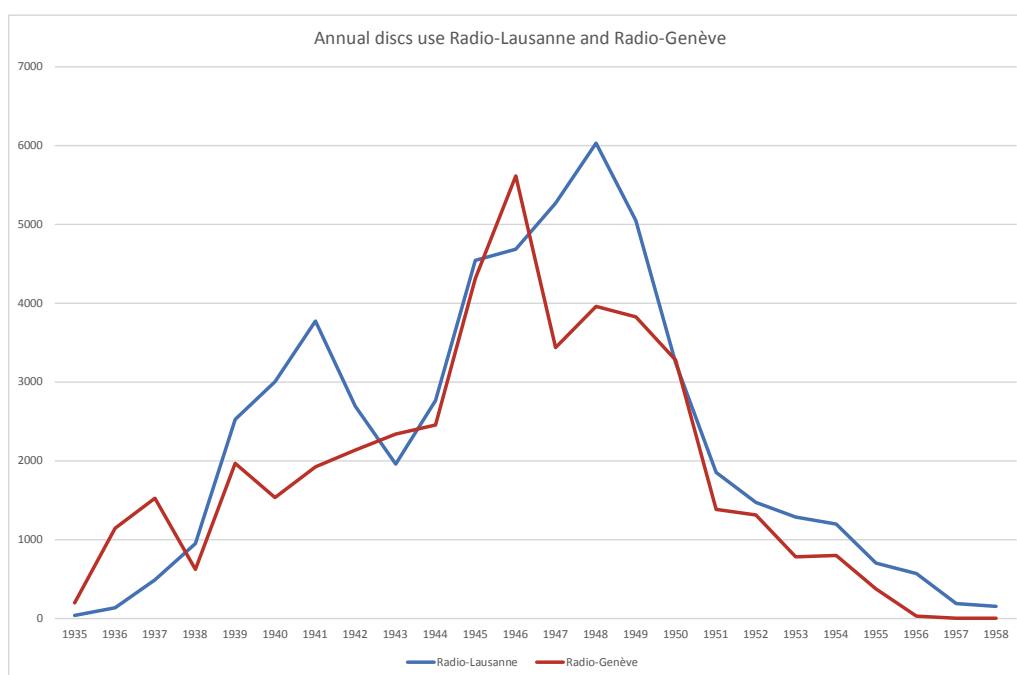


Figure 53 Simlat/Simplex, 5041, 1941, USB micrograph, 250x.
Radio Lausanne, 5041, *L'air du temps*, no 9, 16 April 1941.

Notes

- 1 Brock-Nannestad, 2012, p. 21
- 2 BBC Written Archives Centre R57/46/1, 14 November 1941
- 3 US2,187,512A, Frank L. Capps, patent filed in May 1937
- 4 US2,530,284A, Isabel Capps, patent filed in November 1947
- 5 Capps, 1948
- 6 Read, 1952, p. 103
- 7 Copeland, 2008, p. 50; Davies and Terry, 1942
- 8 Read, 1952, p. 105-106
- 9 Guild Staff, 2014; Read, 1952, p. 106
- 10 BBC Written Archives Centre R57/46/10, 6 March 1950
- 11 Guild Staff, 2014; Davies and Terry, 1942, p. 2
- 12 Read, 1952, p. 107
- 13 BBC Written Archives Centre R57/46/8, 5 July 1948; BBC, 1950, p. 28
- 14 Read, 1952, p. 65
- 15 BBC Written Archives Centre R57/49/2, 29 June 1945
- 16 Davies and Terry, 1939, p. 2
- 17 Read, 1952, p. 64
- 18 BBC Written Archives Centre R57/46/10, 6 March 1950
- 19 BBC, 1950, p. 25-26
- 20 BBC, 1950, p. 24-25; Read, 1952, p. 109
- 21 BBC, 1950, p. 28
- 22 BBC, 1950, p. 24, 28
- 23 Guild Staff, 2014
- 24 Davies, 1947, p. 288; BBC, 1950, p. 74; Guild Staff, 2014
- 25 Guild Staff, 2014
- 26 BBC Written Archives Centre R57/46/8, 5 July 1948; BBC, 1950, p. 28
- 27 Brock-Nannestad, 2012, p. 21
- 28 BBC Written Archives Centre R57/46/2, 11 August 1944, 6 February 1946
- 29 Ord-Jolly, 29 October 1937, p. 428; BBC WAC R57/50, 1 December 1954
- 30 BBC WAC R57/50, 1 December 1954; R57/352/1, undated; Wireless World, 19 March 1937
- 31 BBC Written Archives Centre R57/49/1, 29 September 1942; R57/49/2, 29 June 1945, 27 August 1945, 6 February 1946; Powell, 1945
- 32 BBC Written Archives Centre R57/49/2, 5 July 1946
- 33 Barrett and Davies, 1937, p. 2; BBC Written Archives Centre R57/49/1, 29 September 1942
- 34 BBC Written Archives Centre R57/49/2, 24 December 1946; Wireless World, 19 March 1937
- 35 BBC Written Archives Centre R57/46/10, 6 March 1950
- 36 BBC Written Archives Centre R57/50, 1 December 1954; R57/352/1, undated; Powell, 1945
- 37 Powell, 1945
- 38 BBC Written Archives Centre R57/46/9, 1 March 1949
- 39 L'électricité en 1939, 1941, p. 162; Prongué, 2010
- 40 Capps, 1948
- 41 Copeland, 2008, p. 109
- 42 Read, 1952, p. 111
- 43 Read, 1952, p. 108
- 44 The SEM visuals were taken by Stephan Ramseyer, technical collaborator at the Haute Ecole Arc Ingénierie.
- 45 Chenot, Laborelli and Noiré, 2018, p. XX:13
- 46 Research staff of V.G. Manufacturing Recording, Wireless World, 19 March 1937, p. 275
- 47 Pickett and Lemcoe, 1959, p. 23

RTS collection discs



Graph 3 Annual overview of lacquer discs, Radio-Genève and Radio-Lausanne.
Sources: Radio-Lausanne Sonoweb; Radio-Genève: 1935-1958 registers.

Radio Télévision Suisse collection comprises the transcription lacquer discs from the Société Romande de Radiodiffusion Lausanne (SRR) and Société des Émissions de Radio-Genève. One of the first records held by Radio-Lausanne is a news report on Walter Mittelholzer's expedition to Abyssinia and Palestine on 13 February 1935 (Domophon records). Radio-Genève's first archived disc is dated 29 October 1935, a report on the Maison Genevoise by Marcel Suès.

Graph 3 presents the differences in disc consumption between Radio-Lausanne and Radio-Genève. The discrepancy between the two studios from 1935 to 1938 (Graph 3) is a consequence of records management. Since 1935, Radio-Genève registered all the discs in indexes. Radio-Lausanne has not retained such track of the records data. Only the discs that survived can be counted.

Radio-Genève made no recordings between 4 February 1938 and 9 May 1938, resulting in a consequential drop in production¹. Between 1941 and 1943, Radio-Lausanne experienced a significant decline, likely caused by the end of the 1930s stockpile and wartime weakened production. Peak disc consumption was reached in 1946 at Radio-Genève and in 1948 at Radio-Lausanne. That same year, the decline of the disc was observed for both studios, gradually replaced by magnetic tapes. The last lacquer discs were recorded in 1958.

Labels and manufacturers

Both studios used a wide range of international disc manufacturers and trade names:

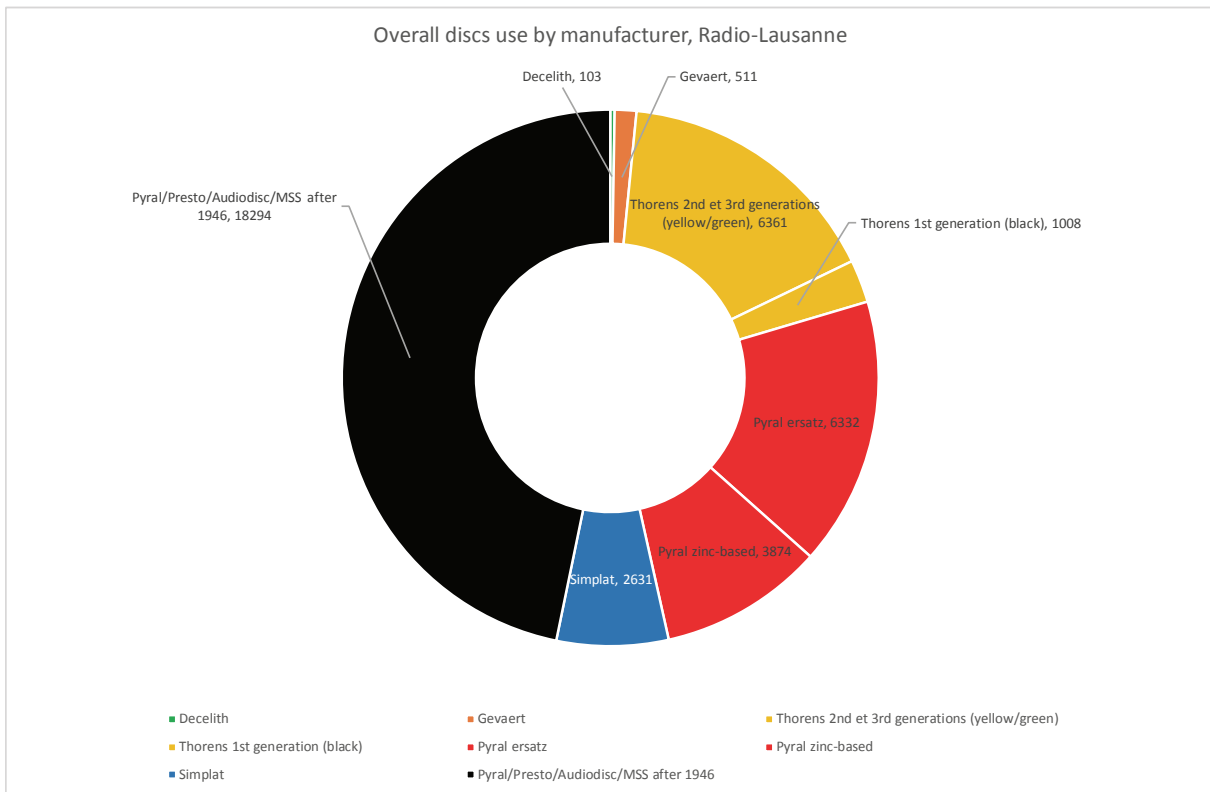
- Audiodiscs (Audio Devices): cellulose nitrate on aluminium,
- Decelith (Deutsche Celluloid-Fabrik): polyvinyl chloride (PVC),
- Gevaphone (Gevaert): cellulose nitrate on aluminium or glass,
- MSS: cellulose nitrate on aluminium,
- Presto: cellulose nitrate on aluminium or glass,
- Pyral: cellulose nitrate on aluminium or zinc,
- Simplat (V.G. Manufacturing Co.)/Simplex (Ramie Union): gelatin on glass,
- Thorens: cellulose nitrate on aluminium.

As there are no records of acquisition at Radio-Lausanne, the proportion of manufacturers cannot be precisely established. Based on 39,000 inventoried discs, the estimates suggest a preference for the disc manufacturers Pyral, Thorens, and Simplat (Graph 4). The acquisition registers of Radio-Genève (Figure 54) are primary sources to assess records use by manufacturers from 1941 onwards. 29% of the collection is composed of Thorens discs, followed by the English manufacturer MSS (28%) and Pyral (15%). MSS accounts for the bulk of disc consumption between 1949 and 1955 (Graph 5). The acquisition ledgers do not contain information on the type of manufacturer between 1935 and 1940 and only 29 discs have been preserved in the collection dating from that period.

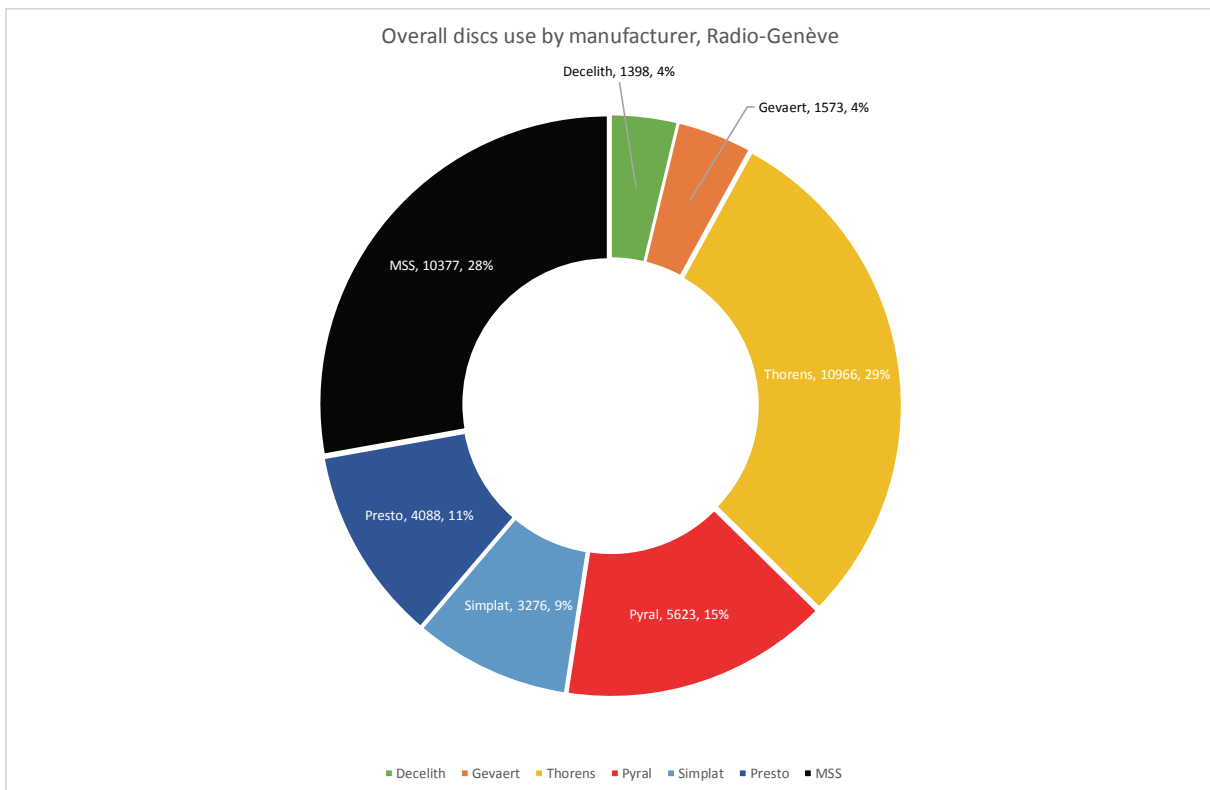
Date	N°	Titre	Subtype	Devis	Nbre	Type	R	Tow	Pos	Enreg.	Op.
21-11	A 4317	Bonjour, ma Bé		25	1	3	27	21	231	1944	K
22-11	B 4317	Bonjour, ma Bé		25	1	3					R
	C 4317	L'horoscope des Russes par F. Gaud		11	3	6	20				R
	D 4317	Discs pour l'abonnement des postes [N. de la rue - Henriette M. Pige]		7	2	3	25				R
18-11	E 4317	Je t'aime - La M. Crystaline	avec voix	51	2	3					R
	F 4317	Donnez-moi le monde à l'écoute [avec 2.2. Disk [par Gaud] - 214 et 211/12 - Contact 222 (Gaud)]		25	2	3					R
14-11	G 4317	Je t'aime - ma Bé		27	3	6	20				R
	H 4317	Conférence: Gendres, VIE [opérateur] - enregistré par H. Schenker	imp. disque	11%	3	6	20		R	VR	R
12-11	J 4317	Ensemble de Radio-Genève [du 22-11] et du 21-11-41		51	2	3			231	1944	R
	K 4317	Chœur de voix supérieures de l'école primaire de Genève-Deley [par F. Gaud]		77%	3	0					R
	L 4317	Les négrinautes du genre [Négrinautes du genre] enregistré par F. Gaud		8	2	3			R	VR	R
12-11	M 4317	F. Gaud - Bébé - Aimée - Je t'aime	avec voix soliste	29%	2	3	24		231	1944	R
	N 4317	Maitrise post-traitée [par R. Vernet]		27	2	0	28				R
11-11	P 4317	Le monde [et ses machines populaires - Lathrop] - int. par H. de St		2	2	3			10	VR	R
	Q 4317	Les de feuille		14	4	2					R
	R 4317	M. Gaud - Je t'aime [enregistrement de H. Henner] - int. par M. de St		8	2	3					R
21-11	S 4317	MSS - Bébé - Roger et M. de Fournet [avec accompagnement] int. par F. Gaud		26	2	3			231	1944	R
	T 4317	Amélioration de l'écoute - par H. de St - H. de St - H. de St [avec Jean Gaud]		7	2	3					R
	U 4317	Je t'aime - ma Bébé [avec - Aimée - Jean de St - Gaud] par M. de St		21	3	3	20				R
18-11	V 4317	Je t'aime		23	1	3	20				R
18-11	W 4317	Je t'aime	Q6	8	2	3					R
11-11	X 4317	Je t'aime - ma Bébé - Aimée [avec H. de St]		27	2	3					R
	Y 4317	Bonjour, ma Bé		25	1	3					R

Figure 54 Extract from the 1943 register of Radio-Genève

Trends can be observed regarding the period of use of the main manufacturers:



Graph 4 Discs use by manufacturers at Radio-Lausanne. Estimates based on 39,000 inventoried discs.



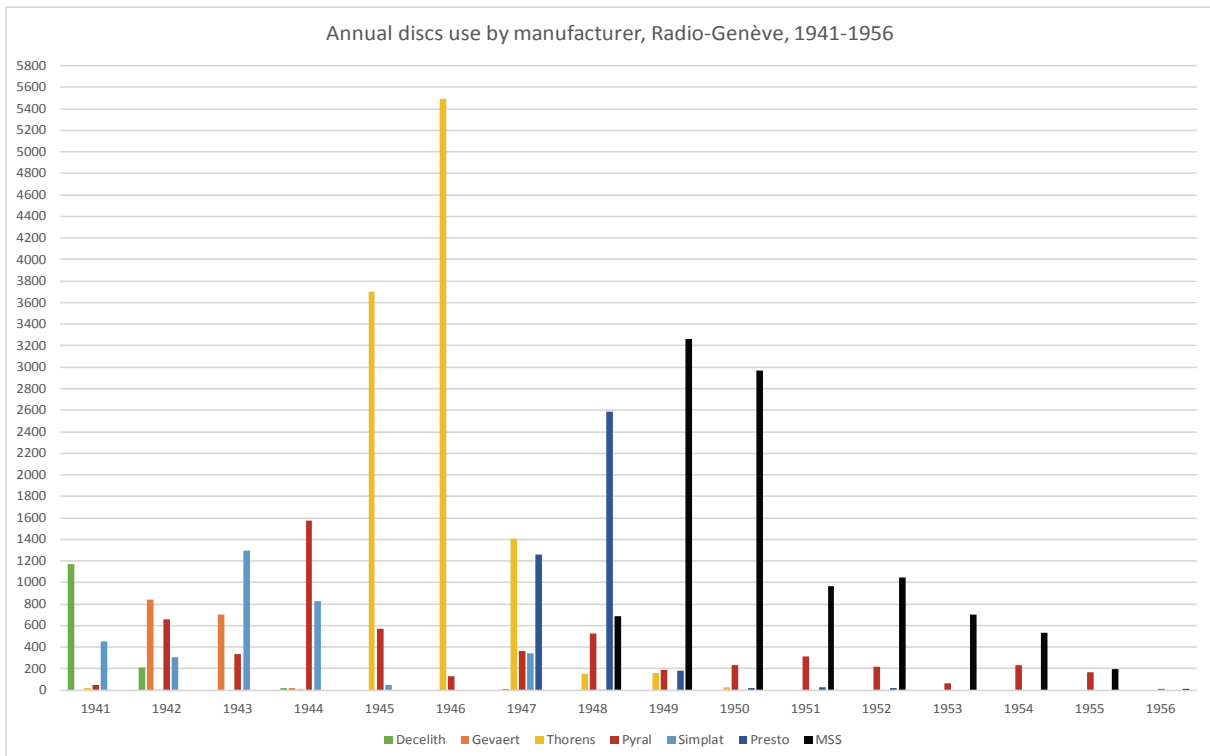
Graph 5 Discs consumption by manufacturer at Radio-Genève, 1941-1956. According to the acquisition register. Total number of records: 37,301.

Table 7 Radio-Lausanne and Radio-Genève lacquer discs trends by trade names/manufacturers

PERIOD	Radio-Lausanne	Radio-Genève
Before Second World War (1935-1939)	Pyral zinc-based Decelith Simplat/Simplex	Decelith ?
First years of the conflict (1939-1941)	Thorens 1 st generation Simplat/Simplex Pyral zinc-based	Decelith Simplat/Simplex
Last years of the conflict (1942-1945)	Pyral ersatz Thorens 2 nd and 3 rd generations Simplat/Simplex Pyral zinc-based	Gevaert-Gevaphone Pyral ersatz Pyral zinc-based Simplat/Simplex Thorens 3 rd generation
After the war (1946-1958)	Pyral Thorens 3 rd generation	Thorens 3 rd generation Presto Pyral MSS

The annual trend in records use (Graph 6) can be divided into 5 periods at Radio Genève:

- 1941: major use of plastic discs (Decelith).
- 1942-1944: alternation between Pyral discs, Gevaphone discs and Simplat/Simplex discs.
- 1945: marked the beginning of Thorens discs' hegemony, which lasted until 1947. In 1947, Thorens discs were caught up by Presto.
- 1947-1948: Presto became one of the official suppliers.
- 1949-1956: British MSS discs dominated disc consumption. Their use is indicative of the decline of lacquer discs, substituted by magnetic tapes.



Graph 6 Annual disc consumption by manufacturer at Radio-Genève, 1941-1956. Number of records: 37,301

Substrates

Four main substrates were used in the lacquer discs collection of Radio-Lausanne and Radio-Genève: aluminium, zinc, glass, and plastic (PVC).

During the early years of records registration (1935-1940), three substrates were mainly used: zinc, PVC and glass. From 1938 to 1940, aluminium use was still in its infancy, with only aluminium discs from the manufacturer Presto. Aluminium substrates eventually dominated from 1940 onwards.

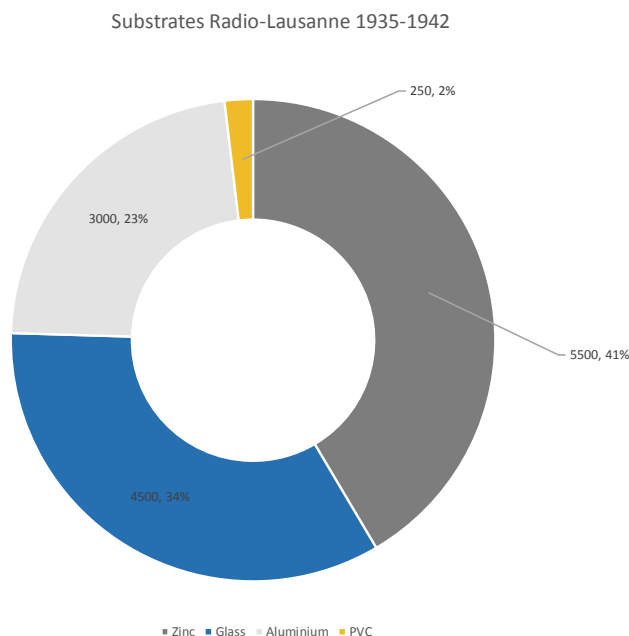
In the first years of the Second World War (1939-1942), the remaining stock from the 1930s (glass, plastic, zinc) was used. It was in 1940 that ersatz coatings on an aluminium base were introduced on the Swiss market (Thorens 1st generation).

Supply difficulties resulting from the increasing consumption of records and the effects of the Second World War compelled studios to seek alternative solutions. Three formats were developed during the war: Pyral red ersatz coating on an aluminium base, Gevaphone red-coated glass and Thorens discs (1st, 2nd, and 3rd generations).

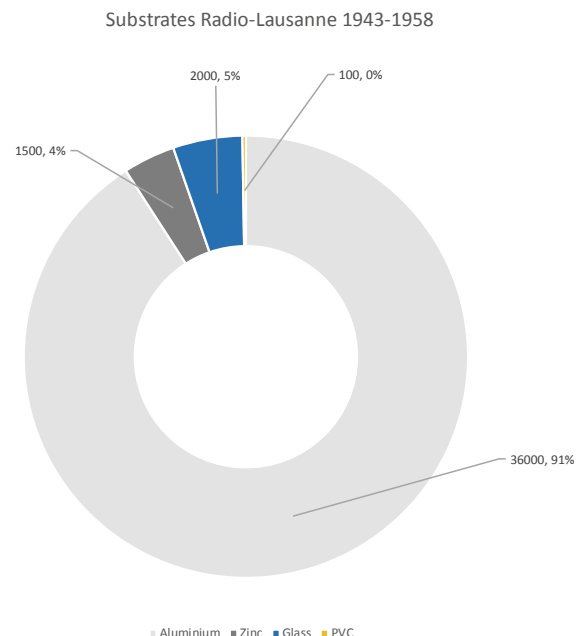
Radio-Lausanne

Two distinct periods can be identified for Radio-Lausanne record substrates: 1935-1942 (Graph 7) and 1943-1958 (Graph 8). Between 1935 and 1942, the main substrates used were zinc (41%) and glass (34%) respectively, followed by aluminium (23%) and PVC (2%). Lacquer discs are mainly recorded on Pyral zinc bases from 1936 to 1938. As early as 1938, Simplat glass discs competed with them. This duality lasted until 1941 when aluminium progressively replaced the other substrates. During these early years, PVC discs and Thorens 1st generation aluminium discs (single-sided coated) are occasionally found.

From 1943 to 1958, the studio employed almost exclusively aluminium-based formats (91%). Zinc (4%) and glass (5 %) were periodically used until 1947.



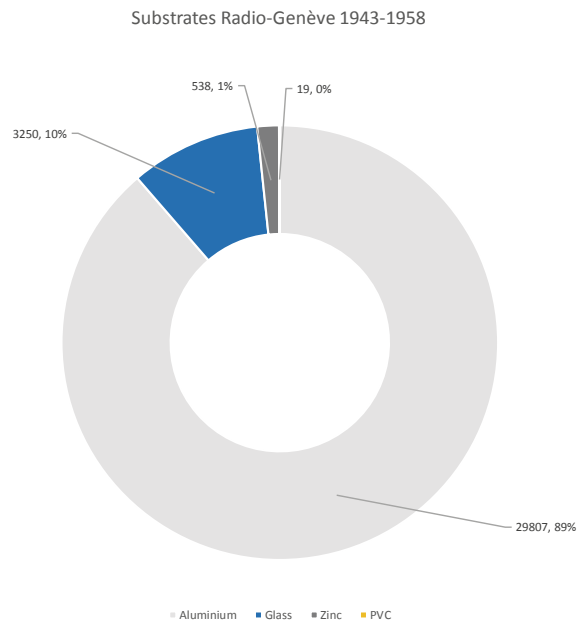
Graph 7 Radio-Lausanne substrates, 1935-1942. Estimates based on 13,250 discs.



Graph 8 Radio-Lausanne substrates, 1943-1958. Estimates based on 39,600 discs.

Radio-Genève

Radio-Genève registers do not indicate the disc substrates used between 1935 and 1939. As most of these carriers were destroyed then, a detailed typology is difficult to establish. However, thanks to the preserved discs digitised during emergency measures between 1993 and 1999, it is deduced that the studio used glass, zinc and plastic cores. Another challenge of the census is related to the fact that, from 1941 on, the registers only mentioned the trade name without specifying the substrate (for example, Pyral produced discs on both zinc and aluminium). Nonetheless, hypotheses formulate that Radio-Genève used primarily glass and zinc until 1940. From 1940, sound production was recorded on PVC (Decelith) and glass discs. Between 1942 and 1947, zinc, glass and aluminium cores were used. After 1947, aluminium replaced the other substrates. Glass-based discs (Simplat/Simplex) were employed for musical recordings until 1947.



Graph 9 Radio-Genève substrates, 1943-1958.
Estimates based on 33,614 discs.

Coatings

In chapter 2, FTIR analyses of the 78 rpm discs recorded by Radio-Lausanne and Radio-Genève determined that the main coating was cellulose nitrate, regardless of the manufacturing period or manufacturer (American, British, French or Swiss). Exceptions are the Simplat/Simplex glass discs with a gelatin emulsion and the German Decelith PVC discs².

Regardless of the studios, the discs present a wide range of colours. These different shades are likely a chemical degradation of the lacquer. Indeed, manufacturers aimed to apply homogeneous and dark coating to facilitate visual inspection of grooves during recording.

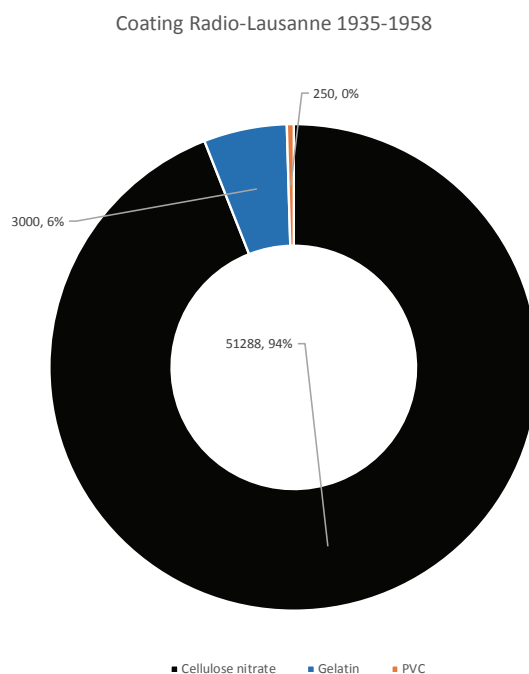
Radio-Lausanne

Cellulose nitrate coatings largely dominated the discs recorded by Radio-Lausanne (94%). Gelatin (6%) and PVC are also used periodically between 1936 and 1945. The actual disc shades are black, red, yellow, green, blue and amber. From 1935 to 1942, the lacquers applied to the metal substrates appear to have retained their original colour. The second half of the war years (1942-1945) saw the introduction of the ersatz discs, with red (Pyrall) and yellow-green shades (Thorens, 2nd and 3rd generations).

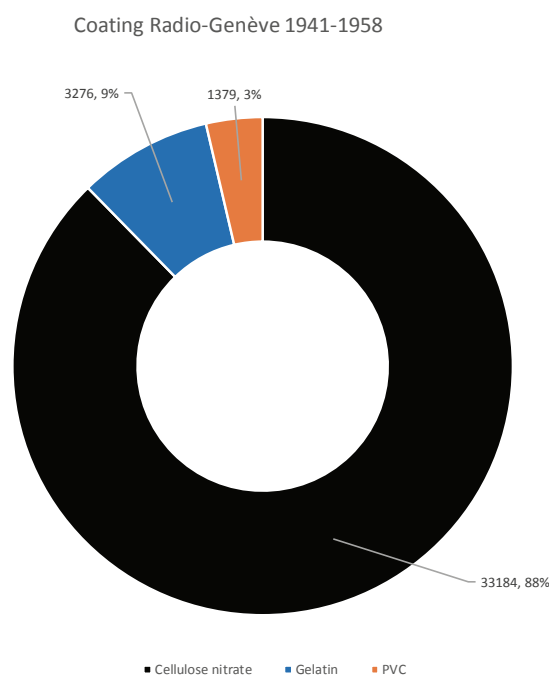
From 1947 until the end of discs recording, Pyral discs have black, blue, green and amber tones. The blue shades of Pyral discs appear to be linked to the blue dye used by the manufacturer, the *purple pencil* ink.

Radio-Genève

As with Radio-Lausanne, cellulose nitrate is the most common coating (88 %). However, discs with gelatin (9%) or PVC (3%) coating are more frequently used than the Lausanne studio. The war's effects introduced Gevaphone red-coating glass disc, Pyral ersatz coating, and Thorens lacquers. PVC-Decelith discs, recorded between 1940 and 1942, discoloured and faded into yellow, amber or blue hues. From 1946 to 1950, the collection consisted of a combination of 3rd generation Thorens (yellow/green/dark green tint), black and dark blue coated discs (Presto, Pyral, MSS). From 1950 up to the end of direct-to-disc recordings, the Geneva studio mainly used black (MSS) and dark-blue coated discs (Pyral, Presto).



Graph 10 Radio-Lausanne coatings. Estimates based on 54,328 discs inventoried.



Graph 11 Radio-Genève coatings. Estimates based on 37,839 discs.

First recording systems and equipments

In 1932, the recording of radio productions became a priority for the studios of the Swiss Broadcasting Corporation (SSR), which included Radio-Lausanne and Radio-Genève. This significant shift in radio soundscape allows deferred broadcasting, editing, national and international exchange of programmes and the archiving of the voices of prominent personalities. Three sound recording systems are mentioned in the 1932 annual report: mechanical recording on disc, photographic recording on film and electromagnetic recording on steel tape⁵.

Radio-Lausanne and Radio-Genève studios used a variety of sound recording systems. The contents of most of these different systems, for practical and cost reasons, were saved only on lacquer discs.

As early as 1934, the SSR studios were equipped with Telefunken-Neumann disc recorders (Figure 55). All studios were supplied with the same device to simplify disc exchange and ensure consistency in recording. These early recording systems were the driving force behind the creation of sound archiving, enabling to preserve the voices of important people, events, entertainment programs and to copy steel tape recordings⁶. A Selenophon system was also introduced in Radio-Genève's studios in 1934⁷.



CREDIT Photo-Hélios, Genève. PRGE.9.34

Figure 55 Telefunken-Neumann disc recorder.

In 1938, Philips-Miller optical recorders were introduced at SSR (Figure 56). This system used a mechanical process for the recording and an optical method for reproduction: a stylus cuts a groove into a coated film and the sound is reproduced with a light beam and photoelectric cell⁸. The General Directorate of PTT, which supplies technical equipment to SSR, stated that the Vaud-based manufacturer Thorens developed a Thorens D 25 disc recorder as a copy of Telefunken's R 5 model, which became impossible to import during the Second World War⁹. During the war, Motosacoche S.A., based in Geneva, developed and introduced a broadband frequency disc recorder on the Swiss market¹⁰. These Motosacoche recorders appeared to have been used until the mid-1950s. They are visible on photographs of the recording studios of Radio-Genève in 1950 (Figure 57) and Radio-Lausanne in 1955 (Figure 58).

In 1948, acetate magnetic tapes were introduced in Swiss studios. The original magnetic tapes from 1948-1955 are rarely found. Expensive at the time, they were erased after broadcast or copied on transcription lacquer discs¹¹. They progressively supplanted disc recording from 1950 onwards. Between 1950 and 1952, Radio-Genève recorded on Paper-tape (Soundmirror), a magnetic tape on paper. These tapes were systematically erased and transferred to lacquer discs or magnetic acetate tapes¹².



CREDIT Victor Andreossy, 1945

Figure 56 Francis Zuber, head of the technical department at Radio-Genève, records *In Terra Pax* on a Phillips-Miller, broadcasted during the Armistice in May 1945.



CREDIT Freddy Bertrand

Figure 57 Motosacoche disc recorder at Radio-Genève, January 1950.



CREDIT Radio-Lausanne, 1955

Figure 58 Radio-Lausanne recording booth no 8, 1955. Foreground, Motas-coche disc recorders, in the background the studio control room.



CREDIT Freddy Bertrand

Figure 59 Carmé and Owyn, technicians at Radio-Genève, 5 November 1949.

Storage conditions

Storage affects the quality of reproduction and discs lifespan. The most common types of storage are cardboard and sealed metal containers¹³. The 'cold storage' in tin containers, in which an interlayer separated each disc, maintained high reproduction quality¹⁴.

Radio-Lausanne

Originally held until 2013 at the Maison de la Radio in La Sallaz, the discs were progressively reconditioned and deposited at the Swiss National Library following digitisation. Records up to 1942 were stored in cardboard boxes containing between 10 and 15 discs (Figure 60). They were separated by paper sleeves to avoid friction between the discs. From 1942 onwards, the discs were placed in metallic containers with a capacity of 30 discs (Figure 61). Each disc was separated by a rounded greaseproof paper spacer.



Figure 60 Sound library of Radio-Lausanne in 1942³.



Figure 61 One of three discotheques in 1955 containing 130,000 discs. Commercial discs, suspended; transcription lacquer discs in metal cans⁴.

Radio-Genève

The collection had several storage sites. From the disc library's office No. 12 to a storage room at Boulevard Carl-Vogt, the Radio-Genève collection (37 linear metres) is currently located at the Swiss National Library. Unlike Radio-Lausanne, the discs were stored in paper sleeves. Originally, the sleeves were placed in cardboard boxes (Figure 62). Large format discs (> 40 cm) were laid flat at the Boulevard Carl-Vogt storage site (Figure 63).



CREDIT Freddy Bertrand

Figure 62 Radio-Genève sound library in 1947, Boulevard Carl-Vogt, office n° 12.



CREDIT Schweizerische Landesbibliothek Kodakky Bertrand. PRGE 9.31

Figure 63 Storage room at Boulevard Carl-Vogt, c. 1990. Observe the large formats are kept flat.

Notes

- 1 According to Radio-Genève's acquisition register, 1936-1942
- 2 Brambilla, 2018; Bretz, 2013
- 3 Drack, 2000, p. 325
- 4 Méroz, 1955, p. 19
- 5 Mémoire N° 7, 1932, p. 1
- 6 SSR, 1934, p. 35
- 7 SSR, 1934, p. 35-36
- 8 SSR, 1935, p. 31
- 9 Prongué, 2010; Archives de la Direction générale de la SSR, Berne, A104.10.01, Technische Einrichtung Radio-Studio 1942-1948: Brief vom Telegraphen & Telephonabteilung, Sektion Telegraph & Radio zum Schweiz. Rundspruchdienst vom 7. Dezember 1942; Firmengeschichte der Hermann Thorens SA und Thorens SA, Sainte-Crois, Herstellerin der Thorens Musikdosen. Zylinderphonographen, Plattenspieler, Plattenwechsler, Radioapparate und Hi-Fi Geräte, p. 1.
- 10 Direction générale des PTT, 1963, p. 312
- 11 Le Radio, XXVIIe année, no 52, 1949, p. 2013
- 12 Dahler and Koelliker, 1999, p. 16
- 13 Davies, Terry and Lent, 1947
- 14 BBC Written Archives Centre R57/46/8, 21 June 1948; R57/46/10, 22 November 1950

Alterations

Manufacturing, recording and storage conditions caused degradations and variations in quality and lifespan of lacquer discs¹. Additionally, most of the instantaneous discs have been mainly designed for their playback quality and manufacture at low cost, thereby privileging sound and mechanical properties over the repercussions for disc conservation².

Causes of alterations

The main causes of disc deterioration are the ageing of the components, inappropriate handling, excessive mechanical reproductions, playback on unsuitable equipment using worn needles, and dust^{3,4}. Surface treatment history also affects the shelf-life, but this historical data remains difficult to confirm.

The Pickett and Lemcoe report, written in 1959 by two engineers at the Library of Congress, is a primary source for the study of direct-to-disc recording degradations. The study is of key interest as it benefited from the collaboration of major firms active in the manufacture of these analogue carriers⁵. The engineers undertook disc ageing tests to explain degradation phenomena and revealed that plasticiser loss is one of the main chemical degradations⁶. Pickett and Lemcoe emphasised that variations in the processes between chemical plants also lead to disparity in the resistance to degradation⁷.

Based on these findings, this chapter explores:

- raw material selection,
- mechanical degradations,
- chemical degradations,
- adhesion defects,
- and micro-organisms.

The following causes of degradation remain speculative and would require larger-scale chemical analyses to validate the theories.

Raw material selection

The lifespan of any sound records is largely influenced by the raw materials used. Many variables are involved, such as the core polymer, additives to provide the desired properties and manufacturing processes. Small quantities or slight variations of specific chemicals added to the synthetic resin and material quality can significantly affect the longevity and performance of the disc⁸ and modify the processing qualities⁹. Manufacturers often used additives in the resin to achieve the desired characteristics and for economic reasons. Plasticisers, fillers, and diluents are the most problematic additives¹⁰. These additives are believed to have the most negative impact on the structural stability of the disc¹¹.

Mechanical degradation: Surface defects

Dust particles, greasy deposits from fingerprints or the choice of a soft coating are some of the main sources of surface defects¹². Impurities embedded in the coating during manufacture, recording or storage¹³. The fingerprints interfere with the readability of the record and attract dust particles. The latter are sources of scratches and prone to mould growth¹⁴. Dust deposits on the surface of the disc in several ways: the felt of the turntable, oils used to ease discs reproduction, discs stored outside their antistatic protection and even cigarette ashes¹⁵.



Figure 64 Gouge.

Radio-Lausanne, 24840, *Impressions d'Egypte par le député Louis Pierard*

Mechanical degradation: Wear and pressure

Scratches (Figure 65) impact the performance of playback and readability¹⁶. Excessive pressure occurs when the discs are overly tight on the shelves or stacked. This pressure breaks the ridges formed by the cutting stylus at the top of the groove resulting in surface noise¹⁷. Large and deep scratches also called gouge are usually intentional to prevent replay for copyright or censorship reasons (Figure 64).

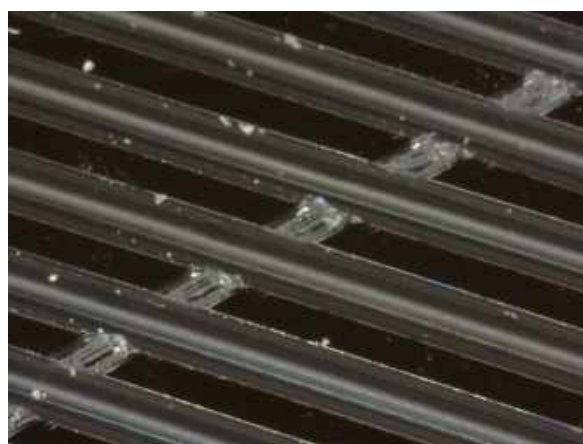


Figure 65 Scratched surface of a Pyral disc, USB micrograph, 250X. Radio-Genève, accession number DE4804, *Indicatifs pour l'Actualité (liaisons musicales)*, 1948.

Chemical degradation: Discolouration

The discolouration of the film into amber and yellow is the first of five degradation stages of cellulose nitrate and photographic films as established by the International Federation of Film Archives (FIAF)¹⁸. Cellulose nitrate coatings in the RTS collection present the same degradation characteristics, mainly the yellowing of Thorens coatings and amber and green discolouration of Pyral discs manufactured after 1945.

The chemical discolouration is an auto-catalytic process. Cellulose nitrate is sensitive to gaseous fumes. Reactive chemicals released by the lacquer decomposition lead to its discolouration. The phenomenon is amplified if the discs are stored in hermetic containers, with an accumulation of pollutants and acidity. pH measurements could determine the acidity of the coating.



Figure 66. Discoloured coating and palmitic acid.

Radio-Lausanne, accession number 23993. Report by Pierre Vandendries on the World Film Festival, 12 May 1947, Brussels.

Cigarettes in recording studios



CREDIT Jean-Jacques Lagrange

Figure 67 Henri Ramseier, nicknamed "Anatole", Radio-Genève presenter, smoking just above a disc.

Recording studios were not without risks. Primarily made of cellulose nitrate, cutting chips, when mixed with air, become extremely flammable³². Roger Wilmut, a BBC technician between 1960 and 2000, recalled a day of training that warned anyone wishing to smoke near the discs³³:

"When I was on the training course at Evesham the lecturer took a handful of the stuff outside onto the concrete and dropped a match on it (I suspect this was to discourage us from trying it). It went up immediately in six feet of flame, and I could feel the heat on my face ten feet away - it's that dangerous."

Smoking was very common in broadcasting studios. Fire was a serious hazard. Anecdotes from technicians and producers smoking cigarettes near the discs are legion (Figure 67). Roger Wilmut reported that legends persisted in the BBC's recording studios³⁴:

"There is a legend that, at the BBC Studios in Oxford Street (which closed in 1957) a producer (later a well-known politician) knocked his pipe out in a bin marked 'fire' (thinking it contained sand) and the swarf in it set fire to the recording channel. At Bush House another producer dropped a match (which had gone out but was still warm) in a bin - this time the engineer had the presence of mind to put his foot on the bin, so there was no fire, but the fumes got into the ventilation system and caused the evacuation of the entire floor."

Discs manufacturing plants were also at risk. Agnes Watts recalled a fire in the spraying room at the MSS factory in Kew as a result of the flammability of cellulose nitrate³⁵.

Chemical decomposition

Cellulose nitrate is a chemically unstable polymer that decomposes overtime to give various nitrogen oxides or acids when reacting with water vapour or oxygen. These gases released by the decomposition process weaken the surface in several ways: reaction with water to form nitrous acid (HNO_2), nitric acid (HNO_3), removal of hydrogen bonds from the molecule, oxidation of the plasticiser or cleavage of the cellulose molecule to produce several organic acids. An autocatalytic reaction can occur if the reactive products of cellulose nitrate decomposition are not removed, including secondary reactions such as oxidation, nitration, nitrification or hydrolysis of another ester groups¹⁹.

Chemical degradation: Plasticiser loss

Chemical decomposition combined with physical forces are the most degrading factor to lacquer discs. The stratified structure results in physical forces originating from the material itself. The inherently unstable nature of this composite structure creates internal stresses that lead to cracking, shrinking and peeling of the coating²⁰.

The loss of raw castor oil, the recurrent plasticiser to facilitate recording in instantaneous discs, is a primary source of these physical stresses. This irreversible hydrolysis process²¹ induces shrinkage of the coating due to the loss of the coating's flexibility properties (Figure 68)²². Since the lacquer is applied on a rigid base, the internal stresses eventually result in shrinkage and, at the most advanced stage, delamination of the coating layer²³. It can also expose small nodules of imperfectly dispersed carbon black or other solid materials²⁴.

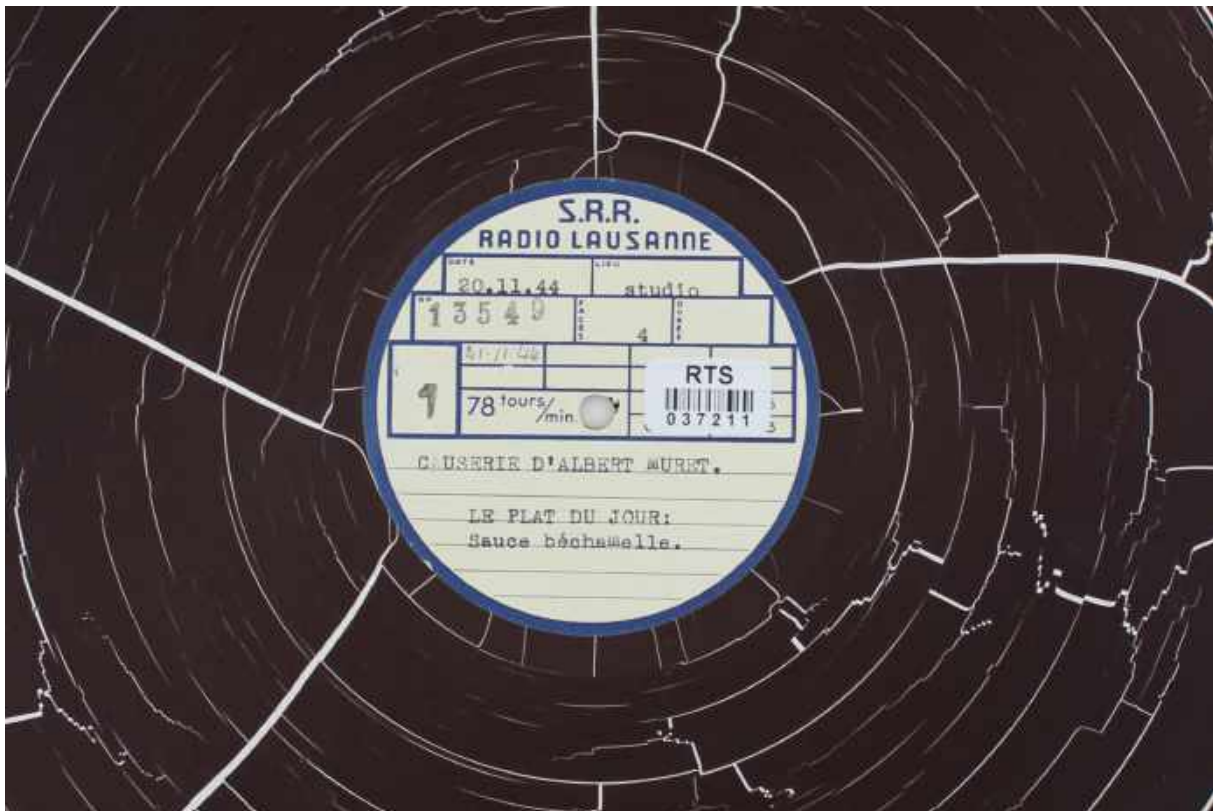


Figure 68 Plasticiser loss of a Pyral ersatz disc. Palmitic acid and cracks.

Radio-Lausanne, accession number 13549, *Conversation with Albert Muret, dish of the day: béchamel sauce*, 20 November 1944.

Raw castor oil is lost by the formation of volatile compounds, by extraction, exudation, water extraction or micro-organism attack²⁵. Plasticiser exudation, the first stage of plasticiser loss forming tiny pores (Figure 69)²⁶, is characterised by white crystals and fatty deposits on the surface of the coating²⁷. Fourier transform infrared spectrometry (FTIR) identified the white deposits as compounds of saturated organic acids, such as palmitic acid, stearic acid or lauric acid²⁸. Palmitic acid is typically associated with the hydrolysis process of the castor oil plasticiser²⁹.



Figure 70 Plasticiser loss. Palmitic acid and peeling of the coating.

Radio-Lausanne, accession number 45105, *Le bonjour de Jack Rollan: indicatif*, c. 1947.

C.J. LeBel, Vice-president of Audio Devices, acknowledged that plasticisers were added in large quantities by disc manufacturers to provide the flexibility properties for recording and reproduction³⁰. As the plasticiser is incorporated into post-war discs with such excess, Pickett and Lemcoe estimated that the loss of more than 25% of the plasticiser would not damage the reproduction qualities of the disc³¹.

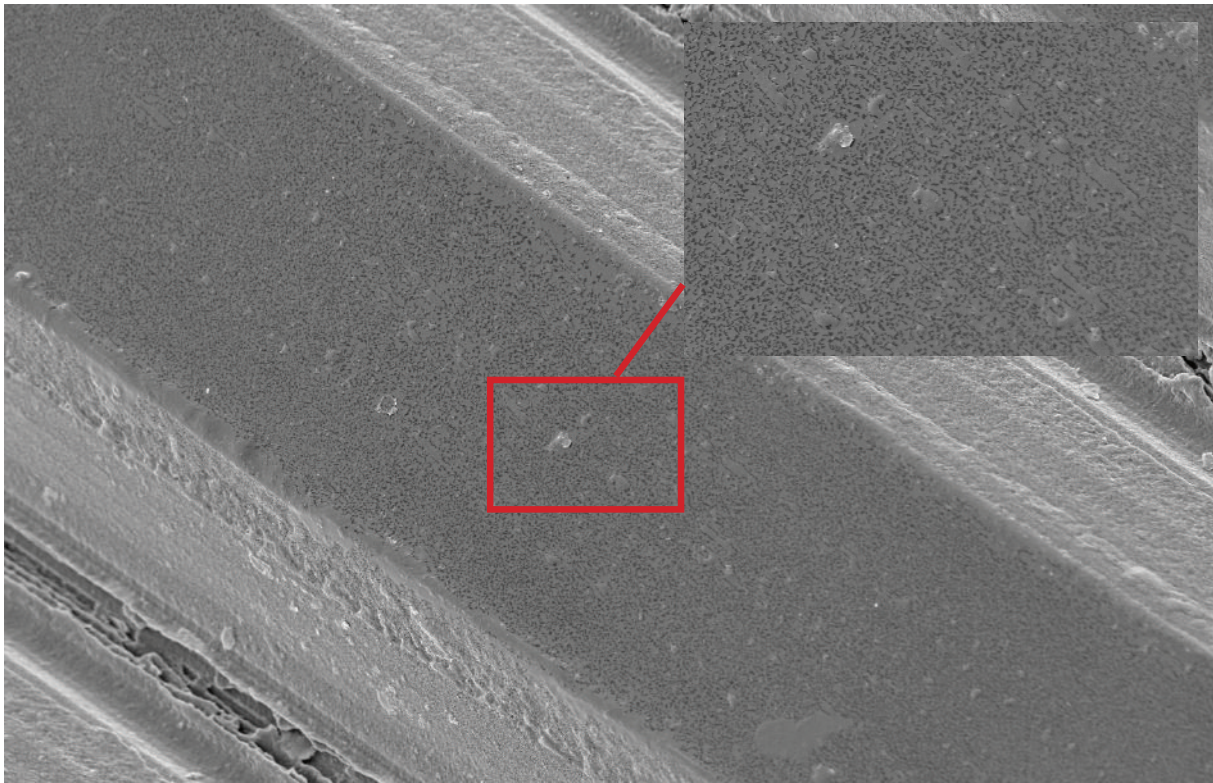
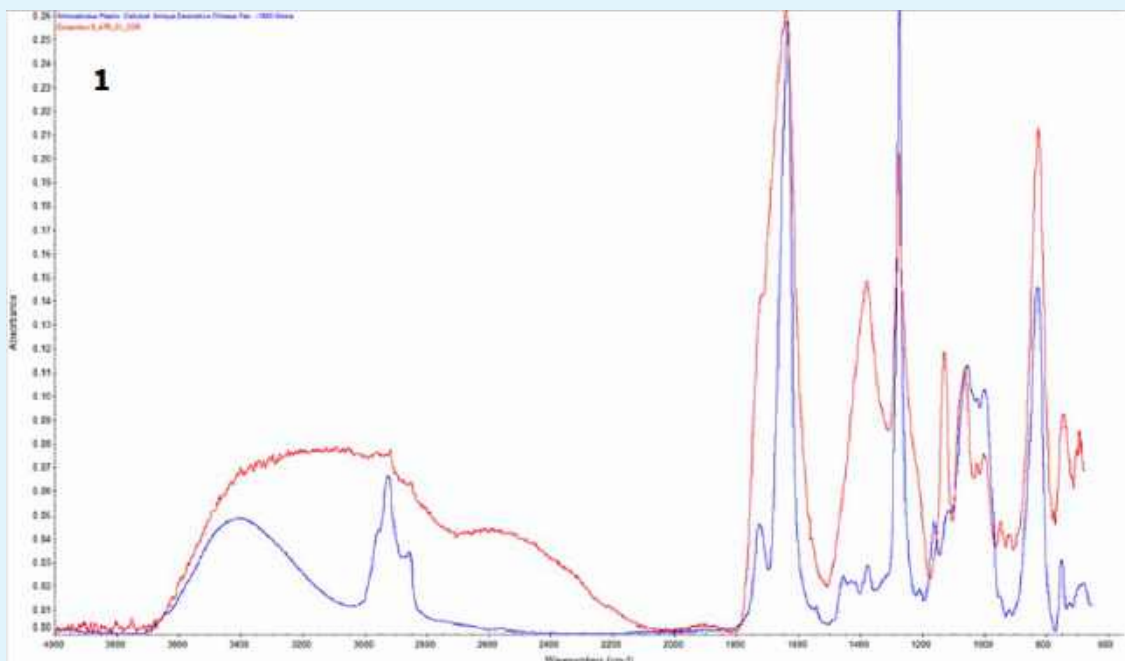


Figure 69 Detail of the SEM micrograph of a Pyral ersatz coating in poor condition. Framed: close-up of the micropores formed by the exudation of the plasticiser.

Radio-Lausanne, accession number 13674, Stettler-Ackermann, *Loch Lomond*, Scottish song, 16 November 1944.

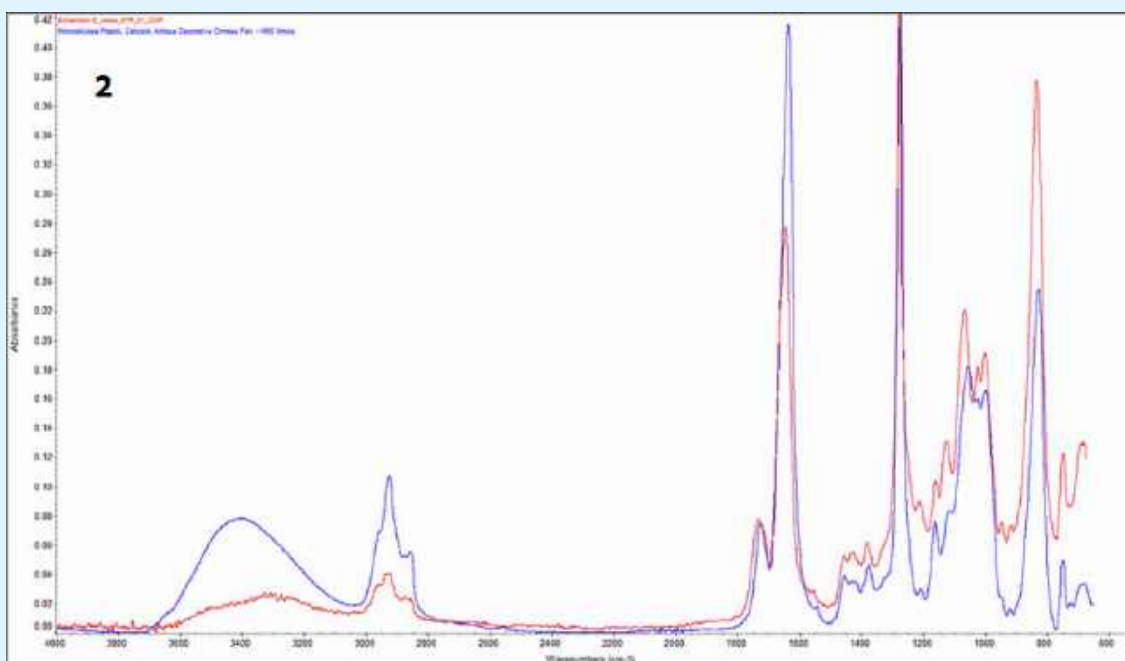
CREDIT Haute Ecole Arc

Chemical study: possible research investigation of plasticiser loss



Spectrum 7 Spectrum ATR-FTIR of a 1944 Pyral ersatz disc on an aluminium base, sample 6, groove side. Radio-Lausanne, accession number 13674, Hugues Cuénod, *The campbells are coming*, 16 November 1944

The molecular analysis results revealed significant variations in absorption in the FTIR spectra (groove and reverse sides) of the Pyral ersatz disc recorded in 1944 (sample 6, groove side: Spectrum 7; reverse: Spectrum 8). The hypothesis is that the sample shows signs of degradation. It is based on the shape of the OH stretch band (very wide, Spectrum 7) and the shape of the peaks at 1800-1500 cm⁻¹ (C-O and N-O)³⁶. The sample was collected from the same Pyral ersatz disc in poor condition used for the SEM micrograph, with significant signs of plasticiser loss (large cracks, shrunken coating, and palmitic acid). Also, the carbonyl group at ~1733 cm⁻¹ (C=O) increases considerably (Spectrum 7). This result is consistent with Edge's study (1990), which suggested that denitration is in part associated with the carbonyl group³⁷.



Spectrum 8 Spectrum ATR-FTIR of a 1944 Pyral ersatz disc on an aluminium base, sample 6, reverse side.

Corrosion

Metallic substrates deteriorate by oxidation and corrosion. As decomposed cellulose nitrate is a source of gaseous nitrogen oxides (NO_x), in contact with humidity, these oxides corrode zinc and form notably nitric acid (HNO_3)³⁸. Oxidation products migrate to the coating and facilitate cellulose nitrate denitration³⁹. A corrosion phenomenon is observed on Radio Lausanne zinc-based discs stored in hermetically sealed metal containers and separated by a greaseproof paper: the cellulose nitrate lacquer is decomposing and disintegrating (Figure 71-Figure 72). The hypothesis is the association of three phenomena amplifying the decomposition process: zinc corrosion (an electrolytic reaction between the metallic container and the metallic core), a presumably chemical reaction with the paper (if it is greaseproof paper, it can release sulphur that corrodes zinc in the presence of moisture⁴⁰) and a high concentration of pollutants and noxious substances contained in the metallic container. This confinement of the disc prevents the removal of pollutants and decomposition products trapped inside the sealed container. A study on the degradation mechanisms of cellulose nitrate films (Edge, 1990) observed a similar phenomenon with tin cans⁴¹.

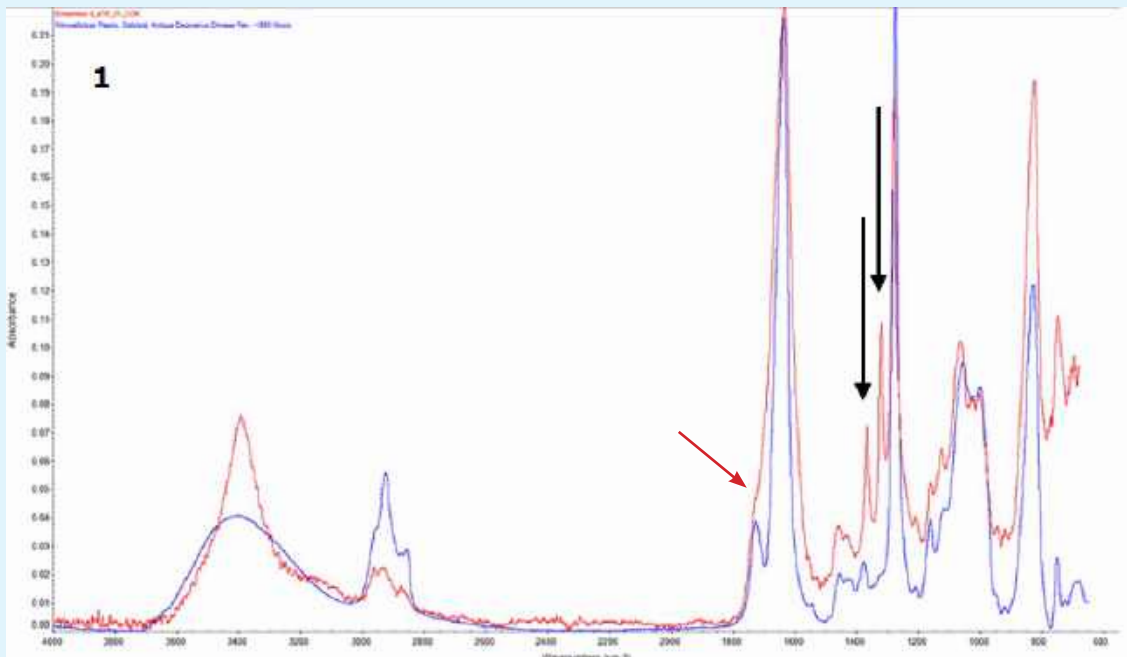


Figure 71 Inadequate storage in metal cans of 1945 Pyral zinc-based discs, resulting in cellulose nitrate decomposition. The greaseproof paper is shredded.



Figure 72 Details of cellulose nitrate decomposition, with burst blisters and white crystals, probably zinc corrosion products.

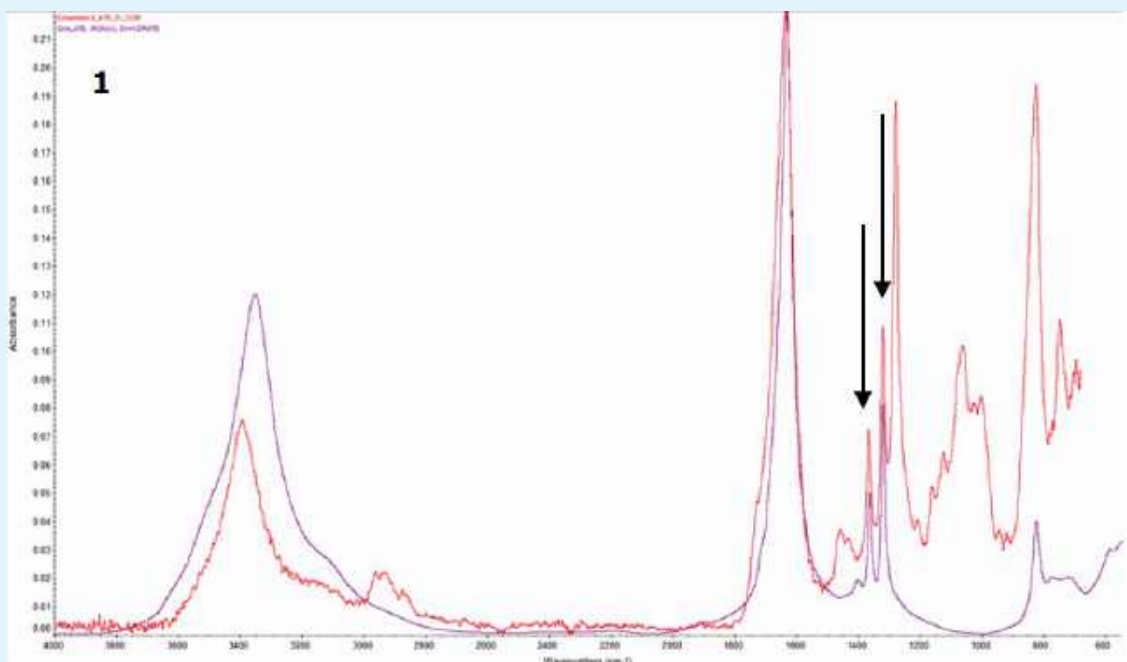
Chemical study: potential corrosion research investigation



CREDIT Haute Ecole Arc, Laura Brambilla

Spectrum 9 Spectrum ATR-FTIR of a 1946 Pyral zinc-based disc coating, sample 9-1, groove side. Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 9-1 (DN4639, *Mon rêve*, 10.1946).

FTIR spectrum of the Pyral zinc-based coating sample from Radio-Genève is a mixture of cellulose nitrate and a metal oxalate (Spectrum 10). The spectrum distinguishes two characteristic peaks of a metallic oxalate (Spectrum 9, black arrows), probably corrosion products modifying the shape of the spectrum⁴⁶. C-O group of oxalate and cellulose nitrate C-O group deformed the peak shape at 1800-1500 cm^{-1} . N-O contribution of cellulose nitrate nearly disappears (Spectrum 9, red arrow)⁴⁷. It is impossible to determine whether it is a zinc oxalate based only on the FTIR spectrum as metal oxalates have very similar FTIR spectra. Zinc can only be confirmed by elemental chemical analysis⁴⁸.



CREDIT Haute Ecole Arc, Laura Brambilla

Spectrum 10 Spectrum ATR-FTIR of a 1946 Pyral zinc-based disc coating, sample 9-1. Purple spectrum: reference spectrum of a metallic oxalate; red spectrum: sample 9-1 (DN4639, *Mon rêve*, 10.1946)

Adhesion defects

Defects in coating adhesion to the metal substrate have several causes: the metal base is not completely degreased before the application of the coating; extreme temperature variations dilate the metal; or extended exposure to air which results in plasticiser loss and causes the coating to shrink⁴². Additionally, water wet abrasion as initially applied by Pyral has lower surfactant properties than a detergent. Therefore, it will only be partially effective against grease, resulting in a weaker adherence of cellulose nitrate to the metallic core⁴³. The complete loss of adhesion between the substrate and the lacquer usually starts with the formation of blisters⁴⁴. A 1946 BBC memo stated that oil used on zinc-based MSS disc coatings penetrated the coating shortly after its application and formed blisters, preventing from adhering with the same tension to the zinc core in all places⁴⁵. Lastly, metallic surface finishes appear to have an impact on the adhesion qualities of the coating. Lacquers applied on porous metallic surfaces with traces of processing (Figure 75, Figure 76, Figure 78) are more easily removed than coatings applied on mirror-finish metallic surfaces (Figure 73, Figure 74, Figure 77).



Figure 73 Presto aluminium-based.
Mirror-finish surface, good adhesion.
Radio-Genève, DY5107. *Jeunesses musicales*, May 1951.



Figure 74 Pyral ersatz aluminium-based.
Mirror-finish surface, good adhesion.
Radio-Lausanne, 13674. Stettler-Ackermann, *Loch Lomond*, 16.11.1944.



Figure 75 Pyral zinc-based.
Lamination marks(?), poor adhesion.
Radio-Lausanne, 150X, *Banquet at the Livery-Club London*, 31 May 1937.

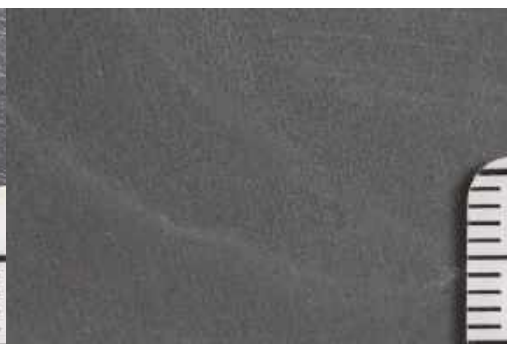


Figure 76 Pyral red zinc-based.
Porous surface, poor adhesion.
Radio-Genève, DN4639. *Mon rêve*, October 1946.



Figure 77 Thorens 2nd generation, aluminium-based.
Mirror-finish surface, good adhesion.
Radio-Lausanne, 7399. *Bon dimanche, radioplay*, 19 February 1942.



Figure 78 Thorens 3rd generation, aluminium-based.
Porous surface, poor adhesion.
Radio-Lausanne, 22110, *La chaîne du bonheur*, 17 January 1947.

Inadequate storage

Physical forces and chemical reactions are the main factors leading to inadequate storage. Some Radio-Lausanne cardboard boxes were not properly vertically stored, causing mechanical deformations of zinc, plastic and thin aluminium bases (Figure 79). The interlayers between the discs in the rusted metal tins caused water retention and accelerated the degradation of the discs.

The storage of Radio-Genève discs was too tight. Discs awaiting digitisation were stored in their original acidic paper sleeves and multiple discs are overlapping without protective interlayers (Figure 80).



CREDIT Rudolf Müller

Figure 79 Half-lying and half-full cardboard boxes, Radio-Lausanne



Figure 80 Overlapping of Thorens discs, without protective interlayers, Radio-Genève

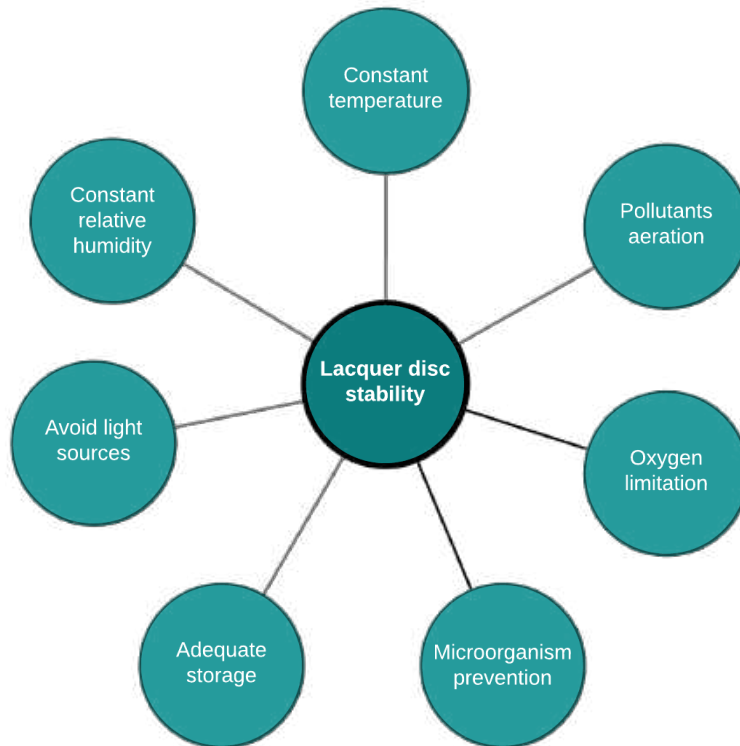
Micro-organisms

Cellulose and gelatin-based coatings are sensitive to hygrometric variations which can result in micro-organisms growth if the discs are exposed to damp storage conditions for an extended period (> 60% relative humidity).

Storage conditions

Cellulose nitrate requires specific conservation measures, including sufficient ventilation to prevent concentrations of the decomposition gases.

The primary factors for lacquer discs stability are as follows:



Graph 12 Ideal equation for a successful preservation of instantaneous discs.

Combustion hazard of cellulose nitrate

In 1996, the Audiovisual Department of the Bibliothèque nationale de France (BnF) commissioned an in-depth study of the possible toxic emissions in the event of a fire involving cellulose nitrate discs. A pyrolysis analysis was carried out by the Analytical Chemistry Department of the Laboratoire Central de la Préfecture de Police de Paris in 1996. The laboratory report revealed the presence of cyanide and highlighted that when Pyral discs burn, they emit toxic and irritating gases such as carbon monoxide and carbon dioxide as well as hydrocyanic acid⁴⁹. The metallic substrates reacted violently with water and produced hydrogen. The Detachment Commander of the Paris Fire Brigade recommended storage facilities equipped with an ion detection system and an automatic water extinguishing system⁵⁰. These results are based on a single report and would require further analyses to determine all the risks incurred.



Temperature

Low temperature (<18°C). Temperature is an important factor in the catalysis of chemical reactions. Excessive temperature will accelerate denitration, exudation of plasticisers⁵¹, oxidation, and growth of bacteria and moulds⁵².

Relative humidity

Constant relative humidity (40-50%). For analogue sound records, humidity is the most critical factor. Most lacquer discs are threatened by hydrolytic decomposition. Excess of humidity induces hydrolysis and exudation of plasticisers and breaks the ester chains of castor oil to form stearic and palmitic acids⁵³. Mechanical carriers are also contaminated by moulds when humidity exceeds 65% RH for an extended period. Conversely, low relative humidity (<30%) dries the coating and leads to delamination. The effects on the discs are similar to inadequate temperatures: shrinking and peeling of the coating⁵⁴.

Constant temperature and relative humidity

Avoid significant thermohygro-metric fluctuations enable to increase the chemical stability of the discs. These variations cause a repetitive movement of the stratified structure resulting in internal stresses, permanent deformation, and delamination. Temperature variations, especially when abrupt, cause an alternation of dilation and contraction which, by mechanical effect, weaken the discs⁵⁵. Since cellulosic polymers, hydrophilic materials, absorb large quantities of water and undergo large dimensional changes, relative humidity should be kept as constant as possible⁵⁶.

Avoid light (UV)

Light initiates or accelerates chemical reactions. Avoid direct exposure to the sun or any other similar source of light as it results in cellulose discolouration.

Oxygen limitation

Cellulose nitrate is highly sensitive to oxidation.

Microorganisms prevention

Micro-organisms find suitable food sources in dust and fats deposited by hands on the surface of the discs.

Acidity and pollutants removals

Sufficient ventilation and filtration of pollutants. Large quantities of cellulose nitrate in the composition of the coating requires specific precautions. The decomposition products of this polymer, such as nitrogen oxides, require sufficient air circulation⁵⁷. The concentration of pollutants in hermetic cans hasten the decomposition of cellulose nitrate. Acidity also accelerates the formation of stearic and palmitic acids, causing an auto-catalytic reaction⁵⁸. Additionally, acid gases released by the cellulose nitrate chemical decomposition accelerates the auto-catalytic process⁵⁹ or increase the corrosion rate. Finally, dust deposits have an abrasive action on the surface, producing surface noise.

Suitable packaging and storage

Mechanical deformations or chemical degradations caused by storage materials. Discs can have high wear resistance but deteriorate rapidly due to storage methods.

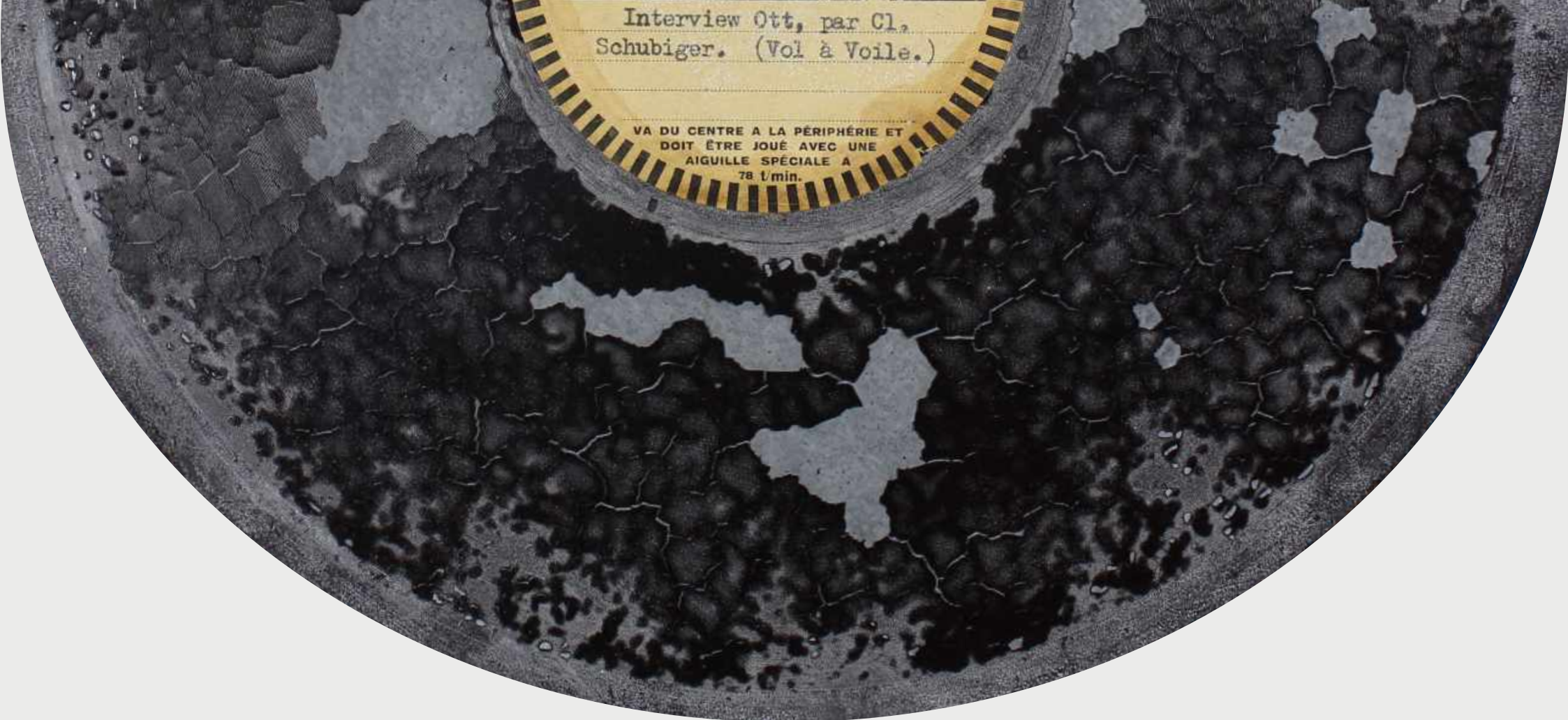
Notes

- 1 BBC Written Archives Centre R57/46/10, 22 November 1950; Pickett and Lemcoe, 1959, p. 2
- 2 Pickett and Lemcoe, 1959, p. 2, 11
- 3 BBC Written Archives Centre R57/46/1, 29 January 1941
- 4 BBC Written Archives Centre R57/46/6, 16 January 1947
- 5 Pickett and Lemcoe, 1959, p. vii
- 6 Pickett and Lemcoe, 1959, p. 16
- 7 Pickett and Lemcoe, 1959, p. 12
- 8 Pickett and Lemcoe, 1959, p. 5-6, 10, 15; BBC Written Archives Centre R57/46/4, 24 August 1946
- 9 BBC Written Archives Centre R57/194/8, 5 June 1942
- 10 Pickett and Lemcoe, 1959, p. 10, 15
- 11 Pickett and Lemcoe, 1959, p. 6, 10
- 12 BBC Written Archives Centre R57/46/2, 13 June 1944; Iraci, 2017
- 13 Powell, 1945; Pickett and Lemcoe, 1959, p. 8, 10
- 14 Iraci, 2017
- 15 BBC Written Archives Centre R57/46/6, 16 January 1947; BBC WAC R57/50, 1 December 1954; BBC Written Archives Centre R57/352/1, undated
- 16 Iraci, 2017
- 17 BBC Written Archives Centre R57/46/6, 16 January 1947; Powell, 1945
- 18 FIAF, 1991, p. 11; Edge, 1990, p. 623
- 19 Pickett and Lemcoe, 1959, p. 15-17
- 20 Pickett and Lemcoe, 1959, p. 16-17; St-Laurent, 2008; Fontaine and Calas, 1996
- 21 Iraci, 2017
- 22 Pickett and Lemcoe, 1959, p. 15-16
- 23 Iraci, 2017; Pickett and Lemcoe, 1959, p. 16
- 24 Pickett and Lemcoe, 1959, p. 23
- 25 Pickett and Lemcoe, 1959, p. 16
- 26 Pickett and Lemcoe, 1959, p. 23
- 27 Iraci, 2017
- 28 Kipfer and Leymarie, 2012, p. 2
- 29 Iraci, 2017
- 30 LeBel, September 1940, p. 80
- 31 Pickett and Lemcoe, 1959, p. 24
- 32 Wilmut, 2007
- 33 Wilmut, 2007
- 34 Wilmut, 2007
- 35 Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984
- 36 Email from Laura Brambilla, 25 June 2018
- 37 Edge, 1990, p. 627
- 38 Selwyn, 2004, p. 42, 170; FIAF, 2002, p. 11
- 39 Robertson, 2002
- 40 INRS, 2006, p. 2
- 41 Edge, 1990, p. 628
- 42 BBC Written Archives Centre R57/49/2, 22 March 1946; R57/46/4, 2 September 1946
- 43 Ramel, 1996, p. 16
- 44 Pickett and Lemcoe, 1959, p. 44
- 45 BBC Written Archives Centre R57/46/4, 23 August 1946
- 46 Email from Laura Brambilla, 25 June 2018
- 47 Email from Laura Brambilla, 25 June 2018
- 48 Email from Laura Brambilla, 3 July 2018

- 49 Certificat d'essai no 82039/96 et 82040/96, 13 novembre 1996
- 50 Correspondance no 81/96 le 24 mai 1996 du Chef de Détachements BSPP Charron à Gérald Grunberg, directeur du département de la phonothèque et de l'audiovisuel BNF (réponse de la correspondance GG/IV/96-169 du 23 avril 1996
- 51 Pickett and Lemcoe, 1959, p. 16
- 52 Wireless World, 19 March 1937
- 53 Pickett and Lemcoe, 1959, p. 16
- 54 The Audio Archive, 2018
- 55 Pickett and Lemcoe, 1959, p. 7; Iraci, 2017
- 56 Pickett and Lemcoe, 1959, p. 7; The Audio Archive, 2018
- 57 Scott Williams, 2017
- 58 The Audio Archive, 2018
- 59 The Getty Conservation Institute, 2017

Part II: Visual alterations notebook & digitisation tips





5-STAGES MODEL OF LACQUER DISCS DEGRADATIONS

Stage 1
No apparent degradation

1

Stage 2
Initial degradation

2

Stage 3
Intermediate degradation

3

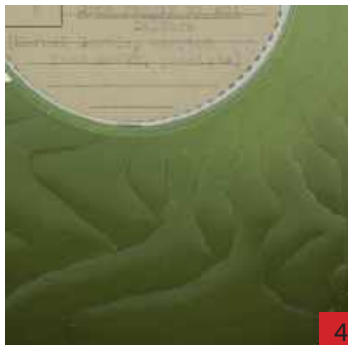
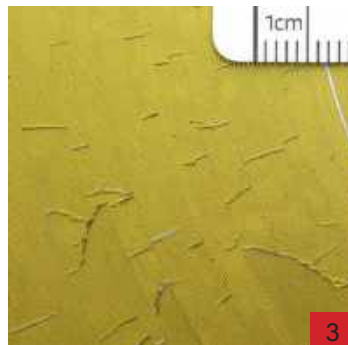
Stage 4
Advanced degradation
constant stylus monitoring

4

Stage 5
Final decomposition

5

5-stages model of lacquer discs degradations



**Cellulose nitrate
Aluminium-based**
Example trade name: Thorens

Crazing network
Aluminium non visible

2

3

4

5

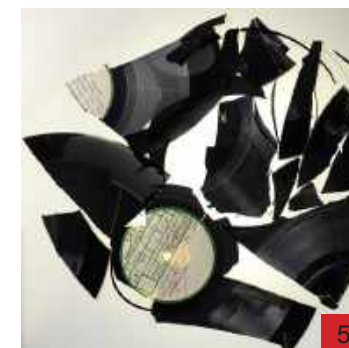
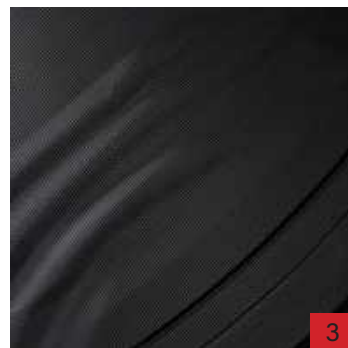
5

Crazing network
Aluminium non visible

Coating flaking, thin cracks

Coating flaking, large cracks

Coating peeling



**Gelatin coating
Glass-based**
Example trade name: Simplat

Coating flaking
Slight flaking

2

3

4

5

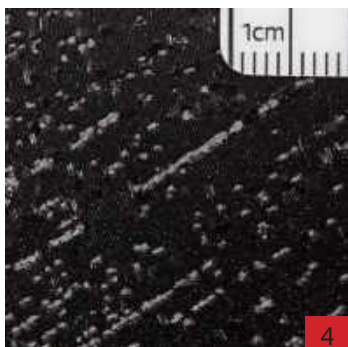
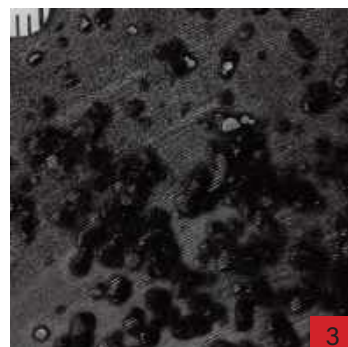
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Coating flaking
Excessive flaking

Coating peeling

Coating peeling

Broken disc



**Cellulose nitrate
Zinc-based**
Example trade name: Pyral

Unburst blisters

2

3

4

5

5

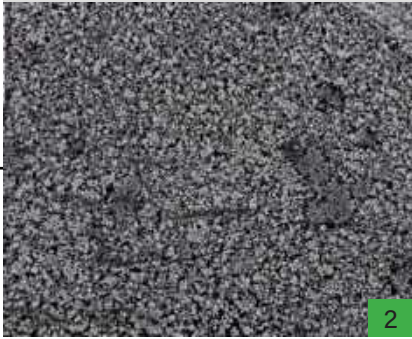
Un/burst blisters

Burst blisters

Burst blisters
'Sandpaper' surface

Coating peeling

Palmitic acid



Description
The coating layer is covered by a waxy mass of white crystals.
IASA term: Waxy exudate

Cause
Plasticiser loss. Palmitic acid is a result of the exudation of the castor oil plasticiser and affects discs coated with cellulose nitrate.

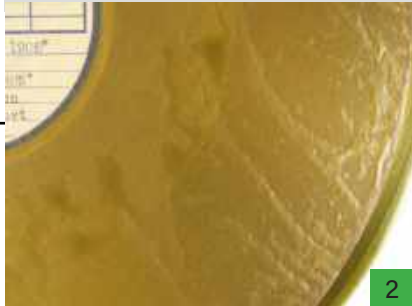
Trends
In Radio-Lausanne and Radio-Genève collections, the discs most affected by this deterioration are Pyral discs (aluminium and zinc bases) and Audiodiscs. The layer of palmitic acid on Radio-Genève discs is thinner than Radio-Lausanne's. Radio-Lausanne's storage conditions - sealed metal cans with interlayers - may have increased the pollutant concentration and could explain this difference.

Pyral (aluminium, zinc)

Presto (aluminium)

Audiodiscs (aluminium)

Greasy deposits



Description
Fat residues cover the coating.

Cause
The first stage of palmitic acid (?) or rifle oil used at the time to ease the playback of the disc.

Trends
Greasy deposits affect Pyral and Thorens discs recorded between 1947 and 1948. Unlike sticky coatings, greasy deposits do not stick to the baking paper, the residues are easily removed, and the surface is non-sticky.

Pyral (aluminium)

Thorens (aluminium)

Mechanical digitisation

Cleaning with osmosis water solution

Sticky coating



Description
It is a form of greasy residue but with sticky properties. Fragments of greaseproof paper stick to the surface.

Cause
Probably a reaction with the greaseproof paper used in the tins.

Trends
Alteration that only affects the red-coated glass discs manufactured by the Belgian manufacturer Gevaert-Gevaphone stored in metal cans and separated using greaseproof paper (Radio-Lausanne). There are also substantial impurities on the surface of the disc.

Gevaert-Gevaphone (glass)

Crazing (perpendicular to the groove)



Description

The coating remains attached to the substrate but has shrunk. Visually, fractures are perpendicular to the groove.
RTS term: rétracté

Cause

Degradation induced by a hydrolysis process: the loss of the qualities of coating flexibility and variations in thermal dilation and hygroscopic properties with the metal base generate tensions that will result in the shrinkage of the coating.

Trends

Considering Pyral zinc-based discs, the engraved surface is rarely affected. However, the periphery and the central part of the disc shrink. Cracked discs reach the most critical level with Pyral ersatz discs, manufactured during the war. These discs present a thin lacquer applied to an aluminium substrate. The cracks in this ersatz coating are very wide (can exceed 5 mm) and cover the whole side of the disc. Pyral black/green hue discs can present a crazing network, with fewer and thinner cracks than ersatz discs. During the war, Thorens manufactured lacquer discs with a thick coating applied on aluminium cores (Thorens 3rd generation, yellow/green hues). These discs, once they start shrinking, peeled and flaked rapidly. The red shade discs of the English manufacturer MSS from (c. 1948) cracked in the outer periphery.

Cracked (perpendicular to the groove)



Crazing (tangential to the groove)



Description

The coating is still attached to the substrate but developed tangential cracks (in the groove direction). Wide cracks result in playback issues if not the impossibility of mechanical reproduction.
RTS term: fendillé

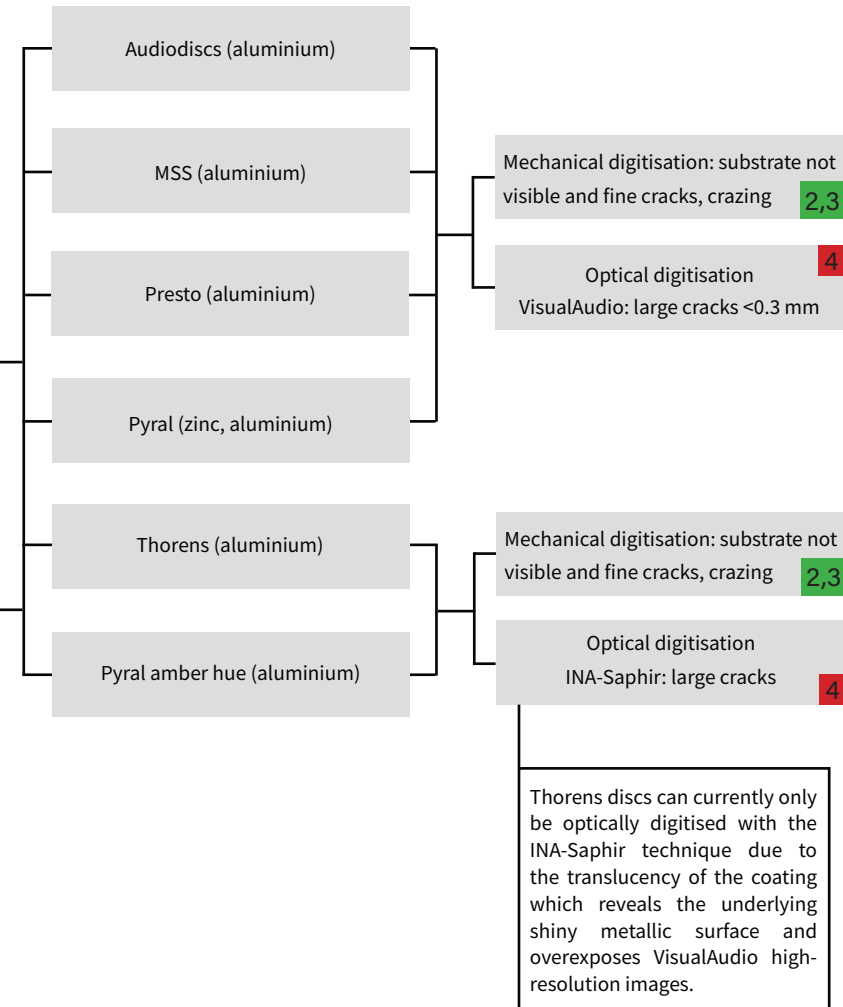
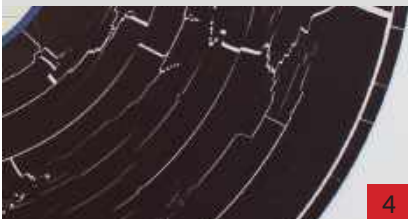
Cause

Degradation as a result of the loss of the flexibility qualities of the lacquer and the differences in thermal and hygroscopic dilation properties between the coating and the metallic substrate.

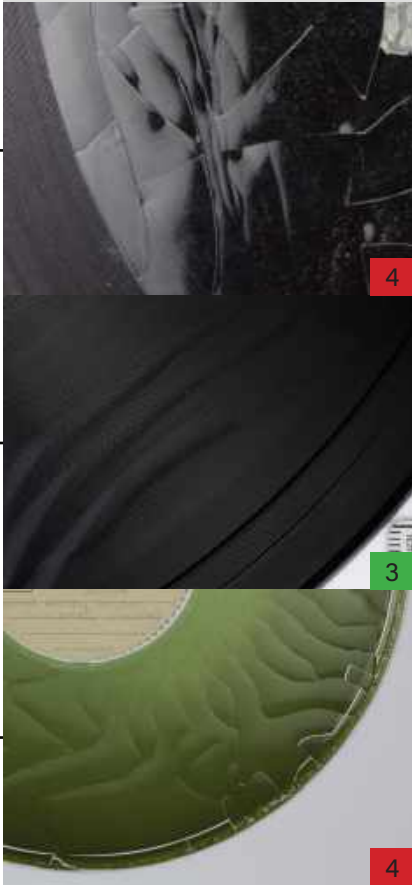
Trends

Same as the “cracked perpendicular to the groove” alteration. Three types of Pyral coatings are affected by this degradation: Pyral ersatz, Pyral with green hue and Pyral zinc-based. The ersatz coating from the war years shows very large and numerous cracks. The cracks of green hue coating are thinner and less numerous. Zinc-based discs present crazing network, where the zinc is hardly visible.

Cracked (tangential to the groove)



Flaking



Description

The coating is flaking but remains attached to the substrate.
RTS Term: soulevé

Cause

Degradation caused by a hydrolysis process: the loss of the flexibility qualities of the lacquer and the differences in thermal and hygroscopic dilation properties between the coating and the metallic substrate result in tensions leading to the flaking of the coating.

Trends

Degradation that affects three types of bases. The first substrate is glass. The coating is never shrunken or cracked but has partly come away. For Simplat/Simplex discs, a certain amount of time is required for the coating to completely detach from the glass base. Conversely, on Gevaphone glass discs manufactured by Gevaert, the whole side of the coating comes off and falls apart. The addition of sodium silicate to ensure the adherence of the gelatin to the glass of the Simplat/Simplex discs can explain this adhesion discrepancy. In the case of aluminium, only 3rd generation Thorens discs flake (yellow/green hues). This lacquer has the characteristic of poor adhesion to aluminium and rapidly switches from cracked to flaking. Zinc bases from the manufacturer Pyral have the particular feature that the unrecorded area on the periphery of the disc cracks and peels off. The engraved part is seldom affected.

Peeling away



Description

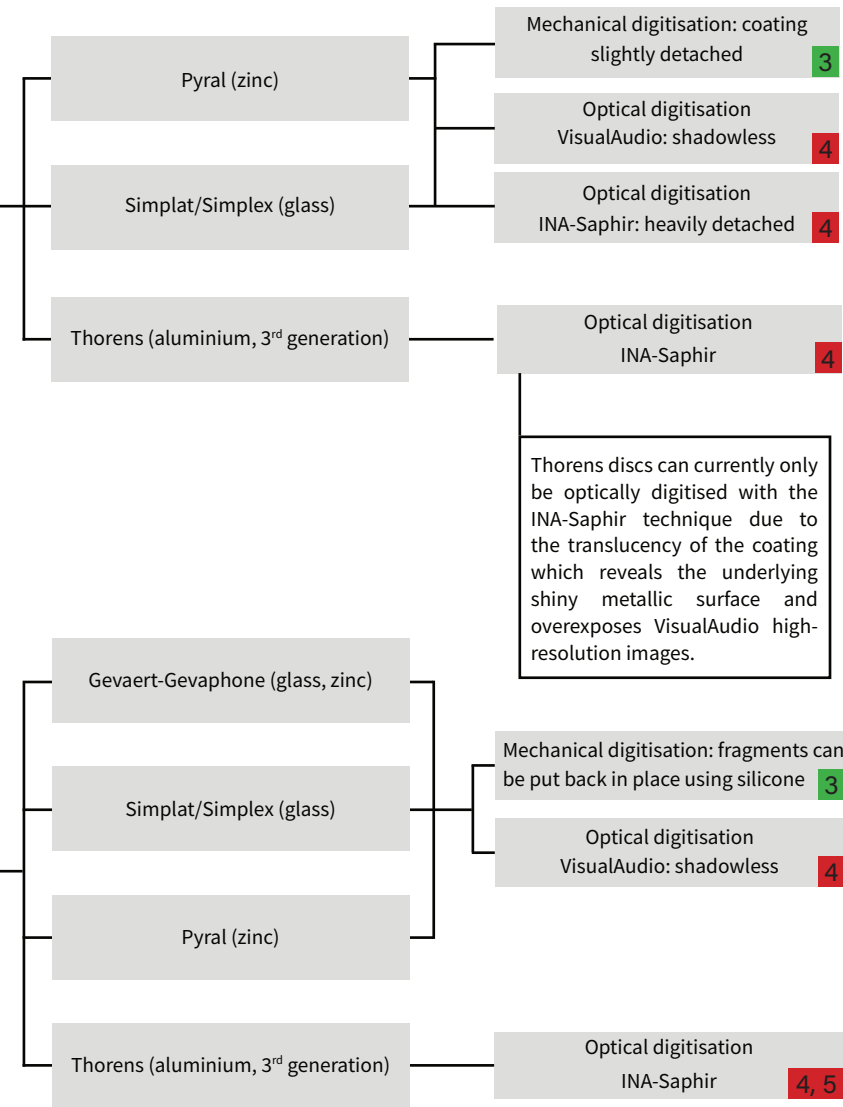
The coating is detached and peels away from the substrate.
Term RTS: délamination, en morceau

Cause

Internal stresses caused by significant thermohygroscopic variations, with a repetitive movement between the rigid substrate and the flexible coating.

Trends

Gevaert-Gevaphone discs with glass bases are the most affected by this degradation. Once the coating cracks, it flakes and peels away. The whole Gevaphone coating on the disc surface comes away. Thorens 3rd generation discs (yellow/green tint) are affected by the same signs of damage. As opposed to other aluminium-based discs, these discs remain the only ones to flake and peel away as soon as they cracked.



5

Blisters, level 1



2

Description

Level 1: The coating remains attached to the substrate but presents a few blisters on the disc surface.

Level 2: The coating is fixed to the substrate but infested with unburst blisters. The surface is becoming highly brittle. Mechanical digitisation may burst the blisters or skip the groove.

RTS term: piqué

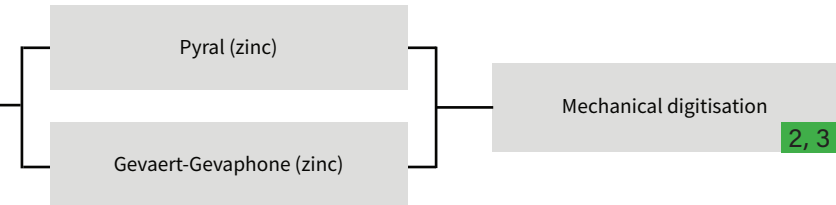
French terminology: surface boursouflée

Cause

Decomposition of the cellulosic lacquer resulting from suspected metallic corrosion.

Trends

Zinc discs are the main substrates affected by this degradation.



Blisters, level 2



3

Burst blisters (corrosion)



4

Description

The lacquer resembles a sandpaper surface and falls into dust. The blisters have burst.

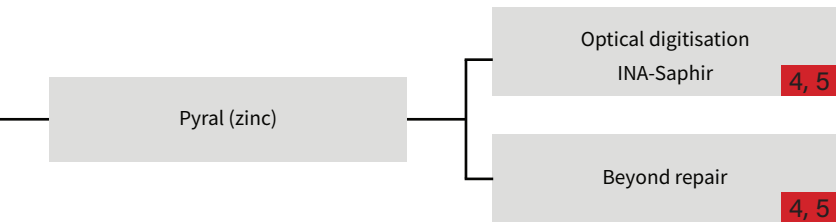
RTS term: criblé

Cause

Decomposition of the cellulosic lacquer resulting from suspected metallic corrosion.

Trends

Since this degradation only affects coatings applied on a zinc substrate, the partial or complete decomposition of the cellulosic coating is probably initiated by metallic corrosion. The phenomenon is systematic for Radio-Lausanne's discs stored in sealed metal containers and separated by sulphurised greaseproof paper. A suspected reaction with the pollutants and the sulphurised paper could be the cause of the extent of the decomposition (the presence of sulphur has yet to be confirmed). Interestingly, the last side of a zinc-based disc stored in a metal container, in direct contact with a piece of cardboard as opposed to greaseproof paper, is usually intact.



5

Warping



4

Description

The coating is in good condition, but the disc is warped and results in turntable arm and reproduction styluses jumping during standard digitisation.

RTS term: gondolé
French terminology: voilé

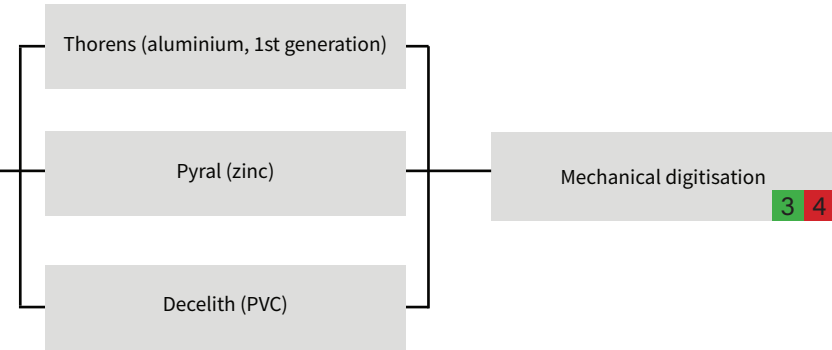
Cause

Mechanical deformation due to unsuitable storage.

Trends

In the Radio-Lausanne collection, the discs impacted are stored in half-filled cardboard boxes: Thorens 1st generation (single-sided coated), Decelith flexible discs, and excessively flexible Pyral zinc-based discs.

Substrates used by the manufacturers of Decelith and Pyral discs are too thin and flexible to remain flat.



Broken (substrate)



4

Description

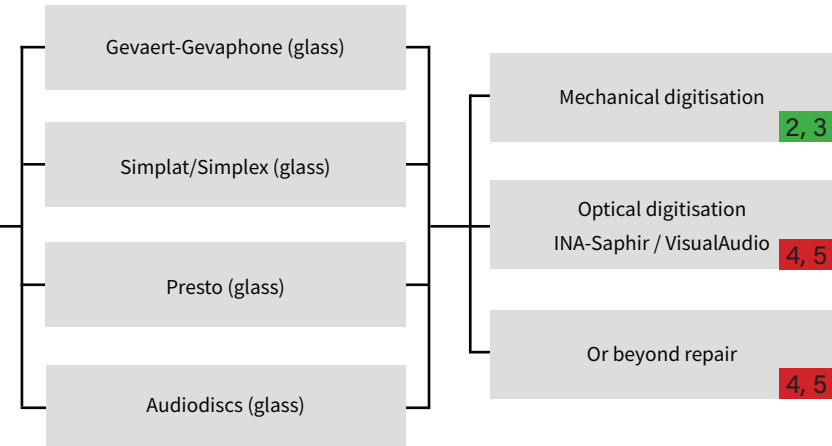
The substrate is broken into several parts.

Cause

Mechanical shock.

Trends

Given the fragility of the substrate, this deterioration affects only glass-based discs (Simplat/Simplex gelatin-coated discs, Presto with glass cores and the Belgian Gevaert-Gevaphone red-coated glass discs). Glass-based discs with central metallic or organic ferrules (Simplat/Simplex/Presto/Audi discs) break more rarely than Gevaphone discs. The latter is not reinforced with a metallic ferrule. The inclusion of a ferrule around the central hole considerably strengthens the glass and prevents central breakage, a frequent deterioration of the Belgian discs.



5



Description

Mould has developed on the surface of the coating. It is identifiable by small white spots/filaments.

Cause

Gelatin and cellulose nitrate are materials highly sensitive to hygrometric variations.

Trends

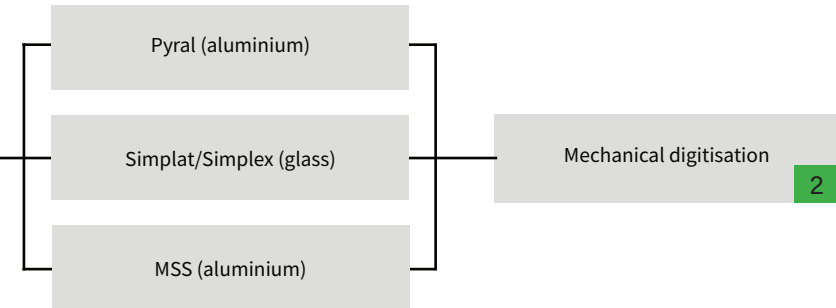
Discs with gelatin-coated glass substrates are favourable targets for mould. Considering Decelith PVC discs, it is still unclear whether the discoloured spots observed in transmitted light are mould spores. Some Radio-Genève MSS discs are seemingly covered with mould, presumably due to damp storage conditions.

Treatment

To avoid reactivating the spores, the discs are kept at a stable relative humidity (ideally at 40-45% RH), protected from dust and not touched with bare hands (grease deposited by the hands is propitious to mould growth).

Mould removal:

- Disc with aluminium substrate: isopropanol
- Disc with glass base: prohibited use of liquid solution (gelatin-based coating).
- Place the disc under a fume hood.
- Digitisation with a microgroove stylus. Operation to be performed using FFP3 masks, nitrile gloves, and safety glasses.



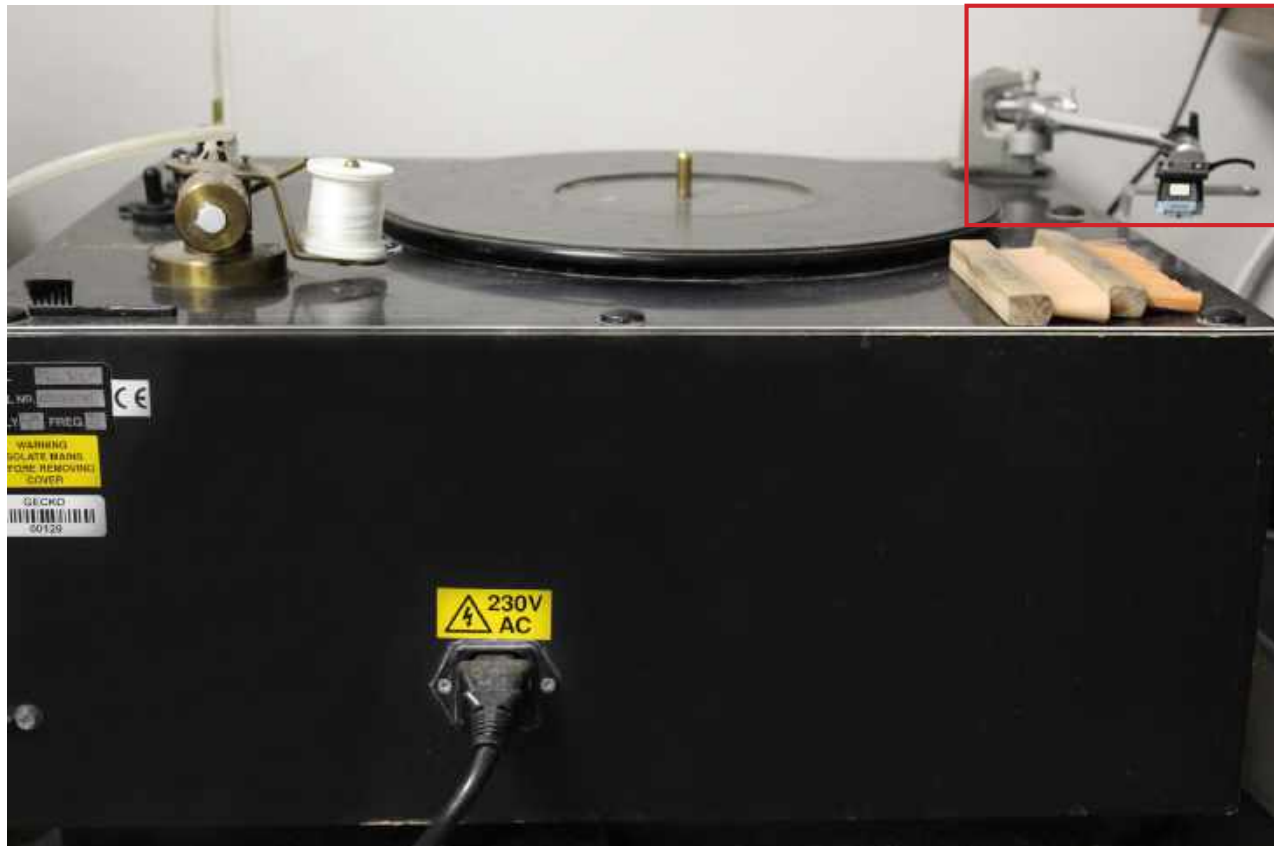
Digitisation tips



Karen Beun

Benjamin Louvet

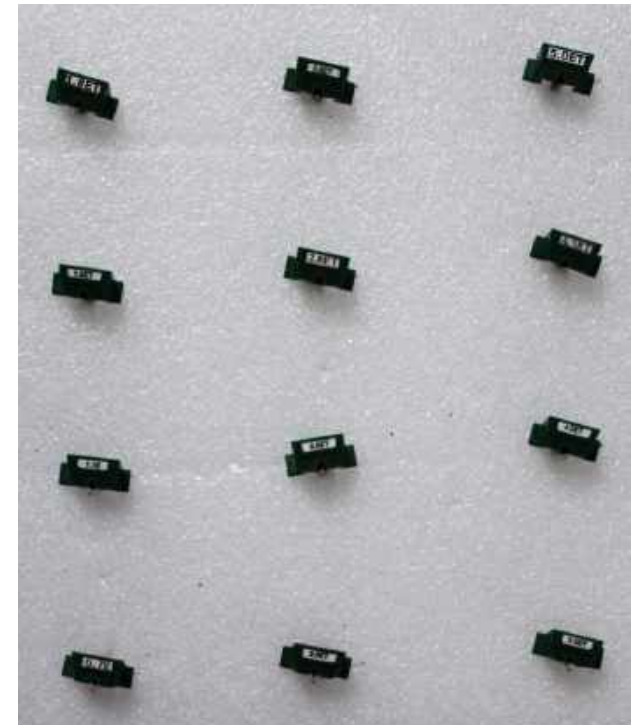
Kévin Deparis



Loricraft Audio with a pre-playback arm

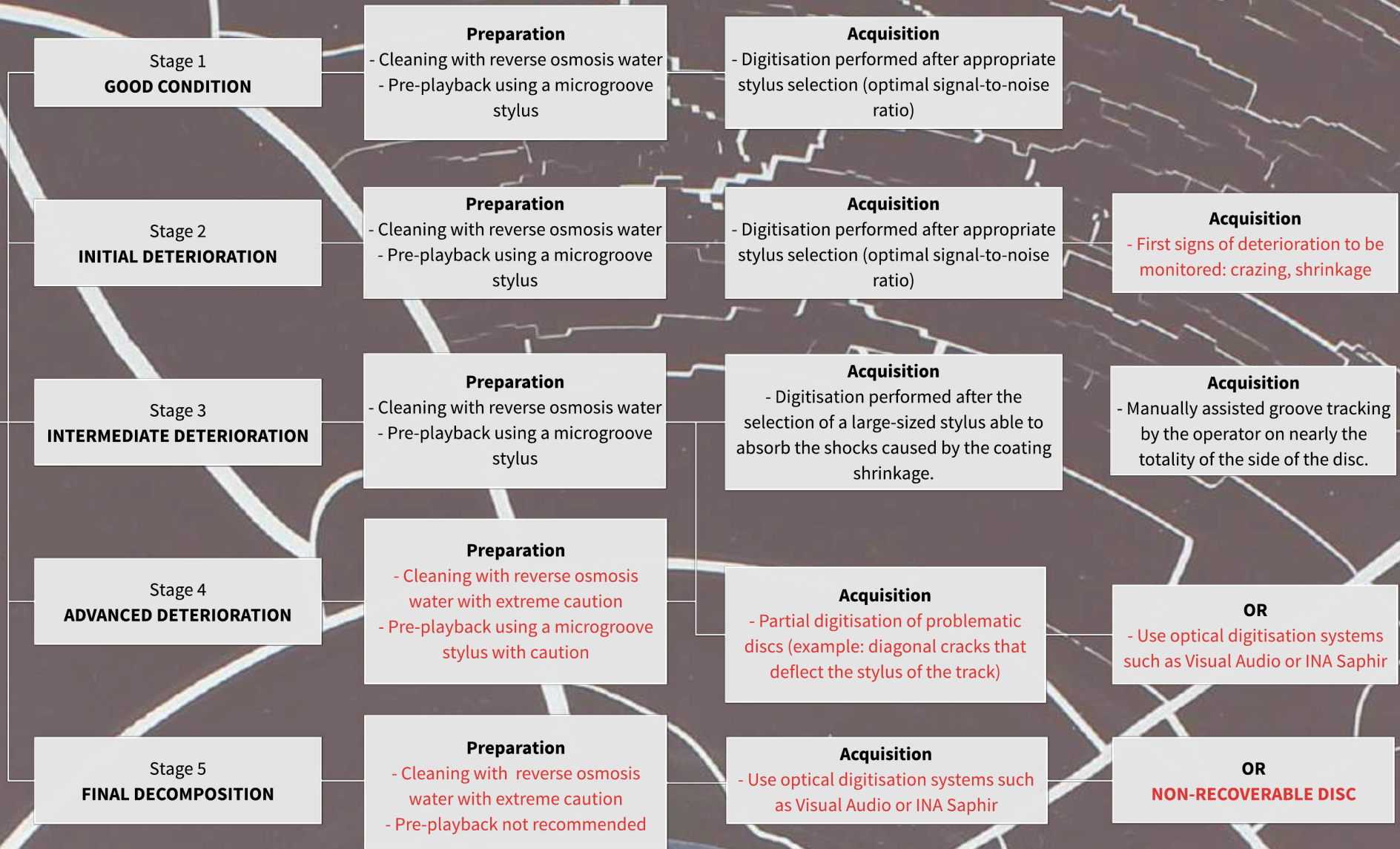


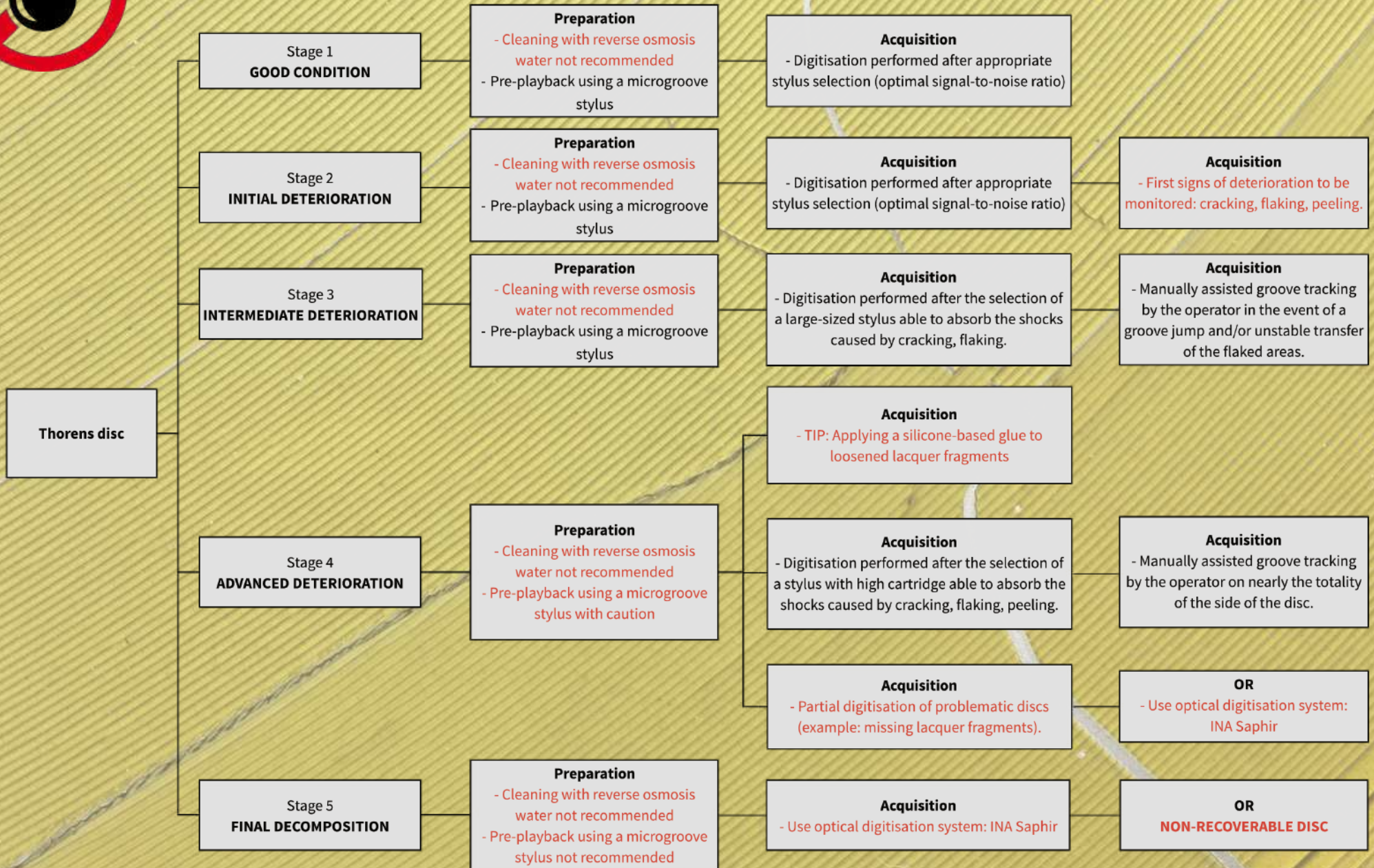
Detail of the pre-playback arm



Selection of different cartridges

**Aluminium-based
Cellulose nitrate
coating**



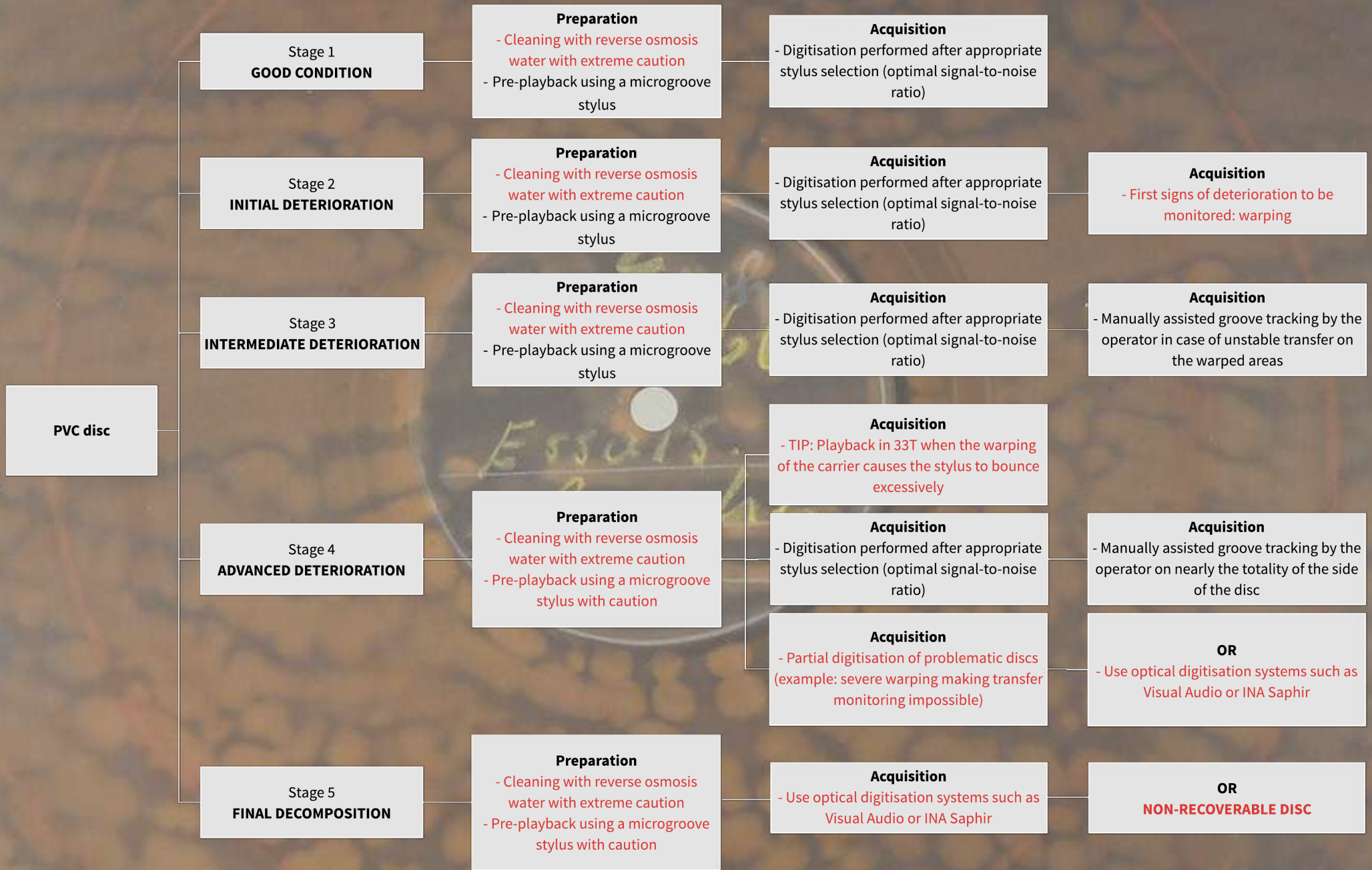






**Glass-based
Gelatin coating**





PVC disc

Stage 1
GOOD CONDITION

Preparation
 - Cleaning with reverse osmosis water with extreme caution
 - Pre-playback using a microgroove stylus

Acquisition
 - Digitisation performed after appropriate stylus selection (optimal signal-to-noise ratio)

Stage 2
INITIAL DETERIORATION

Preparation
 - Cleaning with reverse osmosis water with extreme caution
 - Pre-playback using a microgroove stylus

Acquisition
 - Digitisation performed after appropriate stylus selection (optimal signal-to-noise ratio)

Acquisition
 - First signs of deterioration to be monitored: warping

Stage 3
INTERMEDIATE DETERIORATION

Preparation
 - Cleaning with reverse osmosis water with extreme caution
 - Pre-playback using a microgroove stylus

Acquisition
 - Digitisation performed after appropriate stylus selection (optimal signal-to-noise ratio)

Acquisition
 - Manually assisted groove tracking by the operator in case of unstable transfer on the warped areas

Stage 4
ADVANCED DETERIORATION

Preparation
 - Cleaning with reverse osmosis water with extreme caution
 - Pre-playback using a microgroove stylus with caution

Acquisition
 - TIP: Playback in 33T when the warping of the carrier causes the stylus to bounce excessively

Acquisition
 - Digitisation performed after appropriate stylus selection (optimal signal-to-noise ratio)

Acquisition
 - Manually assisted groove tracking by the operator on nearly the totality of the side of the disc

Acquisition
 - Partial digitisation of problematic discs (example: severe warping making transfer monitoring impossible)

OR
 - Use optical digitisation systems such as Visual Audio or INA Saphir

Stage 5
FINAL DECOMPOSITION

Preparation
 - Cleaning with reverse osmosis water with extreme caution
 - Pre-playback using a microgroove stylus with caution

Acquisition
 - Use optical digitisation systems such as Visual Audio or INA Saphir

OR
NON-RECOVERABLE DISC

Part III: Typology



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p. 105



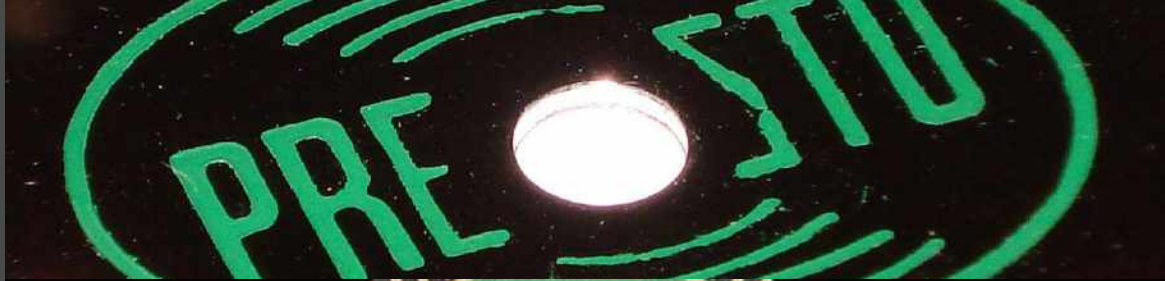
p. 111



p. 115



p. 123



p. 135



p. 152

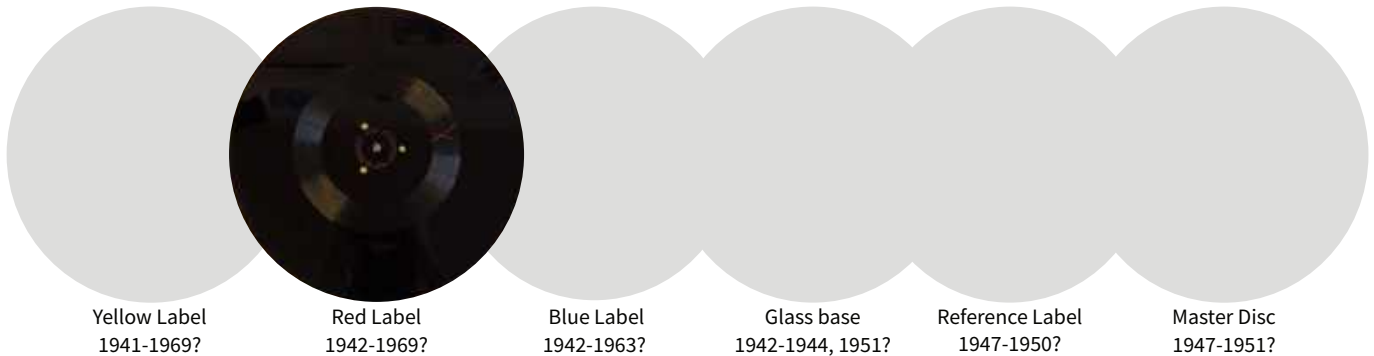


p. 160





Audiodiscs 1937–1973



Yellow Label
1941-1969?

Red Label
1942-1969?

Blue Label
1942-1963?

Glass base
1942-1944, 1951?

Reference Label
1947-1950?

Master Disc
1947-1951?



Yellow Label
1941-1969?

Red Label
1942-1969?

Blue Label
1942-1963?

Ø: 6" (15.24 cm), 6 1/2" (16.5 cm), 8" (20.32 cm), 10" (25.4 cm), 12" (30.48 cm)
13 1/4" (33.65 cm), 16" (40.64 cm), 17 1/4" (43.815 cm)

Identity card

Country of origin	USA (New York)
Manufacturer	Audio-Devices Inc., New York
Trade name	Audiodisc
Coating	cellulose nitrate (?)
Coating colour	black
Substrate	aluminium, glass
Manufacturing techniques	coating using a conveyor system: US Patent 2,607,699



Audiodiscs' ad in Electronics magazine, August 1941

CREDIT: Electronics

Historical background

In 1938, Audio-Devices Inc. became the exclusive American licensee of the patents and expertise of the French manufacturer Pyral, under the trade name Audiodiscs, until their internal research department implemented their manufacturing process¹. During the war, glass substrates partly substituted aluminium cores. In 1973, Audio Devices was purchased by Capitol Magnetic Products and continued to produce Audiodiscs².

Context of use

Years of use by S.R.R. and Radio-Genève³: 1941, 1946-1952.

Radio-Lausanne: discs often recorded by American and Belgian correspondents.

Radio-Genève: discs mainly recorded on Belgian radio (1952).

Audi discs 1937–1973

Recipes

A change in recipe was identified in 1948. A patent filed in 1948 by George M. Sutheim (US 2,607,699) described an improved coating formula to reduce surface noise caused by thermohygro-metric variations. The solution proposed to add specific amounts of inert pigments to the other ingredients of the coating.

Patented Aug. 19, 1952

2,607,699

UNITED STATES PATENT OFFICE

INSTANTANEOUS RECORDING PHONO-
GRAPHIC DISKS

George M. Sutheim, Jamaica, N. Y., assignor to
Audio Devices, Inc., New York, N. Y., a corpora-
tion of New York

No Drawing. Application August 25, 1948.
Serial No. 14,320

11 Claims. (Cl. 188-27)

1 This invention relates to phonographic discs of the instantaneous play-back type and has for its object certain improvements in the method of producing such discs, in the discs themselves as an article of manufacture, in the method of producing the recording lacquer, and in the recording lacquer itself as an article of manufacture.

Phonographic discs of the instantaneous play-back type are formed of a base, such as metal, glass, paper, etc., coated with a recording lacquer. The recording lacquers are made in general of mixtures of cellulose esters or ethins, solvents, plasticizers and dyes. Although various formulas are employed, a typical one is 33.9% of 1/2 sec. nitrocellulose; 18.0% wetting alcohol; 23.2% ethyl acetate; 10.0% dibutyl phthalate; 10.0% castor oil; and 0.9% dye. The coating is dried, by the extraction of volatile solvent, to produce a smooth and uniform surface on the resulting blank phonographic disc. The relatively soft coating on the blank disc is adapted for the cutting of sound grooves or tracks therein by a suitable sound recording or cutting stylus, after which the disc may be played back instantaneously by the use of a suitable sound reproducing point.

One of the main advantages of such recorded discs is in their inherent low surface noise when compared to commercially available recorded phonographic discs of the grooved type.

In humid weather, however, or more specifically during a period of weather in which the temperature rises to 80° F. or higher and the relative humidity to 75% or higher, discs which are quite low in surface noise under more normal conditions, show a very deleterious increase of the noise level, referred to as "climbing." When sound grooves are cut in the disc in humid weather, they appear normal and shiny at first. As the cutting progresses, the grooves change their appearance, they become dull and gray. This change in appearance, of little importance by itself, is invariably accompanied by an increase in noise level. When played back the discs sound noisy to such an extent that the recording becomes practically useless.

Since a similar effect can be obtained by using a defective cutting stylus, it is probable that minute coating particles—or low visibility—adhere to the stylus, which thereupon becomes rough and in turn produces rough and noisy sound grooves. In fact, gentle polishing of the stylus apparently removes the adhering particles, whereupon the cutting proceeds well for a few revolutions; after a short while, however, climbing sets in again.

It is, of course, highly desirable from the view point of the user that blank phonographic discs of the instantaneous play-back type be usable under the most adverse weather conditions with-

out any substantial deterioration in quality, particularly with respect to noise level. That the production of such blank discs is of utmost importance to the manufacturer goes without saying, because otherwise his output is considered faulty, and results in a great deal of customer complaints as well as loss of business.

My investigations have led to the discovery that if a suitable agent is added to and dispersed widely throughout the recording lacquer, before it is applied to the base as a coating, the disadvantages just mentioned are for the most part overcome. The objectionable climbing may be entirely or at least substantially eliminated so that recordings may be made during humid weather without an undue increase in noise level. The special ingredient added to the recording lacquer has a modifying effect on the disc coating, the mechanism of which is not fully understood. The ingredients may be referred to conveniently as a modifying or anti-climbing agent.

As will be seen from the following description, the invention resides in the recording lacquers and the blank phonographic discs, as an article of manufacture.

From the standpoint of the recording lacquer per se for the coating of blank phonographic discs of the instantaneous play-back type, the invention involves a lacquer base having a very finely divided inert pigment widely dispersed therein in amount to inhibit climbing when the lacquer forms a coating on a blank phonographic disc and a sound groove is cut in the coating with a sound recording or cutting stylus.

As far as the phonographic disc per se of the instantaneous play-back type is concerned, the invention comprises a base coated with a recording lacquer containing very finely divided inert pigment widely dispersed therein, the pigment being present in amount to inhibit climbing when a sound groove is cut in the coating with a sound recording or cutting stylus.

As already noted, it is customary in this art to employ as a recording lacquer a mixture of cellulose esters or ethers, solvents, plasticizers, and dyes. Each ingredient functions in its intended manner. The cellulose compounds in large part form the body of the lacquer. The solvents render them soluble for the coating operation. The plasticizers contribute to the pliability of the coatings when the solvents have been extracted in the drying and curing operations. The dyes contribute the desired color. While a variety of dyes may be employed, the one most extensively used is a soluble dye to impart a dark color to the lacquer and hence to the coating on the phonographic disc. Relatively small amounts of the dye are required. The cellulose esters or ethers, solvents and plasticizers vary somewhat in relative amounts, depending to a large extent on the

NO MORE HOT-WEATHER PROBLEMS

... when you record on audi discs®

To the recorderist, the hot, summer months have generally meant plenty of trouble—not because of the heat, but due to the accompanying high humidity. For moisture which is absorbed by the lacquer of a recording disc has a serious effect on the cutting characteristics. The noise level increases progressively while recording, and the cut gets grayer and grayer. This problem has affected the entire lacquer disc industry. But, with Audi discs, it is a problem no longer. You can now record as well on the hottest and dampest day as you could on a crisp day in fall or winter.

This freedom from humidity troubles is the result of an exclusive Audi disc improvement perfected in 1947. It is an improvement which goes far beyond the control of atmospheric conditions during manufacture—far that alone doesn't prevent moisture absorption later on. The moisture problem has been solved at its most vulnerable point—in the lacquer itself!

By the addition of a special moisture resisting agent—without any change in the basic formulation—Audi disc lacquer has been made permanently resistant to humidity. Its outstanding "all weather" performance has been proved by countless tests in our "weather room", under the most severe conditions of temperature and humidity. But the most conclusive proof of all has come from the field. For, during the summer of 1948, one of the most humid on record, none of our customers have reported any difficulties in recording or reproduction due to moisture conditions.

See for yourself what a big difference this improvement can make in your summer recordings. Ask your dealer for Audi discs!

Audio discs are registered in the U.S.A. under various names from F.I.R.L. S.A.B.L. Paris

AUDIO DEVICES, INC.
844 MADISON AVE., NEW YORK 17, N. Y.
EXPORT Dept.: EDECA INTERNATIONAL, 11 EAST 10TH ST., NEW YORK 10, N. Y.

© 1949, U.S. Pat. Off.

George M. Sutheim's patent, 1948 (US 2,607,699)

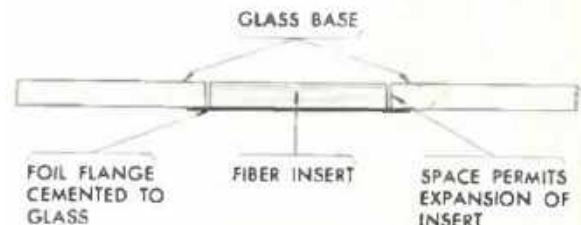
Audio Devices's ad of the newly developed coating, Audio Record, July 1949

Models

According to Allied Catalogs, Audio Devices produced three main Audi discs models between 1941 and 1969:

- **Red Label.** Disc intended for professional use by radio services and professional recording studios.
- **Yellow Label.** Model used in school projects or by studios.
- **Blue Label.** Disc specially developed for home recording.

During the war, glass cores replaced aluminium substrates. Audio Devices reintroduced glass bases in 1951 to counteract the restriction of aluminium for civil use imposed by the American government. Glass-based Audi discs are recognisable by the organic fibre ring inserted around the central hole of the glass base to reinforce the disc⁴.



Fiber ferrule

In 1947, the manufacturer introduced two new models:

- **Reference Disc.** Type of disc intended for recording tests, reference records and to adjust the equipment.
- **Master Disc.** Discs used as a master for future pressing.



Decelith 1935–1948?



Decelith flexible disc
1935-1945?



Decelith Typ-L
1945-1948?

CREDIT Charleston1966



Labels, stamps and inscriptions

1935-1939?

1940-1945?

Decelith flexible discs

Decelith Typ:L, 194?-1948?

Ø: 20 cm, 25 cm, 30 cm

Identity card

Country of origin	Germany (Eilenberg)
Manufacturer	Deutsche Celluloid-Fabrik
Trade name	Decelith
Coating	PVC
Coating colour	black - orange - yellow - purple - grey - red
Substrate	PVC (Decelith flexible), plastic? (Typ-L)
Manufacturing techniques	coating by layer

Context of use

Years of use by S.R.R. and Radio-Genève: 1936-1945

Radio-Lausanne: punctual use of Decelith flexible discs in accession numbers with Roman numerals.

Radio-Genève: widespread use of Decelith flexible discs between 1940 and 1942, occasional in 1943.

Historical background

The brand name Decelith refers to PVC thermoplastic products⁵, manufactured since 1935 at Deutsche Celluloid-Fabrik AG (DCF) in Eilenburg⁶. This dating is made possible with registers of the Reich Patent Office (registered as a new trademark on December 3, 1935)⁷. The trade name Decelith is based on Deutsche Celluloid-Fabrik. The company produced two types of plastic: hard PVC (rigid PVC, PVC-U, non-plasticised) and soft PVC (PVC-P, plasticised)⁸. In addition to discs, sheets, plates, and pipes were produced using Decelith. Records production ceased after the partial destruction of the factory in the last two weeks of the Second World War (between 17 April 1945 and 1 May 1945)⁹. After being dismantled on 23 August 1945, the production of Deutsche Celluloid-Fabrik resumed in October 1945 under provisional Soviet control. It is, however, unclear whether the discs production resumed¹⁰.

Manufacturing

Two types of Decelith discs are currently identified in the heritage collections:

- a flexible and translucent disc consisting of a three-layer structure (Soft Decelith - Hard Decelith - Soft Decelith). They are generally recognisable by different colours when observed with transmitted light: blue, brown, yellow, black and purple. The centre is rough, and one side contains the inscription Decelith and a serial number.
- a later hard disc called Type-L and formed of a white substrate (polymer?) coated with a dark coating recording layer¹¹. These discs are labelled with the paper inscription "Decelith Typ-L".

The process of producing the polymer is described in one of the patents filed by Deutsche Celluloid-Fabrik: “Polyvinyl chloride powder or its copolymers [...] are crushed with water in known devices, plate or colloid crushers, to obtain a completely homogeneous paste, which allows to incorporate dyes, pigments and plasticizers at the same time [...] The paste thus produced can be applied to metal plates or other suitable substrates into a completely uniform layer of any thickness using the appropriate equipment¹².” The German manufacturer’s patents also list some ingredients: polyvinyl chloride and its copolymers with esters acrylics, methyl esters, maleic esters, vinyl acetate, and benzyl halide resins (to produce a waxy surface)¹³.



Extract from the German patent DEU 737,661 filed in 1935 by Deutsche Celluloid-Fabrik

Recording specifications

Decelith discs could be recorded with a diamond, sapphire or steel stylus. The steel stylus proved to be the most effective¹⁴. The discs fall into the category of lateral engravings with standard width grooves (120 µm, rounding radius 30 µm)¹⁵. The recording recommendations are a cutting depth of approximately 0.125 mm, a contact pressure of approximately 100 grams, and a cutting angle of about 87-89° from the disc plane surface. The manufacturer also recommends storing the disc flat, away from light and dust¹⁶. The firm specified that the PVC smooth surface enables to record a high-frequency range, a suitable sound dynamic range (44 dB) and a low distortion factor (6%). This distortion is due to irregularities in the material¹⁷.



Sleeve with use instruction of Decelith discs as specified by the manufacturer.

Identification

PVC



Ø: 20, 25, 30 cm

Trends

Ø 25 (trend from 3 discs)

Weight (grams): 60 (1936) - 76 grams (1940)

Disc thickness, edge (mm): 0.76 (1936) -1.24 (1940) (mean 1.08)

Disc thickness, midpoint (mm): 0.95- 1.205 (mean 1.14)

Ø 30 (trend from 3 discs)

Weight (grams): 99-106

Disc thickness, edge (mm): 0.9 - 1.12 (mean 1.04)

Disc thickness, mid. (mm): 1.025-1.26 (mean 1.15)

Materials and composition:

Coating: PVC

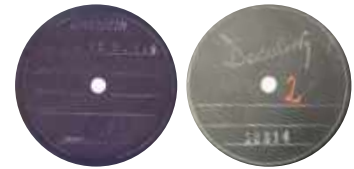
Coating colour: black - orange - purple - yellow - magenta - red - grey

Substrate: PVC

Characteristic/Identification criteria: flexibility, translucency. Decelith inscription with reference number on one side. Label and centre have a rough surface, with a sandblasted appearance.

1936-1939?

1940-1945?



Label with rough centre

30 cm (12")
99-106 grams

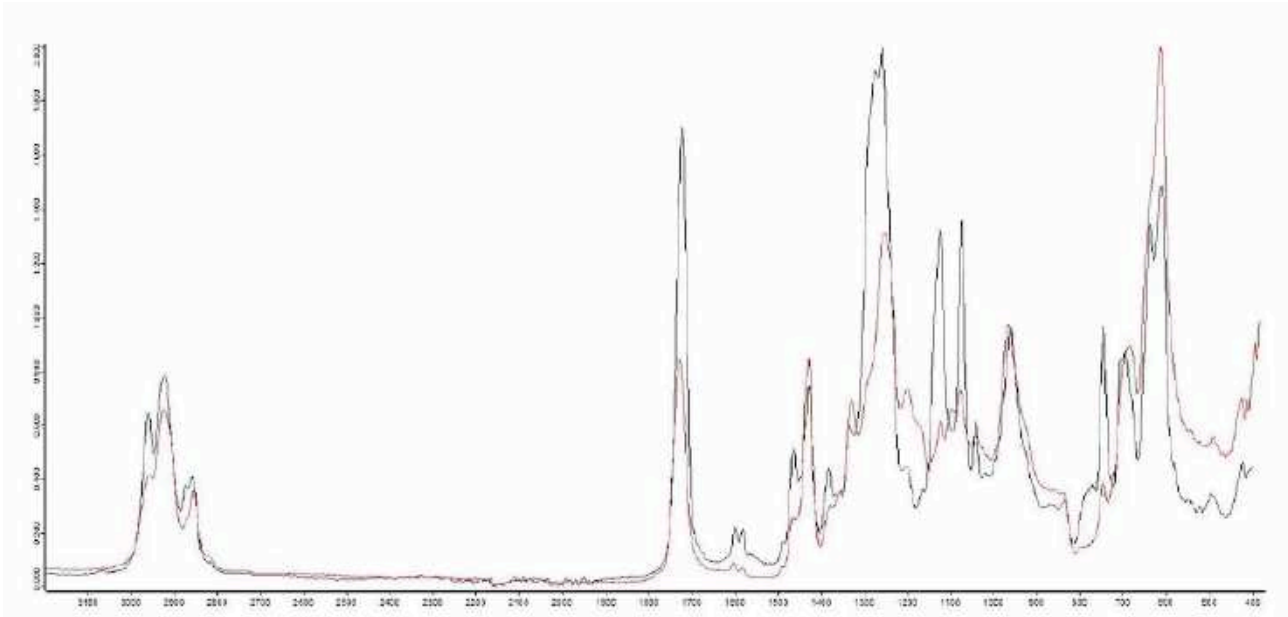


Decelith flexible discs, first introduced in 1935, are composed of a three-layer PVC structure. The base is a hardened Decelith coated on both sides with a thin and coloured PVC film. Its particularity is that the synthetic coating is not applied on a metal or glass base. It is made from a polymer that requires no hardening stage as it hardens itself in the air after cutting¹⁸. This specific feature prevents the cutting stylus from being damaged if hitting the hard substrate when the cut is too deep¹⁹. As a result of this uniformity, the manufacturer emphasised that the substrate is unbreakable, non-flammable, and resistant to moisture and tropical conditions²⁰.

Degradations: warped – white residues – coating discolouration

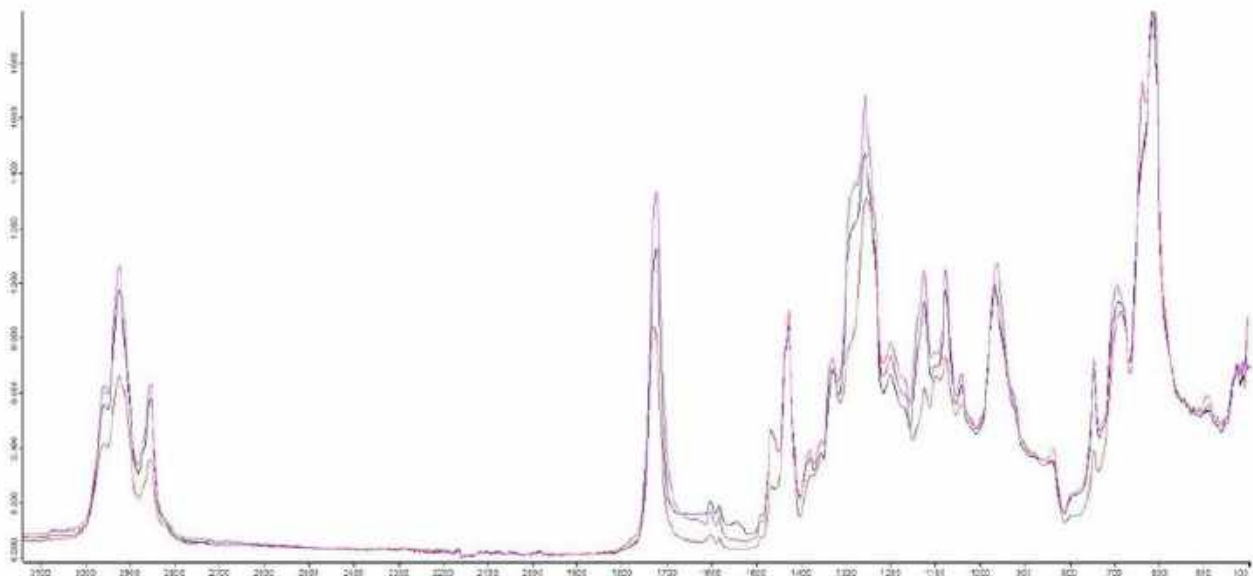
Chemical study

FTIR molecular analyses were undertaken by Nadine Bretz as part of her Bachelor's thesis at the Technische Universität München to identify the composition of Decelith. The analyses confirm PVC as the main polymer used. Although microscopy visuals distinguish different shades, the results of the molecular analysis showed no significant difference between the intermediate PVC layer and two samples of the outer PVC layer. However, the peaks associated with the plasticiser present a lower concentration in the intermediate layer, either to achieve a more rigid core or as a result of incomplete mixing of the plastic mass²¹.



CREDIT Nadine Bretz

*Superimposed FTIR spectra to detect PVC.
Black spectrum: PVC reference spectrum; red spectrum: middle layer of a Decelith disc (SP0165).
The strong peak at 1720 cm⁻¹ indicates the presence of an ester compound, associated with a plasticiser.*



CREDIT Nadine Bretz

*Superimposed FTIR spectra of the central and outer layer of a Decelith flexible disc (SP0165).
Blue spectrum: outer layer SP0165; red spectrum: intermediate layer SP0165; magenta spectrum: outer layer SP0165.*

Microscopic study

The three PVC layers stratigraphy is noticeable under USB microscopy. The groove walls are characterised by parallel striations. Dust deposits inside the groove are frequent.



Decelith flexible, Radio-Genève, L232, 1941. Right: Stratigraphy, cross-section. Left: groove walls striations. USB micrograph, 250x

Radio-Genève, L232, Interview with Edouard Schneider on the conference about the Golden Age of the Comédie Française, by Henri Meyer from Stadhofen, 24 November 1941.



Decelith flexible, Radio-Lausanne, 7X, 1936. Right: Stratigraphy, cross section. Left: groove walls striations. USB micrograph, 250x

Radio-Lausanne, 7X, Un festival se prépare: tir cantonale, 21 June 1936.



Decelith flexible, Radio-Genève, Y272, 1942. Right: Stratigraphy, cross section. Left: groove walls striations. USB micrograph, 250x

Radio-Genève, Y272-1, "La Comédie du Bonheur", radio theatre, 16 June 1942.

Alterations

The deterioration of Decelith flexible discs is very diverse:

- Disc discolouration is the predominant alteration (generalised discolouration or round spots). The precise sources of these phenomena remain currently unknown due to the lack of knowledge about production conditions (external influences or material properties during the manufacturing process) or ageing. Some discolourations may be related to a photochemical reaction, while others may be caused by factors endogenous to the PVC composition²². A study by A. Wesche suspected a migration of dyes or pigments induced by humidity or a change in dye density²³. The change in colour could also be the result of an uneven mixing of the plastic mass during manufacture, variations in the plasticiser quantity, or changes in the quality of the core polymer²⁴.
- Warping due to poor storage conditions.
- White residues with a waxy appearance, the result of plasticiser loss (?). PVC plasticisers are bonded to the synthetic resin by van der Waals forces, which are weak chemical bonds. Plasticiser particles migrate relatively quickly to the surface, even at low temperatures²⁵.
- Dust.
- Greasy residues, with adherence to the grease-proof paper. Conservators recommended removing the acidic paper, as an acidic environment accelerates the ageing of PVC²⁶. Currently, it is unclear if the acidic paper sticks due to the plasticiser loss or whether the solution is formed in contact with the acid paper²⁷.



Decelith flexible, Radio-Lausanne, 2415X, 1940.
“Le français, notre langue”, a conversation with Camille Dudan, 17 April 1940.



Decelith flexible, Radio-Genève, M266, 1942.
Un douze centième anniversaire: Charlemagne, radio theatre, 17 May 1942

Discolouration in the shape of pores. No germ cells.



Decelith flexible, Radio-Genève, J230, 1941. Warped disc.
Onze hommes, radiogame, 16 November 1941.

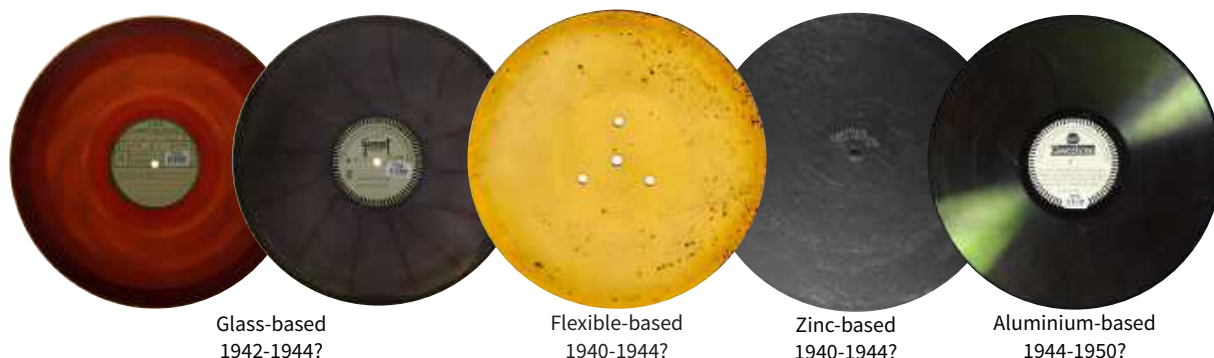
Decelith discs were already regarded as problematic for playback in 1938²⁸. This format is too thin and flexible to remain flat on the turntable. Surface noise was considered excessively high by BBC standards in 1938²⁹. Another problem is the shelf life since the discs warp when stored vertically. The recommendations of the manufacturer are to lay the disc flat (see sleeve p. 106)³⁰.



Decelith flexible, Radio-Lausanne, 654VII, 1940. Left: waxy appearance; right: discolouration in the shape of pores. No germ cells.
“Les aventures épiques de Jean-Louis Grognard”, 6th episode. Radio soap opera, 27 June 1940.



Gevaphone 1940–1950?



Glass-based
1942-1944?

Flexible-based
1940-1944?

Zinc-based
1940-1944?

Aluminium-based
1944-1950?



Labels, stamps and inscriptions

Reverse of flexible-based

1940-1944?

1945-1948?

Gevaphone, zinc-based

Gevaert-Gevaphone,
aluminium-based

Ø : 25 cm, 30 cm

Identity card

Country of origin	Belgium
Manufacturer	Gevaert
Trade name	Gevaphone
Coating	cellulose nitrate?
Coating colour	red - dark red - black - yellow - green
Substrate	glass, zinc, aluminium



Gevaert logo on a interlayer applied to one side of a flexible record.

CREDIT Frits Jonker

Historical background

Founded in 1890 by Lieven Gevaert in Antwerp, the firm Gevaert first developed products for photography. In 1904, L. Gevaert & Cie moved to Mortsel. In 1947, Gevaert manufactured radiographic films. It was merged with Agfa in 1964 to become Agfa-Gevaert³¹. No mention of the production of Gevaphone instantaneous discs was discovered in patents filed by the company.

In the RTS collection, the most common discs are made of a glass substrate. The collection includes a limited number of discs with an aluminium base. These aluminium-based discs are very similar to the French Pyral discs. Since several manufacturers produced discs under license from Pyral (such as the English manufactures EMI and the American firm Audio Devices), it is conceivable that Gevaert may have taken the same initiative.

Identification

Cellulose nitrate?



Glass-based, red coating
1942-1944?



Glass-based, dark coating
1942-1944?

Ø: 25, 30 cm

Trends

Ø 25 (1 disc)

Weight (grams): 207

Disc thickness (mm): 1.84-1.85

Coating thickness (mm): 0.18

Ø 30 (trend from 6 discs)

Weight (grams): 279-314 (mean 297)

Disc thickness, edge (mm): 1.72-1.97 (mean 1.86, median 1.88)

Disc thickness, midpoint (mm): 1.75-1.97 (mean 1.847)

Coating thickness (mm): 0.15-0.21

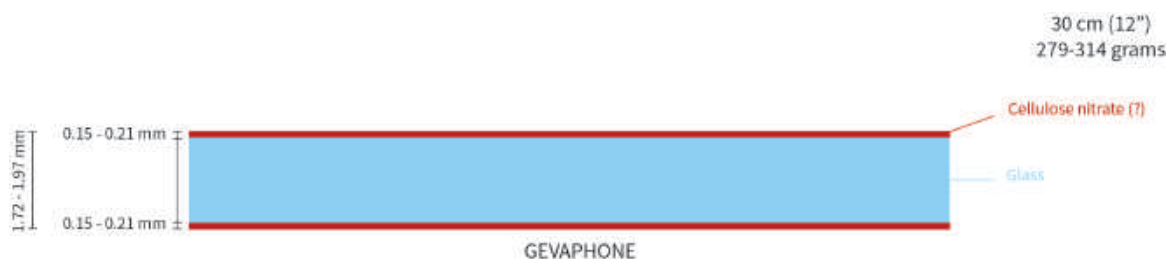
Materials and composition:

Coating: cellulose nitrate?

Coating colour: red - dark red (thicker coating layer) - black

Substrate: glass

Characterisation/identification criteria: glass substrate without metallic or organic ferrule around the central hole, edge of the disc not bevelled (unlike Simplat/Simplex discs). The thickness of the coating is higher (0.15-0.21 mm) than Simplat/Simplex gelatin glass-based discs (0.09-0.14 mm).



Degradations: flaking – coating peeling – broken substrate – sticky coating

Context of use Gevaphone

Years of use by S.R.R. and Radio-Genève: 1942-1943, 1948 (aluminium)

Price 1942 (CHF)³²: 3.-

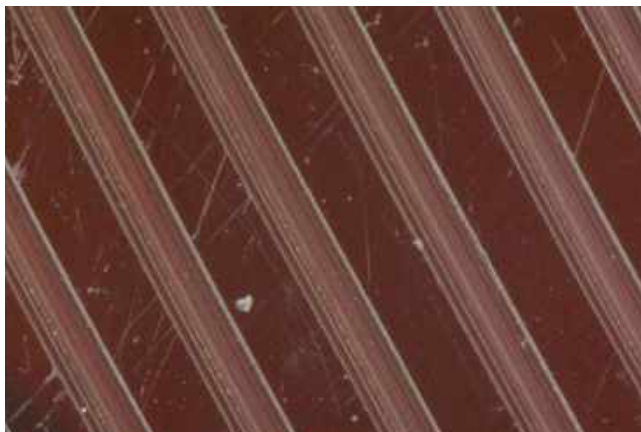
Radio-Lausanne: trademark used in 1942, discs stored in metal cans. There are also some aluminium-based discs (1948), extremely unusual in the collection.

Radio-Genève: frequent use between 1942 and 1943 of glass-based discs. The zinc-based discs are occasionally used between 1941 and 1943, alternating with zinc discs from the manufacturer Pyral. The sides usually are unlabelled.

Microscopic study

Two cutting depths are clearly distinct when observing discs recorded in 1942 at both Radio-Lausanne (9341) and Radio-Genève (K304) studios. Radio Genève's cutting is shallower, and the striations of the groove walls are not as marked as the SRR discs.

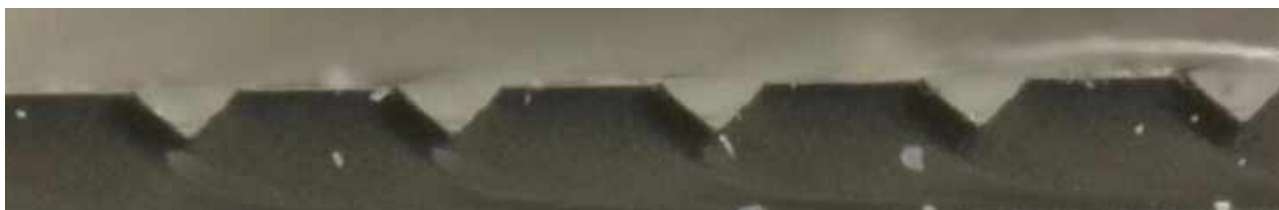
A white layer is visible on the surface of the accession number J282 disc. The sticky layer has at present no explanation: is it the first stage of a process of plasticiser loss or a chemical reaction with environmental pollutants?



Gevaphone, Radio-Genève, K304, 1942. USB micrograph, 250x.
Quatre sur un piano, 30 December 1942.



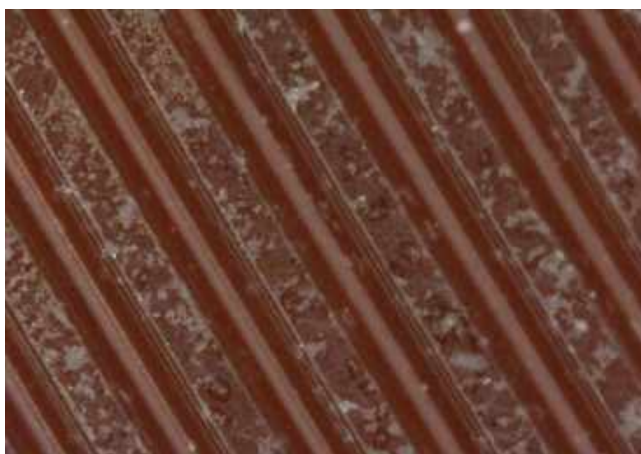
Gevaphone, Radio-Lausanne, 9341. Groove striations.
USB micrograph, 250x. *Reportage Théâtrale de Stella, 02 December 1942.*



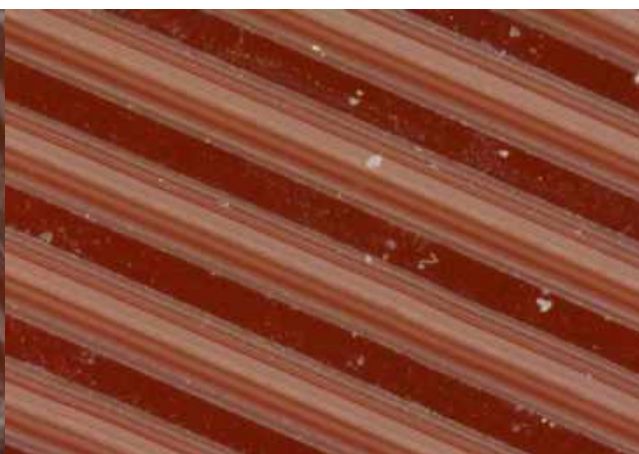
Gevaphone, Radio-Genève, K304, 1942. Stratigraphy, cross-section. USB micrograph, 250x. *Quatre sur un piano, 30 December 1942.*



Gevaphone, Radio-Lausanne, 9341, 1942, Stratigraphy, cross-section. USB micrograph, 250x. *Reportage Théâtrale de Stella, 02 December 1942.*



Gevaphone, Radio-Genève, J282, 1942. White sticky layer.
USB micrograph, 250x. *Report on South Central America, 21 August 1942.*



Gevaphone, Radio-Lausanne, 8632, 1942. Groove striations.
USB micrograph, 250x. *Le quart d'heure du sportif, 18 September 1942.*

Alterations

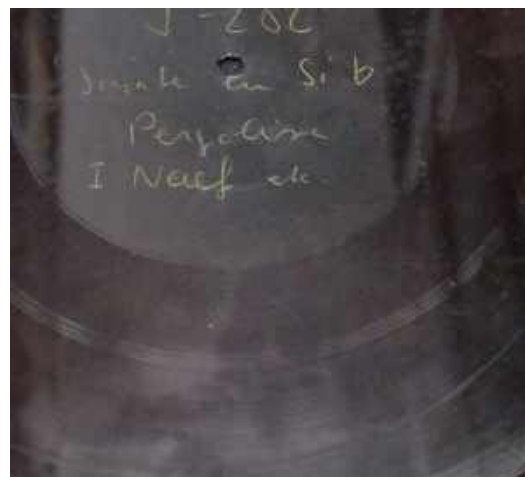
Gevaphone red-coated glass-based discs crack and break into several fragments due to the vulnerability of the substrate. A frequent central breakage is attributed to the lack of a metallic ring/ferrule around the central hole to strengthen the glass and increase the mechanical shock resistance. The highly brittle coating layer adheres poorly to the glass, ruptures and rapidly falls apart. A thin, sticky white layer partially covers the surface of the coating of the discs, especially those stored in metal containers.



Gevaphone, Radio-Lausanne, 8632, 1942.
Complete peeling of the coating layer.
Le quart d'heure du sportif, 18 September 1942.



Gevaphone, Radio-Lausanne, 8648, 1942. Broken disc.
Prélude et fugue en mi bémol, Saint-Saëns, by André Marchal, 26 September 1942.



Gevaphone, Radio-Genève, J282, 1942.
White sticky layer.
Report on South Central America, 21 August 1942.



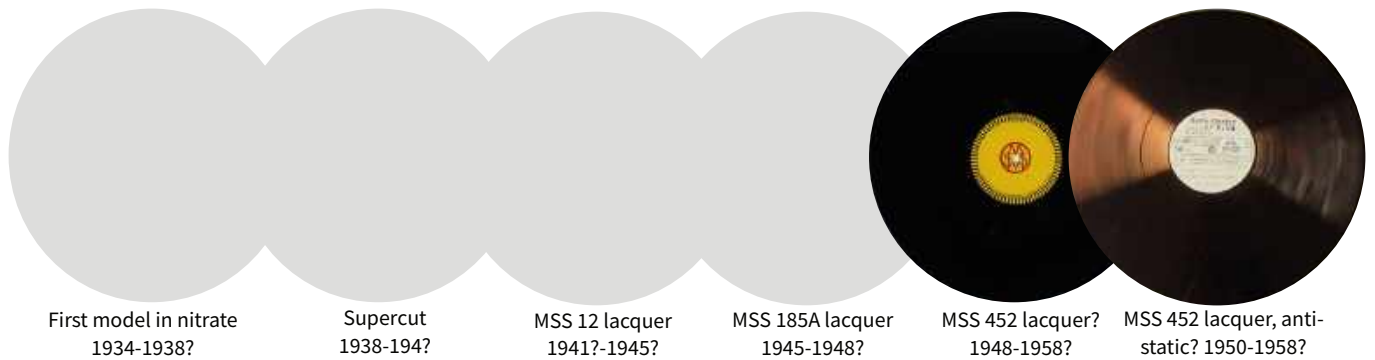
Gevaphone, Radio-Lausanne.
Complete peeling of the coating layer.



Gevaphone, Radio-Genève, A274, 1942. Split disc.
Demain on n'y pense plus, radio theatre, 17 June 1942.



MSS 1930–1968?



First model in nitrate
1934-1938?

Supercut
1938-194?

MSS 12 lacquer
1941?-1945?

MSS 185A lacquer
1945-1948?

MSS 452 lacquer?
1948-1958?

MSS 452 lacquer, anti-
static? 1950-1958?

Labels, stamps and inscriptions



Marguerite Sound
Studios 1936-1938?



MSS, 1941?-1948



MSS
1948-1958?



Master Sound System
c. 1948-1958?



MSS
1950-1958?



MSS, coated centre
white MSS inscription
c. 1948-1958?

Ø: 10" (25.4 cm), 12" (30.48 cm), 13" (33 cm), 16" (40.5 cm), 17¼" (43.24 cm)

Identity card

Country of origin	England (plants in Kew, Colnbrook et Waysbury ³³)
Manufacturer	MSS Recording Company Limited (Co Ltd). Marguerite Sound Studios (1933), Marguerite Sound System (from 1934), Master Sound System (c. 1942). The name 'Marguerite' was a family name and used by the company founder Cecil E. Watts and his wife Agnes for their new business, believing that the name was lucky ³⁴ . Main supplier of discs for the BBC with EMI.
Head office	London Shaftesbury Avenue; 99A, Charing Cross Road, London, W.C.2.83 (1933-1937); The Green, Kew Surrey (from 1 December 1937- c. 1941).
Founder	Cecil E. Watts (1896-1967). The company was managed primarily by Cecil E. Watts. In wartime, the General Post Office took over the running of the plants and developed a new type of coating.
Coating	cellulose nitrate
Coating colour	black - red
Substrate	aluminium (1934 - c. 1958), zinc (1941 - c. 1947)
Identification	slightly larger diameter than other European manufacturers (disc in inches). The discs are either single-sided or double-sided.
Manufacturing techniques	hand-sprayed, dipping

Historical background

Marguerite Sound Studios was created in the early 1930s. The first records made by Cecil Watts were for advertisements agents³⁵. Correspondences held at the BBC Written Archives Centre partly established the chronology of the manufacturer MSS and its connections with the BBC. One of the first mentions of contact between the manufacturer and the BBC dates back to 1933³⁶. The requests were for a supply of recorders, cutters and lacquer discs. In 1936, the main MSS disc defects reported were warping, uneven surface, grit, noise, dye marks, craters, blisters or an off-centre spindle hole³⁷. The BBC research unit required a consultant chemist named Yardley in 1937 to improve the quality of the coating. He identified the reasons for the disc rejections as a filtration problem. An air conditioning system was therefore installed³⁸. The war affected the firm in terms of equipment, accommodation and raw materials supply and led to problems in supplying the BBC. The lack of a skilled workforce also prevented discs production from increasing³⁹.

In late May 1941, BBC correspondence reported that the General Post Office (GPO) was taking over the operation of MSS factory as a wartime measure. Under the Defence of the Realm Regulations, the General Post Office proposed to appoint a controller for the duration of the war to manage the MSS, a necessary condition to ensure a satisfactory supply of discs and recording devices for important government activities⁴⁰. The Post Office appointed Dr. Radley as the controller and Watts as the works manager⁴¹. The takeover of the company by the Post Office, with research conducted at Dollis Hill and a new plant in Colnbrook, led to a considerable improvement in the quality of the discs⁴². In that period, MSS produced discs according to two requirements, one for the BBC and the other for the Post Office, the latter being, according to the BBC, a disc below their standards⁴³. After the war, Cecil Watts did not reprise the running of MSS but began "Cecil E. Watts Limited"⁴⁴. In July 1946, the Plessey Company was in an advanced stage of negotiation to acquire MSS⁴⁵. The company ceased its activity in 1968⁴⁶.



CREDIT BT Archive



CREDIT BT Archive

General Post Office Research Station, Dollis Hill, 1935



CREDIT BBC WAC

Headings of correspondence letters. Top) 1933; Centre) 1934; Bottom) 1935

Manufacturing techniques

The early discs were manufactured with 99% pure aluminium and the grooves were embossed⁴⁷. Cecil Watts' widow, Agnes Watts, recalled the first manufacturing technique for lacquer discs as "amateurish", with air bubbles and pin holes, where the disc was hand-sprayed. The manufacture of the discs occurred out of the studio office hours because of the smell of the components⁴⁸.

The first discs were made in a room in the Charing Cross studio, using spraying booths and racks for drying. Cecil Watts personally developed a system to dry the discs using long wooden bars build into frames. As soon as he had sprayed the discs in the spraying booths, he would lift the discs to the drying racks⁴⁹. Other manufacturing methods included dipping, where aluminium circles were dipped into a cellulose nitrate solution⁵⁰.

Agnes Watts recollects the number of layers and the trials and errors⁵¹:

"In the early days these required a least four coats on both sides, and each had to be applied before the previous one had become too dry. Timing this at first was a hit or miss affair and many hours of labour and valuable material were wasted. Once the first side was sprayed, it had to dry sufficiently to be turned over to spray the reverse side - and yet not be allowed to become too firm when it was time to apply its next coat. As there were eight cellulose spraying operations to carry out with drying intervals between, Cecil generally stayed up until midnight. Then he would set the alarm to wake him in time to put on the next layer and continue like this throughout the night until the operations were complete, allowing time for the final coat to dry, dismantle the booth and tidy up ready to open the studio at nine o'clock."



Cecil Watts, with a model to illustrate the microscopic aspect of the disc groove.

Models

Between 1934 and 1948, the MSS disc coating was altered several times:

- 1934 - 1938: a first model with a cellulose nitrate coating.
- 1938 - 1947: Supercut disc (8", 10", 12", 13", 16")
- 1941 - 1945?: lacquer 12
- 1945 - 1948: lacquer 185A
- 1948 - 1958?: 452 lacquer

Supercut disc

MSS produced a new type of disc at the end of 1938 named Supercut disc. This disc was similar to the American Cleen-Cut reference disc in terms of the coating composition. It required oiling and a vase-line treatment following cutting, presented a surface noise considerably lower than standard Watt's discs and showed wearing properties equivalent to Cleen-Cut discs⁵². Watts described his new disc as a "black acetate" on an aluminium base, with a quiet surface, long shelf-life before use, a broad range recording, and unbreakable. Single-sided and double-sided formats were proposed with the diameters 10", 12", 13"⁵³.

Lacquer 12

Lacquer 12 coating is harder than EMI, Presto and Advance discs⁵⁴. From 1941 onwards, MSS provided two types of lacquer, one for the General Post Office (GPO) and the other for the BBC studios. GPO discs were renowned for their coating properties that did not completely dry out⁵⁵. During this period, Watts used a spray gun bay with an exhaust fan⁵⁶. In July 1941, the BBC Superintendent Engineer Recording (SER) commissioned the General Post Office to improve the MSS coating to reduce its sensitivity to air and moisture⁵⁷. In November 1941, an agreement between the BBC and MSS established that the discs were to be sprayed with the Post Office lacquer designated 12/3⁵⁸.

Lacquer 185A

MSS modified the composition of its coating in 1945 and introduced lacquer 185A. The lacquer 185A was softer and presented a quieter surface noise than the previous models and did not require oiling of the surface⁵⁹. This elasticity caused issues regarding the resistance of materials. These discs were more easily damaged, and greater loss of high frequency was observed on certain turntables⁶⁰. Somerville, from the Research Unit at the BBC, argued that "*the manufacturers in this country seem to be quite unable to produce a real quiet disc without making it too soft*"⁶¹. In 1947, a visual inspection of various MSS disc sizes showed impurities embedded under the surface (especially with the 17¼" format). Discs were easily damaged during transit due to the softer coating and have a tendency to warp⁶².

452 lacquer

A recurring problem with MSS discs was the electrostatic charge of the coating. The surface attracted dust difficult to remove. In 1948, a new MSS lacquer, known as 452 lacquer, was introduced. Oiling of the surface was not recommended as it increased excessively the surface noise⁶³. In 1950, to prevent electrostatic charge problems, a new formula was developed. The BBC conducted tests on the new coating for background noise, wear, frequency characteristics and hardness. The results found the static charge was considerably reduced (but not completely eliminated), and concluded the disc was superior to previous MSS models⁶⁴. However, a memo from October 1950 stated that the antistatic properties of this new MSS coating were inferior to the EMI Pyral lacquer⁶⁵. The same observation was reported in a 1950 NRU report. The Dutch report mentioned that the coating layer was thicker in the periphery and too thin inwards⁶⁶.

DIRECT RECORDING DISCS

These cellulose lacquer aluminium discs are unequalled for their high performance — a frequency range extending to well above 10 Kc/s is easily recorded and reproduced. They consistently permit efficient cutting over a range of ambient temperatures of from 0°C. to 60°C. Used by leading broadcasting stations, film studios, private and commercial recording studios. Can be stored indefinitely either blank or recorded.

CURRENT LIST PRICES

5 in. Double Sided	1/6d.
6 in. Double Sided	2/0d.
7 in. Double Sided	2/6d.
8 in. Double Sided	3/0d.
10 in. Double Sided	4/6d.
* Single Sided	3/8d.
12 in. Double Sided	6/6d.
* Single Sided	5/3d.
13 in. Double Sided	8/9d.
* Single Sided	7/9d.
16 in. Double Sided	14/6d.
* Single Sided	11/0d.
17½ in. Double Sided	17/6d.
* Single Sided	13/6d.

* Water available.

MASTER RECORDINGS FOR PROCESSING

M.S.S. Discs are ideally suited for recording "Masters" for processing. "Over-size" discs are necessary — for pressings 16", 12", 10" diam. use discs 17½", 13", and 12" diam. respectively.

M.S.S. RECORDING COMPANY LTD.
FOYLE CLOSE, COLNBRICK, BUCKS., ENGLAND

MSS' ad, June 1949

Identification

Cellulose nitrate



MSS 452 lacquer?, 1948-1958?



MSS 452 lacquer, antistatic?, 1950-1958?

Ø: 10" (25.4 cm), 12" (30.48 cm), 16" (40.5 cm), 17¼" (43.24 cm)

Trends

Ø 10" (trend from 2 discs)
 Weight (grams): 146-151
 Disc thickness, edge (mm): 1.335-1.54
 Disc thickness, midpoint (mm): 1.25-1.32

Ø 12" (trend from 9 discs)
 Weight (grams): 209-222 (mean 216)
 Disc thickness, edge (mm): 1.33-1.50 (mean 1.42)
 Disc thickness, midpoint (mm): 1.24-1.35 (mean 1.296)
 Coating thickness (mm): 0.25-0.27 (edge)

Ø 16" (trend from 3 discs)
 Weight (grams): 486-495 (mean 489)
 Disc thickness, edge (mm): 1.715-1.8 (mean 1.75)
 Disc thickness, mid. (mm): 1.615-1.65 (mean 1.63)

Ø 17¼" (1 disc)
 Weight (grams): 568
 Disc thickness, edge (mm): 1.755-1.81 (mean 1.8)
 Disc thickness, midpoint (mm): 1.62-1.63

Materials and composition:

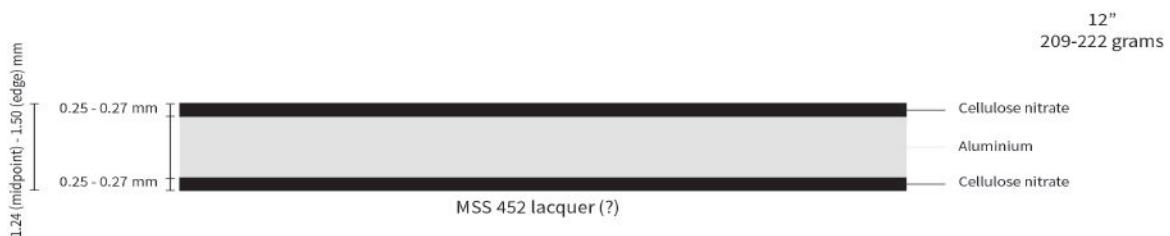
Coating: cellulose nitrate
 Coating colour: black - red
 Substrate: aluminium



Characterisation/identification criteria: The period of disc use by Radio-Lausanne and Radio-Genève matches the model 452 lacquer of the firm. The different colours could be linked to changes in the formula to reduce electrostatic properties. The coating spreads very thinly towards the centre of the discs. Some discs have uncoated edge and centre. In 1948, the BBC requested the spraying of the MSS disc centre, notably for master pressing⁶⁷.



MSS 452 lacquer identification elements



Degradations: first external and internal grooves cracked – moulds

Context of use

Years of use by S.R.R. and Radio-Genève: 1948-1958

Radio-Lausanne: discs recorded by Radio-Lausanne's correspondent in England, Paule Déglon.

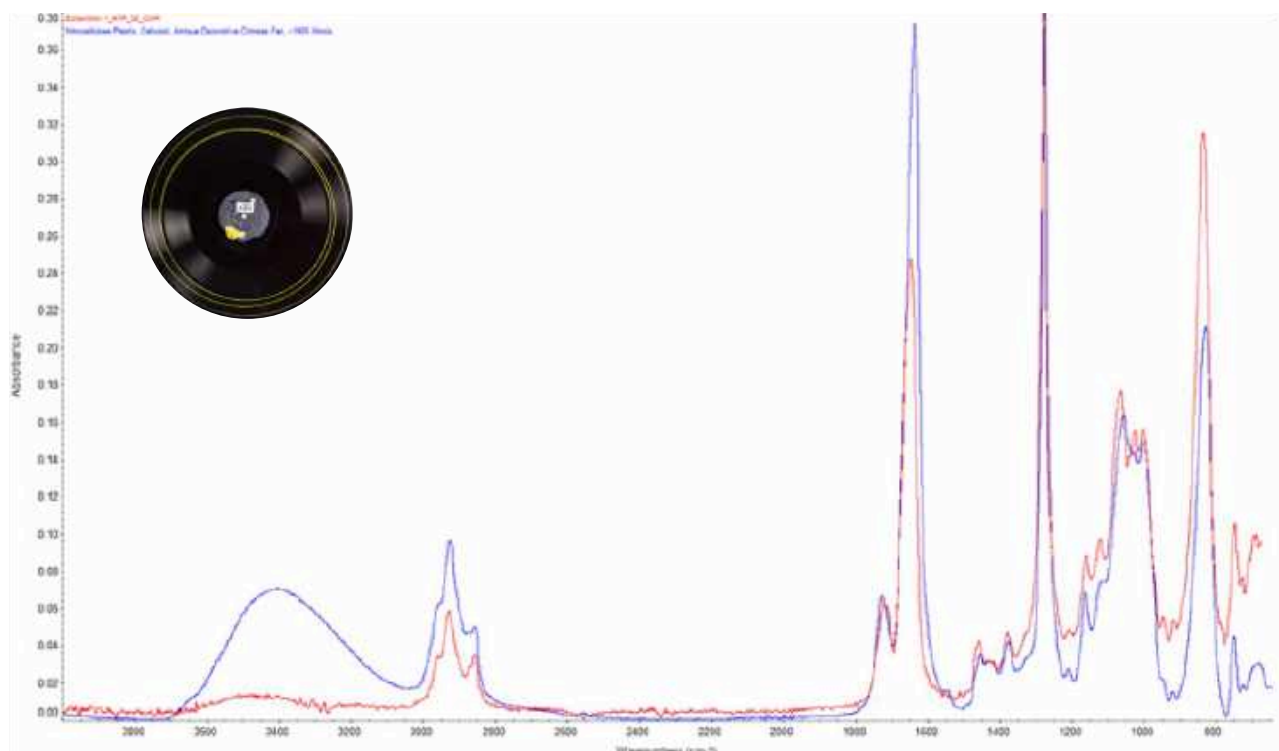
Radio-Genève: MSS is the main manufacturer in use between 1949 and 1956. The label is frequently detached.

Chemical study

FTIR analyses confirmed that the coating of black MSS discs used between 1948 and 1956 is made of cellulose nitrate. The cellulose nitrate sample is characterised by the following values:

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
MSS (1)	stretch band of nitrogen dioxide at 1645 cm ⁻¹	1276 cm ⁻¹	833 cm ⁻¹

As early as the first year of manufacture in 1933, the British manufacturer apparently used exclusively cellulose nitrate coatings. A letter from Cecil E. Watts to the BBC in 1940 listed as ingredients nitrate cotton, butyl acetate, alcohol, gums, and resins⁶⁸ and seemingly emphasised this hypothesis.

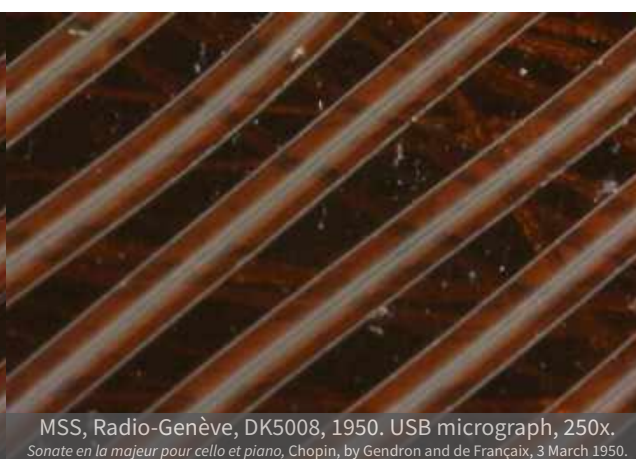
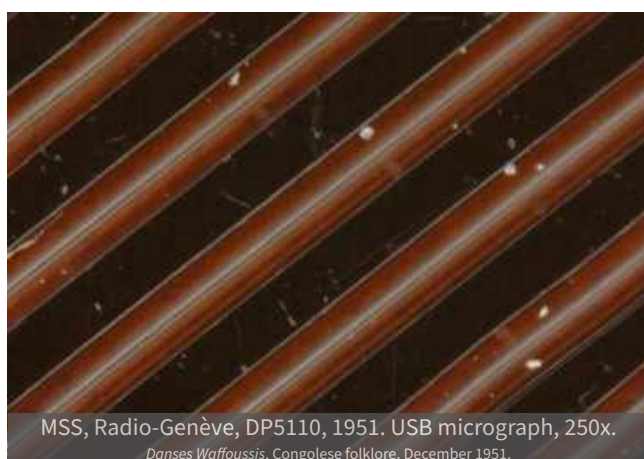
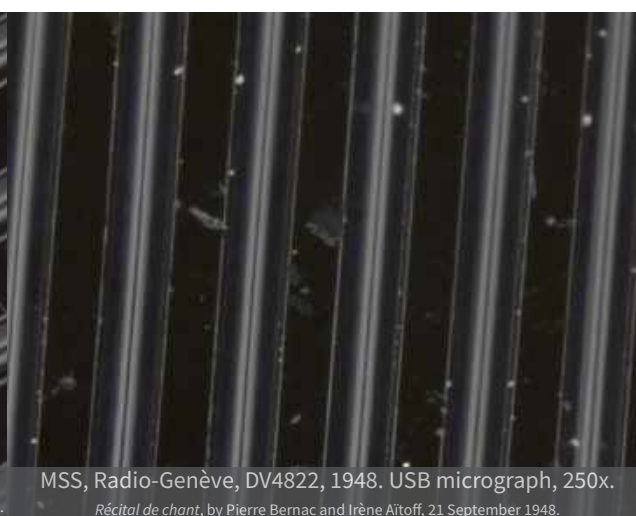
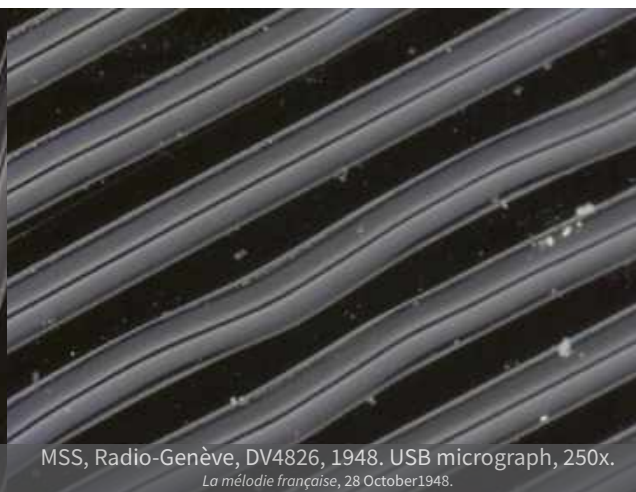
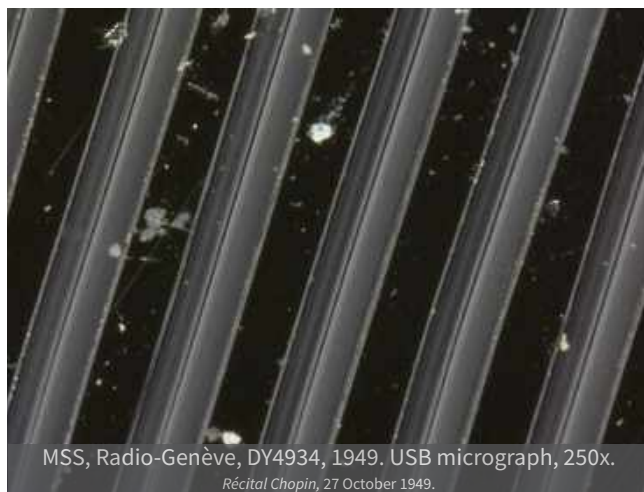


FTIR spectrum of a 1949 MSS disc (sample 1, Radio-Genève, accession number DD4906-4).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 1.

CREDIT Haute Ecole Arc, Laura Brambilla

Microscopic study

On the basis of USB microphotography observations, MSS discs from Radio-Genève have apparently been recorded with homogeneous cutting depths and styluses in good condition. The groove walls are mostly free of parallel striations and the physical condition of the surface groove is visually good. As the discs were recorded after 1946, these results corroborate the recording traces of other manufacturers. Already problematic at the time, the electrostatic properties of the coating attract dust.

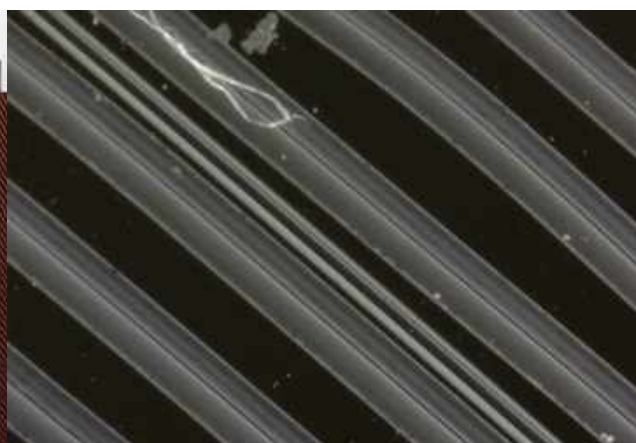


Alterations

MSS discs held at RTS do not present major degradations. Fine cracks and crazing on the periphery occurred on some discs. Circular striations occurred around some few labels of Radio-Genève. The proposed diagnosis is a defect during the gluing of the labels. White residues spread on the surface of some discs. The deposits appear to be mould and are most likely the result of damp storage conditions.



MSS, Radio-Genève, DS5100, 1951. Crazing, macrophotograph.
La vie parisienne, operetta of Jacques Offenbach, 6 January 1951.



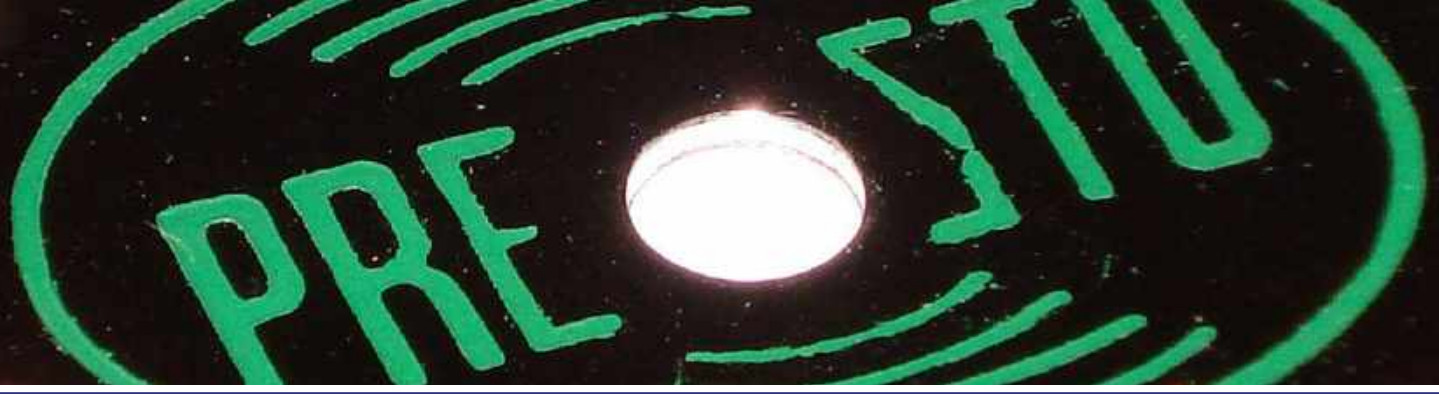
MSS, the cutting or reproduction stylus jump marks?
USB micrograph, 250x.



MSS, Radio-Genève, DT5100, 1951.
Circular striation on the periphery of the label.
Variations sur un thème de Haydn, by René Peter, 17 October 1951.



MSS, Radio-Genève, DD5106, 1951. Mould?
Récital de chant, by Janot Lequien, 27 February 1951.



Presto 1934–1963



Presto Green Seal, lacquer Q, 1938-1946 Presto Black Seal? 1938-1941? Presto Green Seal, glass-based, c. 1941-1945? Presto Orange Seal? 1939?-1947? Presto Green Label 1947-1963? Presto Orange Label 1948-1963? Presto Brown Label 1948-1963?

+ Blue Label Seal, Monograms Discs, Presto White Label, Masters.

Labels, stamps and inscriptions

Presto Green Seal c. 1938 Presto Green Seal, lacquer Q 1938-1946? Presto Orange Seal? 1939?-1947? Presto Orange Label 1948-1963? Presto Blue Label? 1947-1963?

Presto Red Seal 1943? 1938-1947?, lacquer Q 1947?-1963?

Ø: 6" (15.24 cm), 6½" (16.51 cm), 7" (17.78 cm), 8" (20.32 cm), 10" (25.4 cm), 12" (30.48 cm), 13¼" (33.65 cm), 13½" (34.29 cm), 14" (35.56 cm), 16" (40.64 cm), 17¼" (43.815 cm)

Identity card

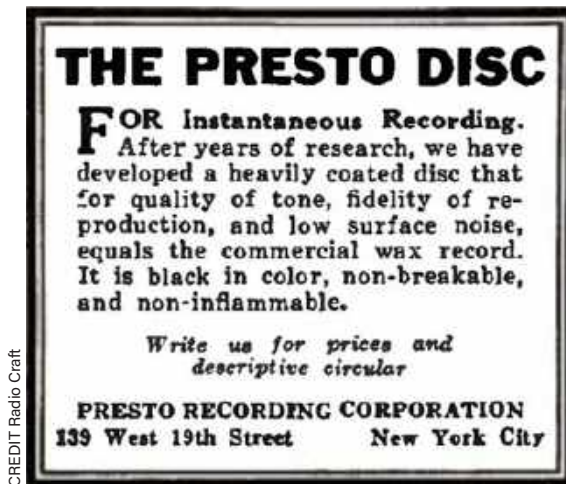
Country of origin	United States (New York, New Jersey)
Manufacturer	Presto Recording Corp. N.Y. Disc supplier for NBC and the United Nations.
Coating	cellulose nitrate
Coating colour	black (1938-1947?) – dark blue (1946?-1963?)
Substrate	aluminium (1934-1963), glass (1942-1944?), steel (1942), cardboard and fibre (1940-1950?). Different thickness of aluminium bases depending on the model. Steel and glass were the main substitutes for aluminium during the Second World War.
Manufacturing techniques	spraying (1934), dipping, conveyor with 95 minutes of travel (from 1939)

Historical background

The first Presto discs were aluminium-based with a cellulose nitrate coating developed by George Saliba. These discs were first introduced in October 1934 and sprayed by hand in a factory in Manhattan. They are recognisable by the coating spreading to the central hole. The next models, Presto Green Seal, were manufactured in a factory in Newark by dipping. They are differentiated from previous models by a painted green label near the centre. In July 1938, the firm introduced the new coating formula lacquer Q. The final factory was set up in 1939 in Paramus, New Jersey. The discs were then, and until 1956, the year the company was sold to Unitronics Corporation of Long Island City, coated using a conveyor system. Presto merged in 1957 with David Bogen Co., acquired 6 months earlier by Unitronics, to become the Bogen-Presto division. The name Presto was dropped in 1963⁶⁹.

A 1940 catalogue by Presto mentioned a formula of 51 ingredients that required 6 years of research⁷⁰. Difficulties in the supply of aluminium during the Second World War forced Presto to introduce glass (Presto Glass Base) and steel discs until the aluminium restrictions were lifted. The glass discs are recognised by a steel ferrule set in the central hole to reinforce the glass⁷¹.

Presto is often credited as the manufacturer who introduced and developed high-quality lacquer discs. This assertion cannot be verified, the same claims are also made by Pyral and MSS. Presto did not patent its lacquer formula. Coating an aluminium substrate with soft material for direct-to-disc recording was a common industrial practice and already in the public domain. The United States Patent Office considered the manufacture of the Presto discs by no means new and therefore non-patentable. Presto has thus never filed a patent. The industry's memory and coating formulas are lost from history⁷².



CREDIT Radio Craft

First advertisement of the Presto disc, Radio Craft, October 1934



CREDIT Alan C. Graves

Discs plant in Paramus

Manufacturing and recording techniques

The coating used is cellulose nitrate and not acetate⁷³. It does not require a finishing or hardening process. The disc is ready for playback directly after cutting. Steel or sapphire styluses can be used⁷⁴.

Presto discs, and more generally American discs, are recognisable by the four holes at the centre of the disc. Three holes are distributed around the centre to stabilise the disc with pins and prevent it from slipping. A fourth hole, central, is used to secure the disc to the centre of the turntable. The recommended cutting depth in 1938 was 55% grooves and 45% wall⁷⁵.

Models

- 1934: hand-sprayed discs in Manhattan
- 1938: introduction of lacquer Q
- 1938?-1947?: *Seal Label Discs*. Aluminium was partially substituted by glass and steel bases. The coating applied to the discs is the same lacquer Q, only the thickness of the substrate varied.

The Seal Discs range was available in 5 models (from Allied catalogues):

- Presto Green Seal. Oversize Green Seal models intended for pressing.
- Presto Orange Seal (Medium aluminium base, steel substrate in 1942),
- Presto Blue Seal (Light aluminium base),
- Presto Red Glass Seal (glass base),
- Presto Black Seal.

In Allied Catalogs, the systematic mention of lacquer Q disappeared after the 1947 catalogue.

- 1940-1950?: *Presto Monogram Discs* (for home recording). The substrate was usually made of cardboard.
- c. 1941-1945: *Presto Glass Base*, discs with a glass base that partially replaced the aluminium discs during the Second World War.
- 1947-1963?: *Presto Green Label*, discs for professional use (base thickness 0.052-0.056").
- 1948-1963?: *Presto Orange Label*. For high-quality recording. The difference to the Green Label model was a thinner aluminium base (0.040").
- 1948-1963?: *Presto Brown Label*. These discs are identical in composition to the Green Label but the manufacturer only guaranteed one side of 'perfect' quality. Identifiable by an embossed seal.
- 1955-1963?: *Presto White Label*. Economical disc, which did not require the quality of the Green Label disc. For cutting tests, reference records, etc. Same coating used as Presto Green Label and Master discs. Recognisable by an embossed seal.

Sources: Allied Catalogs, Electronics Catalog



RECORDING BLANKS FOR ALL PURPOSES

The wide selection of recording blanks below covers all the needs of both the professional and the amateur. Listing includes discs for recording studios, broadcast stations, schools, sales demonstrations, and the home.

Fig. A—AUDIODISC PROFESSIONAL RECORDING BLANKS
All Audiodiscs are manufactured on aluminum base. Lint-free envelopes are supplied with Red Label and Master discs. Av. shpg. wts.: 6½", 8", 7 oz.; 10", 9 oz.; 12", 14 oz.; 12½", 1 lb.; 16", 1¼ lbs.; 17½", 2 lbs.

Fig. B—RECORDISC SEMI-PROFESSIONAL AND HOME-TYPE BLANKS
Popular, instantaneous home and semi-professional recording blanks. Excellent for school use. Uniformly coated with a smooth surface that will not age or dry out.

Red Label
Aluminum base. Smooth coating on both sides. Provide long playback life. For highest quality work in sound studios, broadcast stations, etc.

No.	Dia.	EACH	25 FOR
69-069	8"	.52	11.76
69-070	10"	.76	16.90
69-071	12"	1.21	27.19
69-072	16"	2.23	49.98

Orange Label
Cellulose nitrate coating on processed paper bond base. Double-faced. Avg. shpg. wt., per 5, 1 lb.

No.	Dia.	EACH	5 FOR
69-110	6½"	20c	.72
69-111	8"	30c	1.08
69-112	10"	40c	1.44

Red Label
Heavy .021" aluminum base. Professional grade, cellulose nitrate coating. Avg. shpg. wt., per 5, 1¼ lbs.

No.	Dia.	1-4	5 FOR
69-140	6½"	23c	1.05
69-141	8"	30c	1.35
69-142	10"	47c	2.10
69-143	12"	67c	2.70

"GM" Label
Made to receive wide frequency ranges. Heavy .021" aluminum base. Av. shpg. wt., per 5, 1¼ lbs.

No.	Dia.	1-4	5 FOR
69-190	8"	40c	1.80
69-191	10"	52c	2.40
69-192	12"	67c	3.00

Purple Label
New low-cost discs, with aluminum base. Average wt., per 5, 1 lb.

No.	Dia.	EACH	5 FOR
69-195	6½"	17c	.75
69-196	8"	22c	1.05
69-197	10"	37c	1.65

Blue Label
For home, amateur and demonstration work. Both sides coated.

No.	Dia.	EACH	50 FOR
69-065	6½"	.23	10.29
69-066	8"	.32	14.70
69-067	10"	.49	22.05

Master Discs
For outstanding quality pressings. Give fine results with gold sputtering or silvering process. Two sides.

No.	Dia.	EACH	25 FOR
69-076	13½"	2.03	44.83
69-075	17½"	3.40	74.97

KNIGHT ALUMINUM BASE
Nitrate coating on both sides. Comparable in quality to professional discs.

No.	Dia.	Wt.	EACH
69-180	6½"	8 oz.	20c
69-181	8"	10 oz.	25c
69-182	10"	12 oz.	40c

Fig. C—PRESTO RECORDING DISCS
Professional discs for commercial, educational and home recording. Green Label discs are the finest standard size Presto recording blanks, and have aluminum base with smooth lacquer coating on both sides. Both sides are guaranteed perfect. They are especially recommended for microgroove recordings. Brown Label discs are identical to Green Label discs except that only one side is guaranteed perfect. The other side may be used for reference instead of professional recording. Orange Label discs are low-cost blanks with same high quality lacquer coating on both sides but have a lighter aluminum base. These are recommended for all general purpose recordings—schools, artists and home recording enthusiasts. Masters are identical to Green Label discs, but are larger in diameter for processing. All types have lacquer coatings of same quality. *Weight is for standard package.

Stock No.	Size	Label	Base Thickness	NET EACH	Std. Pkg.	Wt. Lbs.*	NET PER PKG.
69-012	17½"	Master	.064"	3.67	20	.33	58.80
69-006	16"	Green	.056"	2.44	25	.30	48.75
69-003	16"	Brown	.056"	1.68	25	.30	33.75
69-011	13½"	Master	.052"	2.28	20	.25	36.50
69-007	13½"	Green	.052"	1.68	30	.30	40.50
69-005	12"	Green	.052"	1.35	25	.15	27.00
69-004	12"	Brown	.052"	.97	25	.15	19.50
69-023	12"	Orange	.040"	1.00	50	.22	30.00
69-008	10"	Green	.052"	.85	25	.10	17.25
69-022	10"	Orange	.040"	.75	50	.18	22.50
69-021	8"	Orange	.040"	.50	50	.15	15.00
69-020	6½"	Orange	.040"	.35	50	.16	10.50

Selection of Presto models, Allied Catalog no. 124, 1951

Models

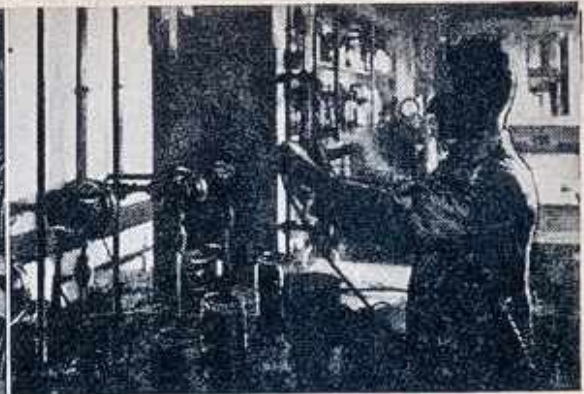
MODEL	Diameter (Inch)	Base thickness (Inch)	1938	1939	1940	1941	1942	1943	1946	1947	1948	1949	1950	1951	1952	1953	1954		
Presto "Green Seal" Discs	6, 8, 10, 12, 16	0.051, 0.052, 0.056, 0.064, 0.066	Aluminum base, 0.051"	Lacquer Q, Aluminum base thickness: 0.051"	Aluminum base, Lacquer Q, 0.051" (6", 8", 10", 12"), 0.064" (16")	Aluminum base, Lacquer Q, 0.051" (6", 8", 10", 12"), Overall thickness 0.051"	Lacquer Q, Glass base 12", 13 1/2", 15", Overall thickness 0.104"	Lacquer Q, Glass base 12", 13 1/2", 15", Overall thickness 0.104"	Lacquer Q, Aluminum base, 0.052" (12", 13 1/4"), 0.056" (16"), 0.066" (17 1/4")										
Overize "Green Seal" Discs	11 1/2, 13 1/2, 17 1/4	0.079		Overize Q "Green Seal"		Aluminum base	Aluminum base	Glass base Thickness unknown											
Presto Black Seal Discs	6, 8, 10	0.021																	
	6, 8, 10, 12	0.021																	
	12	0.025																	
Presto "Orange Seal"	6, 8, 10, 12	0.036, 0.036		Q Orange Seal 0.036"	Q Orange Seal, Base thickness 0.036"	Lacquer Q, Steel base 0.036" (7", 8", 10", 12"), Overall thickness 0.046"	Lacquer Q, Steel base 0.036" (7", 8", 10", 12"), Overall thickness 0.046"		Lacquer Q, Aluminum base (medium), 6 1/2", 8", 10", 12", Thickness: 0.036"	Lacquer Q, Medium aluminum base 6 1/2", 8", 10", 12"									
Q Orange Seal Discs	16	0.051																	
Presto Monogram (Home recording)	6, 8, 10, 12, 16				Lacquer Q, Cardboard base, 6", 8", 10", 12", Overall thickness 0.05"	Light aluminum base	Lacquer Q, Paper base, 6", 8", 10", 12", Thickness 0.05"	Lacquer Q, Paper base, 6", 8", 10", 12", 13 1/2", 16", Thickness 0.05"	Lacquer Q, Bond base, 6 1/2", 8", 10", 12", 16", Thickness 0.05"			Bond base 6", 8", 10", 12", 16"							
Presto Blue Seal (Semi-professionals)	6, 8, 10	0.025																	
Glass base types	12, 16						Q coating, Overall thickness 0.105"												
"Red Seal" Glass Base	10, 12, 16							Glass base, Thickness 0.075-0.104"											
"Green Label" Discs	10, 12, 13 1/4, 16	0.052, 0.056								Lacquer Q, Aluminum base 12", 13 1/4", 16"			Aluminum base, thickness 0.052" (10", 12", 13 1/4"), 0.056" (16")	Aluminum base, thickness 0.052" (10", 12", 13 1/4"), 0.056" (16")	Aluminum base, thickness 0.052" (10", 12", 13 1/4"), 0.056" (16")	Aluminum base, thickness 0.052" (10", 12", 13 1/4"), 0.056" (16")			
"Green Label" Type B Discs	12, 16																		
Overize Master Discs	13 1/2, 17 1/4	0.052, 0.064								Lacquer Q, Aluminum base			Aluminum base, thickness 0.052" (13 1/2"), 0.064" (17 1/4")						
"Orange Label" Discs	6 1/2, 8, 10, 12	0.040									Medium aluminum base			Medium aluminum base, thickness 0.040"					
"Brown Label" Discs	12, 16	0.052, 0.056																	Aluminum base, thickness 0.052" (12"), 0.056" (16")

Inch	cm
6	15.24
8	20.32
10	25.40
11 1/2	29.21
12	30.48
13 1/2	34.29
16	40.64
17 1/4	43.82

Source: Allied Catalogs



Aluminum discs are polished to mirror finish before automatic processing for coating of acetate lacquer. The high polish assures uniform coating.



Rigid control of high-quality lacquer is maintained in Presto chemical laboratory. Much research is done on lacquer coating methods and compositions.

Home Recording Disc Marriage of Aluminum and Acetate

THE BLANK recording disc is to phonograph records what unexposed film is to photographs. Any record groove ever played with a pickup was originally cut on a recording disc. This is as true today, in the age of high-fidelity tape masters and LP records, as it was in the days of Caruso and acoustical recording.

On the old-fashioned disc, the groove was formed in wax. But the modern disc is made of a special acetate lacquer compound on a metal base. It is much less destructible than a wax disc—an important advantage for home recordists. Repeated playbacks with a high-grade pickup will not mutilate the groove.

From the processing of the aluminum blank through the compounding of the lacquer to the coating, aging and inspection of the surfaces, the manufacture of a modern recording disc is a task for perfectionists. The accompanying photographs, taken at the Paramus, N. J., plant of Presto Recording Corporation, show some of the steps in the making of a high-quality lacquer disc.

—50—



Automatic conveyor carries disc blanks through coating and drying operations with controlled temperature and humidity. Lacquer is dispensed in chamber at left. Discs are then racked and stored.



Careful inspection and grading come next, after which records are punched (right) and labeled.



SOME THINGS CAN'T BE RUSHED

**IT TAKES TIME
TO DRIVE
SOME THINGS HOME...**

...and it takes time to make a good recording disc

This is the era of short cuts in every industry. But PRESTO will not cut corners—or cut quality. There are six basic steps in making a PRESTO Recording Disc...and not a single step is ever hurried.

PRESTO'S great investment of time...pays off in dividends for you. It assures you of the most brilliant performance in recording discs, and the greatest permanence as well.

**PRESTO GREEN • ORANGE • BROWN
AND WHITE LABEL DISCS ARE
USED THROUGHOUT THE
WORLD—WHEREVER
FINE RECORDING IS DONE**



PRESTO RECORDING CORPORATION
PARAMUS, NEW JERSEY

Export Division: 25 Warren Street, New York 7, N. Y.
Canadian Division: Instantaneous Recording Service, 42 Lombard St., Toronto

WORLD'S LARGEST MANUFACTURER OF PRECISION RECORDING EQUIPMENT AND DISCS



**TIME CONSUMING
STEP #2
IN MAKING A PRESTO
RECORDING DISC**

Lacquer "makes" the surface of a recording disc. That's why PRESTO has a special lacquer formula and guards it as closely as atomic material. It is stored in constantly-agitated vats to insure even consistency. It is slowly flowed on to the polished aluminum blanks to precisely the thickness required. Then comes the long, leisurely, 1½ hour trip of the discs through the processing tunnel. PRESTO wouldn't shorten this trip by a second... because time is of the essence in making a fine recording disc.

Identification

Cellulose nitrate



Label identification Presto Seal Discs, Lacquer Q

CREDIT Randy Riddle

Ø: 6", 8", 10", 12", 13¼", 13½", 16", 17¼"

Ø Presto Black Seal 10"

Weight (grams): 66-71

Disc thickness (mm): 0.81-0.86

Substrate thickness (inch): 0.021

Trends

Materials and composition:

Coating: cellulose nitrate

Coating colour: black

Substrate: aluminium (different thickness depending on the model).

Glass and steel during the Second World War.

Coating name: *lacquer Q*

Models: *Presto Green Seal Label*, *Presto Blue Seal Label*, *Presto Orange Seal Label*, *Presto Black Seal Label*, *Presto Red Seal Label*

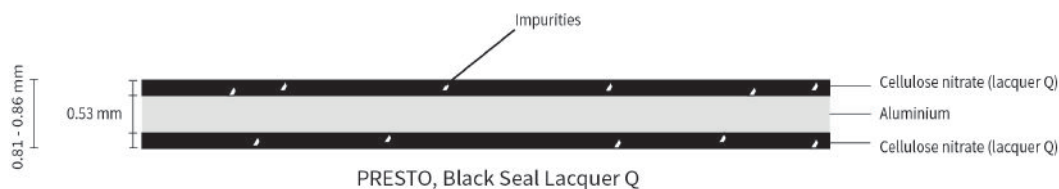
Characterisation/identification criteria: These discs are recognisable by the stencil-printed central Q. The colour around the central hole varies according to the Seal discs models (Black Seal, Green Seal).



Presto lacquer Q disc illustration, 1940 Presto catalogue

CREDIT Presto Recording Corp. Catalog

10"
66 - 71 grams



Degradation: plasticiser loss

Context of use

Years of use by S.R.R. and Radio-Genève: 1940-1941

Radio-Lausanne: some records between 1940 and 1941. The disc centre is black, probably the Black Seal model

Radio-Genève: no known example

Presto Orange Seal

1939?–1947?

Identification



Cellulose nitrate



CREDIT ebay



Identification elements for Presto Orange Seal, c. 1947

Ø: 6", 8", 10", 12", 16"
Ø 10" (trend from 7 discs)
Weight (grams): 116-127 (mean 121)
Disc thickness, edge (mm): 0.97-1.11 (mean 1.045, median 1.034)
Disc thickness, midpoint (mm): 1.195-1.33 (mean 1.26, median 1.27)
Coating thickness (mm): 0.17-0.195

Trends

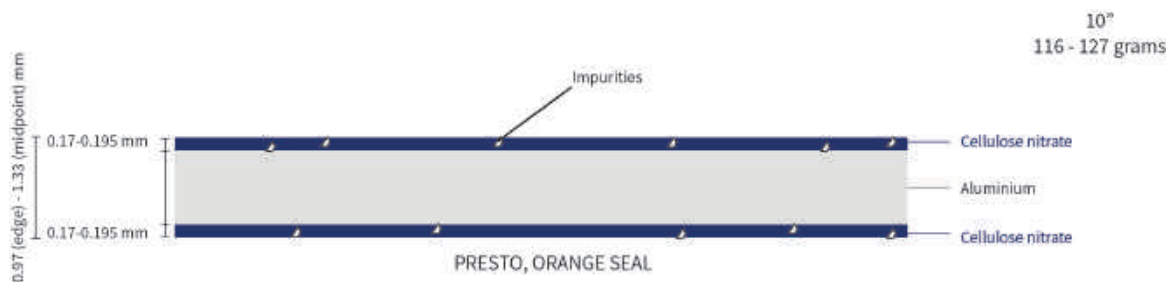
Materials and composition:

Coating: cellulose nitrate

Coating colour: dark blue but black in appearance.

Substrate: aluminium (different thickness depending on the diameter).

Characterisation/identification criteria: uncoated disc centre, thinner coating thickness at the edge and centre of the disc.



Degradation: wear

Context of use

Years of use by S.R.R. and Radio-Genève: 1947-1948

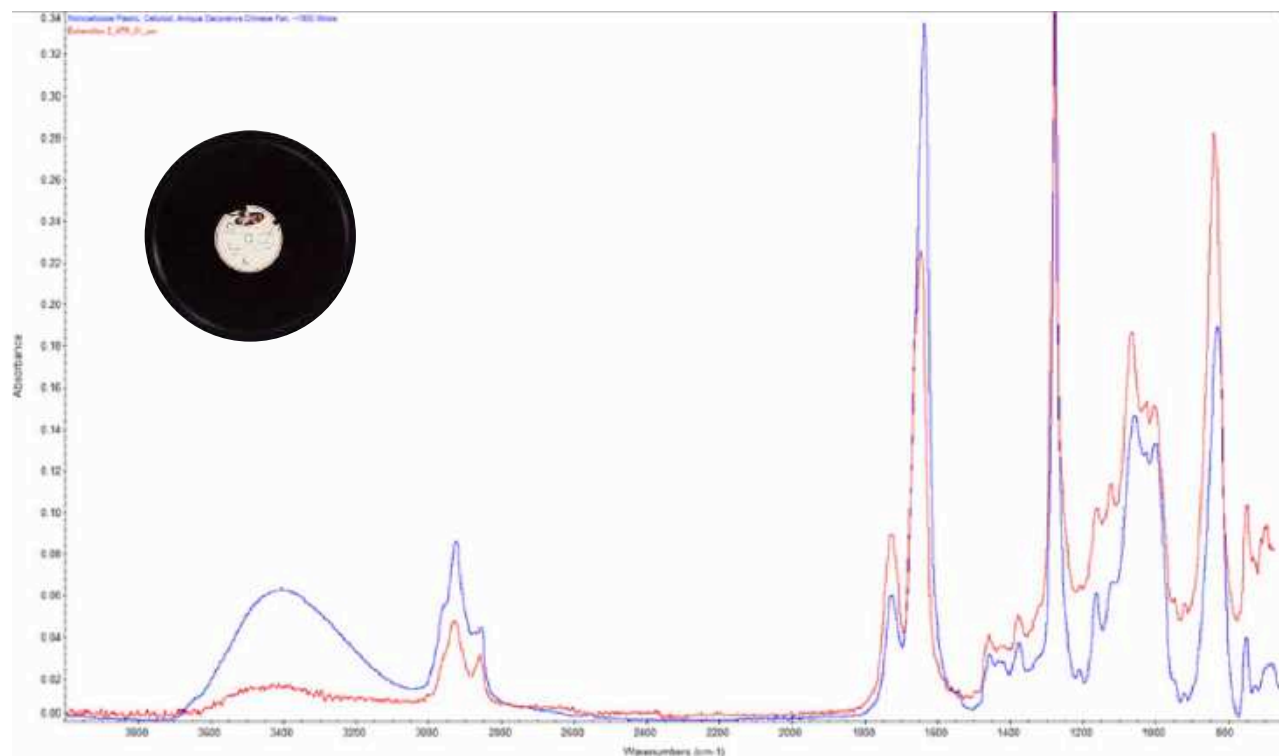
Radio-Lausanne: no known example

Radio-Genève: regular model in 1947 and 1948

Chemical study

FTIR analyses confirmed that the coating of 1948 Presto Orange Seal discs is cellulose nitrate. Thus, from the early days of manufacture in 1934, Presto presumably exclusively applied cellulose nitrate coatings.

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Presto (2)	1644 cm ⁻¹	1276 cm ⁻¹	836 cm ⁻¹



FTIR spectrum of a 1948 Presto Orange Seal disc (sample 2, Radio-Genève, accession number DU4852).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 2.

CREDIT Haute Ecole Arc, Laura Brambilla

Identification



Cellulose nitrate



Identification elements for Presto Green Label: blue edge on the edge; Green Label stamp, Blue Label but with the green inscription Green Label, 1947-1963?

Ø: 10", 12", 13¼", 16", 17¼"

Ø 12" (trends from 11 discs)

Weight (grams): 206-223 (mean 214.5, median 211)

Disc thickness, edge (mm): 1.24-1.37 (mean 1.325)

Disc thickness, midpoint (mm): 1.23-1.52 (mean 1.38, md. 1.31)

Coating thickness (mm): 0.18-0.21

Trends

Ø 16" (trends on 6 discs)

Weight (grams): 408-422 (mean 413.5)

Disc thickness, edge (mm): 1.31-1.48 (mean 1.4)

Disc thickness, mid. (mm): 1.31-1.38 (mean 1.35)

Ø 17¼" (trends on 3 discs)

Weight (grams): 577-579 (mean 578)

Disc thickness, edge (mm): 1.61-1.68 (mean 1.64)

Disc thickness, mid. (mm): 1.57-1.6 (mean 1.587)

Materials and composition:

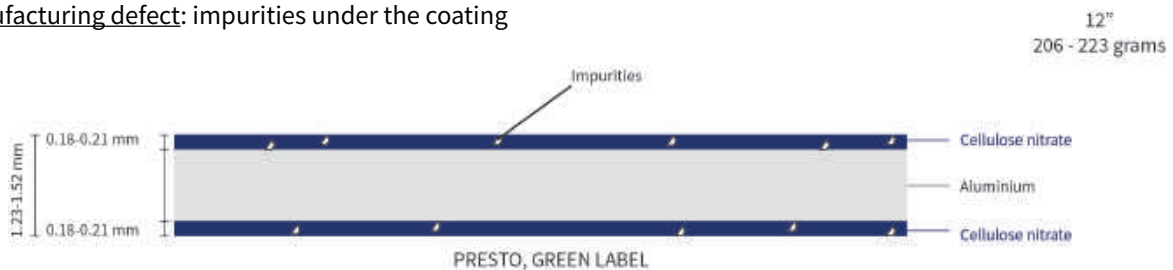
Coating: cellulose nitrate

Coating colour: dark blue

Substrate: aluminium

Characterisation/identification criteria: The coating initially appears black, but the thin lacquer layer at the edge of the disc indicates bluish tones (the blue edge also found on Soundcraft discs). This tint could indicate the use of a blue dye, such as purple pencil also used by the manufacturer Pyral. The disc centre is occasionally uncoated, with a thinner coating layer. Coating fragments present good pliability, without tearing.

Manufacturing defect: impurities under the coating



Degradations: plasticiser loss (palmitic acid) – crazing – coating peeling (rare)

Context of use

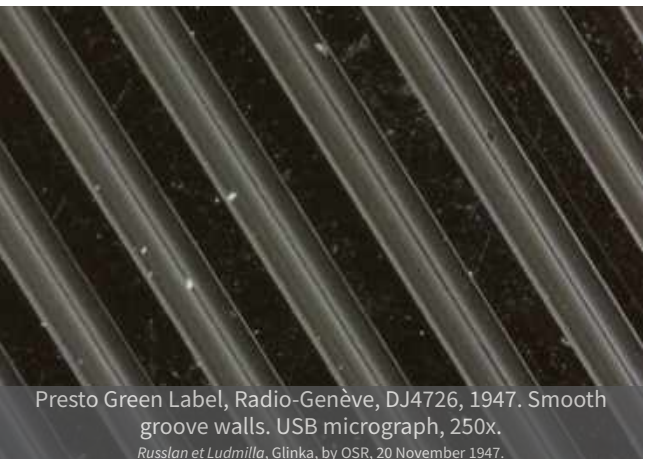
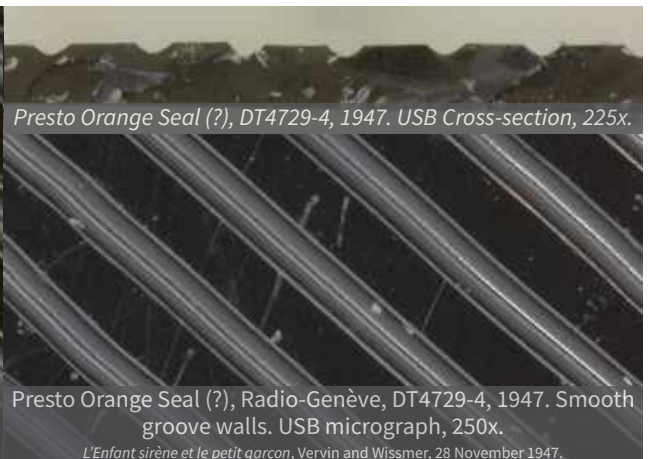
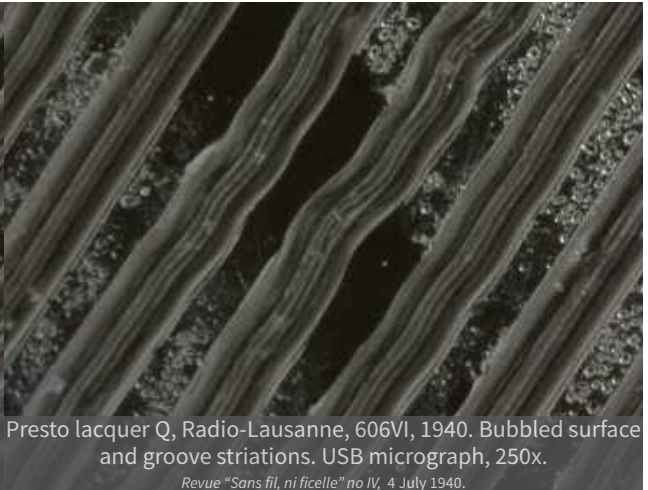
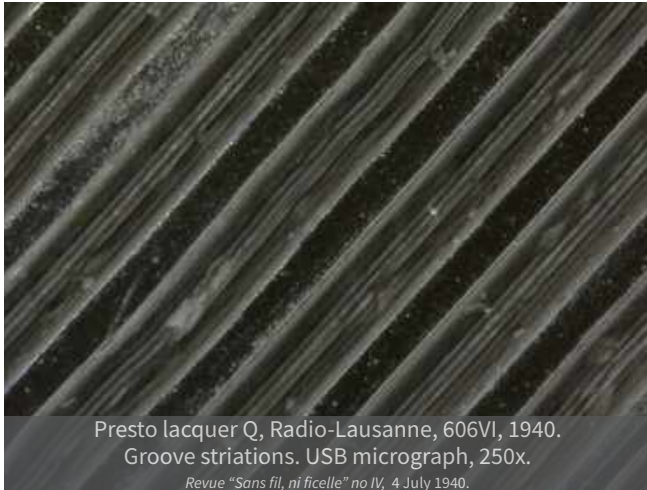
Years of use by S.R.R. and Radio-Genève: 1947-1957

Radio-Lausanne: mainly used by the American correspondent Paul Ladame and Italy correspondent Pierre Briquet.

Radio-Genève: frequent use between 1947 and 1948

Microscopic study

The micrographs of a disc recorded in 1941 (606VI) show typical characteristics of Radio-Lausanne's recording conditions, namely a wide cutting depth and parallel striations on the groove walls. A bubbled surface (606VI) may indicate the first signs of plasticiser loss. For discs recorded after 1946, the grooves present smooth walls and a regular baseline for Presto Orange Seal and Presto Green Label discs (DT4729, DJ4726, R98).



Alterations

Presto discs were already seen as extremely satisfactory discs in the manufacturer's catalogues and the BBC research reports, presenting a solid coating and low surface noise. The observations in the RTS collection found Presto discs have been more resistant to the effects of time than any other manufacturer from a conservation point of view. Scratched surfaces are a standard mark of wear. Some discs are covered with a thin layer of palmitic acid, and, more rarely thin crazing and cracks have occurred. The peeling of the coating remains an exceptional occurrence in the RTS collection.



Presto Green Label, Radio-Genève, DY5107, 1951.
Palmitic acid layer.

Jeunesse musicale, symphonie des psaumes, May 1951.



Presto Green Label, Radio-Genève, DY5107, 1951. Coating peeling away from the metallic substrate.

Jeunesse musicale, symphonie des psaumes, May 1951.



Presto Green Label, Radio-Genève, DY5107-5, 1951.
Macro photograph of palmitic acid layer.

Jeunesse musicale, symphonie des psaumes, May 1951.



Presto Green Label, Radio-Genève, DY5107-6, 1951.
Macro photograph of thin cracks, light palmitic acid layer.

Jeunesse musicale, symphonie des psaumes, May 1951.



Pyral 1929–1987



Pyral zinc-based, black
1936-1947?

Pyral zinc-based, red
1942-1947?

Pyral red ersatz
1941-1947?

Pyral blue/green dye
1946-1958?

Pyral Néo-cire
1946?-195?

Labels, stamps and inscriptions



Ø: 15 cm (6"), 17.5 cm (7"), 20 cm (8"), 25 cm (10"), 30 cm (12"), 40 cm (16")

Identity card

Country of origin	France (Créteil)
Manufacturer	Pyrolac, then Pyral
Trade name	Pyral Main supplier for French Radio Broadcasting
Coating	cellulose nitrate, cellulose acetate (FR778,988)
Coating colour	black - red - green - blue - amber
Substrate	cardboard (6", 8"), aluminium (10", 12", 16"), zinc (8", 10", 12")
Manufacturing techniques	conveyor belt system



Aerial view of the Pyral Plant,
Rue de l'Echat, Créteil

CREDIT Edition LAPIE

Historical background

The Société des Vernis Pyrolac, located in Créteil and specialised in industrial paints⁷⁶, was founded in 1929 by three engineers: Barbier Saint Hilaire, Ravel, and Chadapaux. A subsidiary called Pyral (*Pyr*, the Greek word for fire, *al* for aluminium) was created in 1932 to manufacture lacquer discs⁷⁷. Pyrolac would also refer to pyroxyline⁷⁸, a nitrocellulose compound containing approximately 10.5 to 12.5% nitrogen⁷⁹.

Originally a supplier of paints and varnishes for the automobile industry in Créteil, Société des Vernis Pyrolac initially developed a solid coating layer on a fibrous substrate. Subsequently, the coated aluminium discs were sold under the trade name Pyral. The company, now based in Avranches, ceased disc production in 1987 but remains active in the manufacture of magnetic tapes for cinema and television⁸⁰. The English manufacturer EMI started producing discs under license from Pyral in 1947⁸¹ and the American firm Audio Devices was licensed in 1938⁸².

Manufacturing

Pyrolac filed a series of patents between 1933 and 1950 on phonographic disc production machines. One of the first machines was built on the principle that “[...] the discs, blanks or plates to be coated are driven on a conveyor belt passing under a dispensing device formed by a tank filled with varnish or lacquer; the height of the lacquer dispenser orifice with respect to the surface of the flanks to be coated is adjustable so that the thickness of the coating layer can be varied as required⁸³.” The excess varnish was scraped off and the thickness of the varnish was precisely adjusted using a system of graded screws. One of the company’s patents specifies that the most delicate step to obtain industrial mass production was a rapid and efficient drying of the varnished discs. Hence, Pyrolac added a dust-free air-drying tunnel to the machine⁸⁴. In 1946, Pyrolac, then its subsidiary Pyral, made major modifications to its system by completely automating the installation with the elimination of manual intervention to transfer the discs from the coating machine to the pre-drying machine. This new device prevented dust deposits⁸⁵.

A BnF study in 1996 benefited from the historical oral testimony from J.J. Carpentier, a former employee of Pyral during the manufacture of instantaneous discs. The report also described three chemical analyses conducted in 1982 at the National Centre for Cinema and the Moving Image (CNC) which identified that the metallic substrates were zinc or an aluminium alloy with a low percentage of zinc (440 ppm zinc). The aluminium sheets of Pyral discs were manufactured by Alcor and degreased with anhydrous alcohol. Wet abrasion was used for surface preparation to increase the adhesion of the coating to the metal: a pad with polyurethane foam and silicon carbide, followed by wetting with a detergent solution to remove the aluminium oxide. Water abrasion was less effective, resulting in poor adhesion and surface imperfections⁸⁶.

Pyral cellulose nitrate compound was composed of ester-soluble category B cellulose denitrate from SNPE Nitrocellulose E32, plasticised with blown castor oil. The two solvents used were ethyl acetate and butyl acetate. Pyral applied two types of lacquer coloration. Initially, the colouration of the coating solution used lampblack. A blue dye called purple pencil was later incorporated, such as the one found in inks for schoolchildren. Since it is an ultraviolet absorbing dye, it prevents discolouration by light⁸⁷.

A Radio-REF article transcribed details of the discs’ manufacture following a visit to the Pyrolac factory in 1939 (see next page).

Context of use

Years of use by S.R.R. and Radio-Genève: 1936-1958

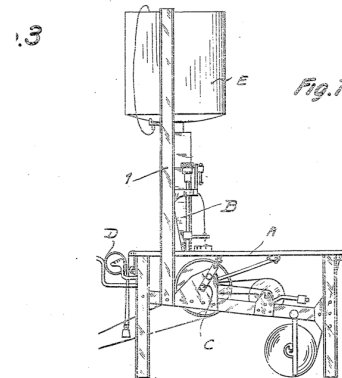
Price 1942 (CHF): 2.-

Radio-Lausanne: the most common manufacturer in the studio, from the very beginning of the recordings (zinc bases from 1936 to 1947), during the war (ersatz) and until the end of direct-to-disc recording c. 1956 (black/green tones Pyral).



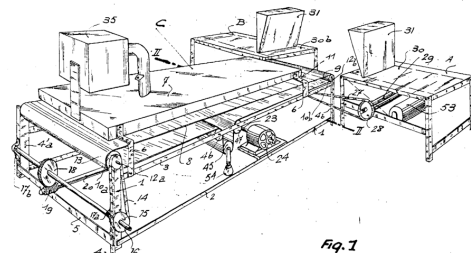
Patent FR 777,988 (1933) Patent FR 1,001,269 (1946)

Société des Verres Pyralac (S. A. S. E.) 3 planches. — Pl. I



View of the apparatus in 1939, with the coating tank (E). Addition No 50,439, (1939) of patent FR 777,988 (1933)

N° 849,922 Société des Verres Pyralac (S. A. S. E.) 3 planches. — Pl. I



Perspective view of the conveyor machine. Patent FR 849,922 (1938)

LA FABRICATION DES DISQUES SOUPLES

Nous avons eu l'occasion, grâce à l'aimable obligeance de « Pyrolac », de visiter l'usine de Créteil où se fabriquent les disques d'enregistrement direct, qu'emploie maintenant la presque totalité des centres d'enregistrement. La place me manque pour donner une description complète de la fabrication. Néanmoins, il nous a paru utile d'en indiquer le principe pour ceux de nos Camarades — et ils sont tous les jours plus nombreux — que la question d'enregistrement intéresse.

Le produit cellulosique qui est utilisé en la circonstance, après avoir été préparé, malaxé, filtré, est prêt à être mis sur un support en zinc ou en aluminium, qui constitue le support du disque.

Les disques sont posés, pour être recouverts, sur un long ruban de papier dont la largeur est celle du disque lui-même. Les disques sont posés côte à côte et ce ruban passe ensuite sous une hotte que l'on pourrait assimiler à un énorme tire-ligne, dont la largeur est celle du ruban et qui se trouve à une distance permettant de déposer une couche de 10/100 mm sur le support du disque. La partie sur laquelle ne repose pas le disque se trouve également recouverte du produit cellulosique, qui est récupéré aussitôt.

L'opération terminée, le disque aussitôt recouvert est mis dans un tunnel de séchage, à une température de 25° et est entraîné par un tapis roulant, marchant très lentement.

Le déplacement, qui dure quelques dizaines de minutes, le met entre les mains d'un manutentionnaire, qui le place ensuite dans un séchoir à température un peu plus élevée, où il reste pendant 24 heures.

Il repasse ensuite sous le « tire-ligne » dont il est parlé plus haut, de façon à être recouvert d'une couche sur l'autre face.

La fabrication actuelle de ces disques s'est chiffrée pour 1938 à environ 232.000 disques et suit chaque année non seulement une progression très grande mais une amélioration qui donne satisfaction à tous ceux qui les utilisent : absence de taches, pas de bruits de fond, régularité dans la fabrication, etc... Nous avons, pour notre part, essayé des disques souples de fabrications différentes : sur carton, gélatine, etc..., et nous sommes toujours revenus aux disques « Pyrolac », d'une fabrication absolument impeccable.

La Maison « Pyrolac » n'est pas une inconnue pour ceux que la question d'enregistrement intéresse ; elle consent à nos Camarades des conditions particulières et nous a donné, cette année, 25 disques qui seront attribués aux gagnants de la Coupe du REF 1938 et 1939. Je profite de l'occasion pour la remercier très vivement.

G. BARRA FELA.

Identification

Cellulose nitrate



Pyral zinc-based, black
1936-1947?



Pyral zinc-based, red
1942-1947?

Ø: 25 cm, 30 cm

Trends

Ø 25 (trend from 6 discs)

Weight (grams): 141-152 (mean 147)

Disc thickness, edge (mm): 0.60-0.82 (mean 0.74)

Disc thickness, midpoint (mm): 0.60-0.77 (mean 0.72)

Coating thickness (mm): 0.145-0.17 (c. 1936-1941), 0.17-0.22 (c. 1942-1944)

Ø 30 (trend from 6 discs)

Weight (grams): 225-238 (mean 231)

Disc thickness, edge (mm): 0.70-0.84 (mean 0.77)

Disc thickness, mid. (mm): 0.68-0.76 (mean 0.73)

Materials and composition:

Coating: cellulose nitrate

Coating colour: black (c. 1936-1947) - dark red (c. 1942-1947)

Substrate: zinc

Characterisation/identification criteria: thin and flexible zinc base. By way of comparison, the zinc substrates used by the BBC (MSS or EMI) are thicker and heavier. Differences in thickness exist between the models produced before and after 1940. An article published in August 1939 in Radio R.E.F. on the manufacture of Pyrolac flexible discs reported a cellulosic coating thickness of 16/100 mm (0.16 mm). The lacquers thickness of discs manufactured between 1936 and 1941 (0.15-0.17 mm) is close to the value of the R.E.F. article. Later dark red nitrocellulose coatings thickness vary between 0.17 and 0.22 mm (c. 1942-1946).



Pyral zinc-based identification

25 cm
141 - 149 grams



25 cm
142 - 152 grams

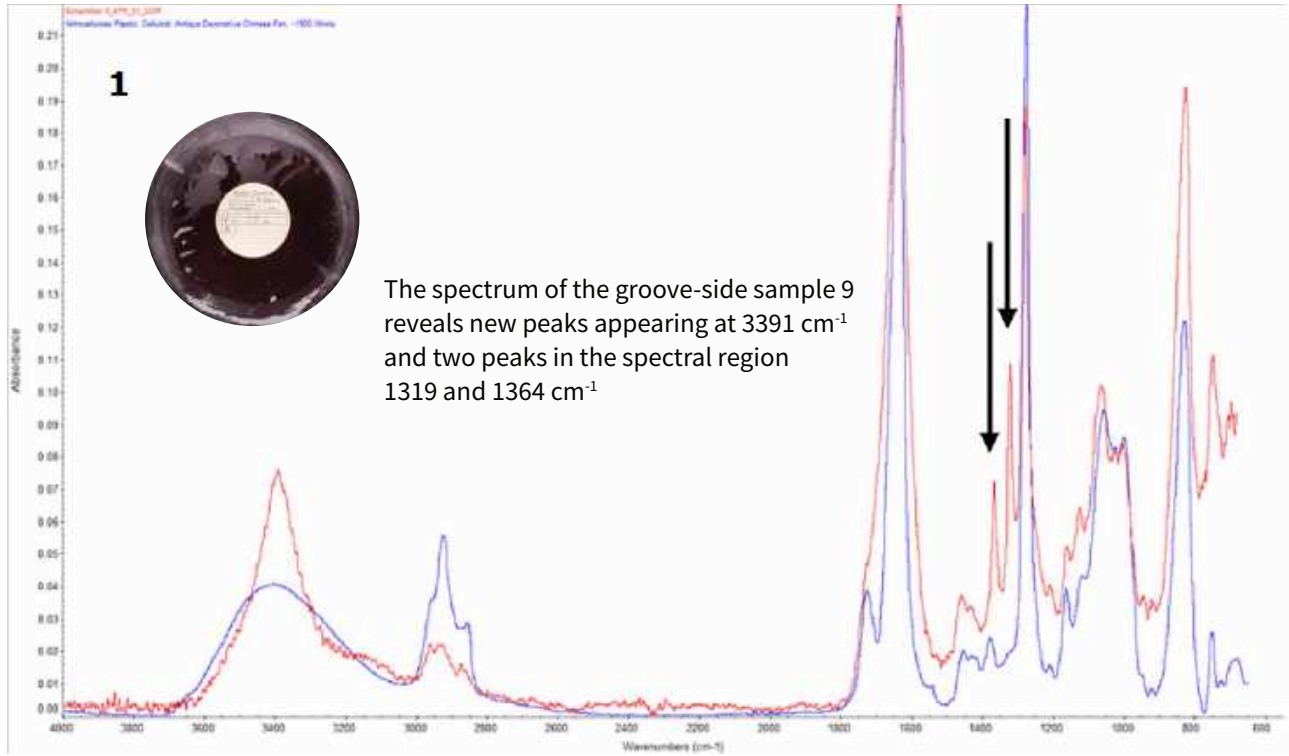


Degradations: discolouration – blisters (unburst) – blisters (burst) – crazing – unrecorded coating cracked – warped

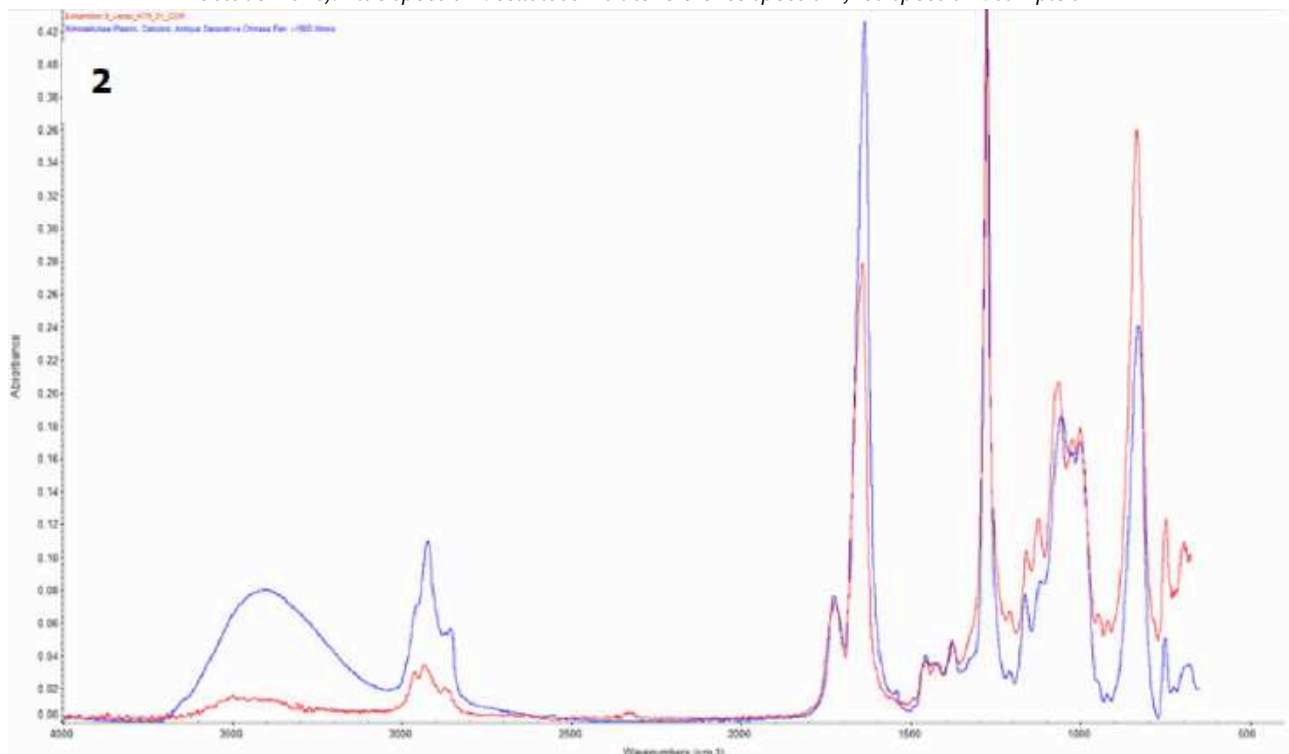
Chemical study

The compound identified by molecular analysis is cellulose nitrate and characterised by the following values:

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Pyral zinc (9-1)	1632 cm ⁻¹	1276 cm ⁻¹	822 cm ⁻¹
Pyral zinc (9-2)	1643 cm ⁻¹	1275 cm ⁻¹	833 cm ⁻¹



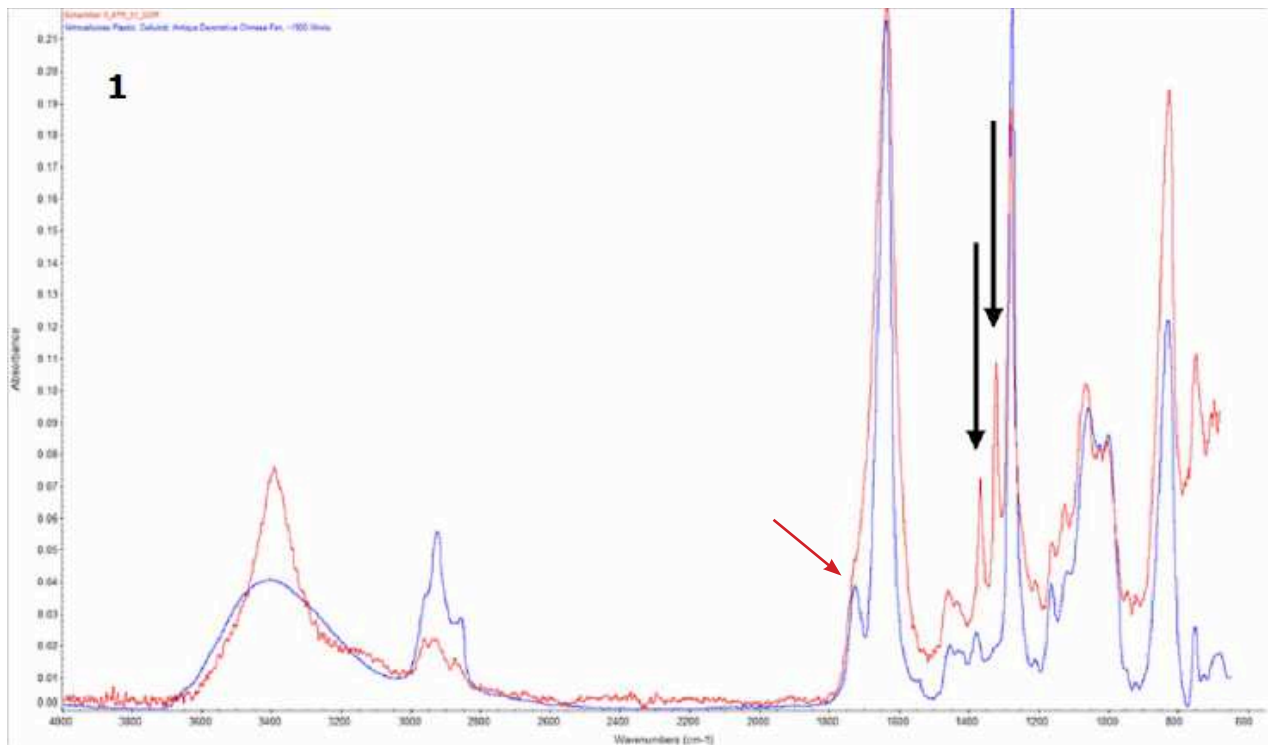
FTIR spectrum of a Pyral disc, 1946 zinc-based, sample 9-1, groove side (Radio-Genève, accession number DN4639, Mon rêve, October 1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 9-1



FTIR spectrum of a Pyral disc, 1946 zinc base, sample 9-2, reverse (Radio-Genève, accession number DN4639, Mon rêve, October 1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 9-2

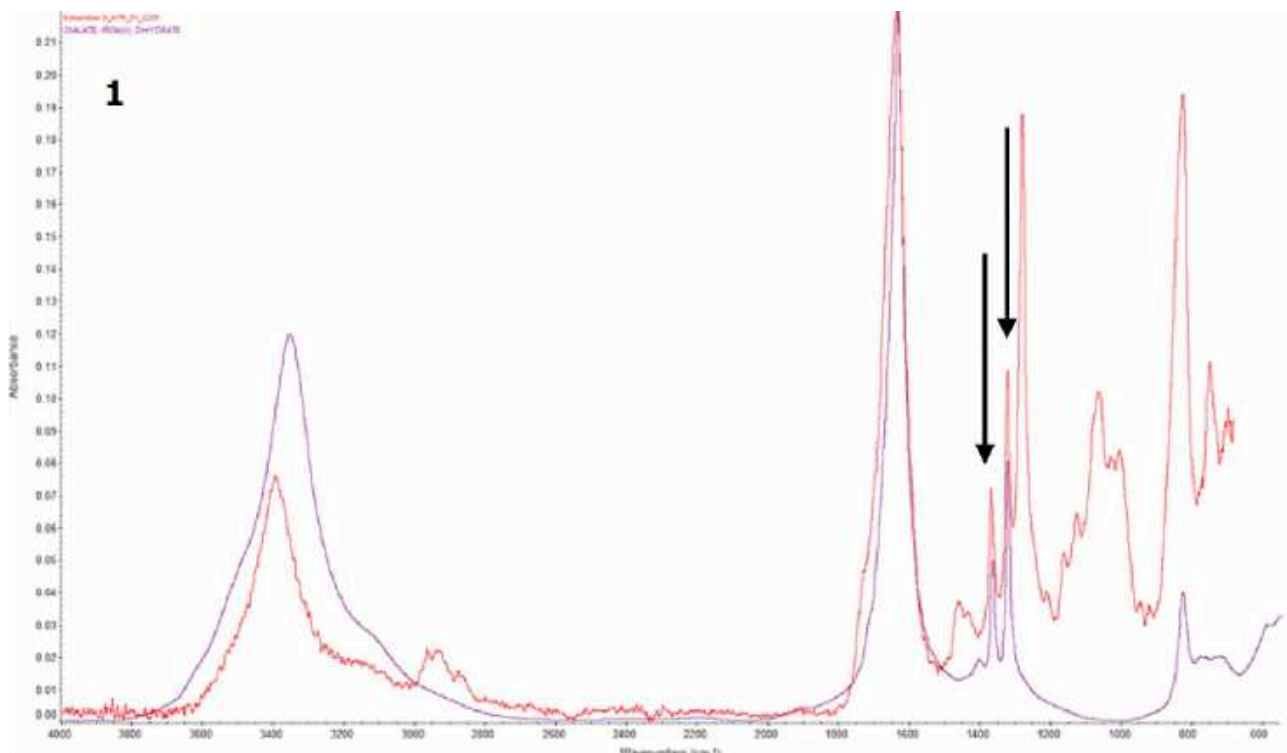
Chemical study: precision

FTIR analysis of the Pyral zinc-based disc sample (groove side) revealed two characteristic peaks of a metallic oxalate (black arrows) that modify the shape of the spectrum and are probably corrosion products⁸⁸. The spectrum is a mixture of cellulose nitrate and a metal oxalate. The presence of an oxalate C-O group and cellulose nitrate C-O group deformed the shape of the peak 1800-1500 cm^{-1} . The N-O contribution of cellulose nitrate nearly disappears (red arrow)⁸⁹. Since metal oxalates have very similar FTIR spectra, the presence of zinc oxalate can only be confirmed by elemental chemical analysis⁹⁰.



FTIR spectrum of a Pyral disc, 1946 zinc-based, sample 9-1, groove side (Radio-Genève, accession number DN4639, Mon rêve, October 1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 9-1

CREDIT Haute Ecole Arc, Laura Brambilla

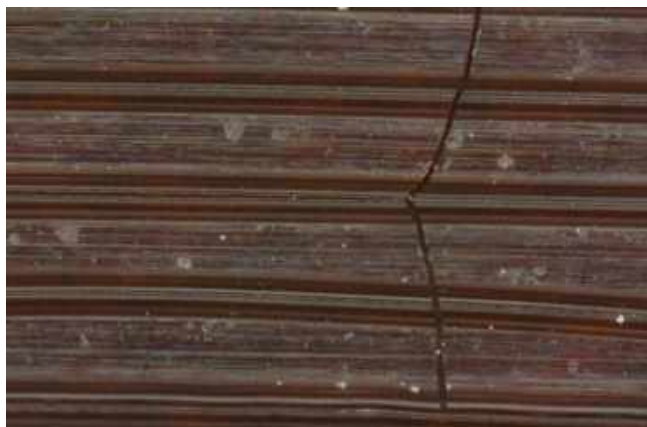


FTIR spectrum of a Pyral disc, 1946 zinc-based, sample 9-1, groove side (Radio-Genève, accession number DN4639, Mon rêve, October 1946). Purple spectrum: reference spectrum of a metallic oxalate; red spectrum: sample 9-1

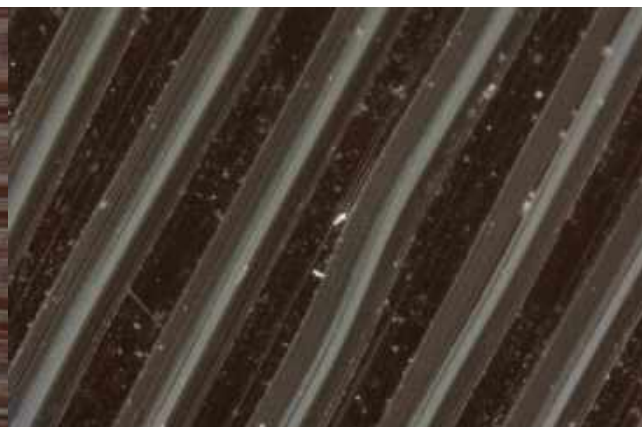
CREDIT Haute Ecole Arc, Laura Brambilla

Microscopic study

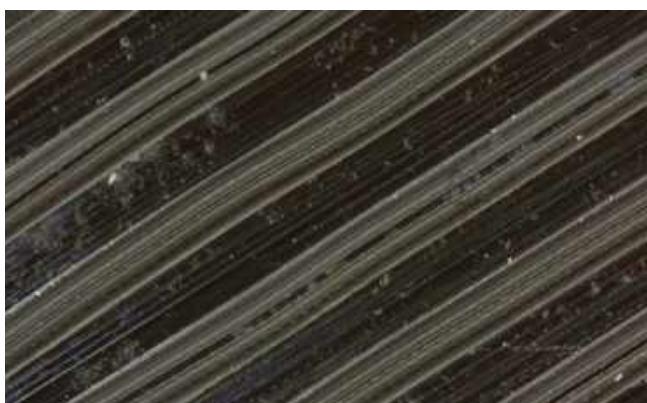
The distinctive shades are visible under the microscope, from burgundy red to dark red and black. Marks of the styluses shape used by Radio-Lausanne between 1940 and 1941 can be seen, with numerous parallel striations.



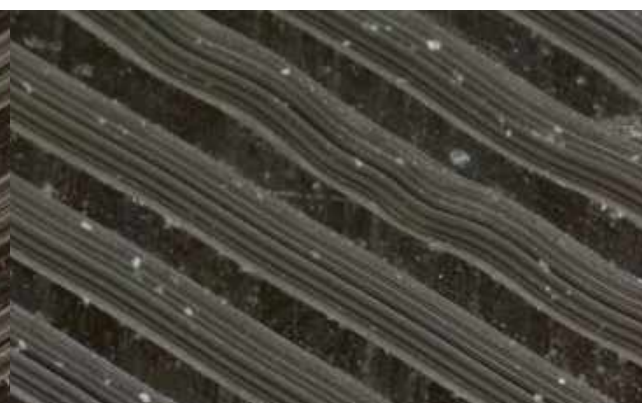
Pyral zinc-based, Radio-Genève, DN4639, 1946. Red coating. USB micrograph, 250X. *Mon rêve*, October 1946.



Pyral zinc-based, Radio-Lausanne, 20378, 1946. Dark red coating. USB micrograph, 250X. *Voici Paris*, no 3, 11 July 1946.



Pyral zinc-based, Radio-Lausanne, 130IX, 1940. Black coating, groove striations. USB micrograph, 250x. *Récital de piano*, by Suzanne Stoun, 15 February 1940.



Pyral zinc-based, Radio-Lausanne, 130IX, 1940. Black coating, groove striations. USB micrograph, 250x. *Récital de piano*, by Suzanne Stoun, 15 February 1940.

Alterations

The main degradations of Pyral zinc-based discs are a chemical decomposition of the cellulosic coating in the form of pitting and blisters. Peeling, delamination of the coating and palmitic acid are also common. Storage conditions affect the extent of the lacquer coating decomposition. Radio-Lausanne nitrocellulose coating discs stored in metal cans are decomposing, resulting in a sandpaper-like surface. High concentrations of pollutants likely accentuated the corrosion phenomenon in the hermetic containers.



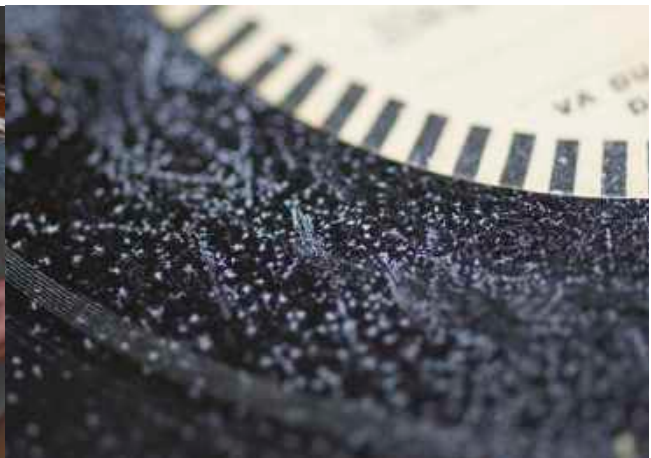
Pyral zinc-based, Radio-Lausanne, 17653, 1945. Burst blistered coating. Observe the degradation following the direction of the metal rolling. *Interview with William Aguet, by Marcel Suès, 8 December 1945.*



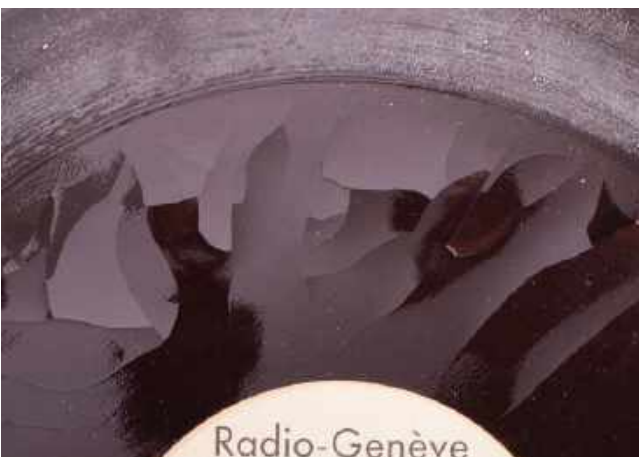
Pyral zinc-based, Radio-Lausanne, 150X, 1937. Coating in pieces, zinc corrosion? *Banquet at the Livery Club of London at Beau-Rivage, 31 May 1937.*



Pyral zinc-based, Radio-Lausanne, 25126, 1947. Decomposed cellulosic coating and zinc corrosion (?). *Interview Yves Baudrier, by Madeleine Angelvin, 7 February 1947.*



Pyral zinc-based, Radio-Lausanne, 5X, 1936. Coating with burst blisters. *Switzerland-Italy match, April 1936.*



Pyral zinc-based, Radio-Genève, DN4639, 1946. Flaking coating. *Mon rêve, October 1946.*



Pyral zinc-based, Radio-Lausanne, 5X, 1936. Coating with burst blisters. *Switzerland-Italy match, April 1936.*

Alterations



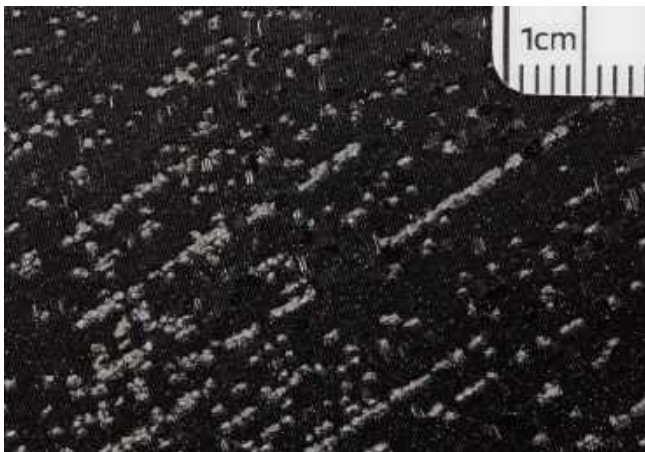
Pyral zinc-based, Radio-Lausanne, 22X, 1936. Burst blisters, flaking coating, zinc corrosion, palmitic acid layer. *Interview Ott (gliding)*, by Cl. Schubiger, 11 September 1936.



Pyral zinc-based, Radio-Lausanne, 22X, 1936. Macrophotograph of flaking coating, zinc corrosion and palmitic acid layer. *Interview Ott (gliding)*, by Cl. Schubiger, 11 September 1936.



Pyral zinc-based, Radio-Lausanne, 22X, 1936. Macrophotograph of a coating with burst blisters. *Switzerland-Italy match*, April 1936.



Pyral zinc-based, Radio-Lausanne, 14060, 1944. Macrophotograph of burst blisters coating. *Le Quart d'heure du sportif*, 1 December 1944.



Pyral zinc-based, Radio-Lausanne, 181X, 1937. Macrophotograph of blisters and flaking coating. *25th anniversary of the Waldensian Scouts, scenic game*, 6 June 1937.

Identification

Cellulose nitrate



Pyral ersatz dark red
1941-1942, 1947



Pyral ersatz red
1943-1946

Ø: 25, 30 cm

Ø 25 (trend from 3 discs)

Weight (grams): 95-104

Disc thickness, edge (mm): 0.94-1.02 (mean 0.98)

Disc thickness, midpoint (mm): 0.92-0.97 (mean 0.95)

Trends

Ø 30 (1941-1942, 1947) (trend from 11 discs)

Weight (grams): 158-166 (mean 162)

Disc thickness, edge (mm): 1.03-1.21 (mean 1.075)

Disc thickness, midpoint (mm): 1.01-1.07 (mean 1.035)

Coating thickness (mm): 0.18

Ø 30 (1943-1946) (from 19 discs)

Weight (grams): 140-154 (mean 143)

Disc thickness, edge (mm): 0.92-1.11 (mean 0.98)

Disc thickness, midpoint (mm): 0.90-1.05 (mean 0.935)

Coating thickness (mm): 0.15

Materials and composition:

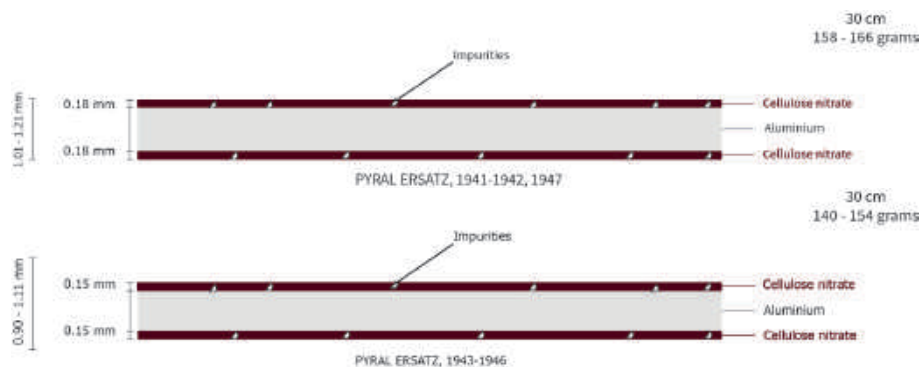
Coating: cellulose nitrate

Coating colour: red - dark red - black

Substrate: aluminium

Characterisation/identification criteria: Two types of ersatz discs have been identified, each with differences in disc thickness and red shades of the coating: dark red Pyral ersatz (c. 1941-1942, 1947) and red Pyral ersatz (c. 1943-1946). Red Pyral ersatz discs are lighter and thinner than dark red Pyral discs. They are recognisable by rough impurities beneath the coating and their degradation characterised by large cracks (radial and tangential to the groove). The origin of this difference in thickness may be rationing of the coating during the second half of the Second World War.

Manufacturing defect: many large impurities under the lacquer - coating burr

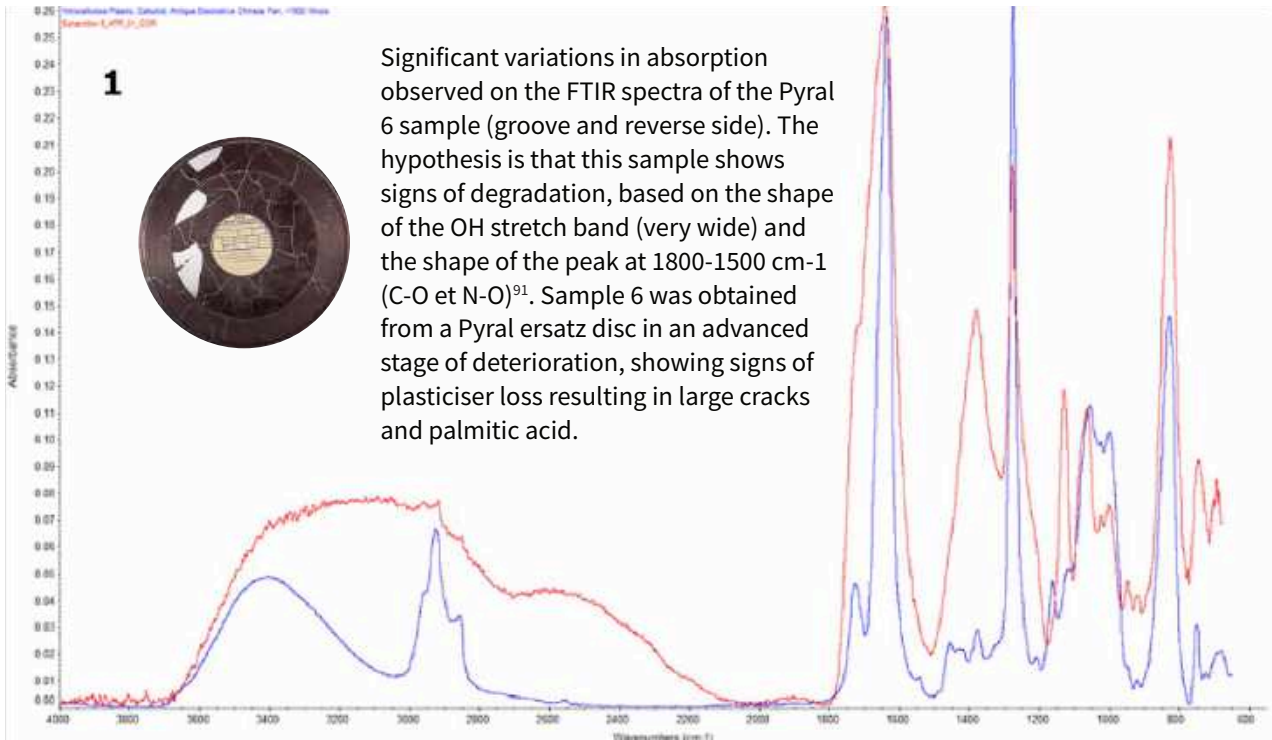


Degradations: crazing - large cracks (radial and tangential to the groove) - palmitic acid - greasy deposits

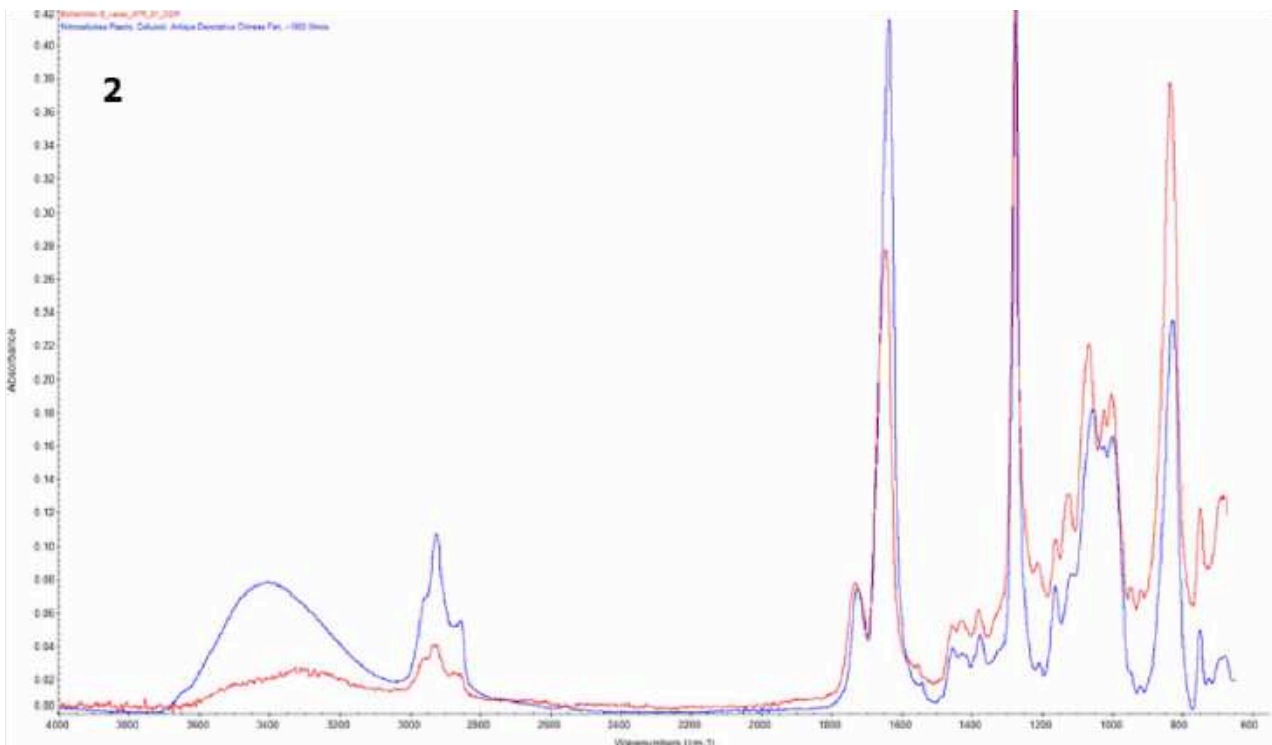
Chemical study

The cellulose nitrate sample is characterised by the following values:

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Pyral ersatz (6-1)	1639 cm ⁻¹	1274 cm ⁻¹	825 cm ⁻¹
Pyral ersatz (6-2)	1643 cm ⁻¹	1275 cm ⁻¹	833 cm ⁻¹



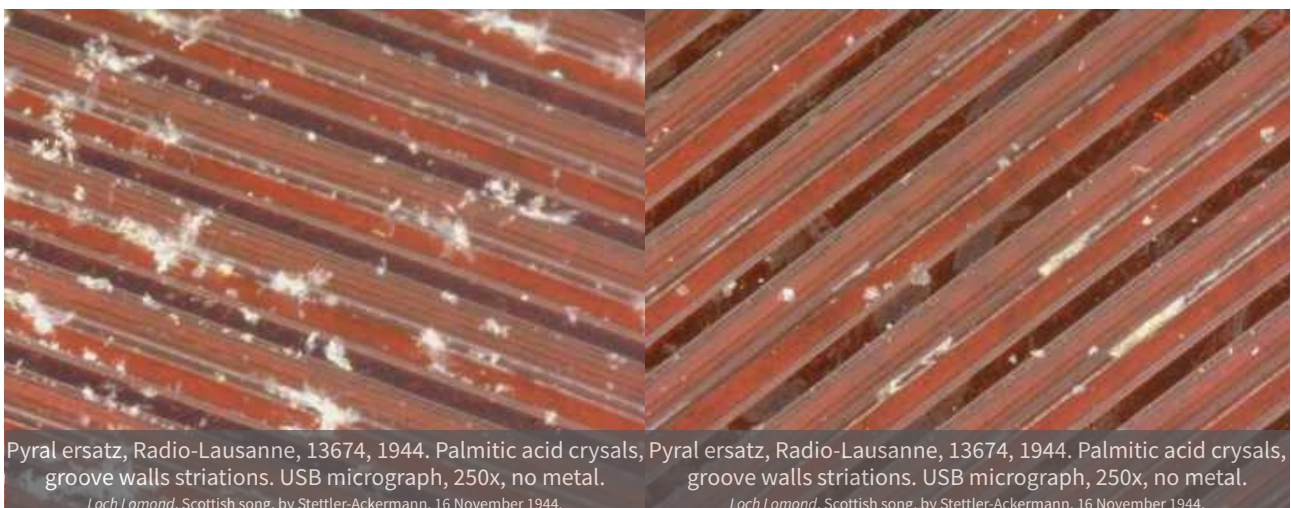
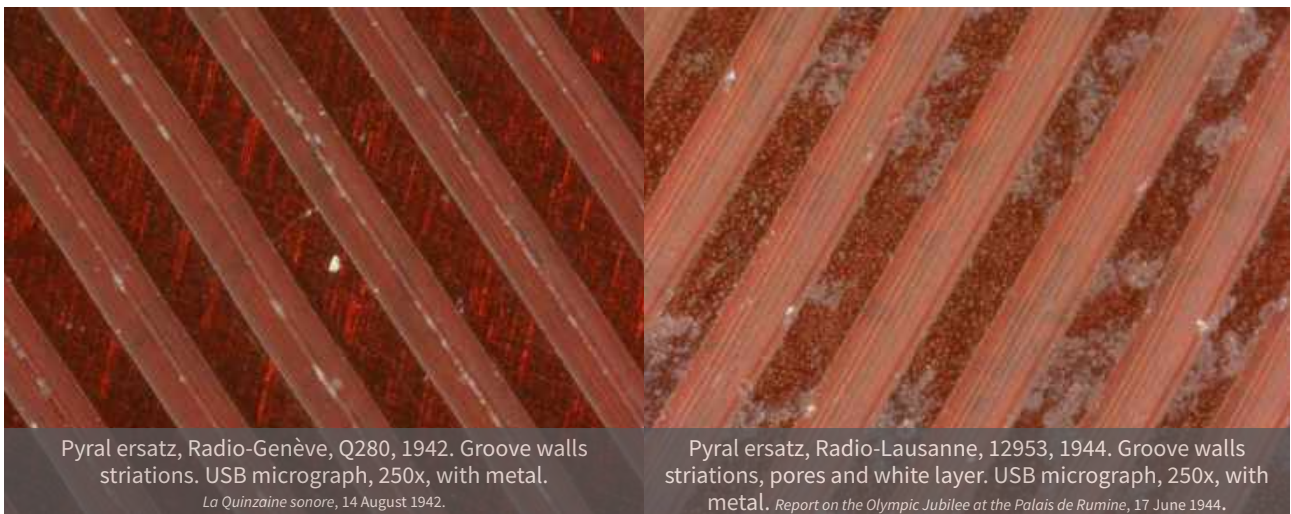
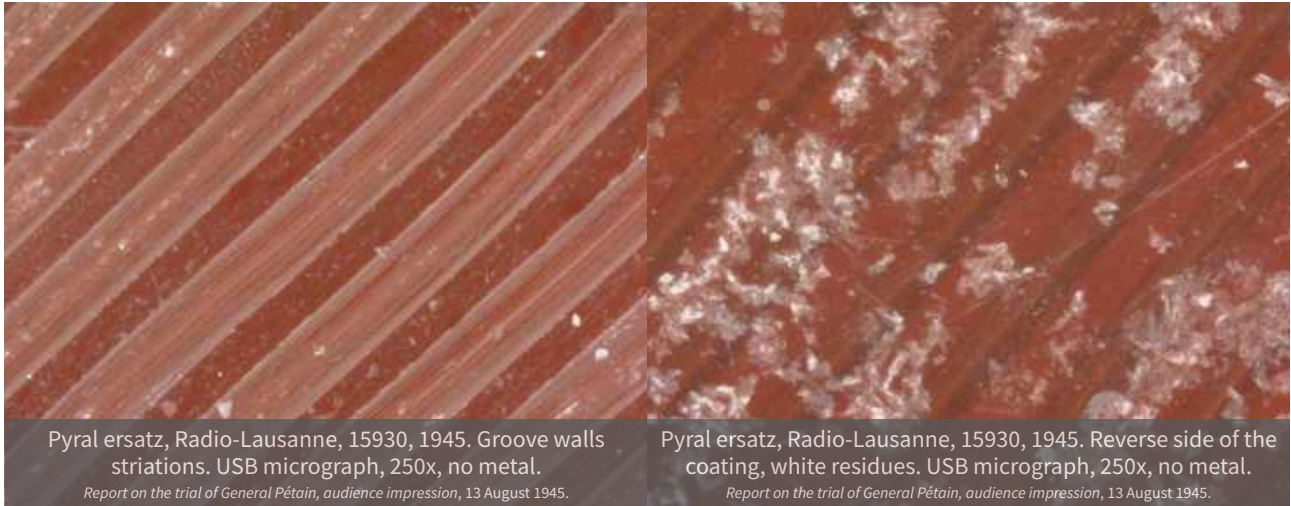
FTIR spectrum of a 1944 Pyral ersatz disc, sample 6-1, groove side (Radio-Lausanne, accession number 13674-A, Hugues Cuénod, *The campbells are coming*, 16.11.1944). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 6-1



FTIR spectrum of a 1944 Pyral ersatz disc, sample 6-2, reverse side (Radio-Lausanne, accession number 13674-A, Hugues Cuénod, *The campbells are coming*, Scottish song, 16.11.1944). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 6-2

Microscopic study

The microscopic images show a wide range of red shades of Pyral ersatz discs, from burgundy red to scarlet red. Regardless of whether the discs were recorded at Radio-Lausanne or Radio-Genève, the parallel striations on the walls of the groove are visible. Microscopic pores covered the SRR 12953 disc surface, probably indicative of plasticiser loss. The characteristic white crystals of plasticiser exudation obstruct the groove. The reverse side of the SRR 15930 disc coating is covered with white residues, presumably a reaction with the underlying aluminium.



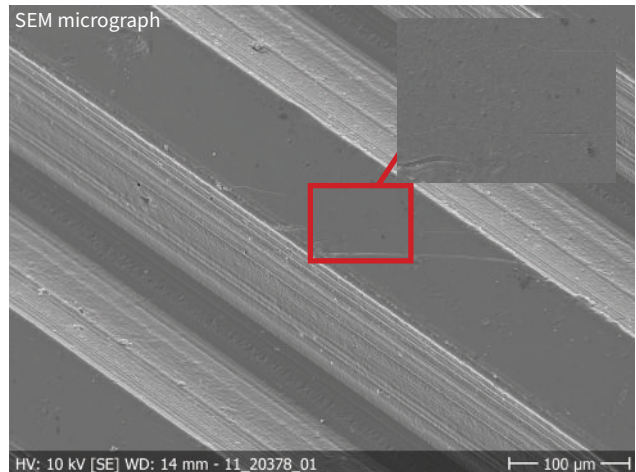
Microscopic study: SEM comparison of zinc and ersatz lacquer

SEM samples of lacquer applied on zinc bases show a difference in cutting depth between the Radio-Lausanne (20378) and Radio-Genève (DN4639) studios. Micro-pores covered the surface of the ersatz coating, associated with the exudation of the plasticiser. The two ersatz groove fragments examined under the microscope (13674, 15930) were concealed by white crystals of palmitic acid before cleaning. The coating applied on zinc substrates (20378, DN4639) are exempts of micro-pores and palmitic acid layer. The four SEM micrographs feature different groove baseline geometries: wide and narrow, associated with the stylus shape. The groove baseline of the SRR 13674 disc is believed to have been torn, either by unsuitable cutting stylus or wear reproduction styluses.



USB micrograph, 250x

Pyral zinc-based, Radio-Genève, DN4639, 1946. No micro-pores.
Mon rêve, October 1946



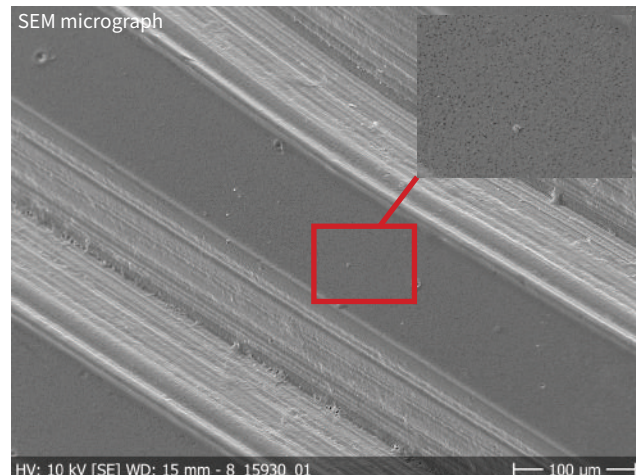
USB micrograph, 250x. Dust.

Pyral zinc-based, Radio-Lausanne, 20378, 1946. No micro-pores
Voici Paris, no 3, 11 July 1946



USB micrograph, 250x. Sample cleaned.

Pyral ersatz, Radio-Lausanne, 13674, 1944. Micro-pores.
Loch Lomond, Scottish song, by Stettler-Ackermann, 16 November 1944



USB micrograph, 250x. Sample cleaned.

Pyral ersatz, Radio-Lausanne, 15930, 1945. Micro-pores.
Report on the trial of General Pétain, audience impressions, 13 August 1945

Alterations

Numerous wide cracks (up to 5 mm wide) are characteristic degradations of ersatz discs, and the cracks are usually too large for mechanical digitization. Optical digitisation techniques (INA-Saphir and VisualAudio) are currently the few methods in Europe able to digitise the content. Additionally, a thick layer of palmitic acid on the disc surface is frequent. The decomposition of cellulose nitrate emits a strong nauseous smell.

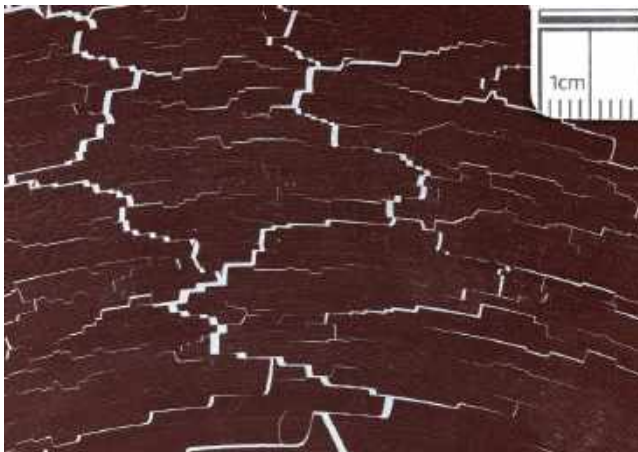


Pyral ersatz, Radio-Lausanne, 12953, 1945.
Large cracks network.

Report of the football match Servette-Lausanne Sport, by Squibbs, 27 May 1945.



Pyral ersatz dark red, Radio-Genève, Q280, 1942.
Crazing network. *La Quinzaine sonore*, 14 August 1942.



Pyral ersatz, Radio-Lausanne, 12953, 1945.
Macrophotograph of large cracks network.

Report of the football match Servette-Lausanne Sport, by Squibbs, 27 May 1945.



Pyral ersatz, Radio-Lausanne, 12953, 1945.
Macrophotograph of large cracks.

Report of the football match Servette-Lausanne Sport, by Squibbs, 27 May 1945.



Pyral ersatz, Radio-Lausanne, 16314, 1945.
Macrophotograph of large cracks.

Léon Savary Chronical: D'une page à l'autre, 8 August 1945.



Pyral ersatz, Radio-Lausanne, 10945, 1943.
Macrophotograph of large cracks.

Report on the 80th anniversary of the Alpine Club, 29 August 1943.

Pyral blue-green dye

1946–1958?

Identification

Cellulose nitrate



Ø: 25, 30 cm

Ø 25

Weight (grams): 103

Disc thickness, edge (mm): 1.02

Disc thickness, midpoint (mm): 0.97

Ø 30 (c. 1947-1955?) (trend from 16 discs)

Weight (grams): 193-213 (mean 205, median 206)

Disc thickness, edge (mm): 1.21-1.5 (mean 1.30)

Disc thickness, midpoint (mm): 1.20-1.32 (mean 1.25)

Coating thickness (mm): 0.19 (centre)-0.265 (edge)

Ø 30 (c. 1946-1950?) (trend from 23 discs)

Weight (grams): 160-166 (follow ersatz, c. 1946-1950?) (mean 164)

Disc thickness, edge (mm): 1.035-1.13 (mean 1.095)

Disc thickness, midpoint (mm): 1.01-1.07 (mean 1.042)

Coating thickness (mm): 0.175-0.185

Trends

Materials and composition:

Coating: cellulose nitrate

Coating colour: dark blue - dark green.

The disc often appears black with green reflections (c. 1946-1958).

Colour discolouration: amber - green

Substrate: aluminium



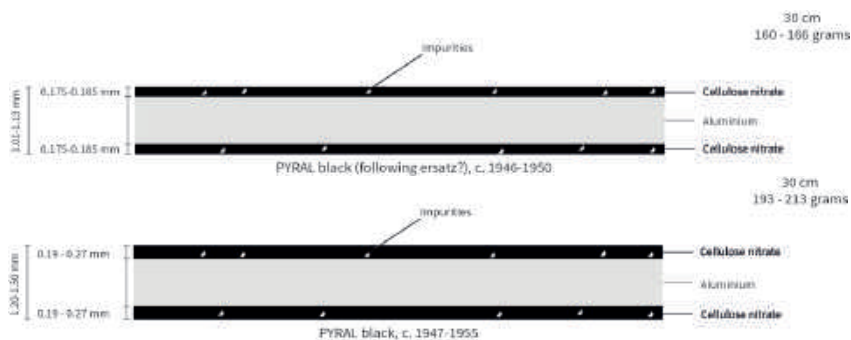
Identification elements for Pyral blue-green dye

Characterisation/identification criteria: By comparing the edges and weight of two Pyral discs from the same period (1946-1958), two types of discs emerge. It could be a combination of Pyral discs expressly manufactured for direct recording and Néo Cire Pyral, used as a master disc. Paradoxically, a BBC report stated that the Néo Cire disc is more suitable to use than the discs specially developed by Pyral for direct-to-disc recording⁹². The various colours of the coating indicate the use of an ink dye (blue and green?), replacing the lampblack as described by J.J. Carpentier, a former employee at the plant⁹³. Given the different colours of the labels and inscriptions, it is also conceivable that Pyral proposed a range of models like its American equivalent Audiodiscs.

Manufacturing defects: impurities under the coating – coating burr



Pyral, 45105, no date. Bevelled aluminium edge, green coating



Pyral, DR4722, 1947. Bevelled aluminium edge, blue coating.

Degradations: coating discolouration – crazing – cracks (radial and tangential to the groove) – palmitic acid – greasy deposits

Microscopic study

In contrast to the zinc-based and ersatz discs, the groove walls are clean and polished, as observed on the USB micrographs. Changes in cutting depths are apparent. Discolouration of the coating (amber, accession number 27733) is evident, significantly changing the visual perception of the groove. White crystals associated with plasticiser loss completely obstruct the groove and surface of some discs.



Alterations

Palmitic acid is the most common degradation, ranging from a thin layer to an opaque covering. The dark coating is frequently discoloured, from green to amber hues. The weight and thickness of the discoloured discs present similar values to the discs that retained their original colour. Discolouration occurs predominantly with Radio-Lausanne discs stored in sealed containers. A suspected chemical reaction with grease-proof paper or the accumulation of pollutants and acidity are the main hypotheses. Surfaces untouched by the interlayer paper - centre and edge of the disc or covered by textile strips - have retained their original colour. Coating shrinkage is characterised by thin cracks.



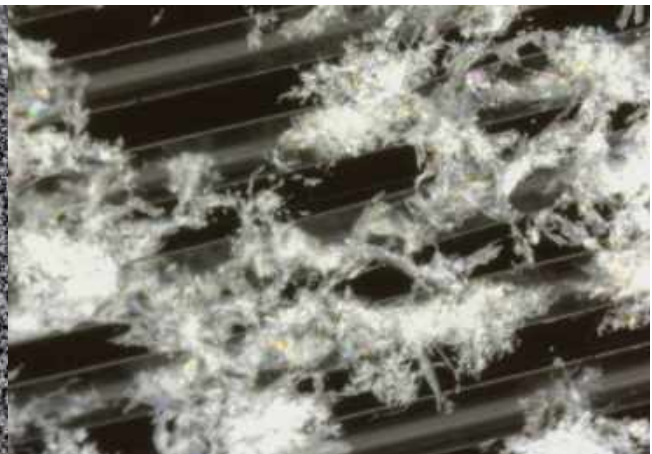
Pyral, black with green hues, Radio-Lausanne, 29948, 1948. Thin cracks and palmitic acid. *Toute une époque*, August 1948.



Pyral, Radio-Lausanne, 31428, 1948. Macrophotograph of thin cracks, light palmitic acid. *Entrée libre*: *London Harmonist*, 26 November 1948.



Pyral, Radio-Lausanne, 34420, 1949. Macrophotograph of palmitic acid layer. *Le Saint à Miami*, 1st episode, July 1949.



Pyral, Radio-Lausanne, unknown accession number. White palmitic acid crystals. USB micrograph, 250x.



Pyral, amber, Radio-Lausanne, 29980, 1948. Coating discolouration (caused by the emanation of the greaseproof paper?). Observe the mark left by the textile strip. *Travel to South America*, report by William Aguet, 29 July 1948.



Pyral, black with green and amber hues, Radio-Lausanne, 30171, 1948. Discolouration of the coating (migration of the dye?). *Interview Roberto Rossellini*, by John Pasetti, September 1948.



Simplat/Simplex

1934–1947?



Labels, stamps and inscriptions

<p>Simplat labels</p>			<p>Simplex label</p>	<p>Simplex stamp near the central hole</p>	<p>Simplex inscription on paper sleeve. NED. OCTR. A 72793 inscription is referring to a filed patent</p>

Ø: 7" (17.78 cm), 10" (25.4 cm), 12" (30.48 cm), 14" (35.56 cm), 16" (40.64 cm)

Identity card

Country of origin	England; The Netherlands
Manufacturer	The V.G. Manufacturing Co. (London); N.V. Ramie Union (Enschede)
Trade name	Simplat; Simplex
Coating	gelatin
Coating colour	black
Substrate	glass
Manufacturing technique	patents GB438029A (1934) and NL48190C (1937)



Simplat disc patent, GB 438,029, filed in 1934.

Historical background

In 1935, British manufacturer V.G. Manufacturing Co. launched the production of Simplat discs, glass discs coated with a colloidal coating developed by Dutch inventor Frederik Marinus van Gelderen (patent filed in 1934)⁹⁴. Simplex discs, developed by Saueressig and manufactured by the N.V. Ramie Union in Enschede (same supplier as Draloston discs), were introduced on the Dutch market the same year. These discs are made of glass and coated with an emulsion composed of 60% gelatin. Like Simplat, these discs were hardened by formaldehyde or formol⁹⁵. The relationship between Simplat and Simplex remains uncertain, as there is two different Dutch inventor's names. Also, Simplat and Simplex disc labels are identical, using the same geometric pattern. Donald Aldous, who helped promote the Simplat in the UK, specified it is a Dutch development⁹⁶.



Aerial view of the N.V. Ramie Union plant in Enschede, c. 1938

CREDIT Kon. Luchtv. Mij. Phototechn.

Manufacturing technique

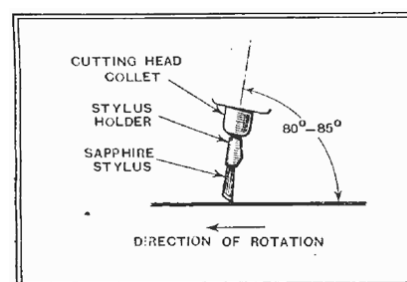
The British patent GB438,029A (filed in 1934, validated in 1935) provided the manufacturing process for Simplat discs:

- The selection of the glass (for example a window panel).
- The glass plate is perforated with a hole on a central axis and cut into a circular shape.
- The peripheral edge is bevelled.
- The surface of the disc is cleaned and degreased
- The surface is treated with a diluted alkaline sodium silicate solution ('water glass') to ensure good adhesion to the gelatin.
- The gelatin preparation follows, mixed with a water-soluble oil (sulphated castor oil, 1% to 10%) and a colouring dye. Adding oil simplifies cutting and reproduction without having to harden the substance.
- The glass is positioned horizontally and in rotation. The gelatinous substance, in liquid or fluid form, is then poured onto the glass plate. If the glass is kept perfectly horizontal, a uniform layer is formed and adheres to the glass thanks to the sodium silicate. The manufacturer emphasised in the patent that the most important element of the invention is the method of application. The technique used ensures uniform thickness and spreading aided by the rotation of the plate held in a completely horizontal position.
- The disc is dried.
- After recording and to extend the shelf-life of the disc, it is rubbed or treated with a hardening solution (formaldehyde-based). The surface can also be rubbed with grease or other polishing/lubricating substances including wax compounds using a soft cloth⁹⁷. The disc is wiped with the hardening solution and dried for about five minutes before the polishing agent is applied. This solution reduces surface noise and enables the disc to be played more than 200 times compared to 10 times without any polishing or hardening process. The hardening and polishing process requires approximately five minutes but can be accelerated with hot air contact, for example, with a hair dryer⁹⁸.

A specific feature found on both Simplat and Simplex discs is a metal ferrule (brass) embedded in the central hole. The metallic ring was patented in 1940 in the Netherlands by Simplex, Ramie Union (NL48190C, 1937). The mention of another patent NED. OCTR. A 72793 is inscribed on a Simplex paper sleeves. The Netherlands Patent Office does not hold this copy and indicates that the inscription A means that the patent has been filed but not validated⁹⁹.

Recording specifications

A sapphire stylus is required to obtain a perfectly clean-cut. The groove cut is smoother, cleaner and more polished in comparison to a steel stylus. This statement can be verified under a microscope where the steel-cut often leaves a rough, shredded edge, causing surface noise and distortion. The sapphire stylus, when fixed in the cutter head holder, should have an angle of approximately 80 to 85 degrees to the horizontal¹⁰⁰. Since the disc coating is relatively hard and to ensure a clean-cut, it is necessary to record a shallow groove (not exceeding 50%). The surface noise level achieved was regarded as very satisfactory using these different recommendations. A 1938 BBC report stated that the high-frequency response was slightly higher than MSS discs. As an additional advantage, the base does not distort, and the surface noise is exceptionally low, with excellent recording quality for music production. However, the drawbacks, which have prevented regular use by the BBC, are the weight, vulnerability of the glass, sensitivity to moisture, and inability to use the disc as a master for pressing¹⁰¹.



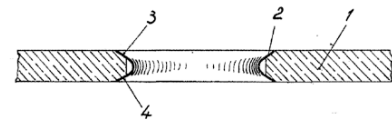
Method of mounting the sapphire cutting stylus to record Simplat discs

Storage condition

The manufacturer Simplat recommended storing the discs in a room exempt from strong temperature variations, maintained at approximately 10°C, and exposed the disc to a slightly humid atmosphere for twenty-four hours before cutting. This step required certain expertise as the thickness of the coating was only about 100 microns: a disc too soft would cause the groove to tear or the stylus to come in contact with the glass base. Conversely, using a coating that is too hard, the cutting depth will be insufficient and affect the durability of the reproduction stylus¹⁰².

Identification

Gelatin on glass



Central hole enclosed by a brass ferrule to strengthen the disc. Glass (1), metal ferrule (2), bevelled glass (3, 4) to facilitate). Detail of the Dutch patent NL 48190C, 1937

Ø: 7", 10" (25.4 cm), 12" (30.48 cm), 14" (35.56 cm), 16" (40.64 cm)

Trends

Ø 10" (trend from 6 discs)
 Weight (grams): 196-224 (mean 209, median 207.5)
 Disc thickness, edge (mm): 1.63-1.92 (mean 1.76)
 Disc thickness, midpoint (mm): 1.70-1.96 (mean 1.83)
 Coating thickness (mm): 0.06-0.14 (mean 0.10)
 Ø 16" (1 disc)
 Weight (grams): 665
 Disc thickness (mm): 2.24
 Coating thickness (mm): 0.11

Ø 12" (trend from 5 discs)
 Weight (grams): 292-308 (mean 300)
 Disc thickness, edge (mm): 1.72-1.875 (mean 1.84)
 Disc thickness, mid. (mm): 1.82-1.92 (mean 1.88)
 Coating thickness (mm): 0.09 (edge)

Materials and composition:

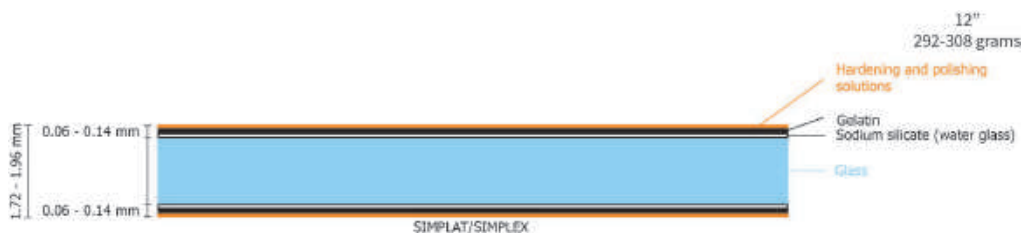
- Coating: gelatin
- Coating colour: black
- Substrate: glass
- Adhesion solution: sodium silicate ('water glass')
- Hardening solution: formaldehyde
- Polishing solution: waxes compounds

Characterisation/identification criteria: edge of the disc honed, polished¹⁰³ and bevelled, centre with a metallic ferrule (brass).

Ideal disc for musical recordings¹⁰⁴.



Bevelled edge, x30. Simplat/Simplex, Radio-Lausanne, 2308X.



Degradations: coating flaking – gelatin coating peeling – broken substrate

Context of use

Years of use by S.R.R. and Radio-Genève: 1936-1947

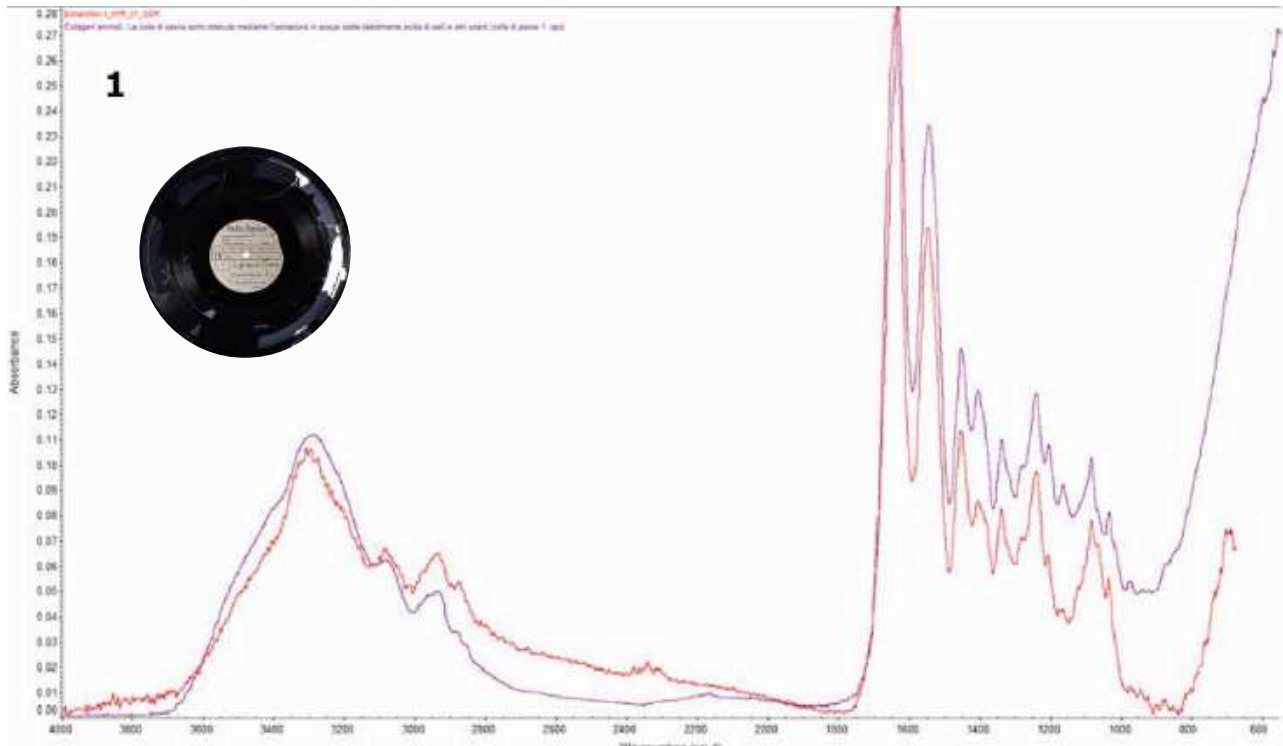
Price 1942 (CHF): 2.50/3.-

Radio-Lausanne: the majority of glass-based discs are Simplat/Simplex discs.

Radio-Genève: the studio used mainly Gevaert's glass discs. However, from 1941 to 1945, the disc repository listed several Simplat/Simplex discs. 10" disc is the most frequent. In 1947, the majority of musical productions were recorded on Simplat/Simplex discs.

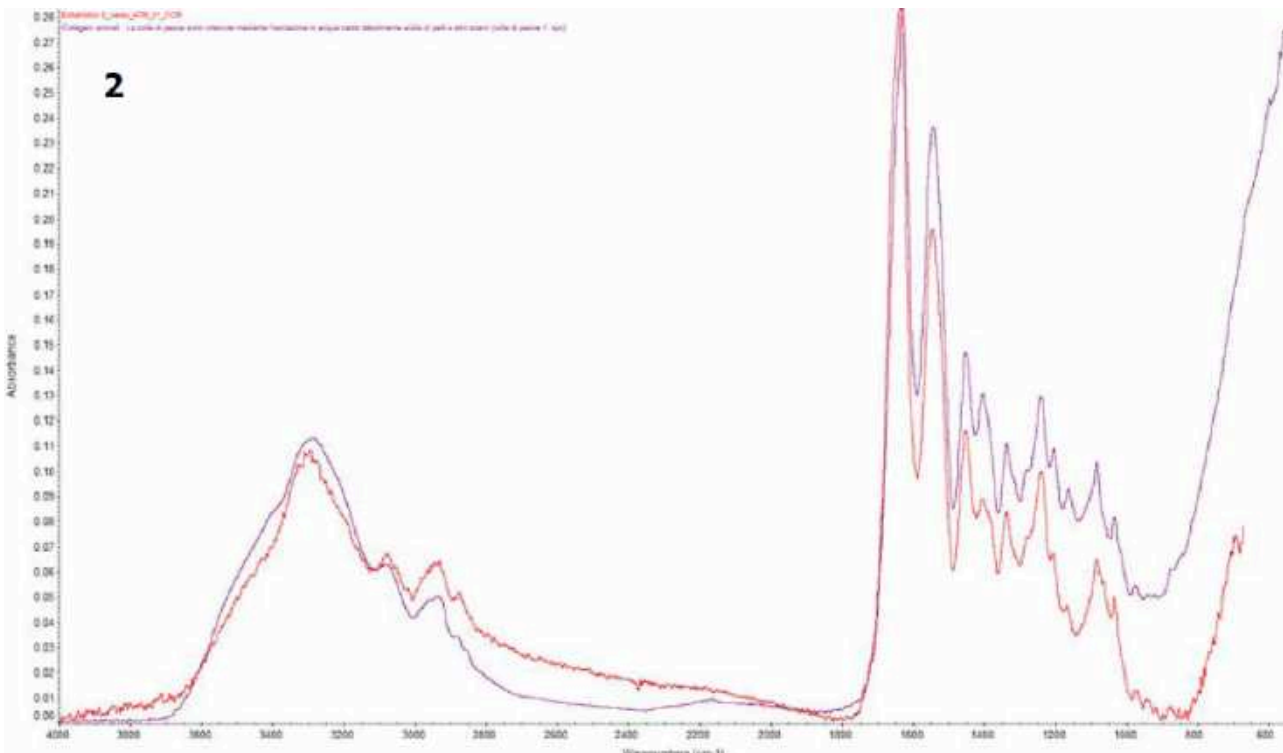
Chemical study

Molecular analyses confirmed historical sources and the manufacturer information which indicated a gelatin coating. The FTIR spectrum of the sample is very similar to collagen¹⁰⁵. Characteristic peaks are located at 3307 cm⁻¹, 1634 cm⁻¹, 1544 cm⁻¹ and 1238 cm⁻¹ (groove side) and 3295 cm⁻¹, 1633 cm⁻¹, 1544 cm⁻¹ and 1242 cm⁻¹ (reverse).



CREDIT Haute Ecole Arc, Laura Brambilla

FTIR spectrum of a 1936 Simplat/Simplex disc, recorded in 1945, sample 3-1, groove side.
(Radio-Genève, accession number P4506, *Les chevaliers du Roy II: une poule sur un mur*, 23.02.1945).
Purple spectrum: reference spectrum of collagen; red spectrum: sample 3-1

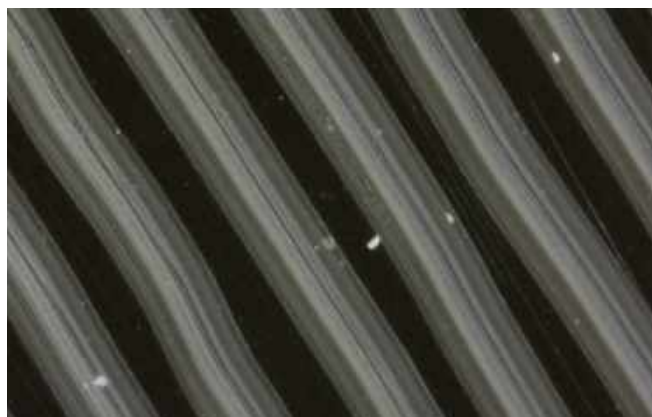


CREDIT Haute Ecole Arc, Laura Brambilla

FTIR spectrum of a 1936 Simplat/Simplex disc, recorded in 1945, sample 3-2, reverse side.
(Radio-Genève, accession number P4506, *Les chevaliers du Roy II: une poule sur un mur*, 23.02.1945).
Purple spectrum: reference spectrum of collagen; red spectrum: sample 3-2

Microscopic study

The micrographs obtained using a DinoLite microscope on Simplat/Simplex discs provide a broad overview of the recording techniques and procedures of radio studios in French-speaking Switzerland. At Radio-Lausanne, two cutting depths are identified observing two discs recorded in the same month (126I, 88VII). The parallel striations of the groove walls are visible in 1938, less in 1940. The groove geometry can be very shallow, either with U-shaped or V-shaped grooves (cross-sections). BBC cutting instructions stipulate that the cutting depth should not exceed 50%¹⁰⁶. The groove baseline can be irregular and presents an alignment of small lines evenly spaced. The RCA archive diagram suggests the causes of this defect is either an incorrect cutting angle, a worn stylus tip or dust¹⁰⁷.



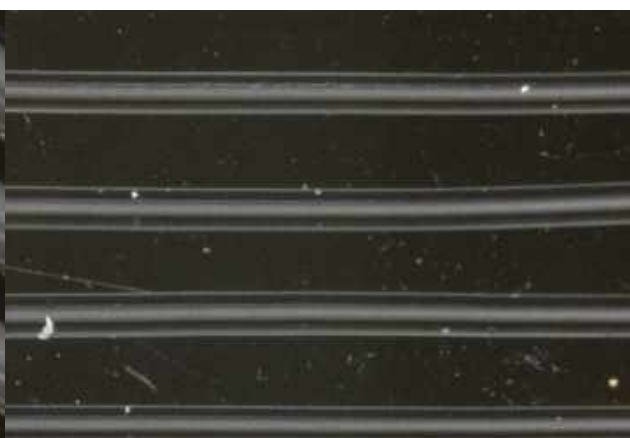
Simplat/Simplex, Radio-Lausanne, 126I, 1938.
Groove walls striations. USB micrograph, 250x.
2 danses de Brahms, by ORSR, 19 September 1938.



Simplat/Simplex, Radio-Lausanne, 88VII, 1938.
Groove walls striations. USB micrograph, 250x.
Farinet ou l'or dans la montagne, radio play, 6 September 1938.



Simplat/Simplex, Radio-Lausanne, 2308X, 1940. Baseline worn.
USB micrograph, 250x. *Interview Monsieur Buenzod, 20 June 1940.*



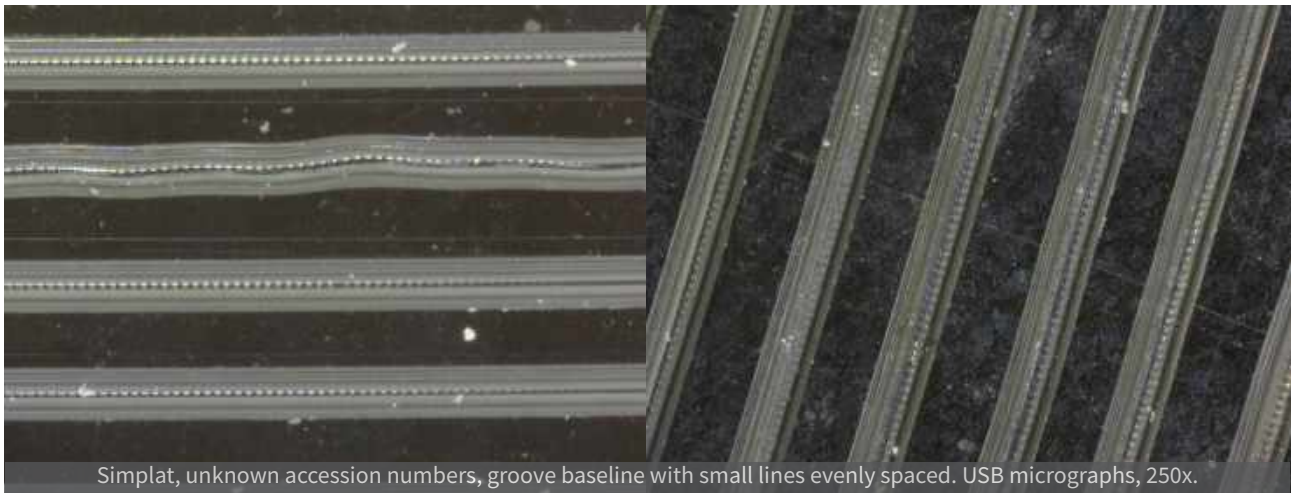
Simplat/Simplex, Radio-Lausanne, 2865, 1940. USB
micrograph, 250x *Tristan & Yseult, 19 October 1940.*



Simplat/Simplex, Radio-Lausanne, unknown accession number. Stratigraphy, cross-section.
U-shaped. Very shallow cut. USB micrograph, 250x.



Simplat/Simplex, Radio-Lausanne, 2865, 1940. Stratigraphy, cross-section.
V-shaped cut. USB micrograph, 250x. *Tristan & Yseult, 19 October 1940*



Simplat, unknown accession numbers, groove baseline with small lines evenly spaced. USB micrographs, 250x.

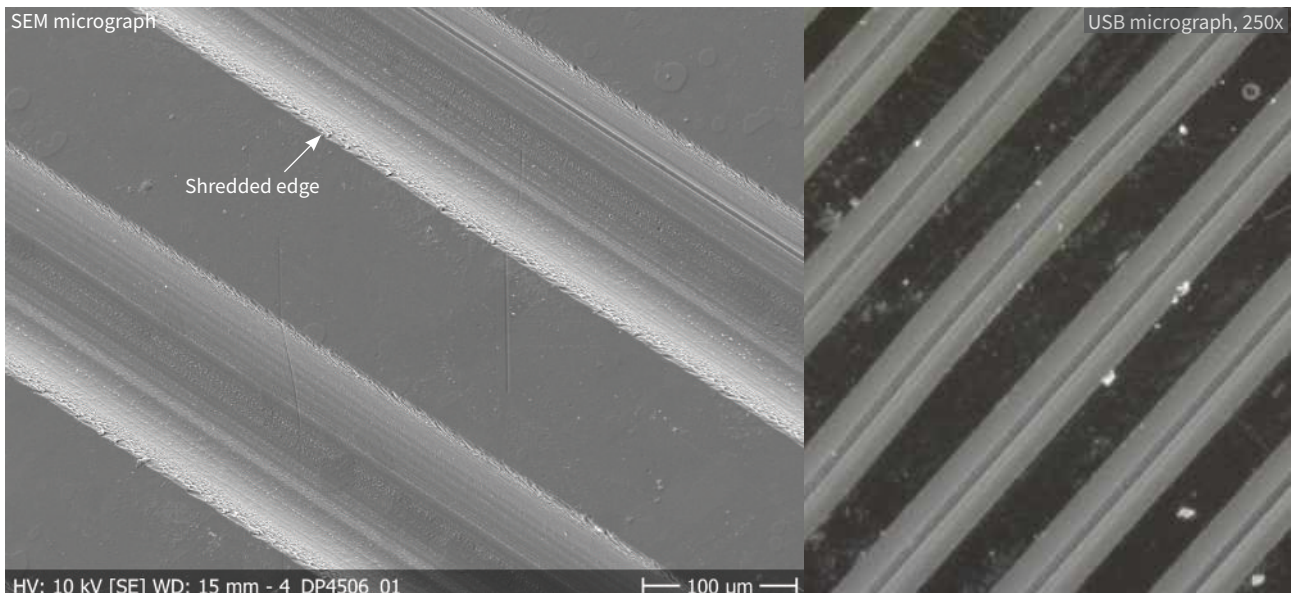


CREDIT: RCA

The most striking example of the different recording procedures is the same Radio-Genève disc recorded in 1936 (A-side, a report on the Escalade Race in December 1936, accession number H28) and 1945 (B-side, accession number P4506). DinoLite micrographs indicate a cutting difference between A-side and B-side. SEM micrographs distinguish the ridge of A-side (H28). The tear observed at the top of the groove wall on B-side corroborates the findings of the research team at V.G. Manufacturer Co (manufacturer of Simplat discs) which stated that a cut with a steel stylus leaves a rough and shredded edge, resulting in surface noise¹⁰⁸.



Simplat/Simplex, Radio-Genève, H28, A-side. *Report on the Escalade Race*, December 1936.



Simplat/Simplex, Radio-Genève, P4506, B-side. *Emission pour la jeunesse La Nursery, pièce pour piano à 4 mains*, 23 February 1945.

Alterations

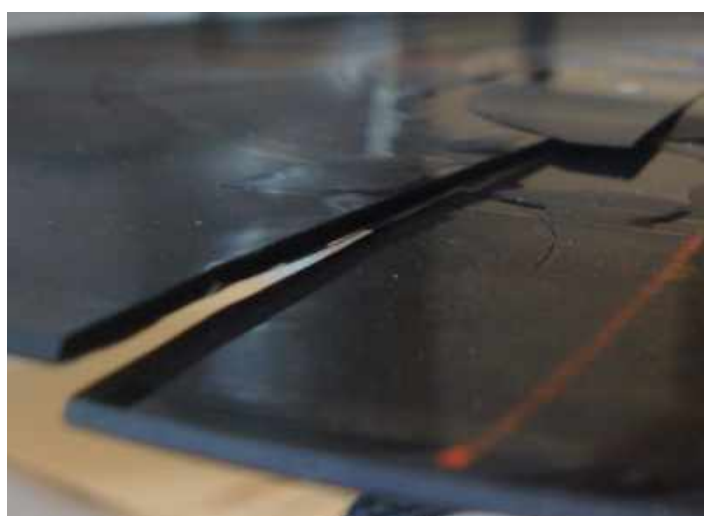


Simplat/Simplex, Radio-Genève, K4329, 1943.
Gelatin coating peeling away.
Roulez tambours, 6 November 1943.



Simplat/Simplex, Radio-Genève, C4328, 1943.
Gelatin coating peeling away.
Bach Cantate 123, by Diego Ochsbein, 6 October 1943.

Simplat/Simplex discs can remain in an excellent state of conservation if stored in suitable thermohygrometric conditions. Conversely, thermohygrometric variations cause the gelatinous coating to peel and flake. The substrate fragility remains one of the major weaknesses of glass discs, resulting in split or broken glass. By 1944, cracking and peeling of the coating from the base were already observed¹⁰⁹. Additionally, gelatin is an organic material highly sensitive to moisture and biological contamination (moulds) that can occur once the relative humidity exceeds 60% for an extended period.



Simplat/Simplex, Radio-Lausanne, 228VI, 1939. Split disc.
Chez le docteur, Badès et Bernier, 30 September 1939.



Simplat/Simplex, Radio-Lausanne, 55ATP, 1941. Broken disc.
Quatuor vocal militaire, 10 May 1941.

Alterations



Simplat/Simplex, Radio-Lausanne, 300, 1937.
Macrophotograph of flaking coating.
Conversation with Blanche Richard, 27 December 1937.



Simplat/Simplex, Radio-Lausanne, 8132, 1942.
Macrophotograph of cracked and flaked coating.
Visit to Salon romand du livre de Neuchâtel, 27 May 1942.



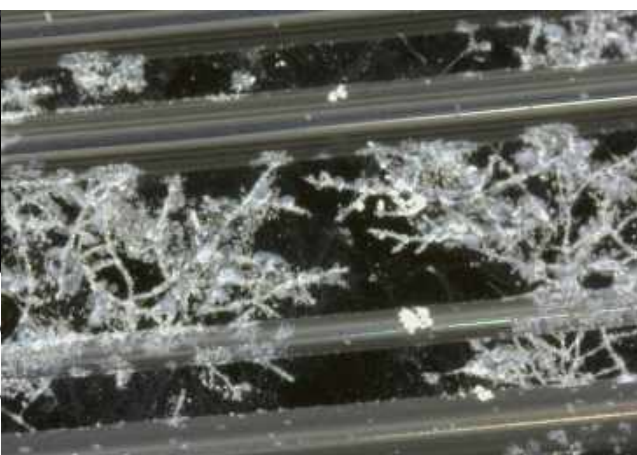
Simplat/Simplex, Radio-Lausanne, 8132, 1942.
Macrophotograph of flaking and peeling coating.
Visit to Salon romand du livre de Neuchâtel, 27 May 1942.



Simplat/Simplex, Radio-Genève, A260-2, 1942.
Macrophotograph of gelatin coating peeling away.
Quatre sur un piano, La chère maison, 6 April 1942.



Simplat/Simplex, Radio-Lausanne, 6165, 1941.
Macrophotograph of mould contamination.
La vie tragique de Charles Baudelaire, radio theatre, August 1941.



Simplat/Simplex, Radio-Lausanne, 6165, 1941.
Mould contamination. USB micrograph, 250x.
La vie tragique de Charles Baudelaire, radio theatre, August 1941.



Thorens 1940–1950



First period
1940-1942

Second period
1942-1944

Third period, yellow
1945-1950

Third period, green
1945-1950

Third period, dark green
1945-1950



Label BnF

Labels 1940-1944

Labels 1945-1950

Inscription 1945-1950

Ø: 25 cm, 30 cm

Identity card

Country of origin	Switzerland (Sainte-Croix)
Manufacturer	Thorens
Coating	cellulose nitrate
Coating colour	<ul style="list-style-type: none"> • First period (1940-1942): black • Second period (1942-1944): light yellow/light green • Third period (1945-1950): from yellow to dark green
Substrate	aluminium
Manufacturing techniques	spraying, scraping, spreading (?) The edge of the disc is uncoated.

Context of use

Years of use by S.R.R. and Radio-Genève:
1940-1950
Price 1942 (CHF): 3.60.-

Radio-Lausanne: regular use of 1st generation discs (single-sided discs) between 1940 and 1942. Yellow/green ersatz coating of the war years (2nd and 3rd generation discs) used from 1942 to 1950, with a peak of use between 1946 and 1947.

Radio-Genève: frequent use between 1945 and 1947, sporadic use from 1948 to 1950.

Thorens 1940–1950

Historical background

Thorens has been manufacturing gramophones and radios since 1898. The firm partly replaced foreign manufacturers for the manufacture of instantaneous discs during the Second World War due to the shortage of discs¹¹⁰. The war forced Switzerland to be self-sufficient to guarantee records supply. Named Thorens S.A. in 1952, the company merged in 1962 with Paillard S.A.¹¹¹.

From the beginning of the war, Robert Thorens, engineer, and director of Thorens, carried out research to manufacture lacquer discs as quickly as possible for studios in French-speaking Switzerland. At first, he called upon the French manufacturer Pyral but without having access to the secret formula of their cellulosic coating. He nevertheless recognised castor oil in the composition of the French coating. Robert Thorens stated the French formulation was “*remarkable, almost impossible to imitate*”, and admitted that he tried to imitate the compound with the help of a chemistry professor from the University of Lausanne by testing different formulas weekly. Having found a fortuitous solution, the discs were manufactured in an isolated room of the varnishing workshops to avoid impurity deposits during production. Robert Thorens remained aware of the lower quality of these discs but concluded: “*This allowed us to provide the studios during the war period*”¹¹².

Historian Dominique Prongué conducted historical research at the Vaud Cantonal Archives, the PTT archives, SRG General Directorate archives and consulted with André Buttex, a collector of Thorens products, to achieve a thorough understanding of the context of use and deterioration of Thorens discs. However, the research provided little information. According to André Buttex, the reason for the disappointing result is that: “*... at the end of the war, Paillard S.A., which manufactured for the Germans, destroyed its archives records since its foundation. (...) the archives of Thorens S.A. would have suffered the same fate in 1963, at the time of its purchase by Paillard S.A. We have no other source that would confirm or refute André Buttex’s information. Given his knowledge of Thorens’ history, there’s a high probability of him being in the right*”¹¹³.



CREDIT Thorens S.A.

Main Thorens plant, c. 1945

Single-sided, black coating

Identification

Cellulose nitrate?



A-side
Coated



B-side
Aluminium

Ø: 30 cm

Ø 30 (trend from 5 discs)

Weight (grams): 131-164 (mean 148, median 156)

Disc thickness, edge (mm): 0.90-1.17 (mean 1.05)

Disc thickness, midpoint (mm): 1.025-1.17 (mean 1.11)

Coating thickness (mm): 0.37 (measures on one sample)

Trends

Materials and composition:

Coating: cellulose nitrate?

Coating colour: black

Substrate: aluminium

Characterisation/identification criteria:

The edge of the disc is uncoated, visible aluminium, single-side coated.

Manufacturing technique: spraying (?)

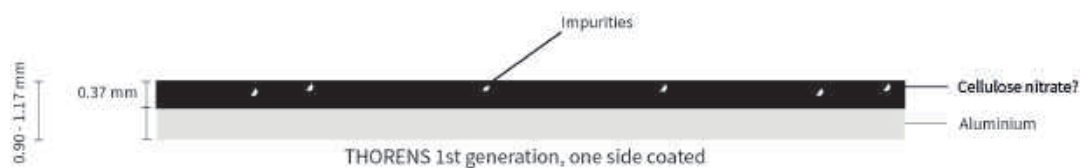
Manufacturing defect: impurities under the coating – casting – blisters



Thorens 1st period, Radio-Lausanne, 4176, 1941. Casting defect?

Revue L'Air du temps, no 6, 21 February 1941.

30 cm
131-164 grams



Degradations: warped disc – cracked (perpendicular to the groove) – peeling (rare)

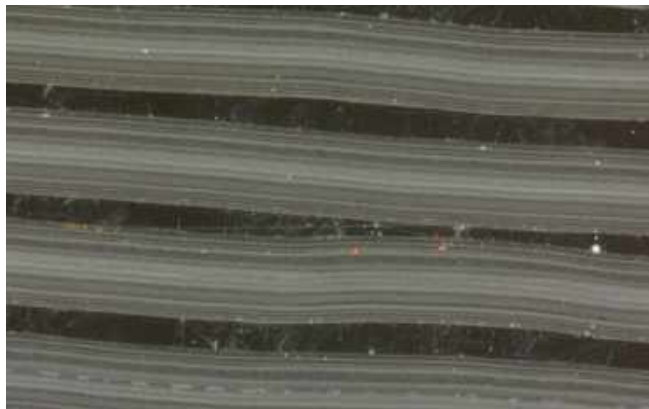
The first period Thorens discs (single-sided coated) should not be confused with Thorens label black discs, double-sided (opposite). These discs (diameter 25 cm) have only been identified to date at the Bibliothèque nationale de France (BnF). The label states “La marque réputée” (missing from the other labels of the brand’s lacquer discs) and does not mention “Swiss manufacture”. A new direction to explore...



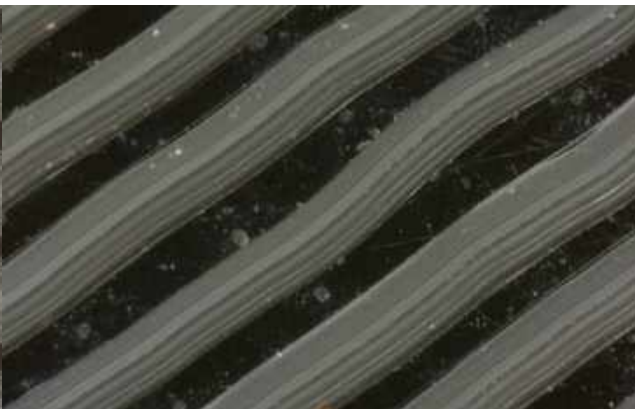
Thorens discs “La marque réputée”

Microscopic study

The first generation Thorens discs were used by Radio-Lausanne between 1940 and 1942. The groove geometry has the same technological traces as the discs manufactured by the other firms and recorded by the same studio. Radio-Lausanne discs recorded between 1940 and 1941 have a distinctive feature of wide cutting depths and multiple parallel striations on the groove walls.



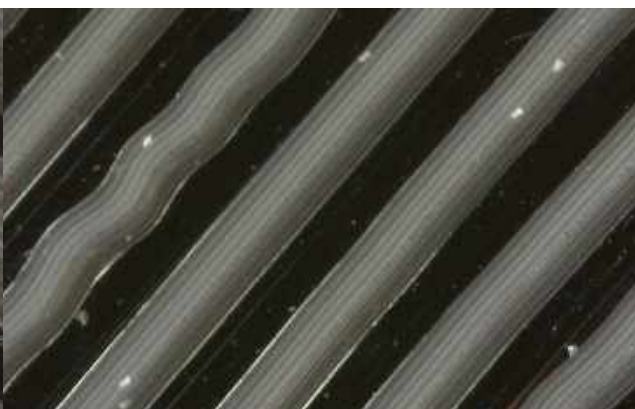
Thorens 1st period, Radio-Lausanne, 4486, 1941. Wide cutting depth and groove walls striations. USB micrograph, 250x.
Revue militaire du Régiment 2, Notre pays, 11.03.1941.



Thorens 1st period, Radio-Lausanne, 4596, 1941. Groove walls striations. USB micrograph, 250x.
Le fils de l'Empereur, radio theatre, 19 March 1941.



Thorens 1st period, Radio-Lausanne, 4386, 1941. Wide cutting depth and groove walls striations. USB micrograph, 250x.
Les Compagnons de la Chanson, 8 March 1941.



Thorens 1st period, Radio-Lausanne, 4176, 1941. Groove walls striations. USB micrograph, 250x.
Revue L'Air du temps, no 6, 21 February 1941.



Thorens 1st period, Radio-Lausanne, 4486, 1941. Stratigraphy, cross-section. > 50% cutting depth. USB micrograph, 250x.
Revue militaire du Régiment 2, Notre pays, 11 March 1941.

Alterations

The most common degradation is the warping of the disc. Inadequate storage and the specific structure of the disc (single-sided coated) are the main causes. The uncoated aluminium surface has traces of oxidation, abrasion, and fingerprints.

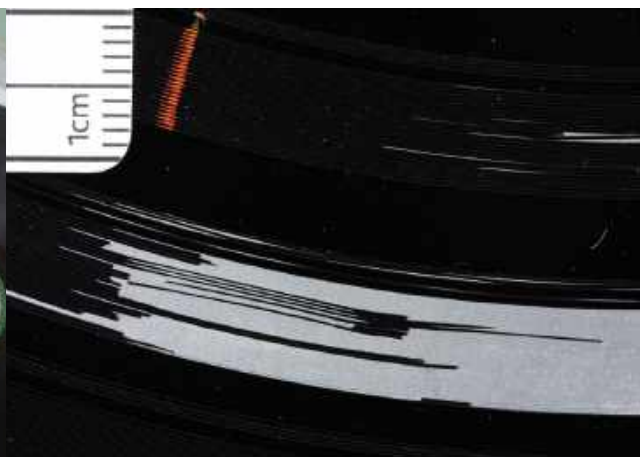


Thorens 1st period, Radio-Lausanne, 4777, 1941. Warped disc. *Report on the Oath of the Grand Conseil*, 8 April 1941.



Thorens 1st period, Radio-Lausanne, 4486, 1941.
Coating peeling away.

Revue militaire du Régiment 2, Notre pays, 11 March 1941.



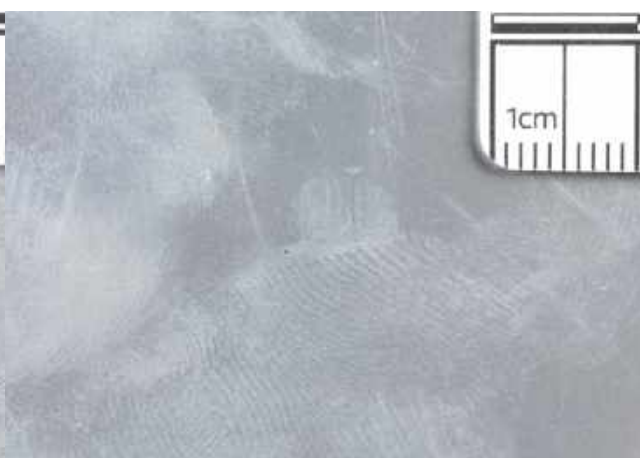
Thorens 1st period, Radio-Lausanne, 4386, 1941.
Macro photograph of coating in threads and peeling away.

Les Compagnons de la Chanson, 8 March 1941.



Thorens 1st period, Radio-Lausanne, 4386, 1941.
Macro photograph of uncoated aluminium, circular striations
caused by the playback on the turntable (?), fingerprints.

Les Compagnons de la Chanson, 8 March 1941.



Thorens 1st period, Radio-Lausanne, 4386, 1941.
Macro photograph of uncoated aluminium,
oxidation stains, fingerprints.

Les Compagnons de la Chanson, 8 March 1941.

Thorens pale coating

Cellulose nitrate

Identification



Ø: 25, 30 cm

Ø 25 (1 disc)

Weight (grams): 103

Disc thickness, edge (mm): 1.15-1.24 (mean 1.18)

Disc thickness, midpoint (mm): 0.98-1.05 (mean 1.01)

Trends

Ø 30 (from 3 discs)

Weight (grams): 150-157 (mean 154)

Disc thickness, edge (mm): 1.09-1.25 (mean 1.15)

Disc thickness, mid. (mm): 1.00-1.17 (mean 1.042)

Coating thickness (mm): 0.18-0.45

Materials and composition:

Coating: cellulose nitrate

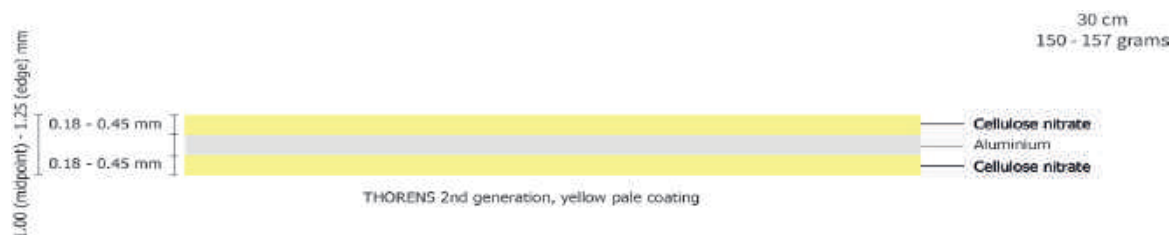
Coating colour: light yellow, light green (discoloured coating, originally black?)

Substrate: aluminium

Characterisation/identification criteria: The edge of the disc is uncoated, aluminium visible. The thickness of the cellulose coating varies considerably for the same layer, between 0.18 and 0.45 mm. This thickness difference is evident at the edge of the disc. Under a microscope, this characteristic is distinguished by curved effects on the disc periphery formed by the convex shape of the coating layer (below).



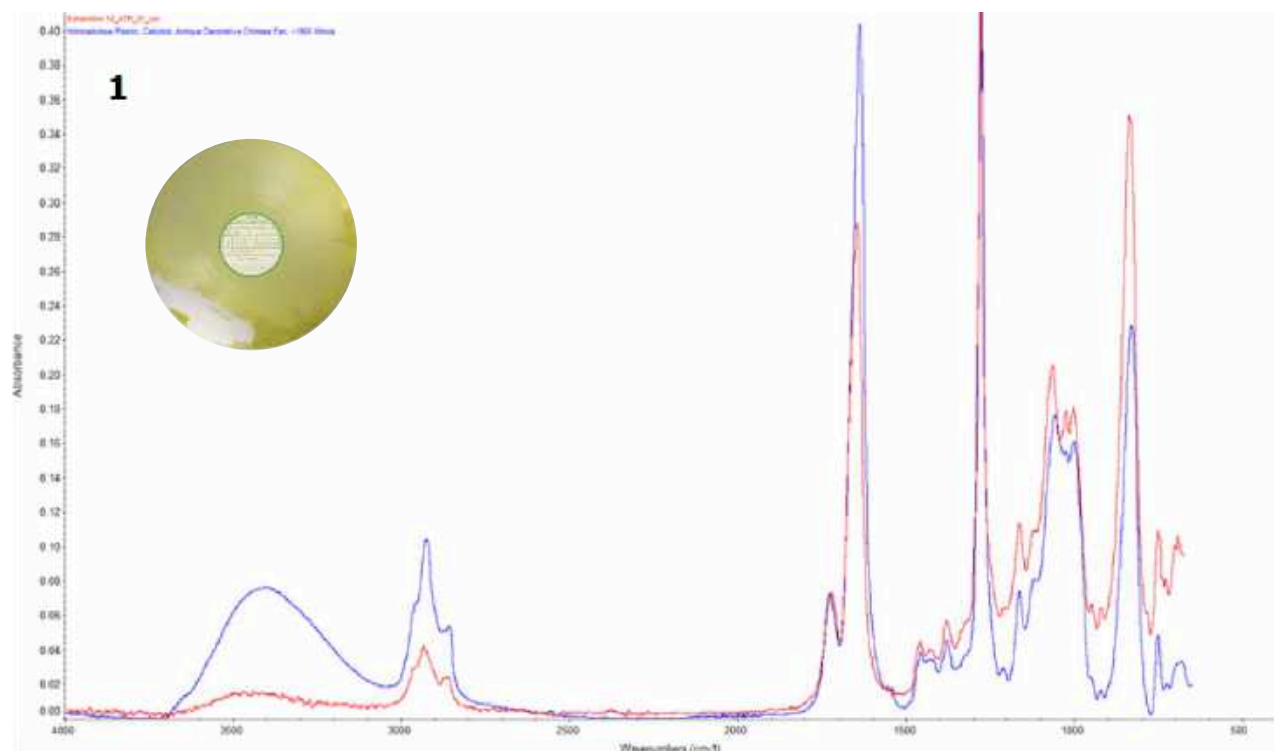
Thorens 2nd generation, Radio-Lausanne, 7399, 1942. Stratigraphy, cross section. USB micrograph, 200x. Curved effect on the periphery of the disc. *Bon dimanche, radio theatre*, 19 February 1942.



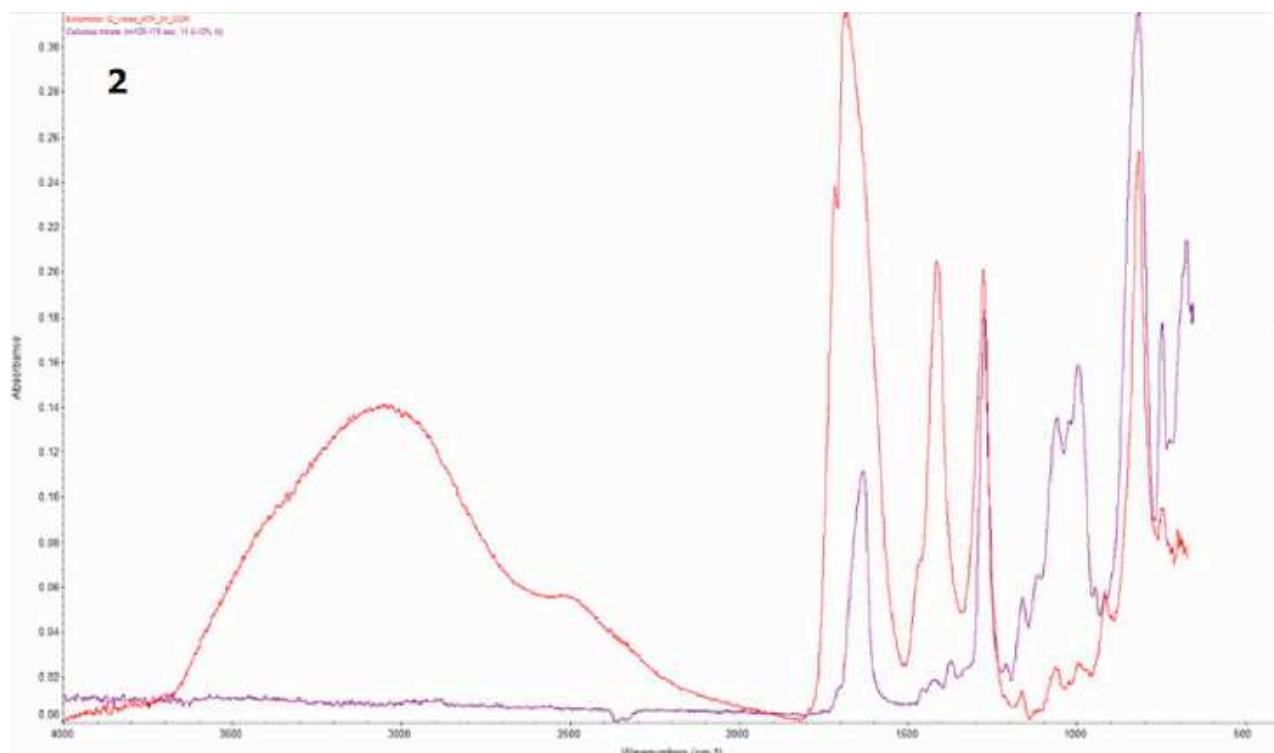
Degradations: discolouration – crazing (tangential to the groove) – cracked (radial to the groove)

Chemical study

Two opposite FTIR spectra are respectively obtained for the groove side and the reverse side of the 2nd generation Thorens disc sample (accession number 7399). The peaks on the sample groove side (12-1) are characteristic of cellulose nitrate: the peak of the NO_2 functional group at 1276 cm^{-1} , the strong nitrogen dioxide stretching band near 1650 cm^{-1} , here at 1643 cm^{-1} , and the N-O functional group at 834 cm^{-1} . Reconstruction of the spectrum of the reverse side (12-2) using Thermo Scientific™ Omnic™ Spectra software identified two distinct polymers: cellulose nitrate and polyacrylic acid¹⁴. This result could explain the wide OH stretch band in the spectral region $2500\text{--}3500\text{ cm}^{-1}$.



FTIR spectrum of a Thorens disc, 2nd period (1942), sample 12-1, groove side (Radio-Lausanne, accession number 7399, Bon dimanche, 19.02.1942). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 12-1



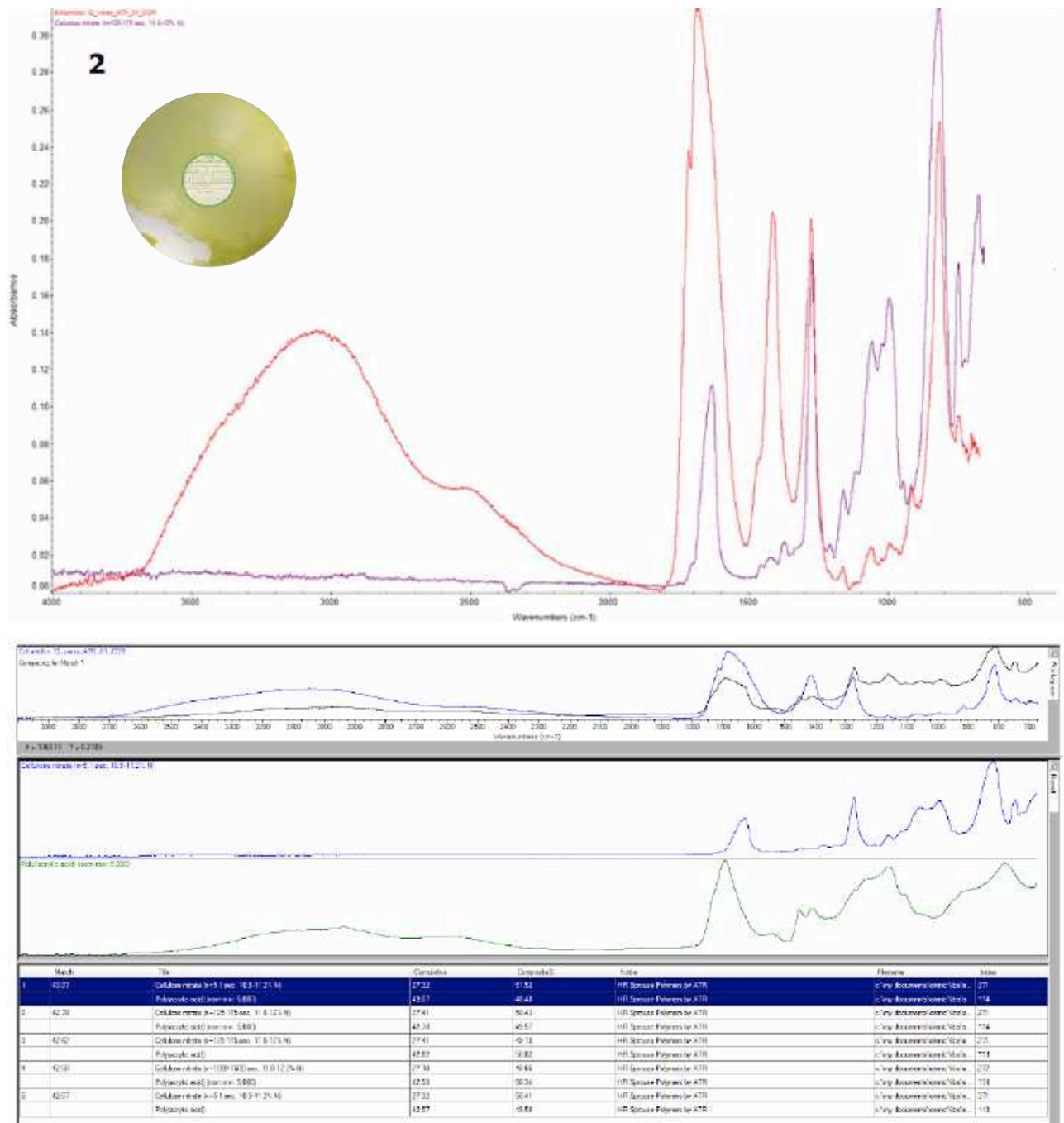
FTIR spectrum of a Thorens disc, 2nd period (1942), sample 12-2, reverse (Radio-Lausanne, accession number 7399, Bon dimanche, 19.02.1942). Purple spectrum: cellulose nitrate reference spectrum; red spectrum: sample 12-2

CREDIT Haute Ecole Arc, Laura Brambilla

CREDIT Haute Ecole Arc, Laura Brambilla

Chemical study: precision

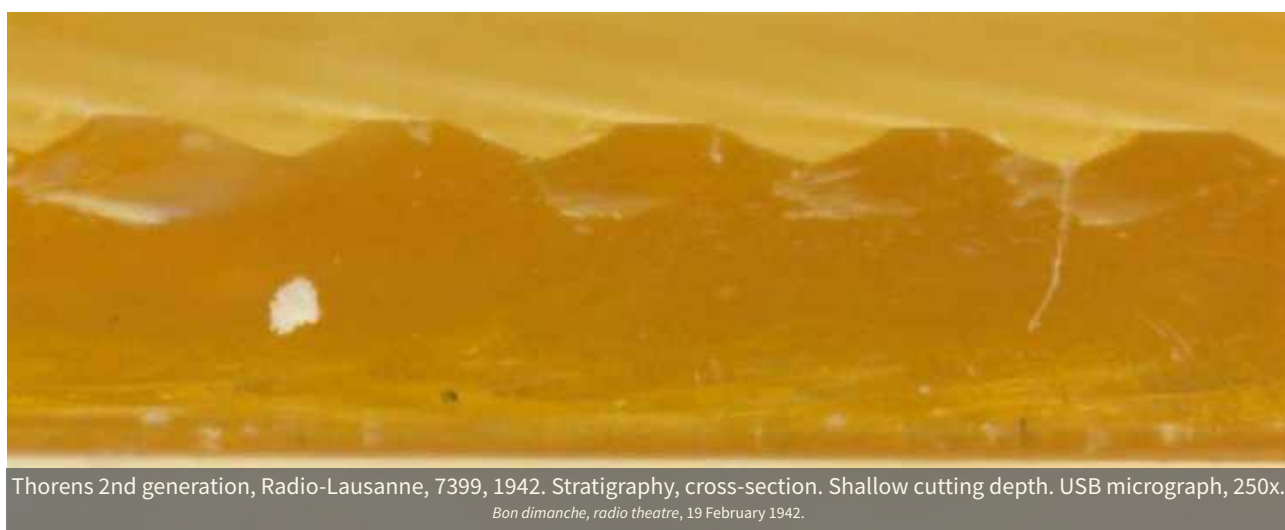
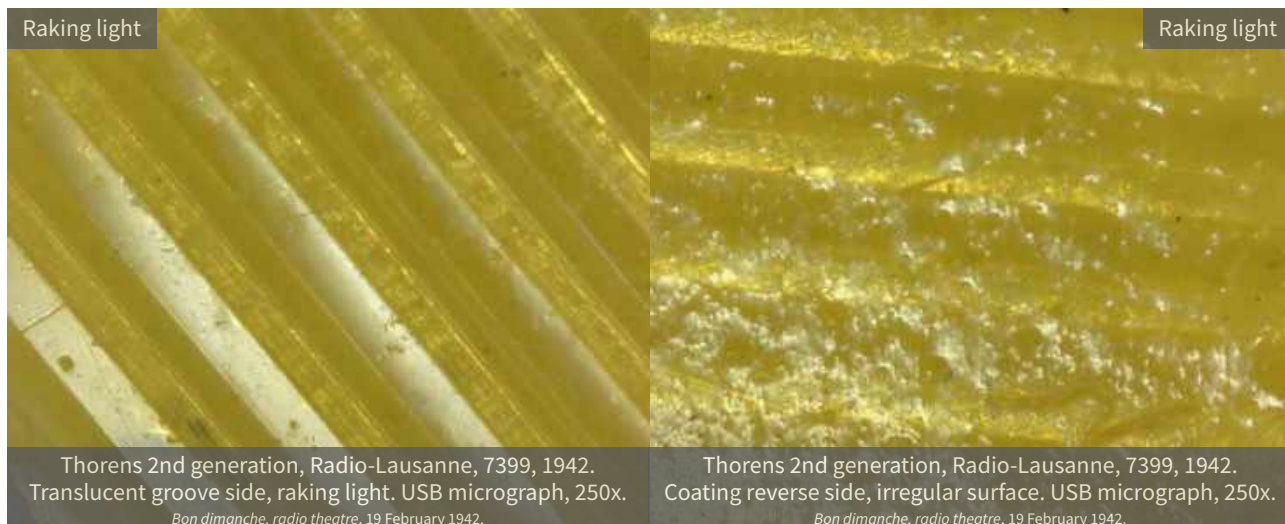
If a sample is a mixture of different compounds, the use of Thermo Scientific™ Omnic™ Spectra software enables multi-component research and deconstructs the composite spectrum to extract each component. The software detected the combined presence of polyacrylic acid and cellulose nitrate on the reverse of 2nd generation Thorens sample¹¹⁵. Referring to the same patents from the historical study, there are seven references to acrylic acid. A Deutsche Celluloid-Fabrik patent described the use of acrylic acid butyl ester as a first coating layer to apply an intermediate layer of cellulose nitrate (Deutsche Celluloid-Fabrik, GB497429, 1937). The current hypothesis suggests Thorens applied a first layer of polyacrylic acid solution to facilitate the adhesion of cellulose nitrate to the metallic substrate.



Top FTIR spectrum of a Thorens disc, 2nd period (1942), sample 12-2, reverse (Radio-Lausanne, accession number 7399, Bon dimanche, no 2, 19.02.1942). Purple spectrum: cellulose nitrate reference spectrum; red spectrum: sample 12-2. Bottom) Spectrum reconstructed with Thermo Scientific™ Omnic™ Spectra.

Microscopic study

Irregular surface topography and covered with small pits characterised the reverse side of the coating. The cross-section also reveals impurities embedded in the lacquer. The groove side micrographs can only partially distinguish the groove as a result of the translucency of the coating. USB micrographs of the grooves of SRR discs 325C and 7498 highlighted the different yellow/green shades.

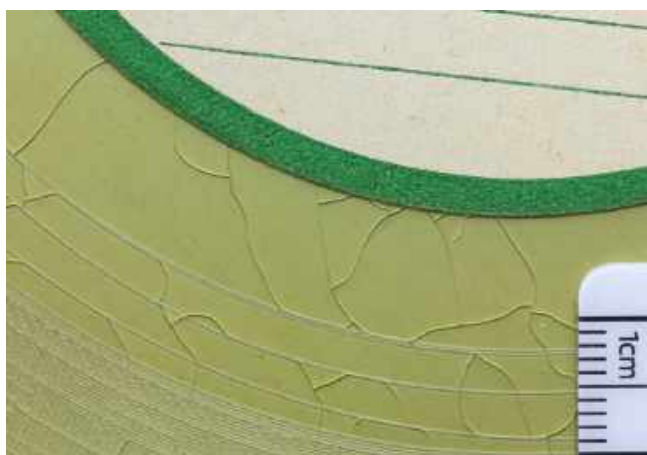


Alterations

As opposed to the 3rd generation Thorens discs, the coating of the 2nd period Thorens discs rarely peeled and flaked but remained attached to the substrate. The cracks are thin and/or wide (up to 1 mm in width).



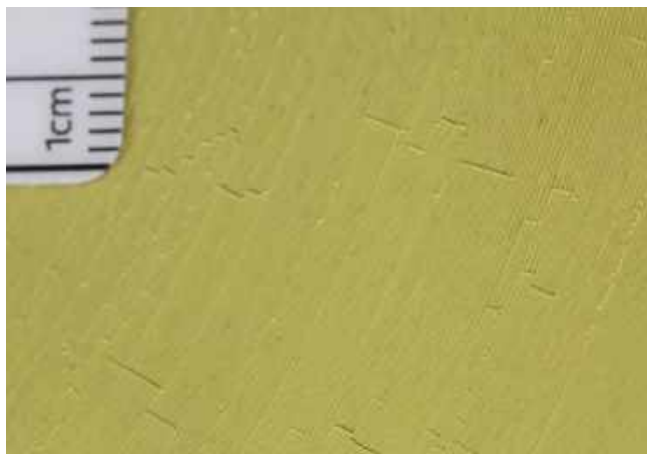
Thorens 2nd generation, Radio-Lausanne, 7399, 1942.
Missing coating pieces.
Bon dimanche, radio theatre, 19 February 1942.



Thorens 2nd generation, Radio-Lausanne, 325C, 1942.
Macro photograph of a crazing network.
Corsier-sur-Vevey bells, 14 May 1942.



Thorens 2nd generation, Radio-Lausanne, 325C, 1942.
Macro photograph of large cracks and crazing. Aluminium substrate visible. *Corsier-sur-Vevey bells, 14 May 1942.*



Thorens 2nd generation, Radio-Lausanne, 325C, 1942.
Macro photograph of a crazing network.
Corsier-sur-Vevey bells, 14 May 1942.



Thorens 2nd generation, Radio-Lausanne, 7498, 1942.
Macro photograph of crazing, aluminium not visible.
Choeur mixte de Moudon, 25 January 1942.

Thorens yellow/green coating

Cellulose nitrate

Identification



Dark green
1945-1950



Green, 1945-1950



Yellow, 1945-1950

Ø: 25, 30 cm

Ø 25 (trend from 7 discs)

Weight (grams): 119-128 (mean 123)

Disc thickness, edge (mm): 1.15-1.41 (mean 1.26)

Disc thickness, mid. (mm): 1.00-1.24 (mean 1.16)

Coating thickness (mm): 0.24-0.37

Ø 30 (trend from 19 discs)

Weight (grams): 184-210 (mean 195)

Disc thickness, edge (mm): 1.20-1.53 (mean 1.36, med 1.34)

Disc thickness, mid. (mm): 1.16-1.45 (mean 1.27, med. 1.25)

Coating thickness (mm): 0.22-0.43

Trends

Materials and composition:

Coating: cellulose nitrate

Coating colour: yellow to dark green (discoloured coating, originally black?)

Substrate: aluminium

A recipe modification was probably made between the 2nd and 3rd generation discs, circa 1944-1945.

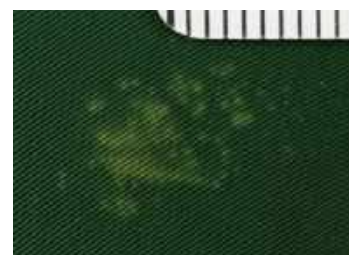
Characterisation/identification criteria: discolouration, traces of manufacturing in the form of small blisters on the edge of the disc (made during the spreading of the lacquer?). Along with Thorens 2nd generation records, this Thorens model has one of the thickest coating of any discs preserved in the RTS collection, with a significant unevenness of thickness (can vary between 0.22 and 0.43 mm). Curved effect on the edge of the disc, with a convex shape.

Manufacturing techniques: scraping, spreading (?)

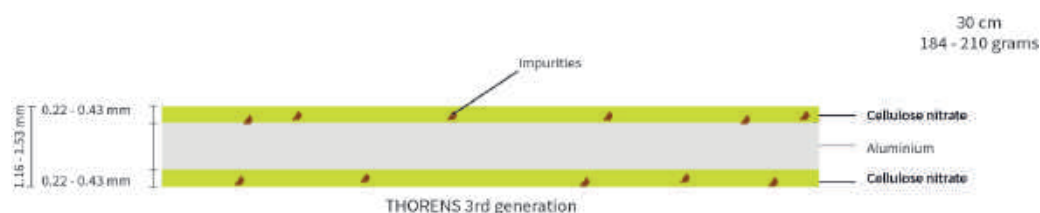
Manufacturing defects: air inclusion on the disc periphery - impurities under the coating causing its discolouration.



Small blisters air inclusion on the periphery of the disc



Impurities under the coating

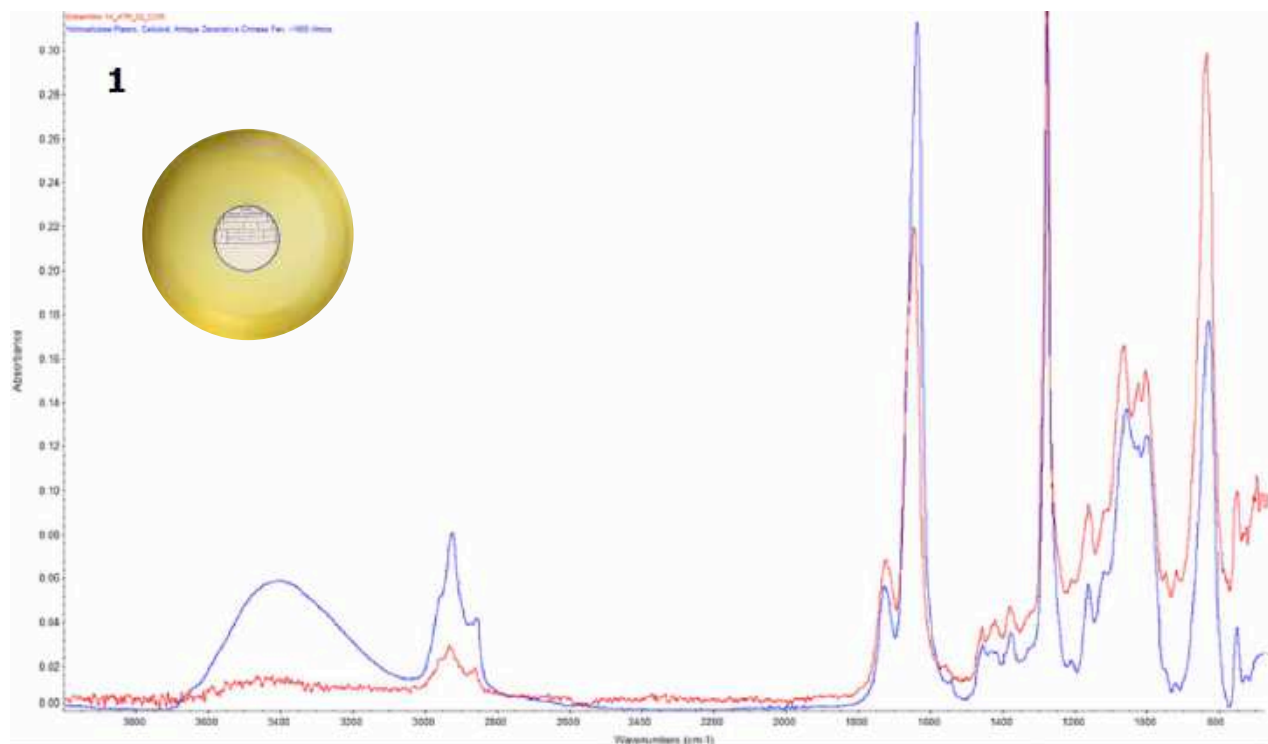


Degradations: discolouration – crazing – cracked (radial and tangential to the groove) – flaking – peeling

Chemical study: Thorens 3rd generation, yellow shade

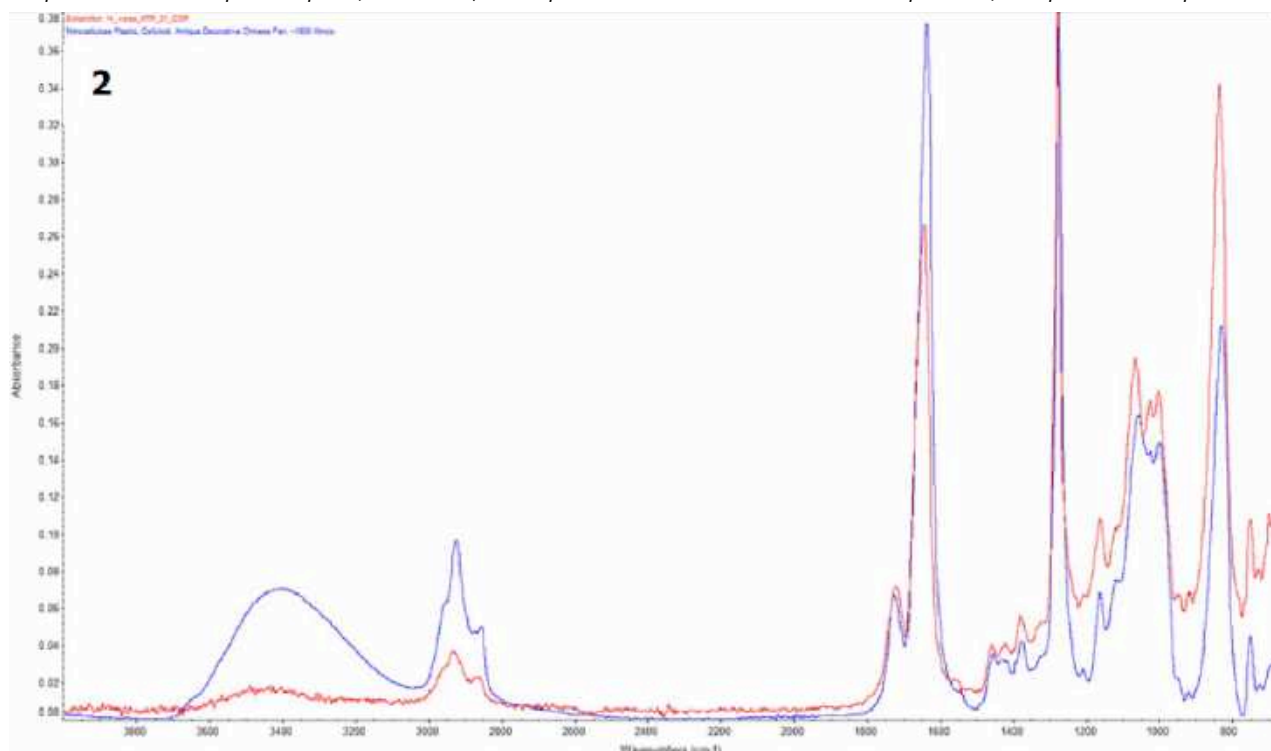
The spectra of 3rd generation Thorens yellow discs samples 14 and 15 are similar. Cellulose nitrate remains the primary polymer and characterises by the following values:

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Thorens yellow (14-1)	1644 cm ⁻¹	1276 cm ⁻¹	832 cm ⁻¹
Thorens yellow (14-2)	1642 cm ⁻¹	1275 cm ⁻¹	833 cm ⁻¹



CREDIT Haute Ecole Arc, Laura Brambilla

FTIR spectrum of a Thorens disc, 3rd period (1945), sample 14-1, groove side (Radio-Lausanne, accession number 16819, Fantaisie parisienne: Parce qu'on en parle, 27.09.1945). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 14-1

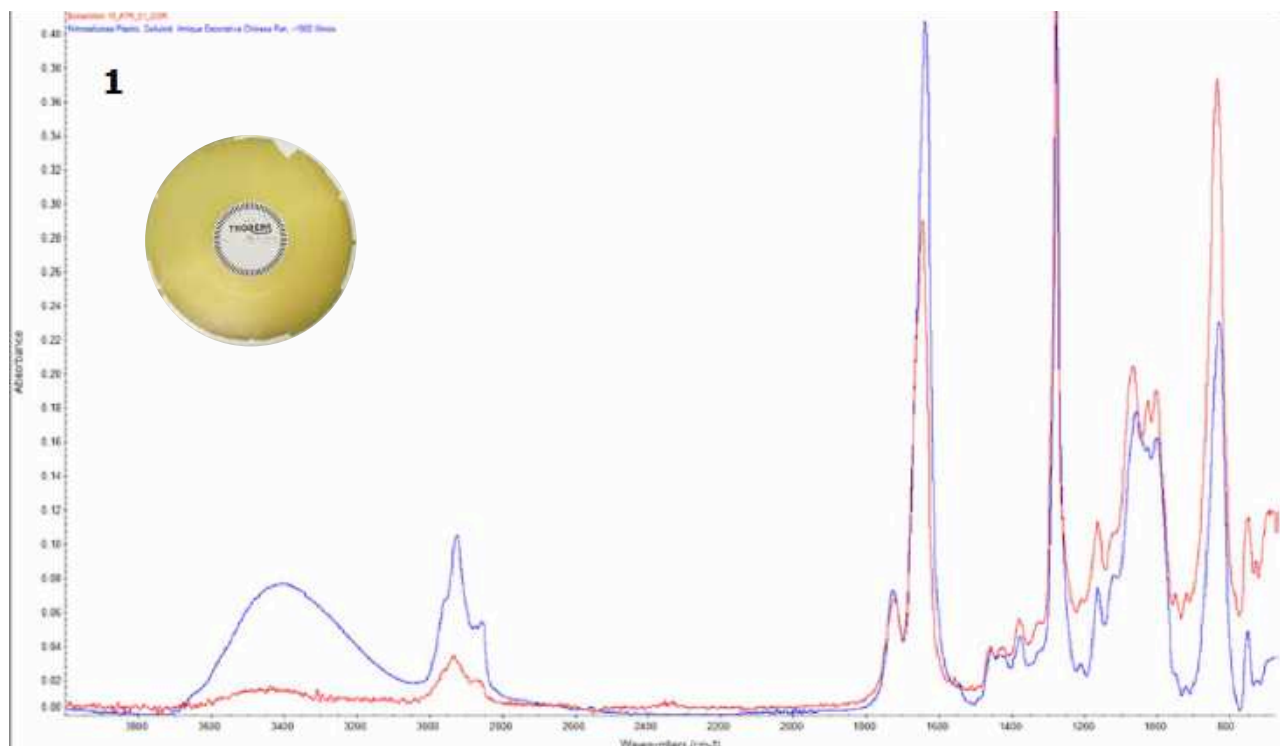


CREDIT Haute Ecole Arc, Laura Brambilla

FTIR spectrum of a Thorens disc, 3rd period (1945), sample 14-2, reverse (Radio-Lausanne, accession number 16819, Fantaisie parisienne: Parce qu'on en parle, 27.09.1945). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 14-2

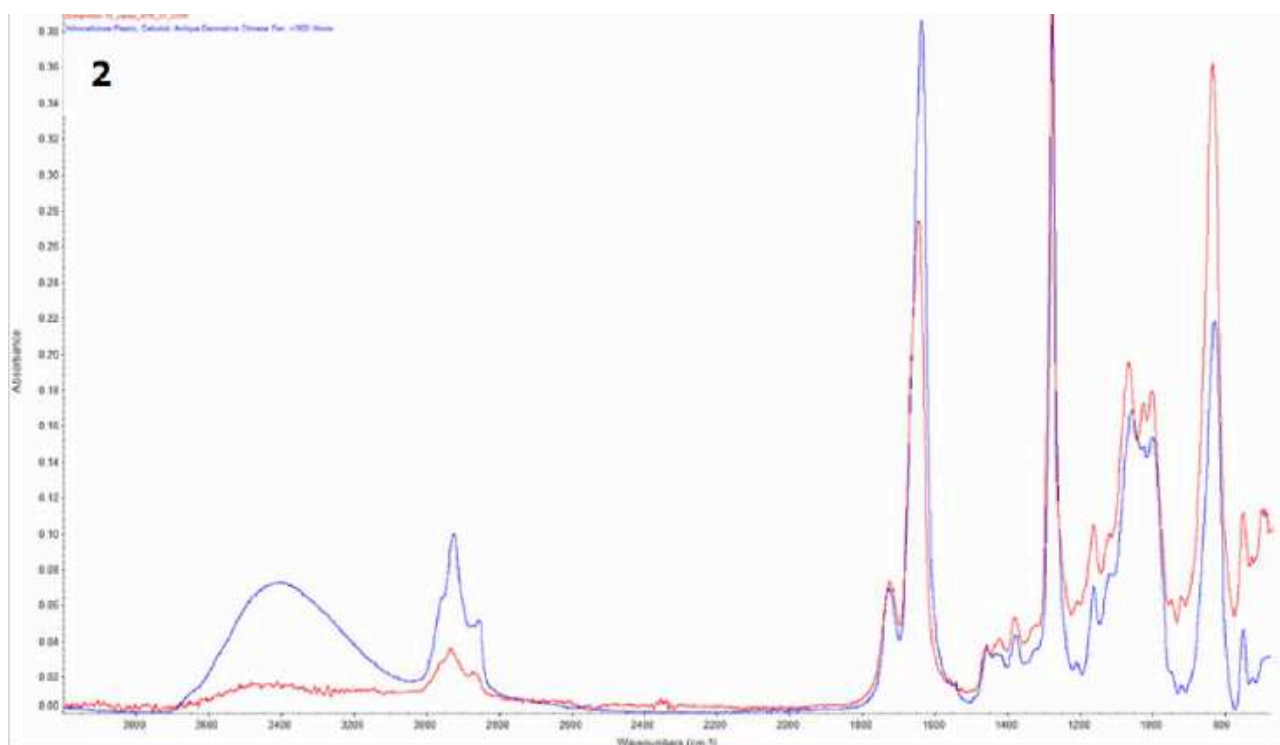
Chemical study: Thorens 3rd generation, yellow shade

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Thorens yellow (15-1)	1643 cm ⁻¹	1275 cm ⁻¹	833 cm ⁻¹
Thorens yellow (15-2)	1643 cm ⁻¹	1275 cm ⁻¹	833 cm ⁻¹



FTIR spectrum of a Thorens disc, 3rd period (1946), sample 15-1, groove side (accession number DX4624, Un quart d'heure avec Norbert Glanzberg, 14.06.1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 15-1

CREDIT Haute Ecole Arc, Laura Brambilla



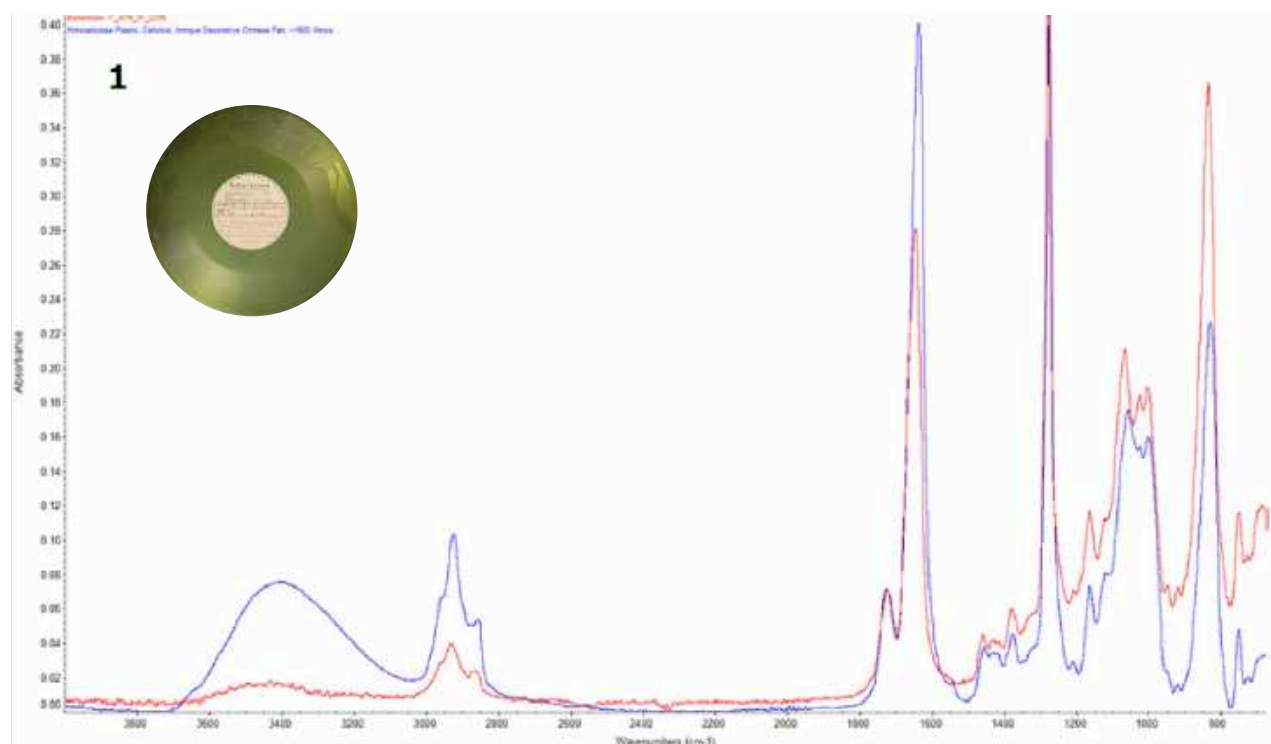
FTIR spectrum of a Thorens disc, 3rd period (1946), sample 15-2, reverse (accession number DX4624, Un quart d'heure avec Norbert Glanzberg, 14.06.1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 15-2

CREDIT Haute Ecole Arc, Laura Brambilla

Chemical study: Thorens 3rd generation, green shade

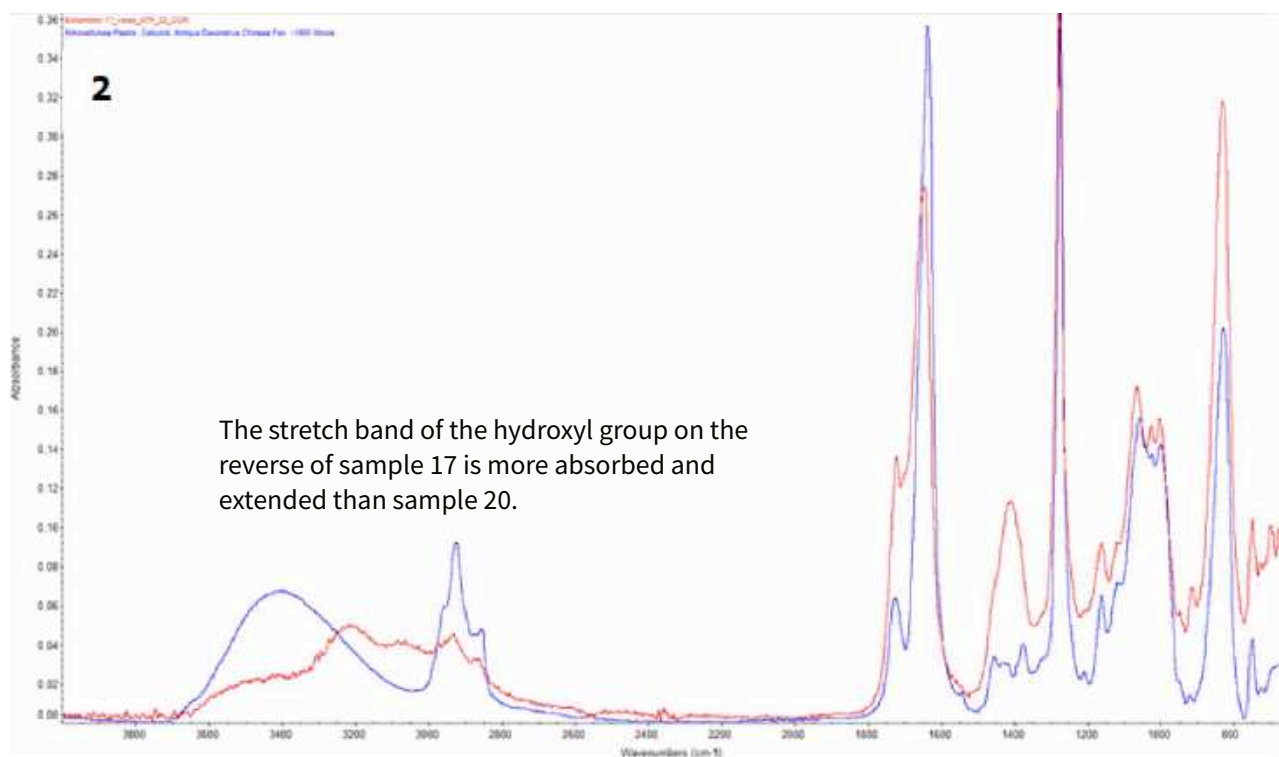
The groove and reverse sides spectra of two Thorens 3rd generation green shades (samples 17 and 20) have values close to those of samples 14 and 15 (Thorens 3rd generation, yellow tone).

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Thorens green (17-1)	1643 cm ⁻¹	1275 cm ⁻¹	832 cm ⁻¹
Thorens green (17-2)	1643 cm ⁻¹	1276 cm ⁻¹	829 cm ⁻¹



CREDIT Haute Ecole Arc, Laura Brambilla

FTIR spectrum of a Thorens disc, 3rd period (1946), sample 17-1, groove side (Radio-Genève, accession number DN4626, Chœur d'enfants de l'Institut Jaques-Dalcroze, 26.06.1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 17-1



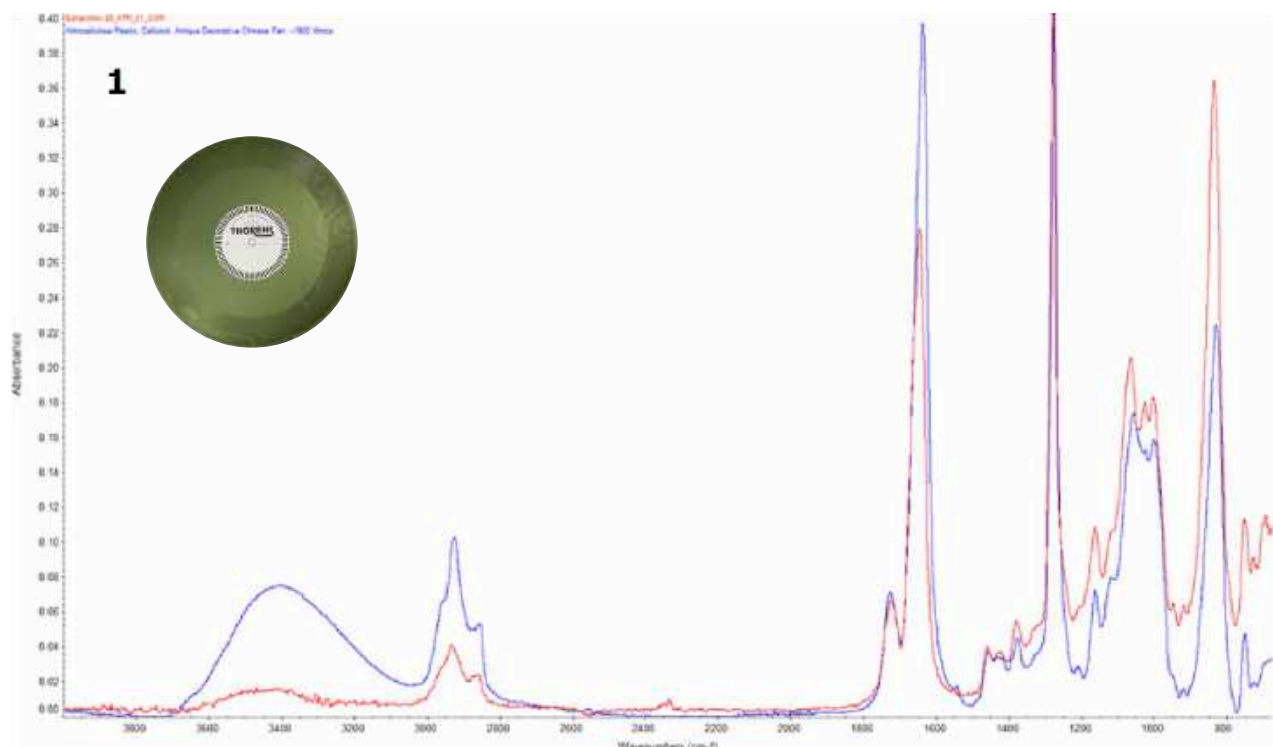
The stretch band of the hydroxyl group on the reverse of sample 17 is more absorbed and extended than sample 20.

CREDIT Haute Ecole Arc, Laura Brambilla

FTIR spectrum of a Thorens disc, 3rd period (1946), sample 17-2, reverse (Radio-Genève, accession number DN4626, Chœur d'enfants de l'Institut Jaques-Dalcroze, 26.06.1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 17-2

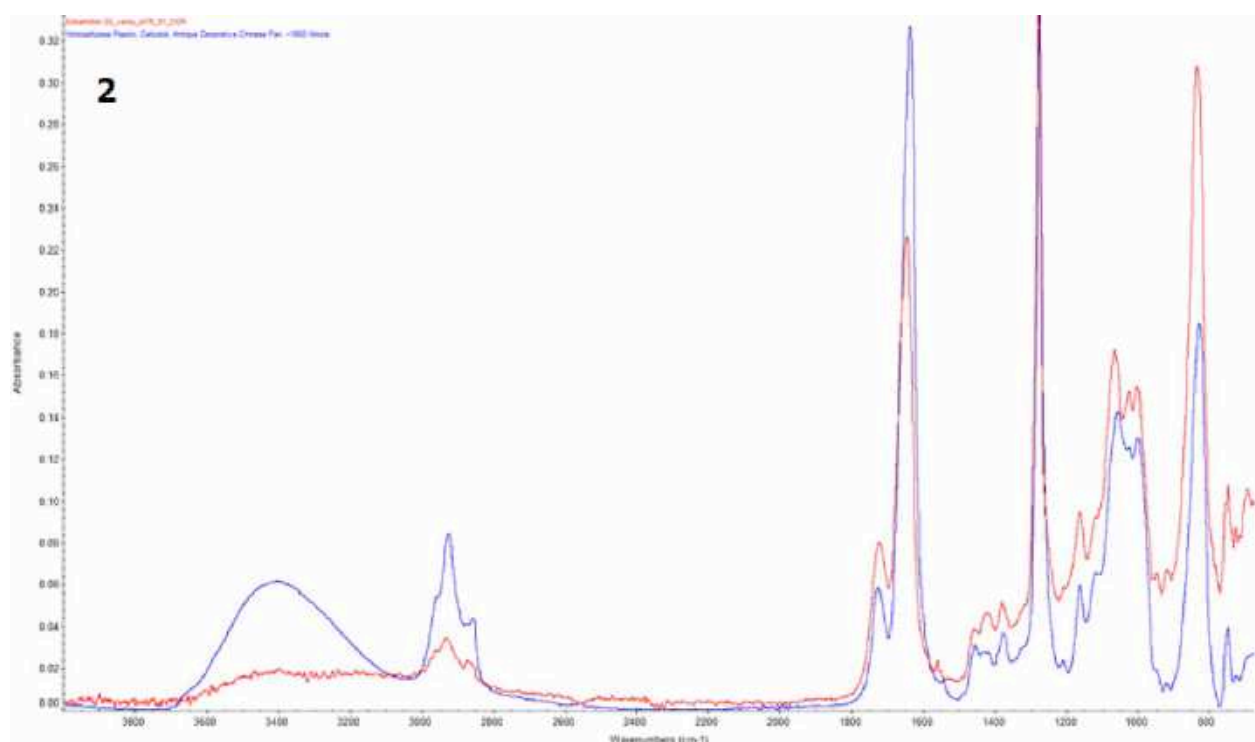
Chemical study: Thorens 3rd generation, green shade

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285–1270 cm ⁻¹	Functional group N-O 890–800 cm ⁻¹
Thorens green (20-1)	1644 cm ⁻¹	1275 cm ⁻¹	834 cm ⁻¹
Thorens green (20-2)	1643 cm ⁻¹	1276 cm ⁻¹	833 cm ⁻¹



FTIR spectrum of a Thorens disc, 3rd period (1946), sample 20-1, groove side
(Radio-Genève, accession number DW4621, Report on Princess Juliana's Arrival: Red Cross for Holland, 23.05.1946).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 20-1

CREDIT Haute Ecole Arc, Laura Brambilla

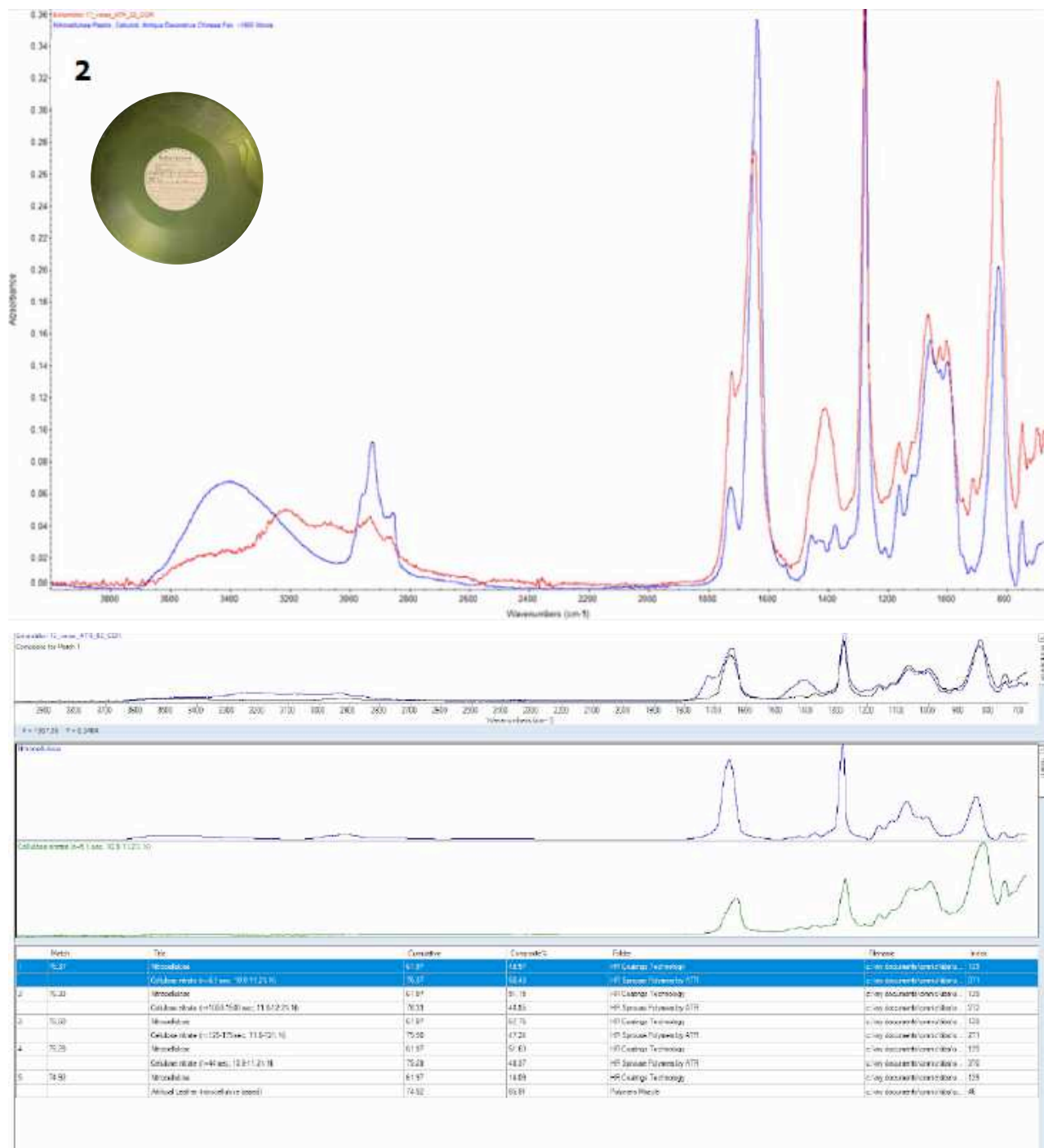


FTIR spectrum of a Thorens disc, 3rd period (1946), sample 20-2, reverse
(Radio-Genève, accession number DW4621, Report on Princess Juliana's Arrival: Red Cross for Holland, 23.05.1946).
Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 20-2

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Chemical study: Thorens 3rd generation, green shade

A wide curve in the spectral region of the hydroxyl group $2800\text{--}3600\text{ cm}^{-1}$ is observed on sample 17 (3rd generation Thorens disc, 1946). Spectral reconstruction reveals a combination of different cellulose nitrates. One hypothesis supposes the sample is composed of cellulose nitrate showing signs of degradation¹¹⁶. It is confirmed by the visual diagnosis of the discs, which revealed large cracks and peeling of the coating.

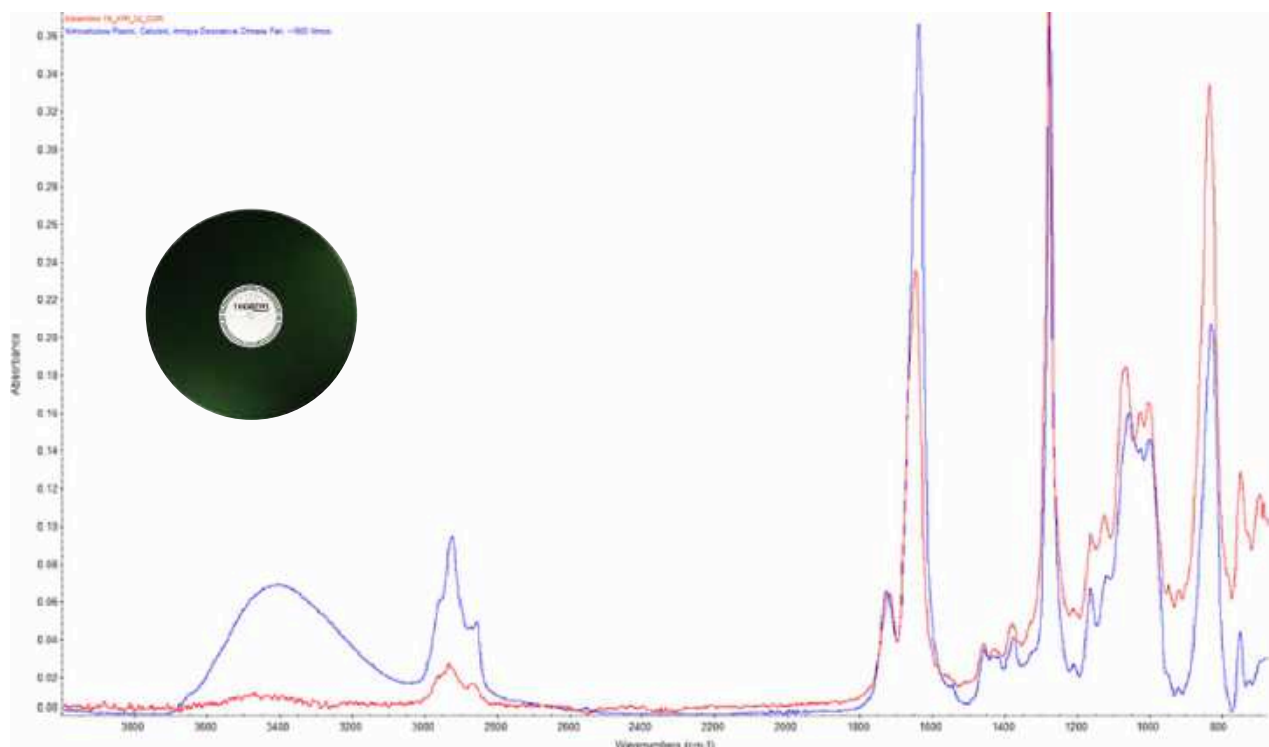


Top) FTIR spectrum of a Thorens disc, 3rd period (1946), sample 17-2, reverse side (Radio-Genève, accession number DN4626, Chœur d'enfants de l'Institut Jaques-Dalcroze, 26.06.1946). Purple spectrum: cellulose nitrate reference spectrum; red spectrum: sample 17-2. Bottom) Spectrum reconstructed with Thermo Scientific™ Omnic™ Spectra.

Chemical study: Thorens 3rd generation, dark green shade

3rd generation Thorens dark green disc sample has an FTIR spectrum and values close to those of the other 3rd generation disc samples. Cellulose nitrate is characterised by the following values:

Sample	Functional group NO ₂ 1660–1625 cm ⁻¹	Functional group NO ₂ 1285-1270 cm ⁻¹	Functional group N-O 890-800 cm ⁻¹
Thorens dark green (19)	1644 cm ⁻¹	1275 cm ⁻¹	833 cm ⁻¹



FTIR spectrum of a Thorens disc, 3rd period (1946), sample 19 (accession number DW4624-2, *Les compagnons de la route*, 14.06.1946). Blue spectrum: cellulose nitrate reference spectrum; red spectrum: sample 19.

CREDIT Haute Ecole Arc, Laura Brambilla

Chemical study: hypotheses

The results of the chemical study revealed that 3rd generation discs have very similar FTIR spectra, regardless of the colour of the coating. The current yellow or green discs were probably dark green or black when they were recorded. The disc colour change is presumably a chemical degradation due to excess moisture or gaseous and acidic emanations from cellulose nitrate decomposition. One of the required parameters during recording is a uniform and dark colour coating to monitor the groove cutting under optimal conditions. Light and translucent coating are ineffective, as the grooves' geometry is barely visible, with the inability to assess the quality of the cut. An example of a partially discoloured 2nd generation Thorens disc (below) supports this hypothesis.



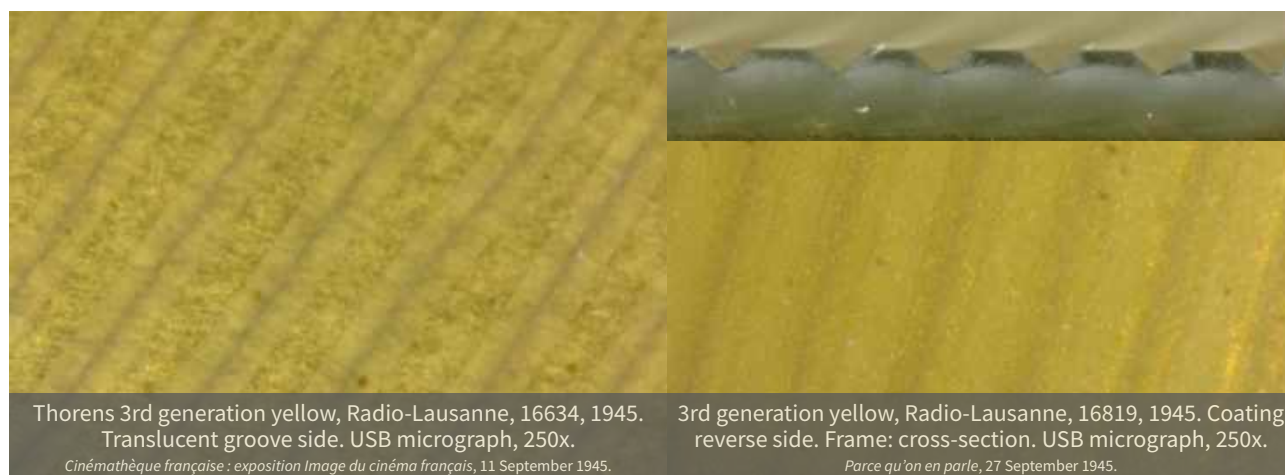
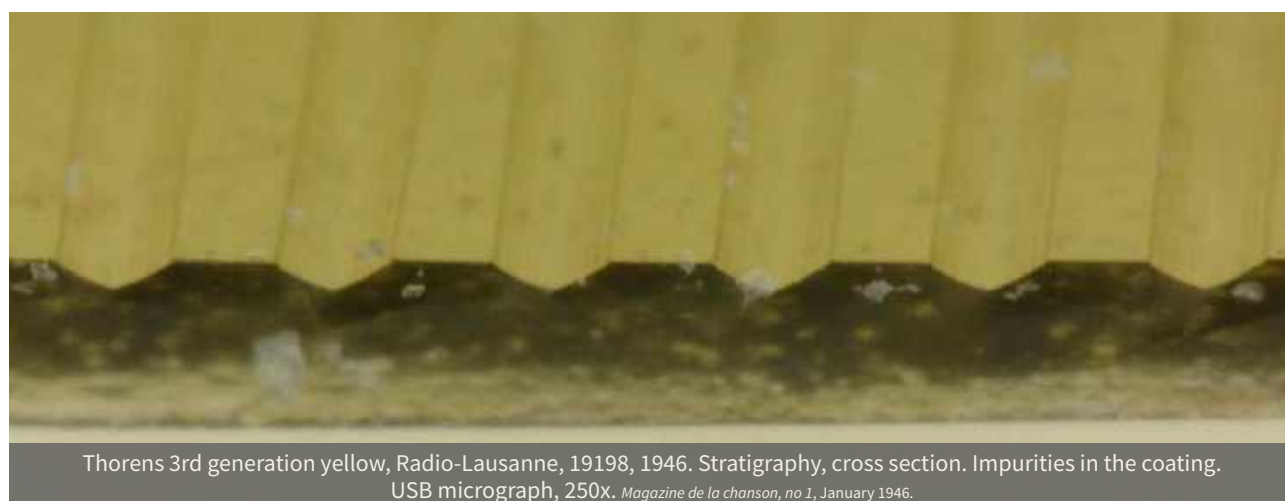
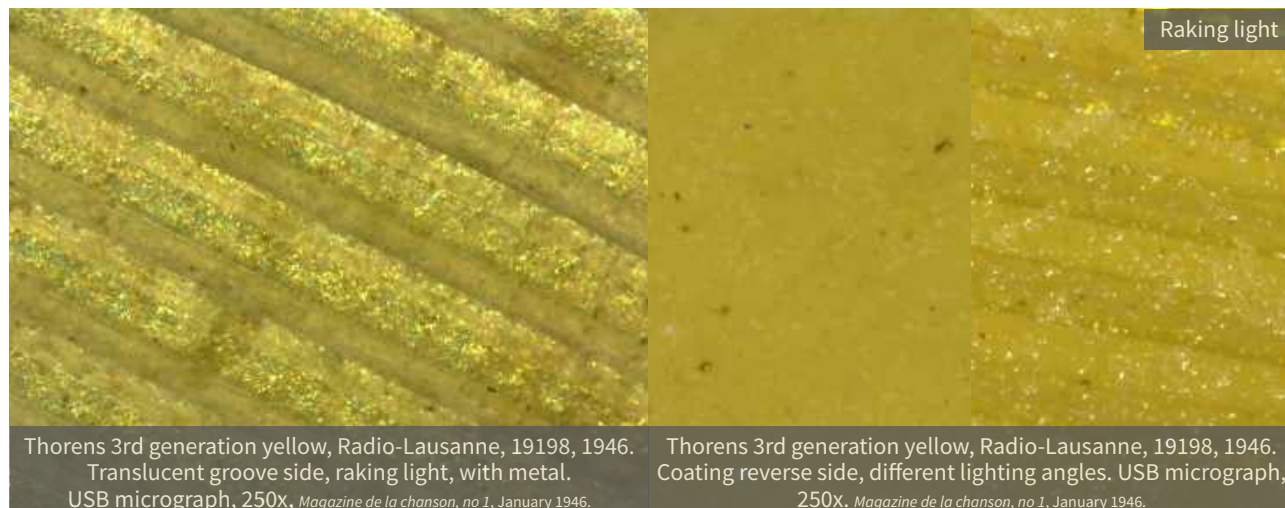
Thorens, 2nd generation disc (?). Right: dark green disc side.
Left: dark green disc side with disc yellowing (photochemical degradation or excessive humidity?).

CREDIT El-Mitch

Microscopic study: Thorens 3rd generation, yellow shade

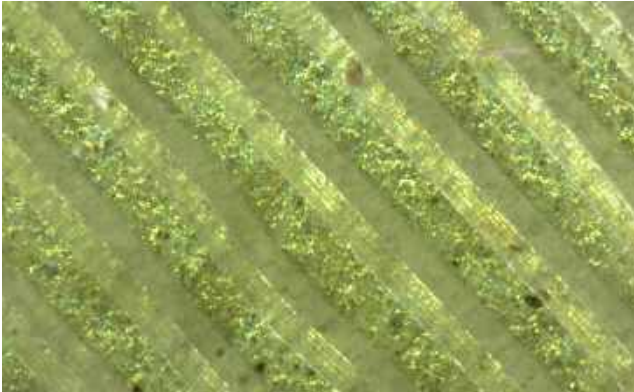
The microscopic study revealed the groove structure to be poorly visible due to the translucency of the coating layer. Few geometric details of the groove are discernible. This translucency may explain the difficulties of photo-based optical digitisation methods. The metallic surface and the translucency of the coating produce an overexposed photograph, preventing the sound from being optically recovered.

The reverse side of the coating layer reveals both white residue and a blistered surface using different lighting angles. The cross-section shows impurities in the lacquer.



Microscopic study: Thorens 3rd generation, green shade

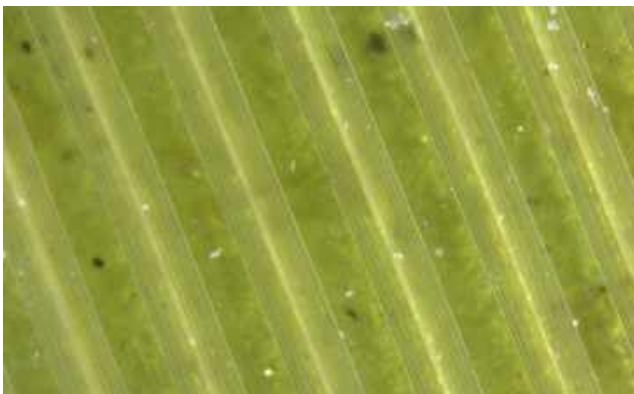
The opacity of the coating enables the groove geometry to be more clearly distinguished than yellow-coloured Thorens, especially the baseline of the groove. The same microscopic characteristics are observed with the dark green Thorens discs. The opacity of the coating provides a higher groove contrast. The cross-sections highlight impurities under the coating and illustrate the different green hues. A white layer is apparent on the reverse side of the coating.



Thorens 3rd generation green, Radio-Genève, DY4621, 1946. Translucent groove side, raking light, with metal. USB micrograph, 250X. *Chœur d'enfants de Genève, 23 May 1946.*



Thorens 3rd generation green, Radio-Lausanne, 26411, 1947. Coating reverse side, white residues. USB micrograph, 250X. *La chaîne du bonheur chez Thorens, 10 December 1947.*



Thorens 3rd generation green, Radio-Genève, DZ4624-5, 1946. Groove side, walls striations, better contrast than yellow coating. USB micrograph, 250X.



Thorens 3rd generation green, Radio-Genève, DW4621, 1946. Groove side, walls striations. USB micrograph, 250X. *Report on Princess Juliana's Arrival: Red Cross for Holland, 23 May 1946.*

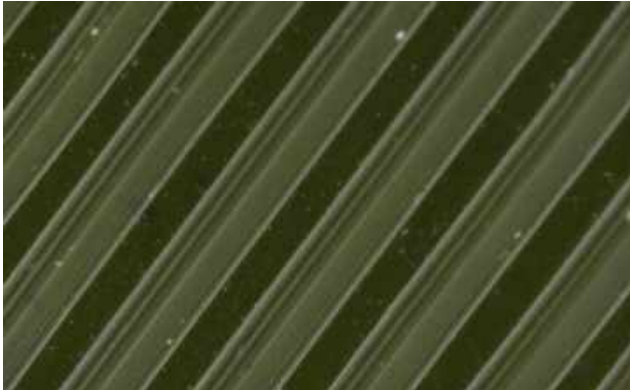


Thorens 3rd generation green, Radio-Genève, DW4621, 1946. Stratigraphy, cross-section. V-shaped cut. USB micrograph, 250X. *Report on Princess Juliana's Arrival: Red Cross for Holland, 23 May 1946.*



Thorens 3rd generation green, Radio-Genève, DN4626, 1946. Stratigraphy, cross-section. U-shaped cut. USB micrograph, 250X. *Chœur d'enfants de l'Institut Jaques-Dalcroze, 26 June 1946.*

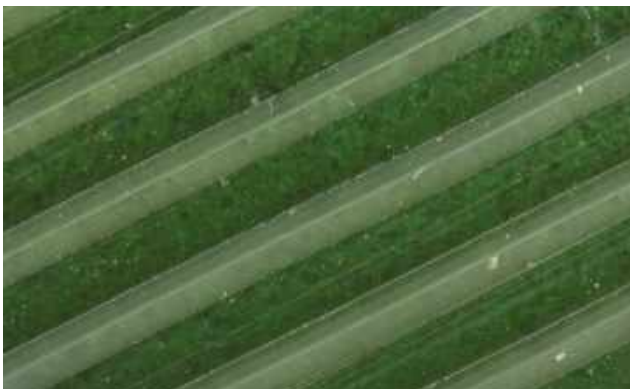
Microscopic study: Thorens 3rd generation, green and dark green shade



Thorens 3rd generation dark green, Radio-Lausanne, 23677, 1947. USB micrograph, 250x.
Forum Radio-Lausanne : la situation des ouvriers dans le monde, 28 April 1947.



Thorens 3rd generation dark green, Radio-Lausanne, 23677, 1947. Reverse, white residue. USB micrograph, 250x.
Forum Radio-Lausanne : la situation des ouvriers dans le monde, 28 April 1947.



Thorens 3rd generation dark green, Radio-Genève, DR4804, 1948. Groove walls striations. USB micrograph, 250x.
Veillée d'Auvergne, 1948.



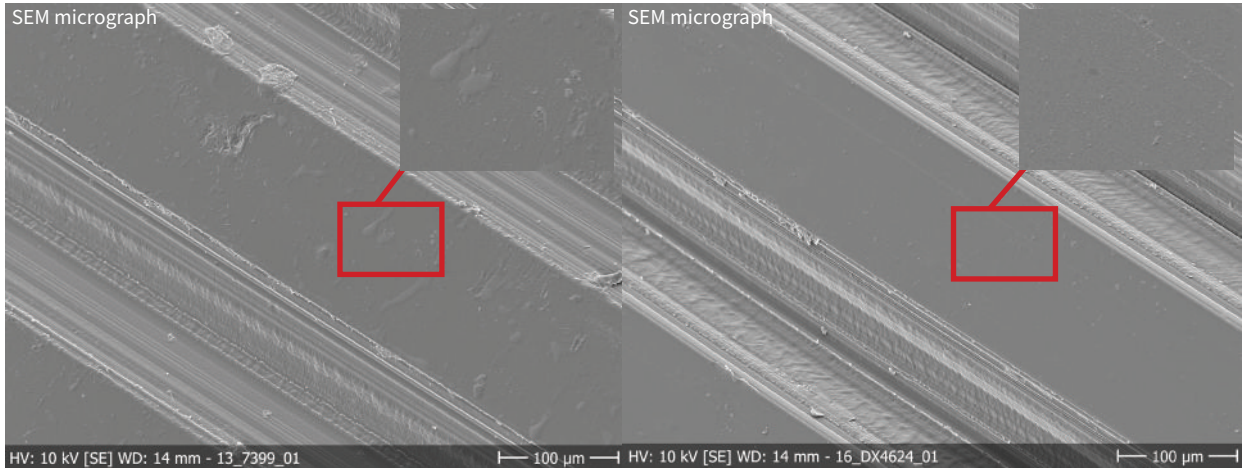
Thorens 3rd generation striations dark green, Radio-Lausanne, 41100, 1947. Groove walls striations and dust. USB micrograph, 250x.
Indian folklore, 1947.



Thorens 3rd generation dark green, Radio-Lausanne, 23677, 1947. Stratigraphy, cross-section. V-shaped cut. USB micrograph, 250x. *Forum Radio-Lausanne : la situation des ouvriers dans le monde, 28 April 1947.*

Microscopic study: comparison of 2nd and 3rd Thorens disc generations

SEM micrographs overcome the difficulty of accurately discerning the groove geometry caused by the translucency of the coating, regardless of the colour and optical properties of the coating. The SEM images were performed on a 2nd generation Thorens disc (1942) and three 3rd generation Thorens discs (a yellow and two green discs, recorded in 1946). A notable distinction between the two-disc models is a surface covered with tiny bubbling cavities on the 2nd generation disc, recorded in 1942. Parallel striations on the groove walls are observed on all the discs and the groove walls on two micrographs appeared badly scratched (DX4624 and DN4626). Dust is embedded inside the grooves. The groove baseline of sample 18 (DN4626) has been torn, either caused by the cutting stylus or a worn reproduction tip. Unlike Pyral discs, Thorens discs have never shown any signs of plasticiser loss. Therefore, there is no indication of exudation micro-pores on any sample.



CREDIT Haute Ecole Arc



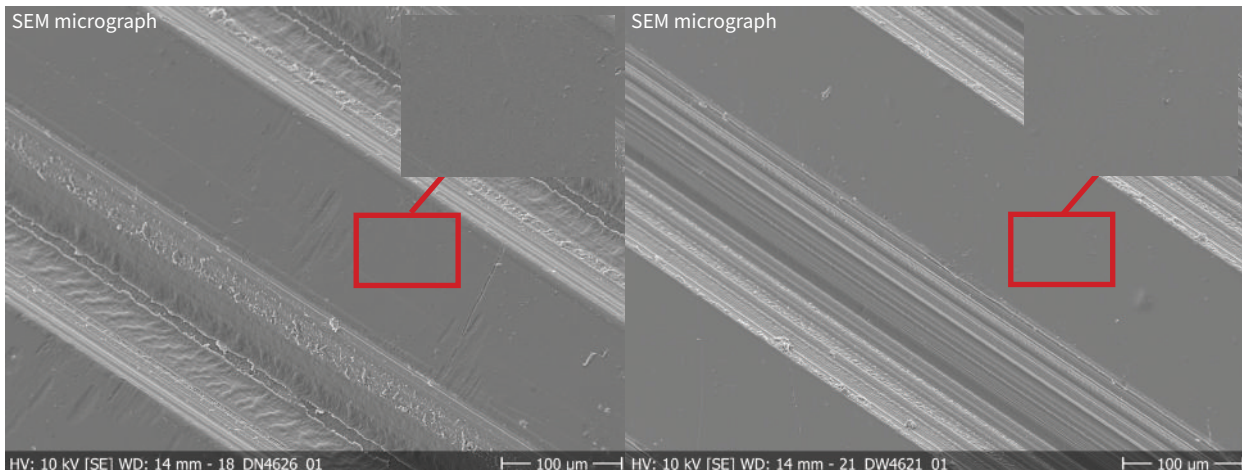
USB micrograph, 250x. Dust.

Thorens 2nd generation yellow, Radio-Lausanne, 7399, 1942. Bubble cavity on the surface disc, scratched wall and groove walls striations. *Bon dimanche, radio theatre*, 19 February 1942.



USB micrograph, 250x. Dust.

Thorens 3rd generation yellow, Radio-Genève, DX4624, 1946. Scratched wall, groove walls striations. *Un quart d'heure avec Norbert Glanzberg*, 14 June 1946.



CREDIT Haute Ecole Arc



USB micrograph, 250x. Dust.

Thorens 3rd generation green, Radio-Genève, DN4626, 1946. Scratched and ripped groove walls and baseline. *Choeur d'enfants de l'Institut Jaques-Dalcroze*, 26 June 1946.



USB micrograph, 250x. Dust.

Thorens 3rd generation green, Radio-Genève, DW4621, 1946. Groove walls striations. *Report on Princess Juliana's Arrival: Red Cross for Holland*, 23 May 1946.

Alterations

As revealed by the chemical study, the supposed recipe modification between the 2nd and 3rd generation discs had an impact on the adherence and ageing qualities of the lacquer. The degradation of 3rd generation Thorens discs is the combination of several parameters: poor adhesion of the coating to the metal substrate (probably resulting from modified chemical composition and an unsuitable metallic surface finish) and inadequate storage conditions. The coating shrinks, cracks and finally peels from the aluminium base. Cellulose nitrate decomposition emanates an irritating smell.



Thorens 3rd generation, yellow. Radio-Genève, DX4624, 1946.
Cracked and peeling coating.

Un quart d'heure avec Norbert Glanzberg, 14 June 1946.



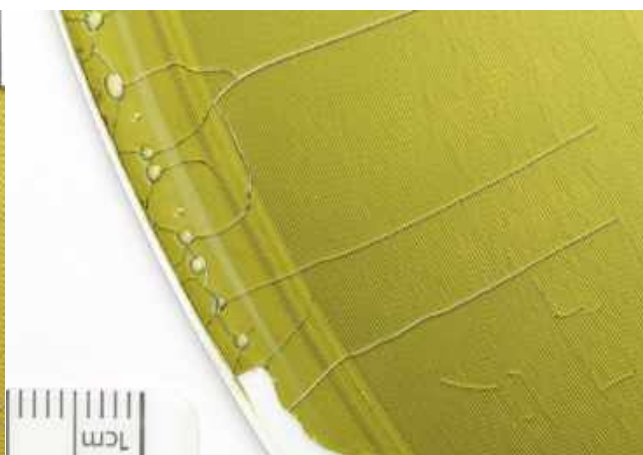
Thorens 3rd generation, yellow. Radio-Lausanne, 30911, 1948.
Macrophotograph of a crazing network.

Interview Jean Rieux by Madeleine Angelvin, October 1948.



Thorens 3rd generation, yellow. Radio-Lausanne, 16634, 1945.
Macrophotograph of a crazing network.

Cinémathèque française : exposition Image du cinéma français, 11 September 1945.



Thorens 3rd generation, yellow. Radio-Genève, DV4653-2, 1946. Macrophotograph of thin cracks. At the edge, observe the blisters, probably manufacturing traces.

Ensemble Tony Bell, 19 December 1946.



Thorens 3rd generation, yellow. Radio-Lausanne, 16634, 1945.
Macrophotograph of a crazing network and cracked coating.

Cinémathèque française : exposition Image du cinéma français, 11 September 1945.



Thorens 3rd generation, yellow. Radio-Lausanne, 16634, 1945.
A network of cracks, radial and tangential to the groove.

Cinémathèque française : exposition Image du cinéma français, 11 September 1945.

Alterations (continued)

Recurring alterations are crazing networks and large cracks. Cracks can be extremely thin (aluminium hardly visible) or very wide, up to 3 mm. The physical constraints between the coating and the metal substrate result in the peeling and flaking of the cellulosic lacquer.

Storage conditions play a significant role in the peeling of the coating. The discs stored in Radio-Genève's paper sleeves, overly tight on the shelves, have a higher peeling percentage than Radio-Lausanne's discs, where the discs are stored in hermetically sealed metallic containers. The pressure applied by the storage conditions of Radio-Genève discs weakens the Thorens coating, already very friable with suitable storage.

The coating discolouration, probably the result of sensitivity to acidic gaseous emanations, implies the coating was initially dark (dark green or black) and gradually discolours to yellow shades over time. This colour fading weakens the adhesion of the lacquer to the metal. Thorens yellow and light green coating is extremely brittle, while the dark green coating is generally in excellent condition, rarely shrunk or peeled.



Thorens 3rd generation, green. Radio-Genève, DE4624-5, 1945. Flaking and peeling coating.

Come raggio di sol, by Marcel Cortis et Kurt Brast, 08 June 1945.



Thorens 3rd generation, green. Radio-Genève, DJ4700-5, 1947. Macrophotograph of a tangential crazing network.

Emission En Scène pour le micro, 18 January 1947.

Thorens 3rd generation, green. Radio-Lausanne, 30911, 1948. Macrophotograph of cracks.

Interview Jean Rieux by Madeleine Angelvin, October 1948.



Thorens 3rd generation, green. Radio-Genève, DJ4700-5, 1947. Coating peeling away.

Emission En Scène pour le micro, 18 January 1947.

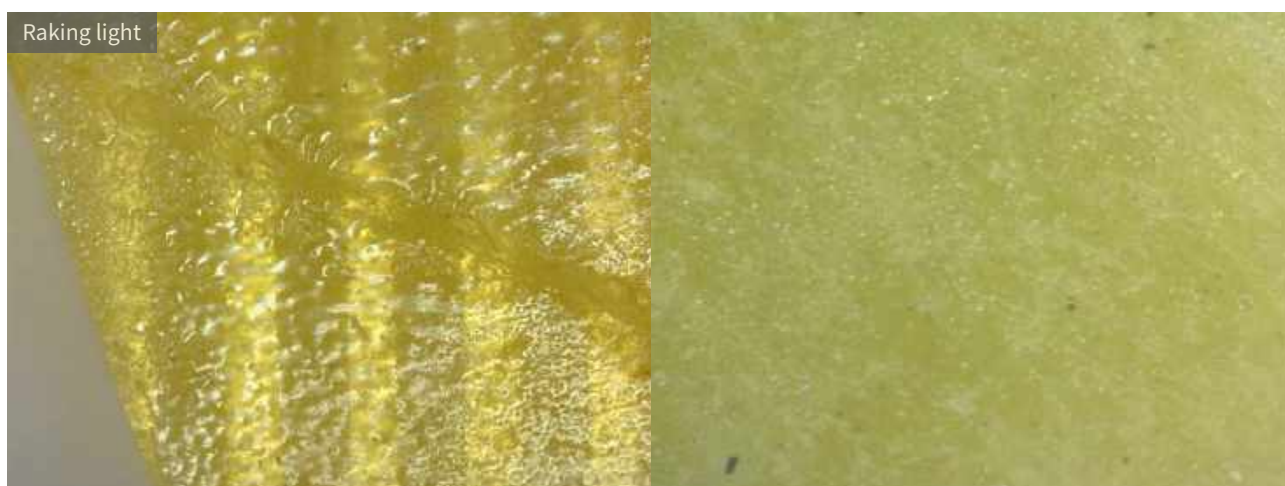


Thorens 3rd generation, dark green. Radio-Lausanne, 23677, 1947. Coating peeling away.

Forum Radio-Lausanne: la situation des ouvriers dans le monde, 28 April 1947.

Alterations: hypotheses

The major issue with discs manufactured by Thorens is peeling and flaking of the coating, especially 3rd generation discs produced after 1944. The lacquer of 2nd generation Thorens discs, manufactured between 1942 and 1944, cracks but remains nevertheless fixed to the metallic substrate. FTIR molecular analyses of the reverse side of the 2nd generation disc (sample 12) detected a polyacrylic acid. This type of chemical compound was notably used by some manufacturers to ensure adhesion between the metallic substrate and the cellulose nitrate layer. The analysis on the reverse side of a 3rd period Thorens coating (sample 17) was not as conclusive. The Swiss firm appeared to have partially modified its formula from 1944 onwards. This hypothesis could explain the discrepancies in adherence observed between the 2nd and 3rd generation Thorens discs. Additionally, the metallic substrate surface finish of discs manufactured after 1944 presents a porous surface as opposed to a polished mirror-finish for discs produced between 1942 and 1944. Lastly, while examining the reverse side of two Thorens coating samples under a USB microscope, a surface distinction is observed: a topography with tiny cavities on the 2nd generation Thorens disc (sample 12) and white residues on the 3rd generation Thorens disc (sample 17). All these observations are potential research leads to explain the adherence difference between the various Thorens models.



Thorens 2nd generation, Radio-Lausanne, 7399, 1942.

Etched topography of sample 12, reverse side. USB micrograph, 250X. *Bon dimanche*, no 2, 19 February 1942.

Thorens 3rd generation, Radio-Genève, DN4626, 1946. White residue on the reverse side of sample 17. USB micrograph, 250x.

Choeur d'enfants de l'Institut Jaques-Dalcroze, 26 June 1946.



Thorens 2nd generation substrate, Radio-Lausanne, 7399, 1942. Macrophotograph of the mirror-finish surface.

Bon dimanche, no 2, 19 February 1942.

Thorens 3rd generation substrate, Radio-Lausanne, 22210, 1947. Macrophotograph of the porous metallic surface finish.

Frame: USB micrograph, 250x.

Les enquêtes de l'inspecteur Patt Baccarat, by William Aguet, 17 January 1947.

Notes

- 1 Brock-Nannestad, 2012, p. 24
- 2 Yentis, 1975, p. 17
- 3 The dates are estimates, educated guess from the observation of the collection and historical research.
- 4 Audio Record, 1951, vol. 7, no 3, March 1951, p. 1-2
- 5 PCW GmbH (new company name), official website, 2018
- 6 Bretz, 2013, p. 14; Beuche 2008, p. 60
- 7 Bretz, 2013, p. 14; Anonymus 1936, p. 119
- 8 Bretz, 2013, p. 14; Beuche, 2008, p. 60
- 9 Bretz, 2013, p. 20; Fleischer, 2004, p. 31
- 10 Bretz, 2013, p. 20; Beuche, 2008, p. 72 f
- 11 Bretz, 2013, p. 18-19; Kühne, 1950, p. 64; Flood & Kummen & Wendelbo, 1983, p. 11; Wonneberg, 2000, p. 76; Elste, 1989, p. 17.
- 12 Patentschrift Nr. 655,950, Klasse 39b, Gruppe 402, 1934, patent filed in March 1934
- 13 Bretz, 2013, p. 15; Patentschrift Nr. 731,516, 1939, S. 2, patent filed in June 1939
- 14 Radio-Amateur, 1938
- 15 Bretz, 2013, p. 19; Wonneberg, 2000, p. 283
- 16 Decelith sleeve
- 17 Bretz, 2013, p. 19; Wonneberg, 2000, p. 169; Wesche, 2007, p. 29
- 18 Barrett and Davies, 1938, p. 9; Leever, 1937
- 19 Radio-Amateur, 1938
- 20 Decelith sleeve
- 21 Bretz, 2013, p. 37-42
- 22 Bretz, 2013, p. 43-44
- 23 Bretz, 2013, p. 45; Wesche, 2007, p. 79
- 24 Bretz, 2013, p. 45; Dolezel, 1978, p. 173
- 25 Bretz, 2013, p. 48; Shashoua, 2001, p. 22
- 26 Bretz, 2013, p. 47; Shashoua, 2001, p. 18
- 27 Bretz, 2013, p. 48
- 28 Barrett and Davies, 1938
- 29 Barrett and Davies, 1938; BBC Written Archives Centre R57/194/5, 22 April 1937
- 30 Decelith sleeve
- 31 Agfa, 2017
- 32 Prongué, 2010, p. 3. All prices come from a Motosacoche handwritten note to the Director of Swiss Broadcasting Services, dated 10 March 1942.
- 33 BBC Written Archives Centre R57/194/8, 29 November 1941
- 34 Street, 2003, p. 156; Street, 2006
- 35 Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984
- 36 BBC Written Archives Centre R57/194/1, 24 October 1933, 18 December 1933
- 37 BBC Written Archives Centre R57/194/5, 8 May 1936; 10 June 1936
- 38 BBC Written Archives Centre R57/194/5, 22 April 1937; R57/194/6, 26 April 1938
- 39 BBC Written Archives Centre R57/194/8, 26 April 1941, 30 May 1941, 19 June 1941, 27 November 1941, 27 July 1942
- 40 BBC Written Archives Centre R57/194/8, 30 May 1941, 19 June 1941, 27 July 1942
BBC Written Archives Centre R57/49/2, 10 July 1946
- 41 BBC Written Archives Centre R57/194/8, 19 June 1941
- 42 BBC Written Archives Centre R57/49/2, 5 July 1946, 10 July 1946
- 43 BBC Written Archives Centre R57/194/8, 5 July 1946

- 44 Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984
- 45 BBC Written Archives Centre R57/194/8, 10 July 1946
- 46 Interview Ken Tink, Oral history of recorded sound project, rec. July 1984
- 47 Interview Cecil Watts, British Library Sound Archive, Developments in recorded sound, Oral History Collection, rec. January 1961
- 48 Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984
- 49 Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984; Brock-Nannestad, 2012, p. 22-23
- 50 BBC Written Archives Centre R57/194/8, 19 December 1944; Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984; Brock-Nannestad, 2012, p. 22-23
- 51 Interview Agnes Watts, Oral history of recorded sound project, rec. April 1984; Brock-Nannestad, 2012, p. 22-23
- 52 BBC Written Archives Centre R57/194/7, 3 November 1938
- 53 BBC Written Archives Centre R57/194/7, undated
- 54 BBC Written Archives Centre R57/49/2, 16 July 1945
- 55 BBC Written Archives Centre R57/194/8, 21 April 1941
- 56 BBC Written Archives Centre R57/194/8, 30 May 1941
- 57 BBC Written Archives Centre R57/194/8, 24 July 1941
- 58 BBC Written Archives Centre R57/194/8, 27 November 1941
- 59 BBC Written Archives Centre R57/49/2, 16 July 1945; R57/46/8, 5 July 1948; Powell, 1945
- 60 BBC Written Archives Centre R57/49/2, 20 June 1946
- 61 BBC Written Archives Centre R57/49/2, 20 June 1946
- 62 BBC Written Archives Centre R57/49/2, 31 March 1947
- 63 BBC Written Archives Centre R57/194/8, 5 June 1942; R57/46/8, 5 July 1948; BBC Written Archives Centre R57/194/9, 14 July 1948; BBC Written Archives Centre R57/194/9, 17 July 1950
- 64 BBC Written Archives Centre R57/194/9, 15 September 1950
- 65 BBC Written Archives Centre R57/194/9, 19 October 1950
- 66 Wolf, 2004; Overeem, 6 maart 1950; Piers, 13 oktober 1954
- 67 BBC Written Archives Centre R57/194/9, 11 August 1948
- 68 BBC Written Archives Centre R57/194/7, undated, c. May 1940
- 69 Biel, July 1979, p. 6, 8; Graves, 2015
- 70 Presto Recording Corporation, 1940, 1033-A
- 71 Graves, 2015
- 72 Email from Alan C. Graves, 26 April 2018; Graves, 2015
- 73 Graves, 2015
- 74 Barrett and Davies, 1938, p. 2
- 75 Barrett and Davies, 1938, p. 4
- 76 Brock-Nannestad, 2012, p. 22
- 77 Prot, 1997, p. 487
- 78 Brock-Nannestad, 2012, p. 22
- 79 Brock-Nannestad, 2012, p. 22; The Editors of Encyclopaedia Britannica, 2018
- 80 Prot, 1997, p. 487
- 81 Yentis, 1975, p. 17
- 82 Brock-Nannestad, 2012, p. 24
- 83 FR50,439, patent filed in February 1939, 2nd addition to the patent FR778,988
- 84 FR849,922A, patent filed in August 1938; FR50,439, patent filed in February 1939
- 85 FR1,001,269, patent filed in April 1946
- 86 Ramel, 1996, p. 6, 7
- 87 Ramel, 1996, p. 7, 8, 13

- 88 Email from Laura Brambilla, Doctors in Chemistry and Scientific Associate in the Applied Research and Development (R&D) team at the Haute Ecole Arc, conservation-restoration, on 25 June 2018
- 89 Email from Laura Brambilla, 25 June 2018
- 90 Email from Laura Brambilla, 3 July 2018
- 91 Email from Laura Brambilla, 25 June 2018
- 92 Davies, Terry and Lent, 1947, p. 5
- 93 Ramel, 1996, p. 8
- 94 GB438,029A, patent filed in March 1934 and accepted in November 1935; Brock-Nannestad, 2012, p. 23
- 95 Wolf, 2004: Aldous; Interview J.H. Saueressig 14 april 1989 en 10 oktober 1990, Jan Dijkstra (werknemer Ramie Union) 31 juli 1991 Saueressig jr. 8 maart 1993.
- 96 Interview Donald Aldous, Oral history of recorded sound project, rec. September 1984.
- 97 Aldous, 9 October 1936, p. 388; Brock-Nannestad, 2012, p. 23; Barrett and Davies, 1938, p. 5
- 98 Ord-Jolly, 29 October 1937, p. 428; Research Staff of the V.G. Manufacturing Co., 19 March 1937, p. 275
- 99 Email from CH. Visser, Public Information Officer, Netherlands Patent Office, 15 March 2018
- 100 Research Staff of the V.G. Manufacturing Co., 19 March 1937, p. 274-275
- 101 Barrett and Davies, 1938, p. 6
- 102 Ord-Jolly, 29 October 1937, p. 428
- 103 La Machine moderne, January 1936, p. 147
- 104 Barrett and Davies, 1938, p. 6
- 105 Brambilla, 2018
- 106 Barrett and Davies, 1938, p. 6
- 107 Read, 1952, p. 108
- 108 Research staff of V.G. Manufacturing Recording, Wireless World, 19 March 1937, p. 275
- 109 BBC Written Archives Centre R57/49/1, 17 March 1944
- 110 Direction générale des PTT, 1963, p. 312
- 111 Berlinger Konqui, 2012
- 112 Jeannin, 2012, p. 376
- 113 Prongué, 2010
- 114 Email from Laura Brambilla, 3 July 2018
- 115 Email from Laura Brambilla, 3 July 2018
- 116 Email from Laura Brambilla, 18 July 2018

Glossary

Acetate discs: denomination of lacquer discs with cellulose acetate coating, mistakenly used to describe radio transcription discs.

Acetone: manufactured chemical, colourless liquid, and solvent used notably to produce plastic and dissolve substances.

Acrylic acid butyl ester (butyl acrylate): acrylate ester, colourless liquid used to manufacture mainly adhesives and paintings.

Aldehyde: chemical organic carbonyl compound characterised by a carbonyl group attached to a hydrogen atom. Used to synthesise other compounds.

Aluminium: silver-colour metallic element characterised by good thermal and electrical conductivity, high reflective finish-surface and generally good resistance to corrosion.

Auto-catalytic reaction: chemical reaction where the catalysis is caused by one of a catalytic agents formed during a reaction.

Bakelite: resin made from phenol, formerly a phenol-formaldehyde condensation product used as electrical insulation and for the manufacture of moulded objects. Trademark of the first plastic entirely made from synthetic components, characterised by a dark brown solid appearance.

Benzene: aromatic hydrocarbon. Clear colourless flammable toxic liquid often used as a solvent.

Bevelled: manufactured-sloping edge of a structure/surface.

Blisters: lacquer disc degradation found on nitrate cellulose coating applied on zinc substrates resulting in blisters and corrosion.

It causes clicks and surface noise during disc reproduction.

Burnishing facet: characteristic of the cutting stylus, behind the cutting edge, that enables to polish the groove.

Butyl acetate: acetate ester of butanol. Organic compound used as a solvent during the manufacture of lacquer.

Calendered: an industrial process that consists to press a material between rollers to obtain smooth surfaces or thin sheets.

Carbon monoxide: colourless, odourless, tasteless, very toxic gas formed by incomplete combustion of carbon.

Carbonyl group (C-O): in organic chemistry, this functional group consists of a carbon atom attached by a double bond to an oxygen atom (aldehyde and ketone).

Cartridge: component of a record player. A small rectangular case that comprises a reproduction stylus and an electromechanical transducer, attached to the tonearm.

Castor oil: pale-yellow or colourless fatty oil extracted from castor beans (seeds of *Ricinus communis*). Often used as an external plasticiser and lubricant for lacquer discs manufacture.

Catalyst: a substance that accelerates the speed of a chemical reaction and is unaltered at the end of the reaction.

Cellulose acetate: cellulose acetic ester. A synthetic polymer formed by the combination of acetic acid, sulfuric acid on cellulose. Used especially for cinematographic/photographic films, coatings, and textiles fibres.

Substituted cellulose nitrate as it is considered safer and less flammable.

Cellulose nitrate (nitrocellulose): a synthetic polymer formed by nitrating cellulose with nitric acid, sulfuric acid on cellulose. Used notably for explosives, plastics, lacquers and produced the first synthetic textile fibres.

Celluloid: highly flammable plastic material composed of cellulose nitrate plasticised with camphor and mainly used in the early motion picture film reels.

Chip: see swarf

Coating: see lacquer

Corrosion: phenomenon under the action of atmospheric agents or chemical reagents, where metals tend to return to their original mineral state, a more stable environment and thus deteriorate their properties.

Degradation of lacquer discs characterised by the decomposition of the cellulosic coating applied on a corroded zinc substrate, resulting in burst blisters and white powder corrosion products.

Corundum: extremely hard mineral (Mohs hardness 9), crystalline form of aluminium oxide and synthesised to be used as ruby and sapphire or abrasive.

Cracks: degradation of lacquer discs characterised by a breakage of the coating, without flaking or peeling. Breakage tangential or radial to the groove.

Crazing: degradation of lacquer discs characterised by a thin fracture network and caused by the plasticiser loss of the coating. Shrinkage tangential or radial to the groove.

Cutting stylus: component of a disc recorder. Triangular chisel shape used to cut the groove. Made of steel or sapphire during transcription lacquer discs period.

Cyanide: a highly toxic chemical ionic compound that contains a cyano group and appears as a colourless gas or crystalline form.

Degree of substitution (DS): the average number of nitrate groups attached per base unit.

Denitration: removal of nitrate, acid nitric, nitro groups, nitrogen oxides from a substance.

Dibutyl phthalate: manufactured chemical. Colourless, oily, odourless liquid mainly used as a plasticiser.

Diluent: agent used to make a mixture thinner or more liquid.

Dinitrate: any compound composed of two nitrate groups.

Electrolytic reaction: a chemical process that decomposes a substance using electric current. It is at the centre of a corrosion reaction.

Elemental analysis: process to identify the elements within a molecule or material and aimed to determine the elemental composition.

Ersatz: inferior substitute used when the original material is too expensive or rare.

Ester groups: a functional group formed by the condensation product of R-OH alcohol and an organic (carboxylic acid) or inorganic (nitric acid) acid, with loss of water.

Ethyl acetate: clear colourless liquid and an organic compound. Used as solvent or dye.

Ethyl cellulose: derivative of cellulose used as coating and food thickeners.

Exudation: process in which the secretion of a liquid through the pores of a material which can later solidify.

Ferrule: metallic or fibre ring put around the central hole of glass-based lacquer discs to strengthen or prevent splitting of the fragile substrate.

Fillers: cheap, solid material added to a mixture to reduce the cost, improve certain properties or increase density, viscosity, and strength.

Flaking: degradation of lacquer discs characterised by loose pieces of the coating that have partially lifted from the substrate.

Fourier-transform infrared spectroscopy (FTIR): molecular analysis used to identify the chemical bonds of the compounds in a sample. When infrared radiation illuminates molecules, its energy is absorbed. By

analysing this absorption, the nature of the molecules can be determined.

Functional group: atom or group of atoms in a molecule that confers characteristic chemical reactions.

Gelatin: translucent, colourless material derived from collagen and obtained by boiling animal tissues.

Gun cotton (nitrocotton): a form of nitrocellulose highly nitrated product used as explosive.

Hydrochloric acid: strong corrosive aqueous solution of hydrogen chloride HCl.

Hydrocyanic acid: extremely poisonous aqueous and flammable solution of hydrogen cyanide HCN.

Hydrogen bond: the electrostatic attraction between a hydrogen atom with a strong positive partial charge and another highly electronegative atom. The hydrogen bond is an attractive force that holds the molecules together.

Hydrolysis: decomposition of a chemical compound by water. A molecule of water causes the rupture of a chemical bond.

Hydroxyl group (OH): a functional group that contains an oxygen bonded to hydrogen. It can be found in sugars and alcohols.

Instantaneous discs: a term used to describe lacquer discs as they can be replayed immediately following the cutting.

Lacquer: a synthetic organic coating applied on a material to form a film by evaporation of a solvent.

Lacquer discs: phonograph record consisting usually of a coating applied on a solid substrate.

Lamination: a mechanical process that consists to roll or compress a material into thinner sheets.

Lampblack: black powder made from soot and used as pigments.

Macrophotograph: close-up photography, where the image produced on the sensor is equal to or larger than the size of the subject itself. The reproduction ratio is 1:1.

Mechanical digitisation: traditional technique to digitise a record using a turntable.

Metal oxalate: degradation product characterised by insoluble salts formed by oxalic acid and a metal cation.

Methyl acetate: flammable, colourless liquid resulting from the condensation of acetic acid with methanol. Often used as a solvent for resins and paints.

Microclimate: enclosed atmospheric conditions different from the surrounding areas.

Micrograph (microphotograph): photography taken using a microscope.

Mirror-finish surface: metallic surface finishing with no defects visible to the human eye, characterised by a high reflectivity.

Nitrate: ester of nitric acid or compound containing the ion nitrate.

Nitration: a chemical process of adding a nitro group to an organic compound.

Nitric acid: colourless and corrosive liquid. Commonly used as a reagent in laboratories, for the manufacture of nitrates and nitrogen compounds such as fertilisers and explosives.

Nitrification: oxidation of nitrites to nitrates.

Nitro group: functional group (NO₂) commonly used to create explosive compounds and synthesised by nitration.

Nitrogen dioxide: highly toxic and poisonous gas composed of nitrogen and oxygen. Produced by combustion and used for the manufacture of nitric acid.

Nitrous acid: unstable acid (HNO₂) that decomposes with heat into nitric acid and resulting from the reduction of nitrogen dioxide NO₂.

Optical digitisation: a technique used when traditional mechanical digitisation using diamond styluses is made impossible by the conservation state of the disc. The techniques can be photo-based (VisualAudio) or video-based (INA-Saphir).

Oxidation: chemical reaction, often induced by oxygen, by which electrons are removed from an atom or molecule. It can also

describe a protective coating that forms on the surface on metal in contact with atmospheric agents.

Palmitic acid: waxy crystalline saturated fatty acid found in waxes, most animal and vegetable fats. Lacquer discs degradation characterised by a waxy exudate and caused by the plasticiser loss of the coating.

Peeling: degradation of lacquer discs characterised by the delamination of the coating and its separation from the substrate.

Pepsin: enzyme that breaks down proteins into peptides.

Plastic: material that contains as an essential ingredient a high polymer mixed with compounds (plasticisers, fillers, stabilisers) to improve its characteristics.

Plasticiser: a chemical compound of low volatility incorporated into a polymer to improve flexibility and elasticity.

Polyacrylic acid: synthetic high-molecular-weight polymer of acrylic acid. Colourless liquid used as adhesives and thickening agents.

Polymer: macromolecular substance characterised by the repetition of one or more atoms or groups of atoms and high-molecular-weight chains formed by polymerisation. Exist in natural conditions (rubber) or are man-made (synthetic polymers, such as cellulose nitrate, polypropylene).

Polyvinyl chloride (PVC): synthetic plastic polymer widely used worldwide to produce wires, electrical insulation, pipes, cables, and vinyl.

Pyrolysis: chemical modification induces by the action of heat and results in the thermal decomposition of the material.

Pyroxilin: highly flammable cellulose nitrate that contains 11.5-12.3% nitrogen. Used in plastics and coating production.

Reproduction stylus: component of a record player mounted in the cartridge. Specific shape tip that enables the following of the groove geometry and to replay the soundtrack.

Resorcinol: organic compound, crystalline

phenol mainly used to produce various resins, dyes, and is used as UV absorbers in resins and plasticiser.

Reverse osmosis: water purification to remove most of its mineral salts, heavy metals, and other toxic substances.

Scanning electron microscope (SEM): type of electron microscope that consists of a beam of focused electrons. The interaction between the electrons and the sample causes the formation of secondary electrons. The electrons scattered are amplified, detected and converted into an electrical signal and allow to reconstruct the topography of the sample and form a three-dimensional image.

Shellac: a binder of animal origin. The only natural resin produced by an animal (mealybugs of *Kerria* type), in the forms of yellow-orange flakes.

Signal-to-noise ratio (SNR): a measure of the ratio of the strength of a signal compared to the level of its background noise. Usually expressed in decibels (dB).

Sodium silicate (water glass): inorganic sodium salt in powdered or flaked forms and soluble in water. Used mainly as a binder and adhesive.

Solvent: a liquid substance with the ability to dissolve or disperse other substances.

Stabiliser: compound added to a mixture to delay, slow down or prevent deterioration process of the polymer structure.

Stearic acid: long-chain of saturated fatty acids found in animals and vegetable fats, oils and used in the manufacture of candles.

Substrate: consists of metal, paper, glass or PVC core on which a coating layer is applied.

Surfactant (surface-active agent): a substance that reduces the surface tension of a liquid to increase its spreading and wetting properties.

Swarf: the part of the coating removed by the cutting stylus, forming a continuous thread. This may be seen as the photo-negative of the disc.

Toluene: aromatic hydrocarbon with a benzene core. Toxic and flammable colourless liquid used notably as a solvent and for the

manufacture of gasoline, lacquers, explosives, dyes, and adhesives.

Transcription discs: lacquer discs recorded by radio broadcasters or intended for radio broadcasting.

USB computer microscope: widely used digital microscope using USB port to connect to specific software for visualisation (e.g. DinoLite).

Van der Waals forces: weak electrostatic attractive forces between electrically neutral atoms and molecules, decreasing rapidly with distance.

Warping: lacquer disc degradation characterised by an uneven and distorted surface shape. It caused the reproduction stylus to jump.

Zinc: blue-silvery metallic element. Used mainly in alloys or as a protective coating to steel or iron (galvanisation).

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p. 144: Simplex label

Ar RSR Genève: figure 29 (PRGE 9.39)

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figures 27 (Columbia Records), 33 (RCA). Downloaded from: https://archive.org/details/The_Recording_and_Reproduction_of_Sound_Oliver_Read_1952, uploaded by Jason Scott.

figure 5; p. 103: Audiodiscs ad, fiber ferrule. Audio Record. Downloaded from: <https://archive.org/details/audiorecord4552newyrich>, uploaded by Mark Graves

p. 129: Presto lacquer Q illustration. Downloaded from: <https://archive.org/details/PrestoCatalog1940>, uploaded by IPTV

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p. 115: Marguerite Sound Studios label. Downloaded from: <https://recordedchurchmusic.org/historic-recordings/1937>

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Bob Thorne: p. 123: Presto Red Seal

BT Archive, Asset Bank: p. 116: General Post Office Crest; General Post Office Research Station, Dollis Hill. Downloaded from: <https://btplc.assetbank-server.com/>

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p. 152: Aerial view of N.V. Ramie Union. Downloaded from: <https://www.enschedeinansichten.nl/collectie/fabrieken/n-v-ramie-union-n-v-kunst-textiel-industrie-kati2554-detail>.
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