Strategies for the preservation of a b/w motion picture film collection in safety film support

Teréz Somfai

Master thesis

Supervisors:

Prof.ª Doutora Ana Maria Ramos, FCT NOVA

Doutor Tiago Baptista, ANIM

Prof.ª Doutora Élia Roldão, FCT NOVA

Lisboa

September, 2019

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA
Departamento de Conservação e Restauro

Strategies for the preservation of a b/w motion picture film collection in safety film support

Teréz Somfai

Master thesis

Supervisors:

Prof.ª Doutora Ana Maria Ramos, FCT NOVA

Doutor Tiago Baptista, ANIM

Prof.ª Doutora Élia Roldão, FCT NOVA

Lisboa

September, 2019

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA
Departamento de Conservação e Restauro

Acknowledgments

I would like to thank my supervisor and co-supervisors, Professora Ana Maria Ramos, Doutora Élia Roldão and Doutor Tiago Baptista for all the help and support they provided me and for being always available.

I would also like to thank the people working at the Arquivo Nacional das Imagens em Movimento for hosting me during this research, especially for Paulo Cartaxo, Margarida Sousa and Rui Machado for sharing their knowledge and experiences.

And finally, my most special thanks for the support of my family and friends Dóri, Orsi and Eszter, who made this all possible.

Abstract

This thesis aims to contribute for reviewing *Safety film* preservation guidelines currently in practice, concerning film identification, film assessment and storage conditions in the archive*, Arquivo Nacional das Imagens em Movimento* (ANIM – National Archive of Moving Images), conservation center of *Cinemateca Portuguesa*.

Since the 1980s, stability issues and degradation factors concerning the oldest type of safety film, cellulose triacetate (CTA), have been studied. Based on the results accomplished with those studies, preservation guidelines were established highlighting the advantages of low temperature and low relative humidity for film stability. Despite the guideline's disclosure, there are practical issues, such as lack of staff, financial restraints and lack of studies regarding polyethylene terephthalate (PET) films decay, that ultimately jeopardize the preservation of motion film collections.

In order to have an overall comprehension of the identification and assessment methods used, a review of relevant literature about national and international guidelines for film preservation was performed. This review endowed a broader understanding of the identification, assessment and monitorization carried out in ANIM archive. Aiming to understand preservation practices, an investigation was undertaken at ANIM*.* Current identification and assessment methods were reexamined, tested and reevaluated. Based on the results accomplished, new identification and assessment tools, as well as, recommendations concerning organization and storage are proposed.

For the experimental part of this work, identification and assessment of film (image and sound) were performed. For this internship and study, it was decided firstly to perform the identification and assessment of 100 films and film cans according to the macro identification and macro assessment methods described in the literature. For macro assessment, Acid Detection (A-D) strips and macro signs of degradation were used to evaluate the condition of the films studied. Moreover, the macro assessment results obtained in 2006 and 2014 were also analyzed. In order to identify possible degradation trends and contribute to the review of the current preservation practice, past and present macro assessment results were compared. Additionally, new assessment methods, such as hardness measurement, hardness (Shore A), were tested.

The results obtained confirmed that free acidity tests are effective methods for monitoring safety film decay. In this study it was also possible to identify degradation trends, specifically concerning magnetic tapes. Moreover, besides CTA film decay, during the macro assessment of ANIM's collection, PET films degraded were found. Based on these results it was possible to propose a new methodology for film preservation.

Keywords: safety film, magnetic sound, condition assessment, motion picture storage, preservation strategies

Resumo

Esta tese visa contribuir para a revisão das diretrizes atualmente em prática, relativas à identificação, avaliação das condições de preservação e de armazenamento de filmes cinematográficos com suporte em triacetato de celulose (CTA) e politereftalato de etileno (PET) também designados como safety films, à tutela do arquivo do Arquivo Nacional das Imagens em Movimento (ANIM), o centro de conservação da Cinemateca Portuguesa.

Desde a década de 1980, foram estudados problemas de instabilidade química do CTA, e respetivos fatores de degradação. Com base nos resultados obtidos com esses estudos, foram estabelecidas diretrizes de preservação destacando as vantagens da baixa temperatura e baixa humidade relativa para a estabilidade do filme. Apesar da divulgação de diretrizes, há questões práticas, como falta de pessoal, restrições financeiras e ausência de estudos sobre a deterioração dos filmes de PET, que acabam por prejudicar a preservação de coleções de filmes de cinema.

De modo a ter uma compreensão global dos métodos de identificação e avaliação utilizados, foi realizada uma revisão da literatura focando as diretrizes nacionais e internacionais para preservação de película cinematográfica. Esta revisão proporcionou uma compreensão mais ampla da identificação, avaliação e monitorização realizada no arquivo ANIM. Com o objetivo de entender as práticas de preservação aí praticadas, foi desenvolvido um estudo no qual os métodos atuais de identificação e avaliação foram reexaminados, testados e reavaliados. Com base nos resultados alcançados, são propostas novas ferramentas de identificação e avaliação, bem como recomendações sobre organização e armazenamento.

O estudo iniciou-se com a análise estatística dos resultados da macro avaliação de uma coleção de cerca de 2000 filmes, realizada no ANIM em 2006 e 2014. Foram selecionados 100 bobines e respetivas caixas de acondicionamento e feita a sua identificação e avaliação do estado de preservação de acordo com os métodos de macro identificação e avaliação descritos na literatura, utilização de tiras de deteção de ácido (*AD strips*) e observação de sinais macro de degradação. Para identificar possíveis tendências de degradação e contribuir para a revisão das práticas atuais de preservação, foram comparados os resultados da macro avaliação passadas e presentes. Além disso, novos métodos de avaliação, como medidas de dureza (Shore A), foram testados.

Os resultados obtidos confirmaram que os testes de acidez livre são métodos eficazes para monitorizar a deterioração dos filmes. Neste estudo também foi possível identificar tendências de degradação específicas em fitas magnéticas. Além da deterioração dos filmes de CTA, durante a observação da coleção do ANIM, foram identificados filmes em PET degradados. Com base nesses resultados, foi possível propor uma nova metodologia para preservação de filmes.

Palavras-chave: *safety film*, som magnético, avaliação do estado de preservação, armazenamento de filmes, estratégias de preservação

Table of Contents

Acknowledgments vii

Abstract ix

Resumo xi

List of Figures xv

List of Tables xvii

Symbols and Notations xix

1. Introduction 1

1.1. A brief historical overview of the birth of international and national film archives 1

1.2. Cinematographic safety films: film structure and composition 2

1.2.1. Film structure 2

1.2.2. Supports for image and sound 3

1.2.3. Emulsion: image and sound registration 4

1.2.4. Other layers: anti-scratch, anti-halation, UV absorbing and subbing layers 6

2. Degradation 6

2.1. Degradation of Safety film support 6

2.2. Degradation of the emulsion layer 8

3. Identification and assessment methods 10

3.1. Non-destructive identification methods 10

3.2. Non-destructive assessment methods 12

3.3. Recommendations for Safety film storage conditions 12

3.4. ANIM's safety film collection: an overview of the current identification and assessment methods, storage condition, and preservation strategy 14

3.4.1. Storage facility 14

3.4.2. Preservation strategy and practice 16

4. Experimental 18

4.1. Methodology 18

4.1.1. Sample selection 18

4.1.2. Macro identification and assessment 18

4.1.3. Identification of the film support with light transmission and polarization tests 18

4.1.4. Assessment with AD strips 19

4.1.5. Colorimetry 19

4.1.6. Hardness measurement 19
4.2. Instruments and methods 19
4.2.1. AD strips 19
4.2.2. Colorimetry 20
4.2.3. Hardness (Shore A) 20
5. Results and Discussion 20
5.1. Identification and assessment of the samples 21
5.2. Hardness measurements 25
5.3. Identification of film cans and their impact on film degradation 26
Conclusions 26
References 27
Appendix 30
I. Type of film elements in the collection of ANIM 30
II. Inventory form - Identification department, ANIM 31
III. Light transmission test results 32
IV. Important ISO standards concerning Safety films 34
V. AD strip and Danchek strip product information and restrictions 35
VI. Plan of ANIM's main building and the location of storage rooms 37
VII. Sample selection; distribution of the film stock regarding age and brand 38
VIII. Assessment of film cans 39

List of Figures

Figure 1 - Components of b/w films 2
Figure 2 - Esterification reaction of cellulose (Balser, 2012, p.354.) 3
Figure 3 - Chemical structure of triphenyl phosphate (Silva, 2009, p.11.) 3
Figure 4 - PET monomeric unit (Bell, 2015, p.36.) 4
Figure 5 - Production of a filmstrip (adapted from Silva, 2009, p.12.) 4
Figure 6 - Optical sound system (Read, 2000, p.28.) 5
Figure 7 - Composition of magnetic tapes (adapted from IASA) 5
Figure 8 - Deacetylation reaction for CTA polymer (adapted from Roldão, 2018. p.68.) 6
Figure 9 - Examples of CTA degradation: waviness (a), plasticizer loss (b), shrinkage (c) and brittleness (d) © Teréz Somfai 7
Figure 10 - CTA deterioration factors and degradation chemical reactions 8
Figure 11 - Detail of cracks on the emulsion layer and plasticizer deposits on the film surface © Teréz Somfai 9
Figure 12 - Examples of the degradation of magnetic emulsion: magnetic particle deposit (a) and lubricant loss (b) © Teréz Somfai 9
Figure 13 - Edge-printing: Safety film © Teréz Somfai 10
Figure 14 - Identification of film supports through light transmission test 11
Figure 15 – Identification of CTA film (left) and PET film (right) through polarization test © Teréz Somfai 11
Figure 16 - AD strips and color scale (right); Autocatalytic point (User's Guide, p.11.) (left) 12
Figure 17 - The organization of ANIM's collections. Numbering inside each category is sequential. 14
Figure 18 - Cooling air supply (left), interior view (middle), control panels (right) © Teréz Somfai 15
Figure 19 - T and RH condition changes in b/w masters' vault 16
Figure 20 - 2006 and 2014 AD strip assessment results 21
Figure 21 - CTA degradation speed according to Image Permanence Institute (IPI) Acetate Wheel 21
Figure 22 - Macro assessment results compared with AD strip results 22
Figure 23 - Preservation state of MAG tapes 23
Figure 24 - Preservation state of Safety films 23
Figure 25 - Color scales and unused strips of IPI and Dancan © Teréz Somfai 24
Figure 26 - Degradation levels measured with Dancan and IPI indicator strips 25
Figure 27 - Hardness measurement 25
Figure 28 - Light transmission test: CA films © ANIM/ Credits: Teréz Somfai 32
Figure 29 - Light transmission test: PET films © ANIM/ Credits: Teréz Somfai 32
Figure 30 - Light transmission test: MAG on CA support © ANIM/Credits: Teréz Somfai 33
Figure 31 - Light transmission test: MAG on PET support © ANIM/Credits: Teréz Somfai 33
Figure 32 - Placement of AD strips on a film reel © Teréz Somfai 36
Figure 33 - Packaging of Danchek strips (left) and IPI's AD strips (right) © Teréz Somfai 36
Figure 34 - Plan of ANIM's main building (Edited from Cinemateca Portuguesa, 1995. p.9.) 37
Figure 35 - Sample selection; Distribution of AD levels measured in 2014 38
Figure 36 - Film supports present in the collection 38
Figure 37 - Brand distribution of the samples 38
Figure 38 - Age distribution of the sample reels 38
Figure 39 – Overall view of film cans of the analyzed reels © Teréz Somfai 39
Figure 40 - Effect of the composition of film cans 39

List of Tables

Table 1 - Milestones in the film production industry (2, 3, 5) *1*
Table 2 - Ideal storage conditions for Safety film collections (adapted from Storage Suitability, 2019) *13*
Table 4 - Storage room conditions in ANIM's vaults *15*
Table 3 - Evaluation guide, ANIM *17*
Table 5 - Most important ISO standards concerning film storage *34*
Table 6 - Properties of IPI's and Dancan's acid detector products *35*

Symbols and Notations

B/W	Black & White
ANIM	Arquivo Nacional de Imagens em Movimento
FIAF	International Federation of Film Archives
IPI	Image Permanence Institute
ISO	International Organization for Standardization
IASA	International Association of Sound and Audiovisual Archives
CN	Cellulose Nitrate
CA	Cellulose Acetate
CTA	Cellulose Triacetate
PET	polyethylene terephthalate (polyester)
PVC	Polyvinyl chloride
MAG	magnetic sound film
TPP	triphenyl phosphate
T	temperature
RH	relative humidity
Tg	glass transition temperature

1. Introduction

1.1. A brief historical overview of the birth of international and national film archives

The idea to preserve cinematographic heritage arose in the early 1930s, four decades after the 7th art was born (1). Shifting production from silent to sound film and consequently depreciating the former, lack of storage space and economic benefits such as the extraction of the imaging silver from the film reel led to a policy of destruction of films, right after a movie run out from film theaters (2). Throughout the history of the film industry, various typologies of films have been produced. Table 1 summaries some major events in the film production industry (2-4).

Table 1 - Milestones in the film production industry (2, 3, 5)

Date	Event
1888	Cellulose nitrate (celluloid) films, 1st silent film (Roundhay Garden Scene)
1920s	Factory tinted film bases before application of the emulsion layer
1927	1st sound film (The Jazz Singer)
1930s	End of tinted films
1930s	End of the silent era
1930s	Standardized perforations for 35 mm and 16 mm films
1949	Introduction of cellulose triacetate film
Mid-1950s	End of the celluloid era
1950s	Eastman color films
1953	Magnetic sound tapes
1960s	Kodak color intermediate materials (orange base) – nonexistent for 16 mm
1960s	Magnetic sound filmstrips and super 8 films on polyester support
Mid-1990s	Widespread use of polyester film

The first film archives were established as an initiative of film-lovers, individuals realizing the need for international cooperation in order to safeguard film heritage. The British Film Institute, the Cinémathèque Française, the Reichsfilmarchiv of Germany and the MoMA Film Library (all funded in the 1930s) were the first institutions to create a cooperative organization, the International Federation of Film Archives (FIAF), created in 1938.

In Portugal, the national film archive, called Cinemateca, opened doors in 1948. The Cinemateca's mission is to "collect, preserve, restore and catalog the cinematographic works and any other moving images of Portuguese and international production"(6). Like other international reference archives in the field of conservation and preservation of motion picture film collections, Cinemateca is a FIAF's member since 1956.

1.2. Cinematographic safety films: film structure and composition

The first motion pictures were produced with cellulose nitrate (CN) support. Due to the high flammability of CN material, in 1949 the cinematographic industry started replacing it by cellulose triacetate (CTA) and later by polyethylene terephthalate (PET) (Table 1). Both CTA and PET films are also known as *Safety films*. Generically, the selection of these materials relied on their optical, mechanical, chemical and thermal properties (5, 7). Beside *Safety films*, cellulose diacetate, cellulose acetate propionate, cellulose acetate butyrate, and polyvinyl chloride were also tested. However, the properties of those were not suitable for motion picture support and for projection. Due to broad use and presence of Safety films in film archives, in this work CTA and PET films were studied.

Besides film supports, changes were also seen in the image of the films, which initially were only black and white (b/w) and later, in the 1950s, color films were introduced (Table 1). This work focuses only on b/w films. In Table 1, milestones for film industry production are presented, briefly summarizing film's production. The production of motion picture film represents a wide period of industrial experimentalism and commercial production of film manufacturers (e.g. Kodak, Gevaert, Ilford, AGFA, Ferrania, etc.). Considering what was said, the production dates, chemical formulation and the industrial production processes varied according to manufacture (8).

1.2.1. Film structure

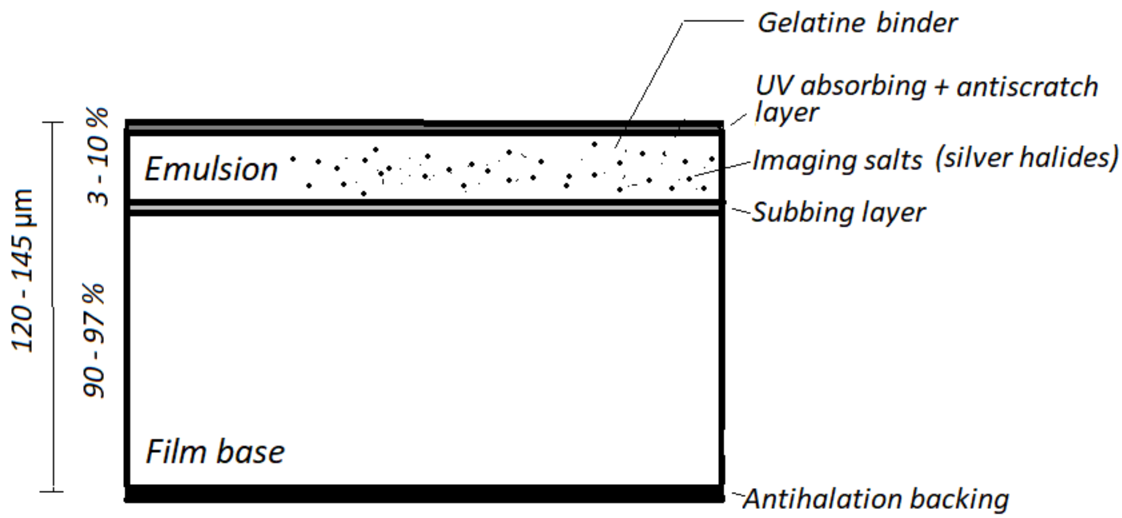

Figure 1 - Components of b/w films

Motion picture film has a complex structure, consisting of two basic elements: a plastic support (CTA or PET[1]) coated with the image layer. The image layer is composed of light-sensitive silver halides (AgBr, AgI, AgCl) and a binding medium, gelatin. Figure 1 shows the structure of b/w motion picture films. Commonly, film's thickness may vary between 120-145 µm (2).

[1] Film supports made of cellulose triacetate or polyester are often referred as safety films. To distinguish these filmstrips from the flammable "NITRATE" films, a word "SAFETY" was marked on their edges (3).

1.2.2. Supports for image and sound

Cellulose acetate is a semi-synthetic polymer, obtained by an acetylation reaction of cellulose fibers. Production starts with the activation/pretreatment of wood or cotton pulp in acetic acid. The swelling of cellulose fibers ensures the homogeneity of subsequent treatments. Acetylation is performed with the addition of acetic acid anhydride and sulfuric acid catalyst, and, depending on the acetylation process[2], glacial acetic acid or methylene chloride. To modify physical properties, enhance flexibility and reduce inflammability (2, 8, 9), plasticizers, most commonly triphenyl phosphate (TPP)(Figure 3)[3] and other additives were added to the viscous fluid. Plasticizer molecules physically couple to small polymer particles, forming polymer/plasticizer agglomerates. The plasticizer can represent up to 11% of the total weight of the CTA (5). To produce thin layers of CTA, this mixture is poured to a conveyor belt, which passes through a drying section to force the evaporation of the residues of solvents (5, 7 – 9).

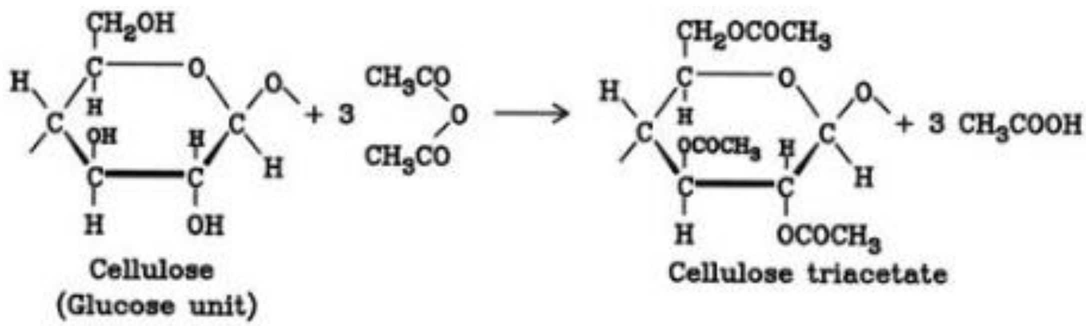

Figure 2 - Esterification reaction of cellulose (Balser, 2012, p.354.)

The resulted polymers (cellulose di- or triacetate) are named after the degree of acetyl substitution, the number of substituting acetyl groups on the glucose unit. The degree of substitution also influences product properties, such as solubility, compatibility with plasticizers, solvents, and mechanical properties.

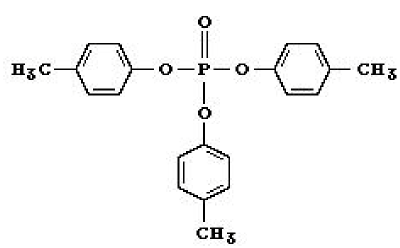

Figure 3 - Chemical structure of triphenyl phosphate (Silva, 2009, p.11.)

Polyethylene terephthalate (PET) (Figure 4), commonly referred to as polyester film, was discovered in 1941. It was introduced in the film industry in the mid-1950s, but it wasn't broadly used as a motion picture film base until the mid-1990s (3, 10). The polymer is formed by mono ethylene glycol (MEG) and terephthalic acid (TA) (11). The thin film rolls of this synthetic, thermoplastic polymer are produced by

---

[2] Processes of acetylation varies by manufacturer. Two common processes of esterification are the acetic acid process and the methylene chloride process.

[3] Diethyl phthalate, dimethyl phthalate, triphenyl phthalate are also used as plasticizers (Schilling, 2010, Balser, 2012; Roldão, 2018).

stretching PET sheets on high temperature around 100°C. Increased dimensional stability is obtained by creating slow cooling conditions (5). PET films are both mechanically and chemically more stable then CTA films (2, 4, 10). High resistance towards microorganisms, low water permeability and a product containing no plasticizers (2, 5) are among the many advantages. However, PET is prone to accumulate static charges, which can impede adhesion of the emulsion layer; therefore, antistatic components are incorporated during production (5).

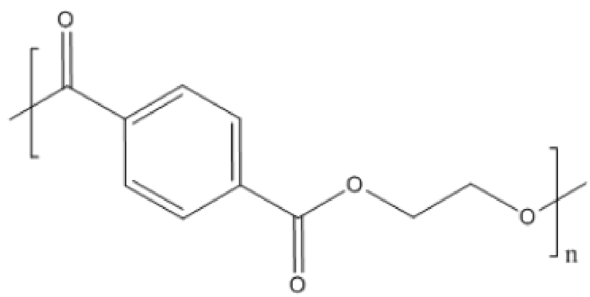

Figure 4 - PET monomeric unit (Bell, 2015, p.36.)

CTA and PET were the two main supports used for registering sound records (section 1.2.3). The first was commonly used for optical sound while the later, since the 1990s, was more used for magnetic sound recording (12). Magnetic sound films (MAG) are produced on both CTA and PET support, although some early magnetic tapes, after the Second World War, were produced on polyvinyl chloride (PVC). In the case of MAG films, polyester support was introduced as early as 1963 (2, 3, 5).

1.2.3. Emulsion: image and sound registration

The image layer of b/w films consist of silver grains suspended in gelatin. Silver grains are produced from pure silver bars, dissolved in nitric acid at high temperatures. Continuous stirring during the cooling process allows the formation of microcrystals, which are subsequently separated with water (9).

Gelatin is obtained by partial hydrolysis of collagen, a protein obtained by acidic or alkaline treatment (with the addition of distilled water, potassium iodide, and potassium bromide) from animal bones and skins (5). The thin, photographic emulsion layer is produced by mixing silver halides (Ag X) to the gelatin solution, creating an emulsion that is poured onto the film support (9). Production phases of the CTA film support and the imaging emulsion are depicted in Figure 5.

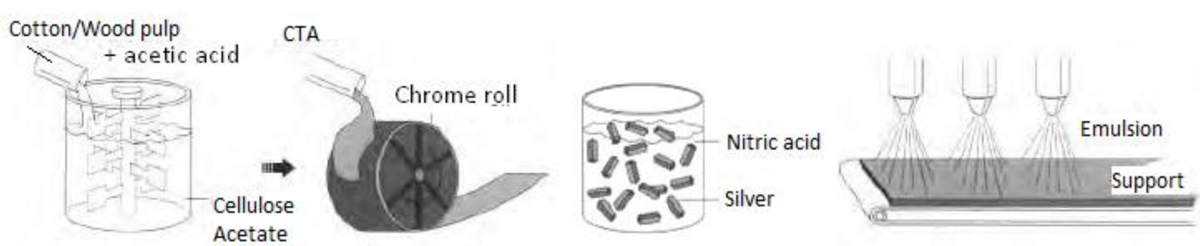

Figure 5 - Production of a filmstrip (adapted from Silva, 2009, p.12.)

Besides the image, sound is also recorded in the emulsion layer. Concerning sound, two main processes were and still are used for sound recording: optical (photographic) or, since 1953, magnetic sound tapes (Table 1). In both cases, the information, sound and image are recorded with separated systems into separate film supports. Afterwards, the synchronization of sound and image was ensured with simultaneous sound reproduction and image projection. Later, to prevent failures, correct synchronization was ensured by incorporating soundtracks onto the image tapes. On positive film prints, sound can appear as an optical track, a magnetic track, or a combination of both (2).

In its physical form, optical sound appears as a photographic image on a filmstrip. At recording, sound waves are first transformed into electrical signs, then to light. Sound intensity and frequency are recorded as image density and width, then, the filmstrip is developed just as other motion picture film (2). Figure 6 shows the recording and reproduction processes of optical sound systems.

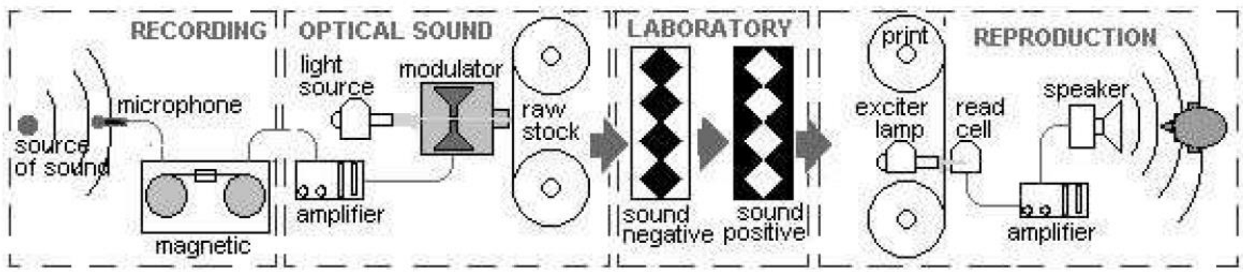

Figure 6 - Optical sound system (Read, 2000, p.28.)

Regarding the composition of the magnetic film (MAG), sound is recorded on an emulsion layer composed of metallic particles (ferric oxide, chromium dioxide or other metal particles) embedded in a binder, such as urethane or PVC elastomer (Figure 7) (13). The process of recording sound in the magnetically neutral emulsion is based on the passage of an electromagnet that will orientate the particles according to the intensity and frequency of the sound waves captured, transforming those waves into electrical signs (2). The emulsion layer of perforated tapes, such as 35 and 16 mm films, was produced with ferric oxide, in which a certain amount of chromium dioxide was also added to increase magnetic stability (5). Aiming to prevent or reduce friction between the tape and the reader, lubricants, fatty acids, and esters were added to the emulsion layer. The nature and composition of those lubricants are not described in the literature consulted (13). In the case of older MAG films, before the late 1950s, magnetic particles were dispersed in CTA binder, later polyurethane, PVC or polyester was used as binders (Figure 7) (5, 13, 14).

Synchronized image filmstrips can contain MAG tracks. In this case, a part of the photographic emulsion is eliminated before or after image development and a MAG track is applied (5).

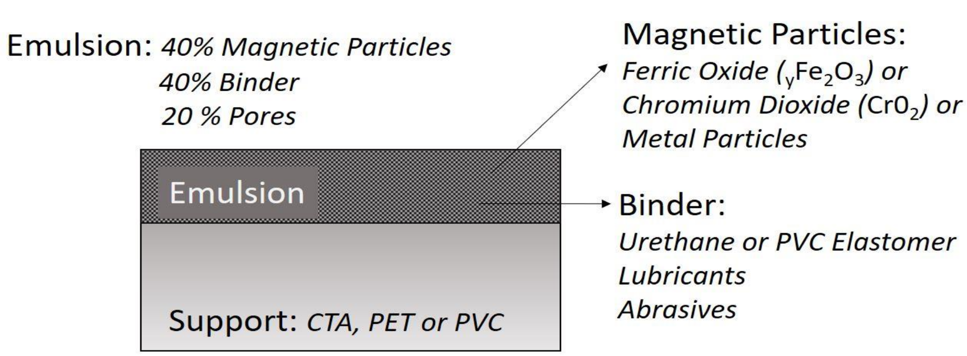

Figure 7 - Composition of magnetic tapes (adapted from IASA)

1.2.4. Other layers: anti-scratch, anti-halation, UV absorbing and subbing layers

The top layer of the film, also called a super coat, is a hardened gelatin layer, aiming to protect the film from mechanical damages.

Image sharpness can be improved with an antihalation backing. If applied as a carbon black and water-soluble layer on the back of the film base (called ramjet), it must be removed before image development. This layer also has antistatic and lubricating properties. Antihalation undercoating can also be applied right under the emulsion layer, made of silver or dyed gelatin. The color is also removed before film development. Together with this antihalation layer, an anti-curl or antistatic layer is applied on the back of the film (15).

A subbing layer aims to facilitate adhesion between the base and the emulsion. This layer could be a mixture of gelatin and CTA or, most of the cases, cellulose nitrate (5, 16, 17).

2. Degradation

Chemical composition of film components (e.g. plastic support, gelatin, urethane, PVC and magnetic particles), impurities from the production, improper packaging, inadequate handling and inappropriate storage conditions (light, high temperature, high or low relative humidity, air pollution) are some of the degradation factors for film decay pointed out in the literature (17). From the influence of those factors, physical and chemical changes occur in the several layers that compose the film (4, 17). From those changes, different signs of degradation (vinegar syndrome, brittleness, blistering, warping and planar distortion, image fading, discoloration, etc.) may be observed (4, 18).

2.1. Degradation of Safety film support

Regarding the degradation of CTA supports, two main degradation reactions may occur: hydrolysis and oxidation (16, 19). Induced by high relative humidity and high temperature, hydrolysis may occur, resulting in the cleavage of acetyl groups from the main chain, the formation of acetic acid and deacetylation of CTA (7) (Figure 8). Figure 10 represent these mechanisms, factors of degradation and physical signs of decay.

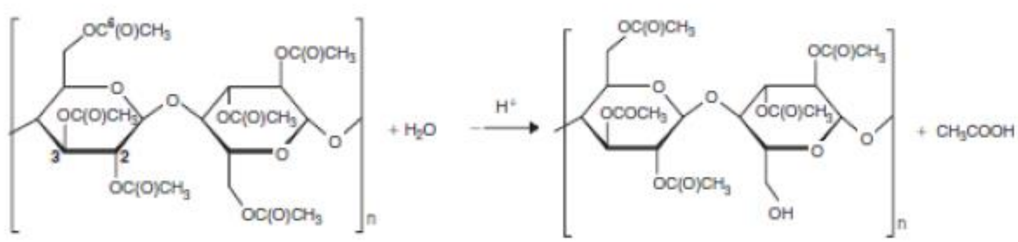

Figure 8 - Deacetylation reaction for CTA polymer (adapted from Roldão, 2018. p.68.)

Hydrolytic degradation results in a decrease in the solubility of CA (decrease of the degree of substitution) that simultaneously became incompatible with the plasticizer, and release of acetic acid. This reaction is moisture and temperature-dependent (16, 20).

Oxidative degradation by formation of an excited state hydroperoxide eventually leads to chain scission (depolymerization), and resulted in a weakened brittle material (18). According to Richardson et al. (21), the changes in the polymer network also influence plasticizer loss. This process is moisture independent (20).

Physical signs of CTA degradation are brittleness, curved/wavy edges, white powder or liquid deposit and vinegar smell (Figure 9). The two most typical macro signs of CTA degradation are vinegar syndrome and plasticizer loss. Vinegar syndrome is characterized by a strong acetic acid smell resulting from the degradation mechanism presented above. Visually, the sign of plasticizer loss is the deposits on the surface of the film rolls (Figure 9b) (20). Crystalline deposit is originated from triphenyl phosphate, while liquid deposit is from triphenyl phthalate plasticizers (5). Shrinkage, waviness, and brittleness are consequences of plasticizer loss (2).

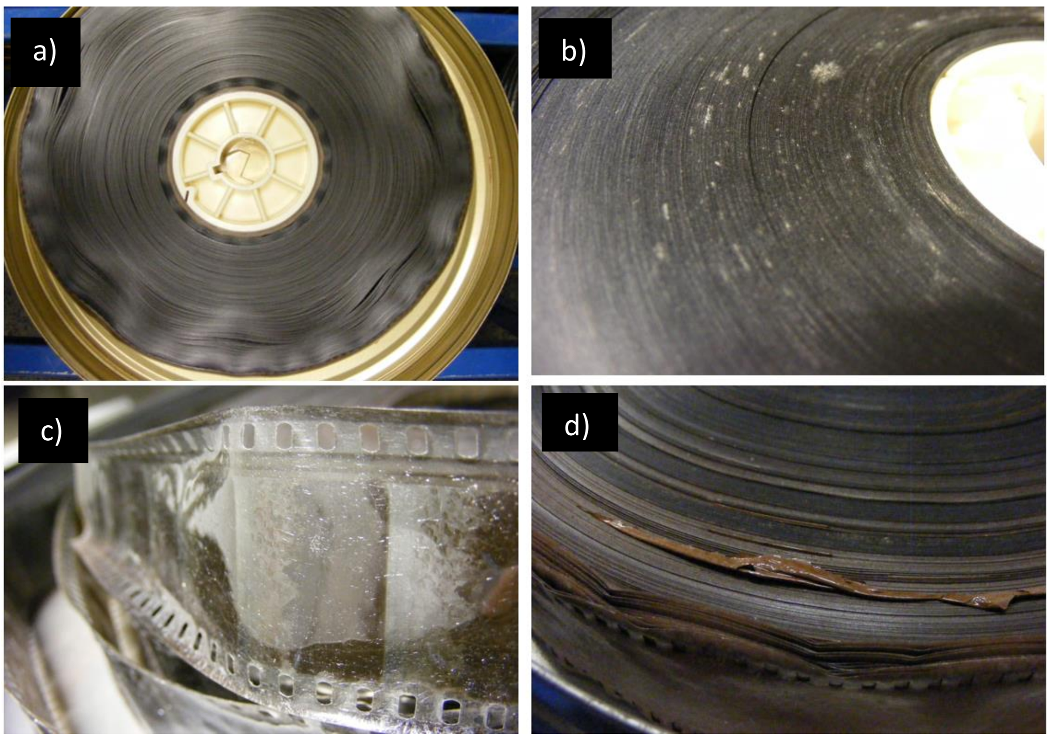

Figure 9 - Examples of CTA degradation: waviness (a), plasticizer loss (b), shrinkage (c) and brittleness (d). © Teréz Somfai

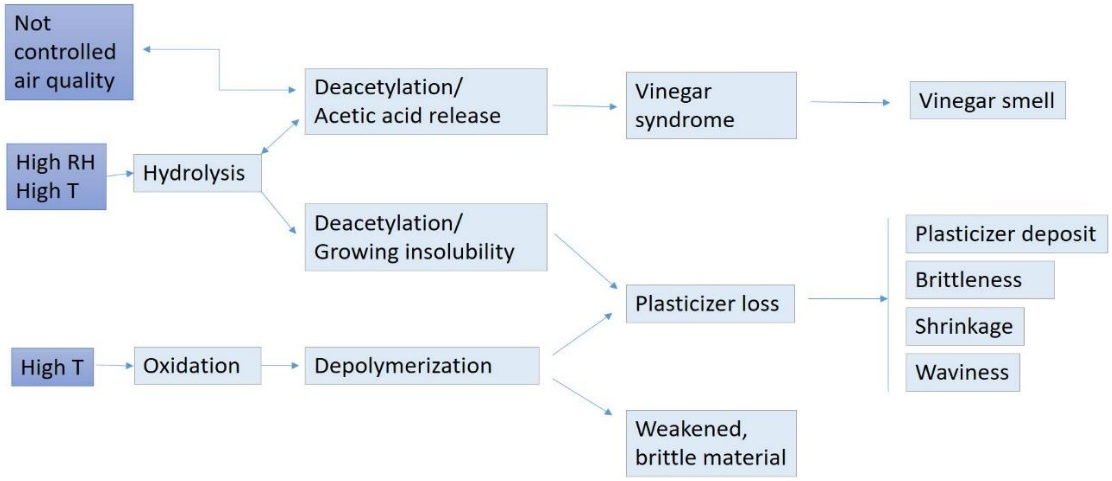

Figure 10 - CTA deterioration factors and degradation chemical reactions

About the degradation of PET films, although environmental conditions can influence the stability of this material, commonly no significant changes have been reported in the literature (5). According to literature, chemical changes can only be observed above the glass transition temperature (Tg) of PET, which is above 78°C (22). The two main degradation factors pointed out for PET decay are ultraviolet (UV) radiation and humidity if accompanied by elevated temperature (11, 22). High T and RH promotes hydrolysis, leading to decreased mechanical properties and microcracking, while UV radiation increases hydrophilic behavior and yellowing (11). Therefore, in the case of PET films, the emulsion is considered to have a shorter life expectancy than the support itself (2).

2.2. Degradation of the emulsion layer

Regarding what was already presented in section 1.2.3, the emulsion layer composition varies according to if it is an image and optical sound or a MAG record layer. Based on this information below a degradation of each typology is presented separately.

Concerning the gelatin-based emulsion for image and optical sound, this layer is chemically stable below 40°C (23). However, it can be attacked by microorganisms (5). Being moisture-sensitive (hygroscopic) and moisture-dependent, RH changes can generate physical transformations as gelatin layers expand or shrink (17), resulting in the formation of cracks (Figure 11) (24).

According to Allen et al. (25), the gelatin emulsion offers some protection to the film base since it might act as an acid scavenger, neutralizing the acidity resulting from the decay of the CA support. Additionally, gelatin emulsion may also act as a barrier against direct contact with the atmosphere. As motion picture films are stored in reels, the emulsion effectively protects interior parts. Cross-sectional analysis showed that degradation mostly appeared on the spool (the reel core), the outer layers, and the edges of the reel (16, 25). As negative films generally have a thicker emulsion layer, they found to be more stable than positive films, demonstrating slower deacetylation (25). Therefore, the presence and thickness of the gelatine layer seem to be beneficial for the stability of CTA film supports.

Figure 11 - Detail of cracks on the emulsion layer and plasticizer deposits on the film surface © Teréz Somfai

On the other hand, according to the literature, the instability of magnetic tapes might be related to the emulsion layer and, consequently, with its composition. In part, the magnetic particles have a catalytic effect on CTA support degradation. Although the magnetic particles, γFe_2O_3, are chemically stable, CTA binders tend to lose metallic particles in a form of dry brown rust. Moreover, the binder is also unstable. According to IASA's archival experiences, pigments from the 1970s and 1980s, are more unstable than in the case of older tapes (14). Comparatively, MAG films on PVC and PET supports are more stable than in CTA supports (5). PVC tapes produced in Germany between 1944 and 1972, show no signs of chemical decay; their major drawback is the elevated electrostatic behavior (13). According to IASA, the decay of PET has not yet been registered in audiovisual archives, however, they point out PET stretching, which behavior might impede sound reproduction.

At a macro level, the degradation signs of magnetic tapes are stickiness, brown powder deposits and/or binder loss (Figure 12). The process of magnetic particle loss is known as *sticky tape* or *sticky shed syndrome* (13).

Regarding lubricants, environmental conditions can promote the migration of these materials to the surface. For example, stearic acid at temperatures below 8°C, while elevated temperatures inhibit this migration (14).

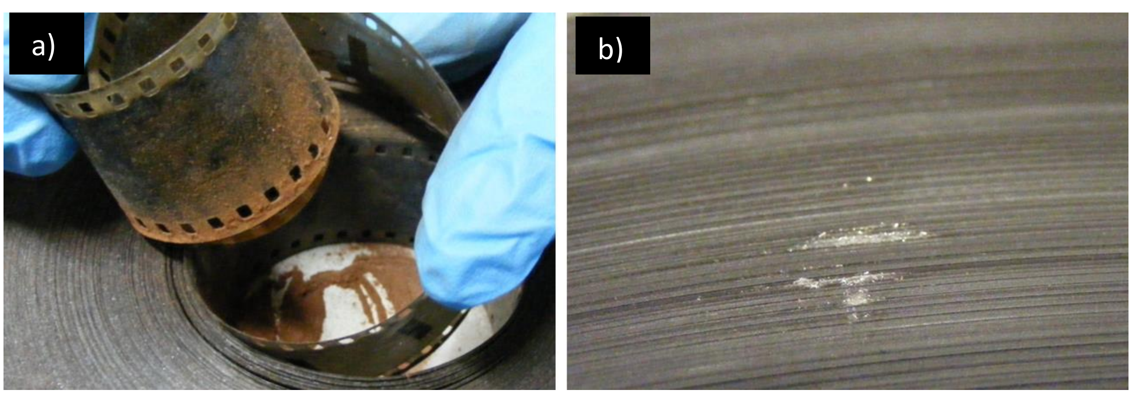

Figure 12 - Examples of the degradation of magnetic emulsion: magnetic particle deposit (a) and lubricant loss (b) © Teréz Somfai

3. *Identification and assessment methods*

In practice, several non-destructive and destructive methods are currently used in film archives for identification and assessment of film collections. In this chapter the most common non-destructive methods are presented.

3.1. Non-destructive identification methods

As stated before, the life expectancy of film stock can decisively be extended with proper storage, keeping in mind that different film components may need different storage conditions. Therefore, correct identification of a film stock should be the first task of a film archive.

Film archives with large collections need to apply the fastest and easiest identification methods, without endangering the object. There are three non-destructive methods of identification: i) macro identification (edge marks, etc.), ii) light transmission test, and iii) polarization test, that, if correctly applied, helps to identify a film with great confidence.

Determining the origins, brand, and age of the film stock, may provide useful information about chemical composition and life expectancy. Macro identification is a set of processes, involving observation of the object. Visual inspection of a filmstrip, searching for edge printings on the side of the strip, can provide relevant information about the brand and the film support. The edge-mark "Safety" refers to both CTA and PET films, and therefore, more information is necessary to distinguish both (Figure 13). An edge-mark holding the manufacturer's name may enable to make assumptions about the date of production, and consequently, may offer more precise identification (see Table 1). Physical appearance helps to identify the emulsion, for example, the presence of image frames are obvious signs of photographic layers. MAG sound tapes are usually covered with brown or grey emulsion layer (2).

Degradation signs, such as vinegar smell or physical deformations are obvious signs of a degrading CTA film (10, 26), brown powder deposit is a degradation sign of the magnetic emulsion (see section 1.2.3.)

Figure 13 - Edge-printing: Safety film © Teréz Somfai

The light transmission test aims to distinguish CTA and PET films. Identification is performed by observing the film reel from the edges, holding it in front of a light source. This method offers fast, safe and straightforward identification. However, results are not always obvious. Theoretically, CTA films undertaken to light transmission test seem opaque, as opposed to the bright and translucent PET films (Figure 14). However, for MAG tapes[4], a reversed behavior is expected, while PET films look completely opaque CTA films let light pass through (3). Figure 14 demonstrates the light transmission behavior for

[4] Tapes with magnetic emulsion.

the different typologies of films selected for this study. Images of CTA and PET films undertaken to light transmission tests are shown in Figure 28-31 in Appendix III.

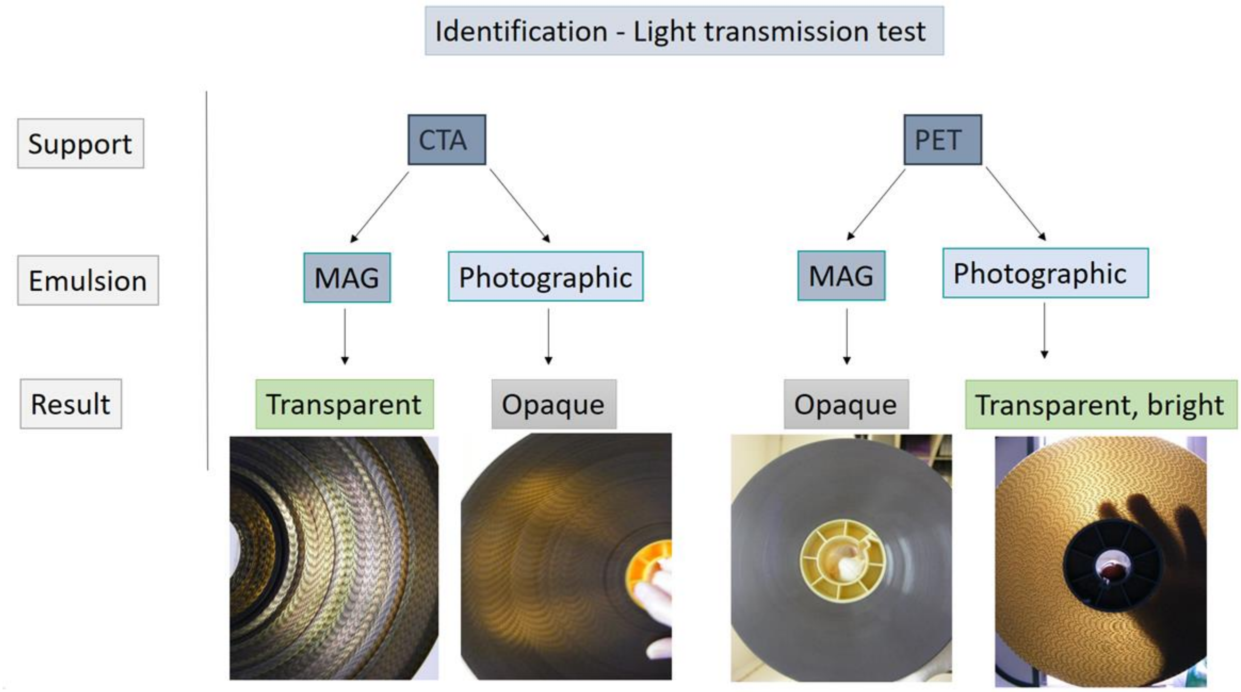

Figure 14 - Identification of film supports through light transmission test

Another method for identification of film support is performed by holding the filmstrip between two layers of polarizing filters. Looking at CTA-based films over cross-polarizing filters, no visual effects are recognized, the dark filters only make the filmstrip look darker. On the other hand, when light passes through the filters and the PET-based film between them, a rainbow effect or phenomenon occurs. This effect is also called birefringence (10). Figure 15 shows a CA and a PET film observing through cross-polarized filters. This method offers distinctive results when light transmission test results are ambiguous. This is a low-cost tool, that can be easily made and easily used by the archive staff. Nevertheless, the test has two disadvantages. As a film reel might be composed of various filmstrips, the reel must be unwound for verification of the entire film. Another drawback is that magnetic emulsion blocks all light, and therefore this test cannot be performed on MAG films.

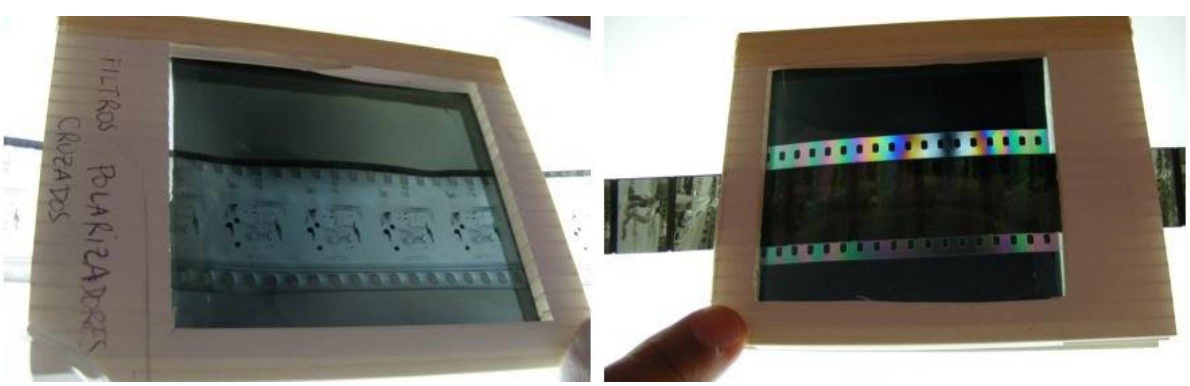

Figure 15 – Identification of CTA film (left) and PET film (right) through polarization test © Teréz Somfai

3.2. Non-destructive assessment methods

Collection assessment aims to understand the actual state of conservation of individual film reels and of the entire collection. Together with regular monitorization, it helps to estimate degradation tendencies, prioritize the preservation processes and it may indirectly suggest if any storage improvement or adjustment should be taken. According to literature, two commonly used methods for collection assessment is macro evaluation and assessment with AD strips (27).

Macro assessment of the preservation of each film reel, involves visual observation of the film support, shrinkage evaluation based on the distance between perforations, stickiness, and the discoloration of the emulsion layer. Additionally, the degree of physical deformations, scratches, tears, odors, are also signs of diverse states of conservation. Macro assessment is most commonly performed when a film arrives in or leaves the archive.

Comparatively, AD strips enable assessment inside the storage room, ensuring a much faster assessment of the entire collection than a macro assessment of individual film reels. Therefore, it is a generally used assessment method in large motion pictures and photographic collections. Developed by IPI in 1997, the tool measures the acidity released from CTA films, offering non-destructive analytical evaluation. The tool requires no scientific training of the archive staff, and helps to estimate the collection's state, without the necessity to watch through all films.

The 1 x 4 cm paper strips containing bromocresol green dye and sodium salts are indicating through color changes the severity of film degradation. After a certain exposure time, the strip changes from blue (level 0 – not degraded) to yellow (level 3 – highly degraded), indicating the free acidity level present inside of the film can. According to studies made by IPI, at AD level 1.5 degradation reaches the autocatalytic point when chemical decay continues much faster (Figure 16), therefore this level is crucial and IPI recommends duplication of these films (4).

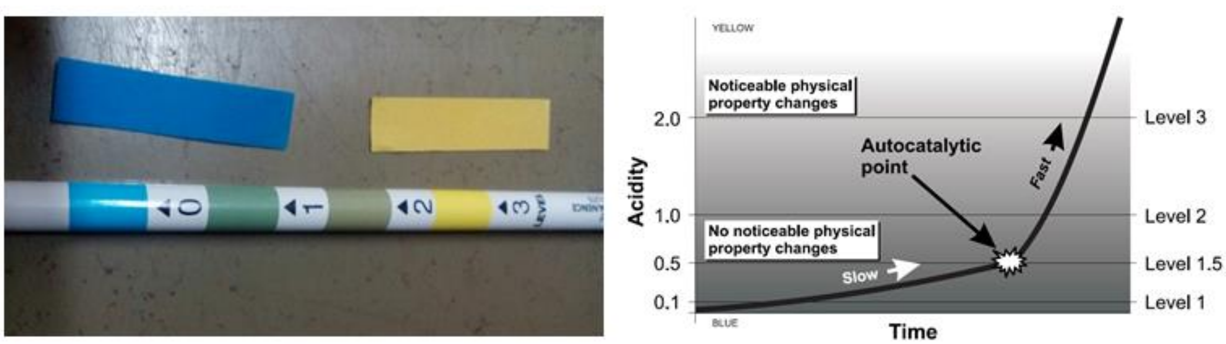

Figure 16 - AD strips and color scale (right); Autocatalytic point (User's Guide, p.11.) (left)

Currently, AD strips are produced and commercialized by two companies, The Image Permanence Institute (IPI) and Dancan. Their product information and AD strip usage restrictions are shown in Appendix V.

3.3. Recommendations for Safety film storage conditions

Despite the ephemeral nature and decay associated with the cinematographic heritage, proper storage conditions can reduce the speed of decay (5).

Concerning the microenvironment, a film can in which a reel is stored may have a direct impact on the preservation state of the object. It gives protection from physical damages; however, by providing specific conditions for each reel, it may affect the degradation speed, specifically of CTA polymer.

The design and material of a film can must be taken into consideration. Motion picture films were originally stored in tin-pleated iron cans, although later researches concluded that metal ions migrating from these cans may impose a severe catalytic effect on degradation. Allen et al. (25, 28) demonstrated that aluminum, polyethylene and glass containers, are better storage alternatives.

The international standard, ISO 18902 describes chemical requirements for plastic and metal storage enclosures. Besides chemical stability that is a basic requirement of appropriate enclosures, film cans must be hydrophobic to avoid further moisture attraction. Plastic cans should not contain plasticizers, and should not be made of chlorinated, nitrate or acetate plastics. Metal cans must not be corrosive and should not be covered by lacquer or enamel. According to ISO standards, all storage materials should pass the photographic activity (PAT) test (29). Appendix IV refers to important ISO standards in relation to Safety films.

Regarding enclosure design, Bigourdan and Reilly (30) concluded that films in sealed metallic and in sealed plastic enclosures degrade the same level, therefore the elimination of the acidic gases liberated during degradation, are more important than the film can's material. Closed, unventilated film cans accelerate aging if acidic gases get trapped inside the enclosure, promoting further degradation. Vented cans eliminate this factor but require monitorization of the storage room's air quality.

To reduce moisture content and acidity level inside a closed can, adsorbents such as silica gel, zeolite molecular sieves, and activated charcoal cloth are used. If the saturation of adsorbents is monitored and replaced regularly, these materials provide extra protection (31, 32).

Regarding the macro environment, monitorization of temperature (T), relative humidity (RH) and air quality inside the storage room are essential (5). In Table 2 ideal T and RH conditions for safety films are presented (3, 23). According to IPI, ideal storage conditions for magnetic tapes are also determined by the type of film support (3). However, Despas (33) differentiates RH recommendations for magnetic tapes: suggesting 30% RH for films covered with a photographic emulsion; and higher, 45% RH for MAG tapes.

Table 2 - Ideal storage conditions for Safety film collections (adapted from Storage Suitability, 2019)

Storage Conditions (30-55% RH)	**B/W Acetate**	**B/W Polyester**	**Rating system**
Room (20°C)	Unacceptable	Acceptable	Unacceptable – Likely to cause significant damage
Cool (12°C)	Unacceptable	Acceptable	Acceptable – Meets ISO recommendations.
Cold (4°C)	Acceptable	Best practice	Best practice – Will provide an extended lifetime
Frozen (0°C)	Best practice	Best practice	

3.4. ANIM's safety film collection: an overview of the current identification and assessment methods, storage condition, and preservation strategy

To this day, ANIM's entire collection includes 41,051 film titles, made between 1896 and 2018. Among these, 33,324 films are recorded on cinematographic film base, the rest are analog or digital video. 20,000 films are of Portuguese production, among which only 988 are feature films, and the majority are short films. The collection grows through voluntary deposit, buying, offer, patrimonial integration, or copying (34). The number of films or reels per title varies, and therefore, the number of films present in ANIM collection is higher than those mentioned for film titles.

Firstly, the collection is organized by type of film base. Two main categories are established: a) cellulose nitrate, b) safety films, which include CTA and PET supports. Additionally, the main categories are divided by levels of subcategories that are supported on film properties such as film length (feature or short), film element[5] (copies or masters) (35), image (b/w or color), and conservation state (e.g. vinegar syndrome). Figure 17 depicts these categories. The collection focused on this study is highlighted in black cells.

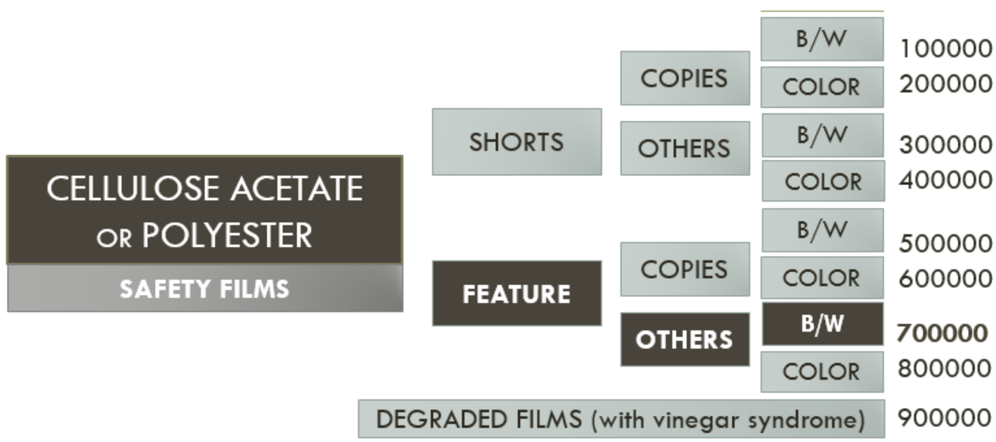

Figure 17 - The organization of ANIM's collections. Numbering inside each category is sequential.

3.4.1. Storage facility

Regarding the storage facility, from 1954 to 1996, the collection of Cinemateca was stored in Palácio Foz in Lisbon (36), where the deposit was equipped with an air-conditioning system, but precise environmental data have not been registered. In 1996 new archive facilities, designated as ANIM, were inaugurated and the collection was transferred to a new building at Quinta da Cerca, Freixial. Based on the knowledge and experiences of FIAF and foreign film archives, the building was equipped with proper storage facilities, with four climatized deposits for safety films, an isolated bunker for nitrate films, with conservation and duplication labs (6).

[5] Production and reproduction of films passes through a chain of products, called as film elements: negative, interpositive, internegative, positive. All of these elements have their own roles during film production, being essential components of film preservation. Masters are negative, interpositive or internegative films; copies describe positive prints that are projected in cinemas (6).

Safety films are stored in ANIM's main building[6]. Appendix VI shows the location of storage rooms (blue highlight) and the placement of the b/w masters' collection (highlighted with yellow). All deposits are equipped with an intermediate room, where films are placed for acclimatization, ideally, for 2 days before entering or leaving the vault (12).

Figure 18 – Cooling air supply (left), interior view (middle), control panels (right) © Teréz Somfai

Environmental conditions are set to comply with the internationally accepted guidelines for the long-term preservation of motion picture films (see Table 2). The walls, grounds, and ceilings are covered with two layers of thermal insulation (36). Low temperature is supported by a cooling system inside the deposit (Figure 18, left). Air quality is not monitored, and the ventilation system turns on periodically, therefore, it is possible to smell vinegar odor inside the vault.

Two acclimatization systems are responsible to maintain environmental conditions. T and RH are monitored with Stec Control SC 320 equipment, sensors are placed on the ceiling inside the deposit, their control panels are located in front of each intermediate room (Figure 18, right). The monitoring system does not perform continuous registration of the values; therefore, T and RH data are verified three times a day (5 am., 1 pm., 10 pm.) and manually registered on a worksheet. An analysis performed on these data sheets[7] in the scope of this thesis shows that b/w masters are stored at an average of 13°C (T) and 29.5% (RH). Figure 19 represents changes in T and RH data over an 8 months period. As for the deposit of color films, acclimatization is set for 3.5 to 4.5°C (T) and 27 to 33% (RH).

Since 2010, due to the lack of storage space in the original vaults five new storage rooms were constructed, and part of the safety collection is being relocated. In these new vaults, temperature for b/w masters will be set at 8°C, and color films will be stored at 4°C (36).

Table 3 - Storage room conditions in ANIM's vaults

Type of film	**Storage conditions**
b/w films	11°C < T < 14°C 27% < RH < 33 %
Color films	3.5°C T < 4.5°C 27% < RH < 33%
Films with vinegar syndrome	Forced extraction of gases, no climatization

[6] Due to high flammability and chemical instability, cellulose nitrate films are stored in an independent building, away from the main building.
[7] Data registered between 2018.10.01 and 2019.06.28.

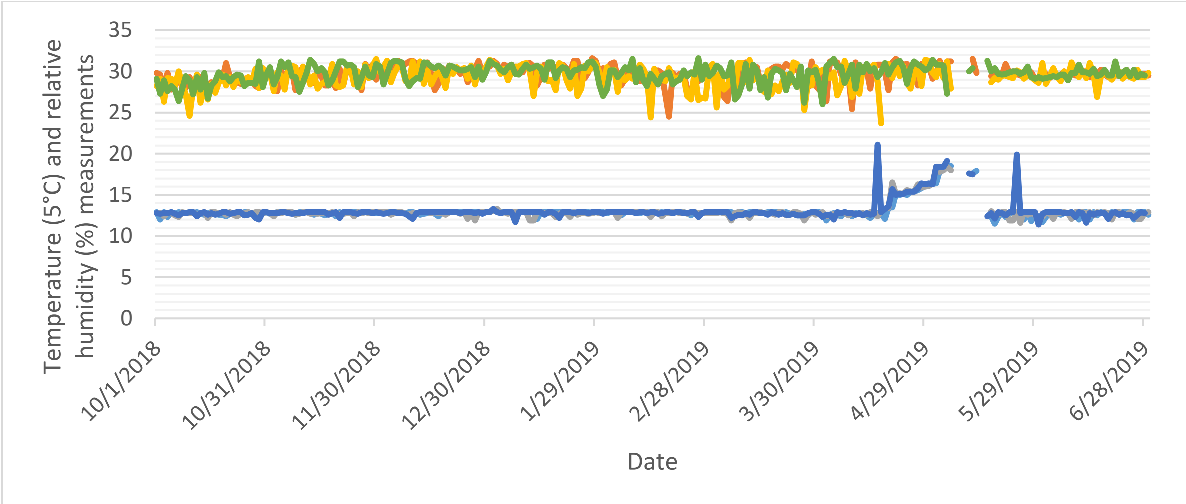

Figure 19 - T and RH condition changes in b/w masters' vault

3.4.2. ***Preservation strategy and practice***

According to Oliveira (6), to "ensure the survival of a film is in fact not only to preserve negatives or copies of it but to produce a specific chain of materials (including intermediates, internegatives or interpositives) to which well-defined functions are attributed and that allow that this film can be seen without risking their integrity"(6). According to the preservation policy of Cinemateca, only those films can be presented to the public, whose preservation chain is complete, ensuring the possibility of reproduction. ANIM preserves films of Portuguese production, meaning that the full preservation chain of Portuguese films is in their focus.

Upon arrival at the facilities of ANIM, the film passes through the identification[8] department, where the full film is watched through for macro identification. Identification covers the topics of the film title, language version, production year, country, length in minutes and meters, type of image (b/w or color), sound process (optical or magnetic). Since CA and PET films are stored in the same vault, identification of the film base is secondary. Commonly the identification of the film support is based on date, edge printing, and visual assessment. Data collected is introduced in the digital catalog for further monitorization. If applicable, brand and year of the film stock are identified by edge-printing information. Projection quality and general film condition are assessed with the help of an evaluation guide, ranking the film on a scale between 9 to 1, where 9 is the best 1 is the worst state. The evaluation guide (Table 4) considers three parameters: the support, the emulsion, and the evaluation of perforations. Finally, the film receives an inventory number, and the film is ready to enter the corresponding storage room.

[8] The archive uses the word "identification" to describe the film as a piece of art, without aiming to identify the composition of the material.

Table 4 - Evaluation guide, ANIM

State	Emulsion	Support	Perforation
9	No visual damages. Excellent material.	No visual damages. Excellent material.	No visual damages. Excellent material.
8	Some occasional scratches on the surface.	Some occasional scratches on the surface.	Very lightly stretched perforations.
7	Some occasional but deep scratches (that doesn't let the light pass through).	More frequent and deeper scratches. Maximum 5 repairs per reel.	Some loss of material in perforations.
6	More frequent and deeper scratches.	Occasional but deep scratches (that doesn't project too much). Maximum 10 repairs per reel.	V-cuts. Less than 3 per reel.
5	More frequent and deep scratches (that don't let the light pass through).	More frequent and deep scratches (that doesn't project too much). More than 10 repairs per reel. Film torn at various places.	More than 3 V-cuts per reel.
4	Frequent and deep scratches (that do let the light pass through). Irreversible dirt (rust, mold, etc.)	Very frequent and deep scratches (that projected intensively).	Evident loss of material, but far-between.
3	Very frequent and deep scratches (that do let the light pass through). A significant number of damages made by the projector.	Very frequent and deep scratches (that projected intensively). Dried film. Adhesive tapes that detach easily and hardly adheres to splices[9].	Easily breaking perforations.
2	Brittle emulsion. Obvious signs of starting color degradation.	Obvious sign of a starting acetic decomposition (smell, loss of hardness, formation of crystals).	Lack of perforations, but just one side of the film.
1	Irreversible damages on the emulsion. Completely degraded color.	Irreversible damages on the support. Acetic decomposition.	Lack of perforations on both sides of the film.

Regarding storage, b/w masters occupy a separate deposit. The b/w masters itself, regarding age, brand, and materials are stored in very diverse film cans (Figure 39). Traditionally, b/w masters were stored in unvented cans and ANIM has started to purchase plastic and perforated cans only the recent years. Adsorbents inside film cans have never been used (37).

In 2006, ANIM initiated a comprehensive assessment of the safety film collection with AD strips repeating the evaluation 8 years later, in 2014. The b/w masters collection consisted of 9388 film reels, in which different film types (e.g. negatives of silent and sound film, internegatives of silent and synchronized films, interpositives, magnetic tracks) were present. Over the first assessment, 1511 reels were tested. In 2014, ANIM intended to evaluate all b/w and color feature films in their safety collection,

[9] A join of two filmstrips (pasted together with adhesive tape).

but due to the large number of specimens, were analised only two reels per element[10]. The examined reels were randomly chosen, altogether 1878 reels were assessed. Results of the two assessments were introduced to a Microsoft Excel® file; subsequent evaluations were completed as a part of this work.

According to ANIM's practice, severely degraded films are taken out of the collection, relocated to a storage room for films considered completely lost. This storage room does not have any conditioning. Currently, there is no policy defining when should the film be transferred from the monitored collection and vault to a highly degraded category, and which films are most probably to be destroyed in the future.

4. *Experimental*

4.1. Methodology

4.1.1. *Sample selection*

One hundred film reels were chosen as samples for further analyses. Selection criteria aimed to enable evaluation of degradation tendencies, thus, samples were chosen among reels undertaken to both previous assessments. The assessment results in 2014 supported the final selection, which was performed randomly, but aiming to choose samples of all AD levels. Figure 35 in Appendix VII shows the distribution of AD levels among the samples.

4.1.2. *Macro identification and assessment*

The objective of a macro assessment is to register any degradation signs observed, which eventually helps to categorize samples and may help to find degradation tendencies. The method also supports identification. A degrading cellulose acetate film can confidently be identified by the vinegar smell. This method can clarify results when light transmission or polarization tests are ambiguous or cannot be performed.

4.1.3. *Identification of the film support with light transmission and polarization tests*

The identification of film supports aims to understand if storage conditions are adequate. Three non-invasive methods were used together to identify film supports; macro assessment, light transmission test, and cross-polarization test.

The light transmission test enables fast identification performed inside the storage room, even on reels that not yet show signs of degradation. However, the results can be ambiguous and it requires the conservator's experience. Another disadvantage of the method is that the reel must be taken out of the can. This may be difficult in case of a large film reel, imposing unnecessary risk on the object.

The identification with polarizing filters provides confident results on film supports covered with photographic emulsion, even in the case when the light transmission test did not offer definite results. The test is performed on an unwind filmstrip, which makes it slightly more time consuming, moreover, it cannot be applied to identify magnetic tapes (see Section 3.1).

[10] Depending on the length of a film, a film may consist of various reels. Most often, but not always, these reels are originated from the same film stock (same brand and year), therefore, their life expectancy is considered to be identical.

4.1.4. ***Assessment with AD strips***

In 2019, already 5 years had passed since the last collection assessment was made by ANIM. To assess the actual state of the collection and to verify the results of previous assessments, a new assessment with AD strips was performed on the selected samples.

Under the unchanged storage conditions degradation was supposed to continue with similar speed, and a high percentage of films at AD level 1 was expected if previous assessment data were correct.

4.1.5. ***Colorimetry***

A comparison between the reference color scale and the AD strips have found to be highly subjective, and it can lead to false results, especially in the case of a large collection, where many archivists are responsible for the assessment. Moreover, the AD strip reference scale represents 4 colors, but according to the AD strip User's Guidelines, intermediate colors also should be considered, representing 7 acidity levels. These intermediate levels make color readings even more subjective.

Colorimetry was used to obtain quantified data of the discolored indicator strips. Colors of unused AD strips and strips exposed to acidity were measured with a colorimeter. This method excludes subjectivity and enables objective registration of the color change.

The colorimeter obtains data on the CIE*Lab color system. To convert these data visually perceptible, L*a*b* colors were converted to RGB colors, with the help of the website convertingcolors.com, then, RBG color data was generated on a Microsoft Excel® worksheet. This method enables easy comparison of the results.

4.1.6. ***Hardness measurement***

With the aim to verify the AD strip assessment results, hardness measurements were performed on CTA and PET films. According to literature (Roldão, 2018), a decrease in hardness may be observed on the degrading CTA polymer. This method aimed to clarify some of the contradictions observed between macro assessment and AD strip results, such as films in visually good conditions representing high AD levels, or the contrary, visually degraded films in low AD levels.

4.2. **Instruments and methods**

4.2.1. ***AD strips***

Two sets of analyses were performed in April and May 2019 using AD strips from the two manufacturers, Dancan and IPI. The previous assessments by ANIM were performed with Dancan's strips called Danchek. These strips were purchased in 2015. Although the manufacturer does not indicate expiry date, due to the dull color of the strips it was decided to compare products and more importantly, validate measurements with more recent strips purchased from IPI.

The assessments were carried out inside the storage room, according to the suggested procedure by IPI exposing strips for 14 days after placement inside closed film cans. Readings were performed in the intermediate chamber in front of the storage room. The strips were transferred in a dark polyethylene bag to avoid color changes imposed by light and the atmosphere. Visual comparison with the color scale and measurements with colorimeter were processed within a few minutes.

4.2.2. **Colorimetry**

The L*a*b* color system of Commission Internationale L'Eclairage (CIE) uses three axes in a three-dimensional space to obtain exact values of a certain color. L* values from 0 to 100 correspond to darkness (0) and brightness (100) of a color. The other two axes represent opposing colors; from blue to yellow (a* values between -60 and +60, respectively) and from green to red (b* values between -60 to +60, respectively).

CIE*Lab values were measured with a DataColor Microflash® colorimeter set on D65. According to routine procedure, the equipment was dark and white calibrated, then three measurements on each indicator strip were registered, calculating an average value and the standard deviation.

4.2.3. **Hardness (Shore A)**

Hardness measurements were carried out with an HP Durometer (model HPSA by Checkline Europe BV). The instrument measures hardness on a Shore A scale from 0 to 100.

As for operating instructions of the instrument, measurements on metallic or glass plates must be avoided. The sample reels were unwinded on a winding table, placing a plastic film can under the filmstrip. Measurement was taken on the back of the filmstrip, on three points: begin (outside), middle (central point) and end (core). Three independent measurements were done on each point. An average and a standard deviation were calculated.

5. **Results and Discussion**

The statistical analyses of the assessments performed in 2006 and 2014 shed light on some key problems that probably gave inaccurate results in the past and therefore must be avoided in the future.

a) Improper registration of the analyzed reel. Feature films are generally composed up to 8-12 film reels stored in separate cans, meaning that each one is surrounded by a unique microclimate. In consequence, each reel should be handled as a unique art object, and the measured degradation level cannot be considered as representative[11].
b) Lack of information about processes that can influence results (e.g. duration of exposure, packaging of the strips, usage of gloves).
c) Errors in readings due to the proximity of colors. A comparison between the strip and the reference scale is fairly subjective, especially in the case of intermediate values. Subjectivity can be excluded by quantitative data analyses, such as colorimetry.
d) Negative tendencies. The statistical analyses revealed 24 cases when the AD level in 2014 decreased from the level measured in 2006, indicating that the preservation state has improved. This result may be explained both with reading mistakes or with a high degradation level in which case a filmstrip may have already liberated all acidic reserve.

According to the statistical analyses of the previous collection assessments performed by ANIM, only 9% of the film reels reached or exceeded the autocatalytic point in 2006, meanwhile, 42% of the reels

[11] Due to the lack of correct registration, it is uncertain which film reels were assessed in 2006. This inaccuracy was corrected in 2014, when the catalog number of the analyzed reels was properly registered.

were at AD level 1.5 or above by 2014 (Figure 20). The assessments revealed that over 8 years the whole collection degraded, shifting towards higher AD levels, with about 0.5. According to IPI (4), this level of degradation should have happened in more than 15 years (Figure 21). This work aimed to understand the backgrounds of this elevated degradation rate.

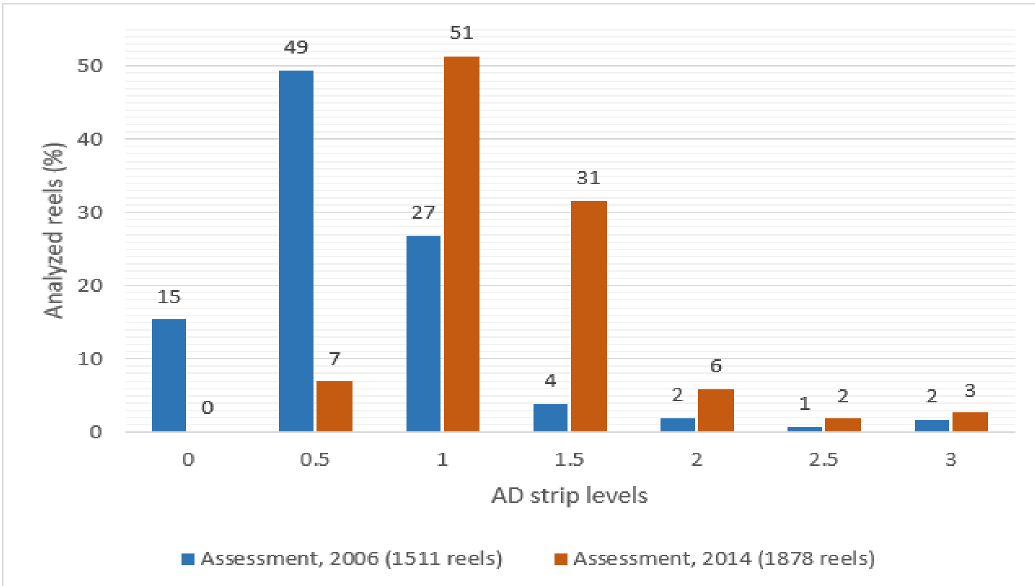

Figure 20 - 2006 and 2014 AD strip assessment results

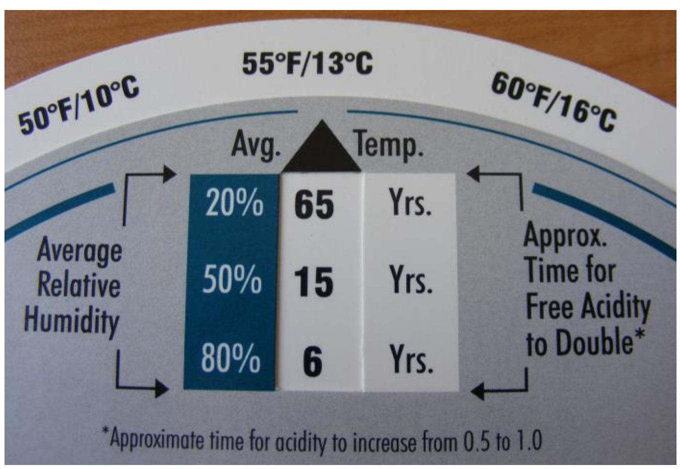

Figure 21 - CTA degradation speed according to Image Permanence Institute (IPI) Acetate Wheel

5.1. Identification and assessment of the samples

For this study, 100 Safety films were selected. ANIM's digital catalog helped to identify the exact age of 52 sample reels. The production year of the samples varies between 1951 and 2000, however, there is no knowledge about the dates of production for 48% of the films selected (Appendix VII, Figure 38). Considering those films for which dates of production are known, the higher percentage of films per decades correspond to the 1990s and the 1960s with 19% and 11%, respectively (Appendix VII, Figure 38). By performing the macro identification of film supports and emulsions, it was possible to conclude that among the 100 samples, 83 reels have a CTA support and 17 reels have a PET support (Appendix VII, Figure

36). From the total set of films with MAG emulsion, nine films were identified with PET support, and twelve with a CTA support. To confirm the first level of identification, a combination of the three non-destructive identification methods presented previously was performed. In some particular cases, it was seen that there is a large combination of different types of films in one single reel, confirming the difficulty of identification and broad comprehension of the degradation factors by film archivists and conservators (Appendix III, Figure 30). From the total film reels, 81 films had the manufacturer brand marked on the fringe of the film. From the identification process performed several brands such as Eastman-Kodak, Agfa, Gevaert and Ferrania, were surveyed (Appendix VII, Figure 37). From the main brands found in this set of samples, Gevaert is the brand most common from the films from the 1960s. According to macro assessment and AD strips results, the films from Gevaert are the most degraded samples. Further analyses involving a larger amount of samples are necessary to verify the correlation between the degradation rate and the manufacturer.

The macro assessment of the set of films selected allowed to conclude that 59 film reels show no signs of degradation. However, throught the AD strip test a high level of acidity was found for 13 reels that are above the autocatalytic point. White crystalline deposits were found on 11 samples, among which 9 were identified as CTA and 2 samples as PET films. The deposit was observed even on CTA films that represented low AD levels, suggesting that plasticizer loss can occur in early stages of degradation. The PET films with crystalline deposits were both covered with MAG emulsion, suggesting that the deposit observed was originated from the binder, as a lubricant loss. Physical deformations are also present in the early stages of degradation, waviness was identified in 3 samples demonstrating AD level 0.5. Vinegar smell is identified mostly in films with levels of acidity above AD level 1.5. Brittleness and magnetic particle deposits were exclusively observed in highly or severely degraded films.

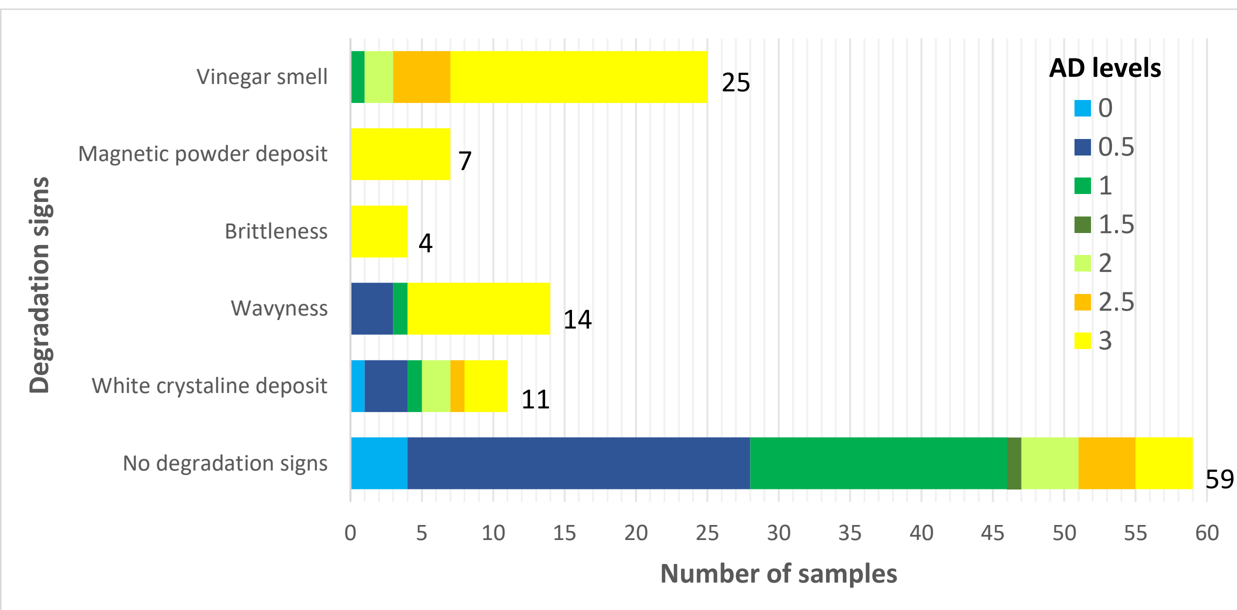

Figure 22 - Macro assessment results compared with AD strip results

In contradiction to literature, in this study films with PET support showing high levels of acidity were found. However, it is important to emphasize that this behavior was found only on films with PET based MAG tapes (Figure 24). In fact, all 21 MAG sample films represent high degradation, at least above AD level 1 (Figure 23). By macro assessing (visually, odors and with AD strips) the safety films selected for this study, it was found that independently if it was a film CTA or PET based, MAG tapes showed the highest levels of degradation (severe degradation and high levels of acidity detected).

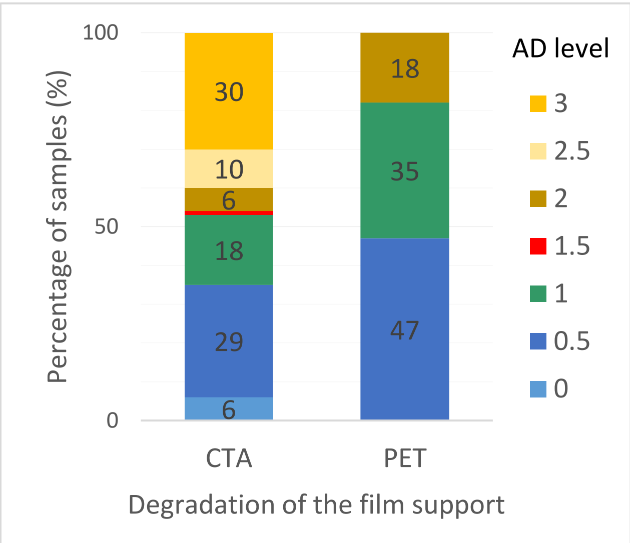

Figure 24 - Preservation state of Safety films

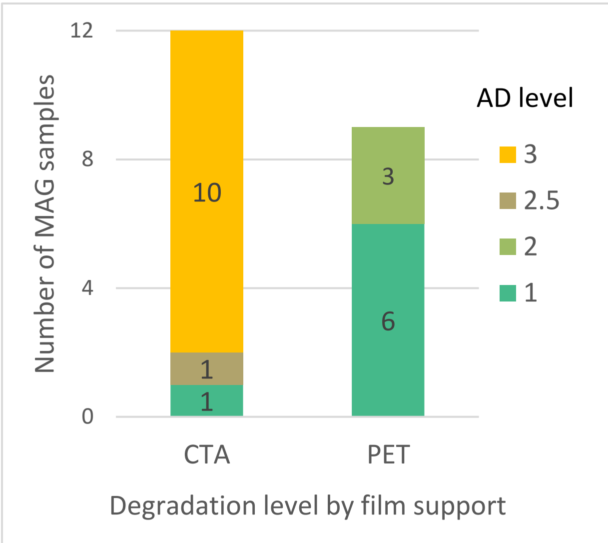

Figure 23 - Preservation state of MAG tapes

Additionally, it was found that MAG films with CTA support have the highest levels of degradation. Therefore, based on the macro assessment results obtained in this study, it is proposed that MAG tapes should be a priority in preservation strategy of safety film collections. Moreover, these results allow proposing that MAG films must be handled as a specific category in the archive and should be separated from the rest of the collection.

Concerning specifically the assessment with AD strips, a test was conducted since differences between acidity detector indicator strips were detected. Two brands were purchased from the two most common manufacturers, IPI and Dancan. The differences between the two products were obvious upon the opening of the packages. In the case of AD strips from IPI, a strong smell of the indicator was noticed. Meanwhile, the Danchek strips were odorless. The strips have the same size and thickness, but there was also a noticeable difference in color intensity. It was considered that the differences detected between products may be a consequence of the type of packages used by the manufactures. While the original packaging of Danchek strips is a single-layer of black polyethylene bag, PE-LD Minigrip®, IPI delivers AD strips in two layers of plastic bags (a tightly sealed aluminum-polyethylene bag, the strips itself are placed in a transparent polyethylene bag). Based on the observation and evaluation performed it was considered that the single layer bag from Dancan is a porous material that may be insufficient to protect the product from getting in contact with the air that may enforce fading and could lead to the loss of effectiveness and reliability of the product.

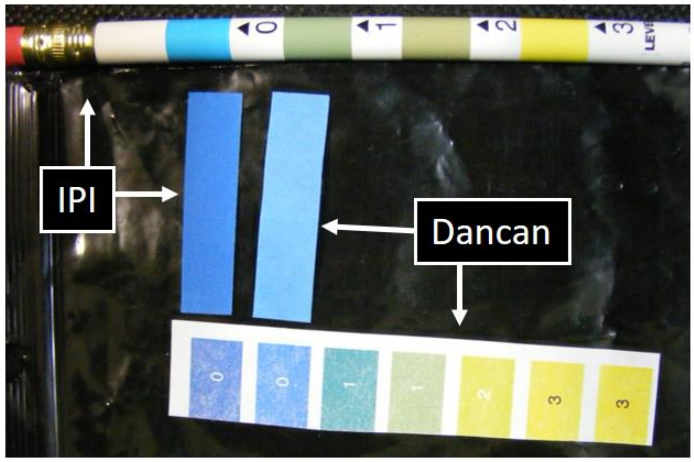

Figure 25 - Color scales and unused strips of IPI and Dancan © Teréz Somfai

Figure 25 shows reference color scales and the color of unused strips of both manufacturers. IPI provides a scaling pencil with 4 colors, indicating that their system enables assessment of 7 different AD levels including intermediate colors as valid results (see Appendix V). The scale of Dancan is a printed-paper strip adhered to the package, representing 7 different shades; two shades for level 0, two for level 1, one shade for level 2 and two shades for level 3.

The two sets of sample assessments, as expected, revealed differences between AD strip and Danchek strip measurements. The assessment of the strips of Dancan gave rise to similar results as of the assessment in 2014 (Figure 26). It was concluded through these results, that the collection has not degraded significantly since the last evaluation. On the other hand, the assessment with AD strips resulted in very different degradation levels. According to AD strip results, a much larger percentage of the samples are under the autocatalytic point as compared to the Dancan results. Whilst the Dancan strips measured 30 reels under level 1.5, the IPI strips measured almost the double, 58 reels under this level. However, not all data shows a decreased degradation level. The IPI strips resulted in 25, the Dancan strips in 23 highly degraded films. This significant difference in the assessments may be explained with the strips sensitivity or the inadequacy of readings. The subjectivity in the readings was excluded from the quantitative evaluation obtained with colorimetry. The registered results provide a database for future assessments.

Nonetheless, these differences may indicate inappropriate results of the previous collection assessments. More certain conclusions may be deducted from a new collection assessment, using samples from this work and colorimetry measurements as reference.

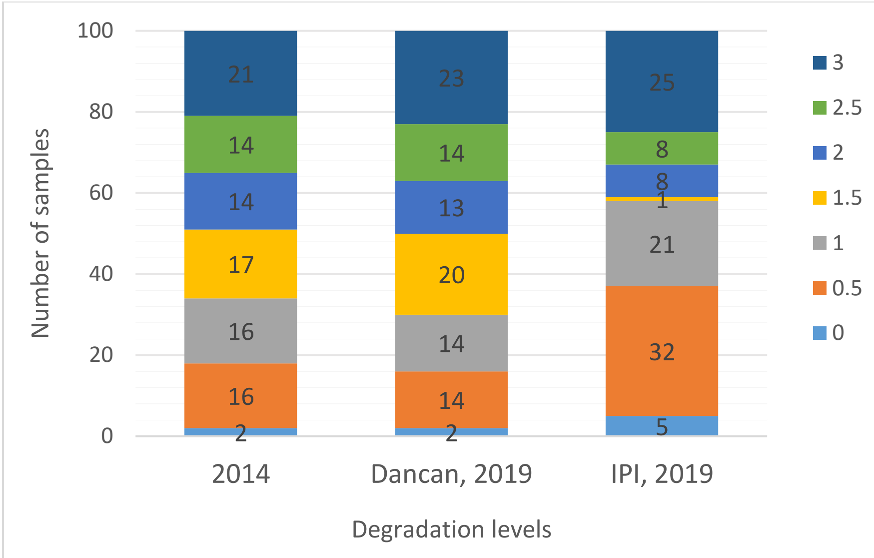

Figure 26 - Degradation levels measured with Dancan and IPI indicator strips

5.2. Hardness measurements

Aiming at proposing new, reliable and low-cost tools for assessment of film collections, hardness measurements were performed to verify if the decrease of mechanical properties occurred. It was also aimed to find if the decay of hardness could be correlated with the increase of the acidity level measured with AD strips. The technique requires to unwind the filmstrip, thus, displacement from the storage room, and therefore, only five samples of CTA reels were analyzed. The main objective was to understand if the technique was sensitive enough to provide conclusions in a future study. The five samples selected represented AD levels from 0.5 to 3.

At AD level 0.5, the hardness value measured at a core and an outside point are coincident, just as it occurred at AD level 1, at a central point and a core. The average hardness values represented a slight decrease along with the increasing AD level (Figure 27). Thus, it is possible to propose that the technique is adequate for measurement of physical decay, however, a much larger number of samples are necessary to gain representative results.

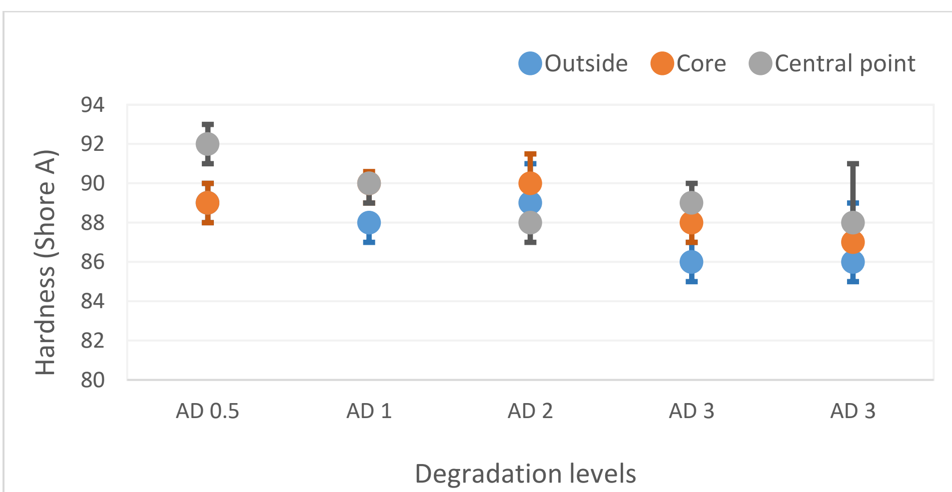

Figure 27 - Hardness measurement

5.3. Identification of film cans and their impact on film degradation

Along with macro identification, a survey of the material constituent of film cans was carried out. 21 different types of film cans were identified. Among the 100 samples, 91 were metal cans and 9 were plastic with different colors and shapes. The impact on the degradation of the films, however, could not be concluded. The statistical analyses based on the AD strip assessment identified both not degraded and highly degraded films inside plastic and metal cans (Appendix VIII, Figure 40). Moreover, it is important to say that the cans, plastic or metal, are not perforated as recommended in the literature. This fact allowed to discuss the macro assessment results with a high level of reliability since the free acidity levels measured correspond to every single film.

Conclusions

Storage conditions, regarding both micro- and macro environment, have a beneficial long-term effect on the life expectancy of motion picture films. However, in some situations, the implementation of storage conditions is not enough for the safeguard of film collections. In this study, that issue became even more clear when considering the treatment of the results obtained on past and present assessment of the safety film collection from ANIM. According to the results presented, the assessment of the collection with the acid-detection free acidity strips is a fast and reliable method for assessment and monitorization of safety film collections. As the results showed, the acid-detection free acidity strips allow detecting the decay of CTA and PET based-films. This work also allowed to understand that independently of the differences found between the two types of strips found, in the end both products showed similar results. Therefore, for this study, these products were considered reliable and effective. Nevertheless, proper storage and evaluation of the condition of the strips is recommended.

Regarding the different typologies of safety films, even though the different film bases (CTA and PET) are commonly stored together, according to the results accomplished it is proposed that a careful identification of the emulsion films should be performed since it allows to distinguish photographic emulsions and MAG tapes. The macro assessment of the samples selected for this study indicates that, independently of the number of films selected, MAG films with CTA and PET supports are more degraded than films with gelatin emulsion layer. This result is of particular importance since it contradicts what has been said about the stability of PET films. Additionally, this result also highlights the severe decay of CTA film supports in the presence of metal particles and, possibly, also due to the urethane layer of the MAG emulsion. Based on the results accomplished, it is proposed that the separation of MAG films may be beneficial for the entire stability of safety film collections. The results obtained with AD strip measurements revealed a high degradation rate of films with magnetic emulsion, suggesting that these films require different storage conditions as compared to films with photographic emulsion. Further studies are necessary to determine ideal storage conditions for MAG films. Due to the elevated rate of degradation, the preservation of MAG films, and especially MAG films on CTA support should be a priority. Moreover, at the second level of priorities, it is considered that with the separation of PET films, archives have the possibility to create a storage room that does not require as low temperatures as CTA films do, offering more cost-efficient storage. The assessment of film cans do not allow concluding if there are significative differences in the effect of plastic and metal can over the degradation rate. This result is in agreement with the literature (Bigourdan and Reilly, (30)). Nevertheless, the design of the film can may impact degradation, and therefore, open, ventilated cans are recommended for not degraded films (AD level 0-1.5) and closed film cans with molecular sieves are recommended for degraded films (AD level above 1.5). Additionally, the storage facility may be improved with monitored air quality and a datalogger that provides continuous monitorization of the environment.

It is believed that this study, performed on a perspective of the daily work of the archive, will contribute to the review of the current preservation practice of ANIM archives, as others, and for the implementation of new preservation strategies. Nevertheless, given the large number of films present in the collections and the lack of staff for the execution of the demanding tasks of preserving those, it is suggested future studies that involve the assessment of the safety b/w collection taking into consideration the above-detailed problematics. Adequate storage conditions for films with magnetic emulsion also need further analyses. A larger set of samples is necessary for obtaining conclusions about the impact of the age and brand, which may help prioritization of preservation processes.

References

1. Dupin, C. 2013, *The Origins of FIAF, 1936-1938.* [Online] [Accessed: 5 10, 2019.] https://www.fiafnet.org/pages/History/Origins-of-FIAF.html

2. Read, P., Meyer, M-P. *Restoration of motion picture film.* Oxford: Butterworth-Heinemann, 2000.

3. Adelstein, P. Z. *IPI Media Storage Quick Reference.* Rochester: Image Permanence Institute, 2004.

4. Reilly, J. M. *IPI Storage Guide for Acetate Film - Instructions for Using the Wheel, Graphs, and Table - Basic Strategy for Film Preservation.* Rochester: Image Permanence Institute.

5. del Amo Garcia, A. *Classificar para Preservar.* Instituto de la Cinematografía y de las Artes Audiovisuales, 2006.

6. Oliveira, L. M., Madeira, M. J., eds. *Cinemateca – 40 anos de actividade.* Cinemateca Portuguesa – Museu do Cinema, 1998.

7. Roldão, É. *A contribution for the preservation of cellulose esters black and white negatives.* PhD Thesis, Universidade NOVA de Lisboa, 2018.

8. Balser, K., Hoppe, L., Eicher, T., Wander, M., Astherimer, H-J., Steinmeier, H., Allen, J.M. Cellulose Esters. *Weinheim: Ullmann's Encyclopedia of Industrial Chemistry*, Wiley-VCR Verlag GmbH & Co. KGaA, 2012.

9. Silva, J. *Conservação de Negativos em Triacetato de Celulose.* MSc Thesis, Universidade NOVA de Lisboa, 2009.

10. Fischer, M.C., Robb, A. *Guidelines for Care & Identification of Film-Base Photographic Materials.* Art Conservation Program, University of Delaware, Winterthur Museum, 1993.

11. Bell, D.T. *PET Film Artificial Weathering: The Action of Degradation Agents on Bulk and Surface Properties.* School of Chemical Engineering, University of Birmingham, 2015.

12. Cartaxo, Paulo. *Archivist, ANIM.* 12 03, 2018.

13. Components of magnetic tapes and their stability. *International Association of Sound and Audiovisual Archives.* [Online] [Accessed: 09 12, 2019.] https://www.iasa-web.org/tc05/22111-components-magnetic-tapes-and-their-stability.

14. Magnetic Tape. *International Association of Sound and Audiovisual Archives.* [Online] [Accessed: 09 12, 2019.] https://www.iasa-web.org/decay-polymers-information-storage-carriers/magnetic-tape.

15. Film Structure. *Kodak*. [Online] [Accessed: 07 15, 2019.] https://www.kodak.com/uploadedfiles/motion/US_plugins_acrobat_en_motion_newsletters_filmEss_04_How-film-makes-image.pdf.

16. Edge, M., Allen, N. S., Jewitt, T. S., Horie, C. V. 1989. Fundamental Aspects of the Degradation of Cellulose Triacetate Base Cinematograph Film. *Polymer Degradation and Stability*, 25:345-62.

17. Reilly, J. M., Bigourdan, J-L. *Environment and Enclosures in Film Preservation.* Image Permanence Institute; Rochester Institute of Technology, 1997.

18. Schilling, M., Bouchard, M., Khanjian, H., Learner, T., Phenix, A., Rivenc, R. 2010. Application of Chemical and Thermal Analysis Methods for Studying Cellulose Ester Plastics. *Accounts of Chemical Research,* 43(6):888-896.

19. Neves, A., Angelin, E.M., Roldão, É., Melo, M.J. 2018. New insights into the degradation mechanism of cellulose nitrate in cinematographic films by Raman microscopy. *Journal of Raman Spectroscopy*, 1-11.

20. Allen, N. S., Edge, M., Appleyard, J. H., Jewitt, T. S., Horie, C. V., Francis, D. 1987. Degradation of Historic Cellulose Triacetate Cinematographic Film: The Vinegar Syndrome. *Polymer Degradation and Stability*, 19:379-87.

21. Richardson, E., Truffa Giachet, M., Schilling, M., Learner, T. 2014. Assessing the physical stability of archival cellulose acetate films by monitoring plasticizer loss. *Polymer Degradation and Stability*, 107:231-36.

22. Kanuga, K. *Degradation of polyester film exposed to accelerated indoor damp heat aging.* St. Paul: IEEE Photovoltaic Specialists Conference, 2011.

23. Storage Suitability. *Filmcare.org.* [Online] [Accessed: 08 27, 2019.] https://www.filmcare.org/storage_categories.

24. Bromberg, N., Palin, H., Burke, L. Washington State Film Preservation Manual - Low-cost & No-cost Suggestions to Care for Your Film. [Online] [Accessed: 11 10, 2018.] https://www.lib.washington.edu/specialcollections/collections/film-preservation-manual/.

25. Allen, N. S., Edge, M., Appleyard, J. H., Jewitt, T. S.., Horie, C. V., Francis, D. 1988. Acid-catalysed degradation of historic cellulose triacetate, cinematographic film: influence of various film parameters. *Eur. Polym. J.* 24:707-12.

26. Messier, P. *Preserving Your Collection of Film-Based Photographic Negatives.* Conservators of Fine Arts and Material Culture, Rocky Mountain Conservation Center, 1993.

27. Nissen, D., Larsen, L., Christensen, T., Johnsen, J., eds. *Preserve then show.* Copenhagen: Danish Film Institute, 2002.

28. Allen, N.S., Edge, M., Appleyard, J.H., Jewitt, T.T., Horie, C.V. 1988. Degradation of Historic Cellulose Triacetate Cinematographic Film: Influence of Various Film Parameters and Prediction of Archival Life. *The Journal of Photographic Science*, 36:194-98.

29. Photo storage, display, & labeling materials - a guide to ISO 18902 "photo-safe" testing. *Image Permanence Institute.* [Online] [Accessed: 12 18, 2018.] https://www.imagepermanenceinstitute.org/webfm_send/851.

30. Bigourdan, J-L., Reilly, J. M. Effectiveness of Storage Conditions in Controlling the Vinegar Syndrome: Preservation Strategies for Acetate Base Motion-Picture Film Collections. [Online] [Accessed: 11 10, 2018.] https://www.imagepermanenceinstitute.org/webfm_send/307.

31. Storage Alternatives: Micro-environments vs Macro-environment. *Filmcare.org*, Image Permanence Institute [Online] [Accessed: 08 27, 2019.] filmcare.org/macromicro.

32. Molecular sieves help Eastman House protect its 20,000 title film archives. [Online] [Accessed: 10 19, 2019.]https://www.kodak.com/motion/support/people_and_planet/product_use/molecular_sieve/default.htm.

33. Despas, B., Fournier, J-L. *Guide de la conservation de films.* Commission Surérieure Technique de L'Image et du Son, 1995.

34. Machado, Rui. *Vice-President, ANIM.* 3 21, 2019.

35. Archives, International Federation of Film. Glossary of Technical Terms Full List. [Online] [Accessed: 8 14, 2018.] https://www.fiafnet.org/pages/E-Resources/Technical-Terms-Full-List.html#start.

36. Cinemateca Portuguesa - History. [Online] [Accessed: 10 21, 2018.] http://www.cinemateca.pt/Cinemateca/Historia.aspx.

37. Baptista, Tiago. *President, ANIM.* 7 24, 2019.

38. ISO Standards (International Organization for Standardization). [Online] [Accessed: 10 03, 2018.] https://www.iso.org/standards.html

39. Image Permanence Institute. [Online] [Accessed: 10 16, 2018.] https://www.imagepermanenceinstitute.org.

40. DANCAN - Danchek AD-Strips. [Online] [Accessed: 8 14, 2019.] https://dancan.dk/?page_id=1072.

Appendix

I. Type of film elements in the collection of ANIM

N	Negative Silent Film
NI	Negative Sound Film
NS	Negative Sound
IN	Internegative Silent Film
INI	Internegative Sound Film
INS	Internegative Sound
INSC	Internegative Synchronized film
IP	Interpositive Silent Film
IPI	Interpositive Sound Film
IPS	Interpositive Sound
IPSC	Interpositive Synchronized film
P	Copy of a Silent Film
P	Silent copy of a Sound Film
PSC	Copy of a Synchronized film
MAG	Magnetic sound
PS	Copy of an optical sound

II. Inventory form - Identification department, ANIM

Cinemateca Portuguesa - Museu do Cinema
Arquivo Nacional das Imagens em Movimento
SECTOR DE IDENTIFICAÇÃO

FICHA DE CADASTRO TÉCNICO [- - - /]

TÍTULO NA PELÍCULA ______________________________

TÍTULO DA OBRA ______________________________

TÍTULOS ALTERNATIVOS ______________________________

____

TÍTULO NAS LEGENDAS ______________________________

VERSÃO ______________________________

ANO ______________ PAÍS ORIGEM ______________________________

ORIGEM – [- - - /]

DURAÇÃO	METRAGEM	STOCK E ANO	PROCESSO PB/COR	PROCESSO SOM	A R

ESTATUTO - | MAT | ET | CVR | CV_ | OM |

ESTADO GERAL - | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

QUALIDADE PROJECÇÃO - | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

OBS.:

DATA: ___/___/_____ ASS: ______________________

III. Light transmission test results

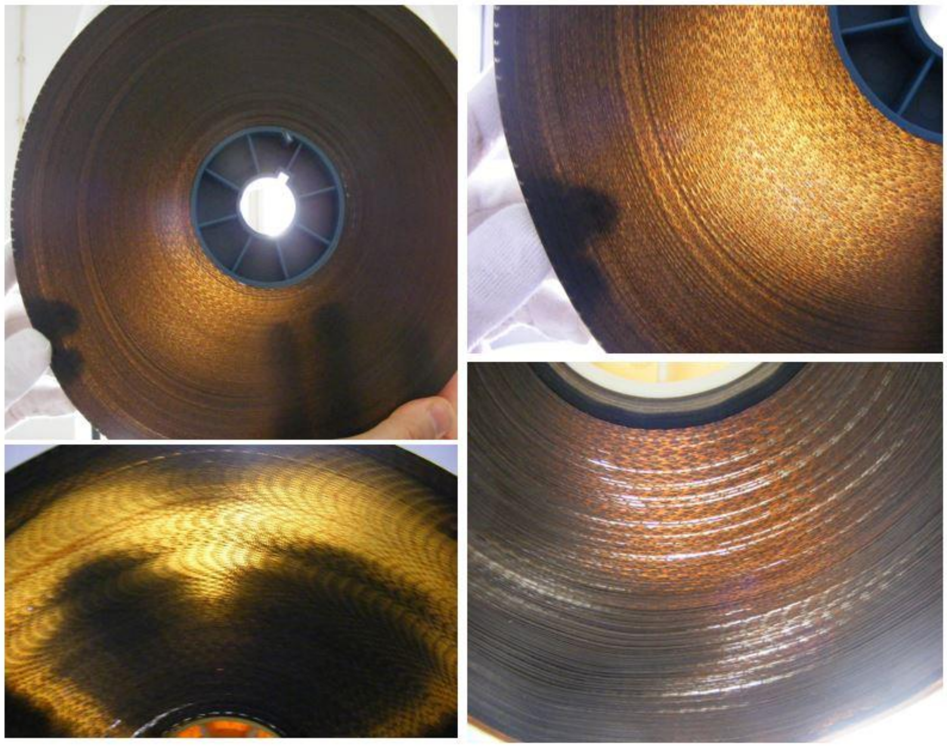

Figure 28 - Light transmission test: CA films © ANIM/ Credits: Teréz Somfai

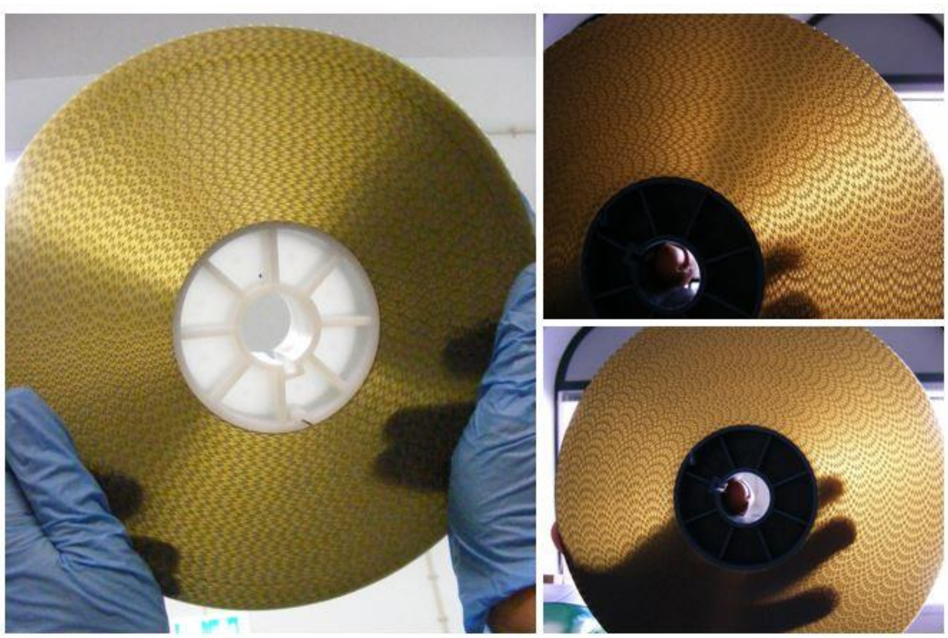

Figure 29 - Light transmission test: PET films © ANIM/ Credits: Teréz Somfai

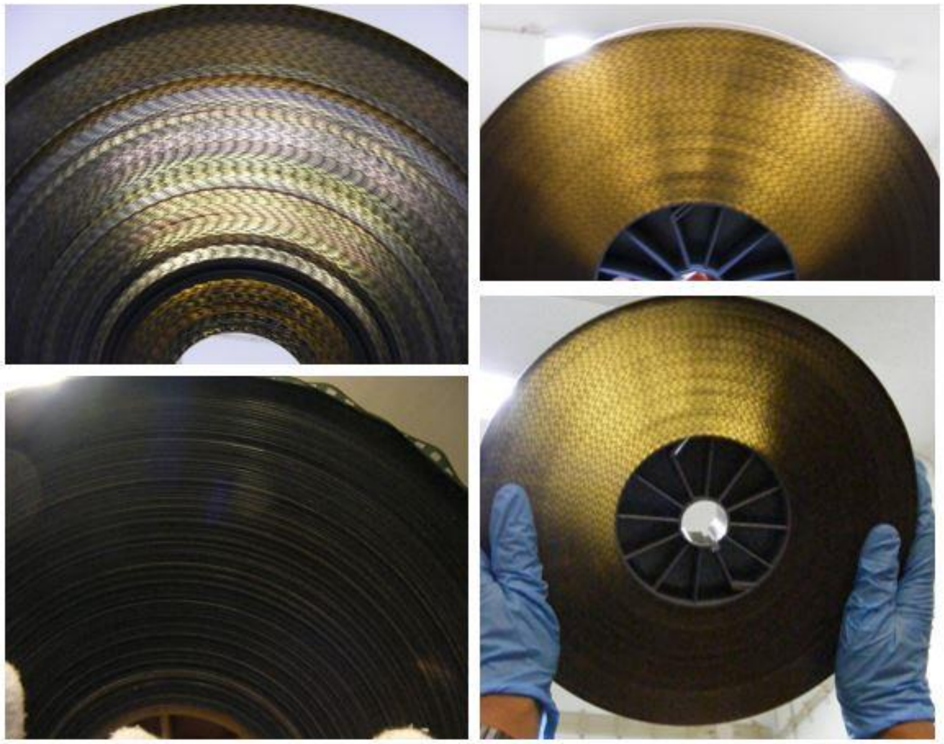

Figure 30 - Light transmission test: MAG on CA support © ANIM/Credits: Teréz Somfai

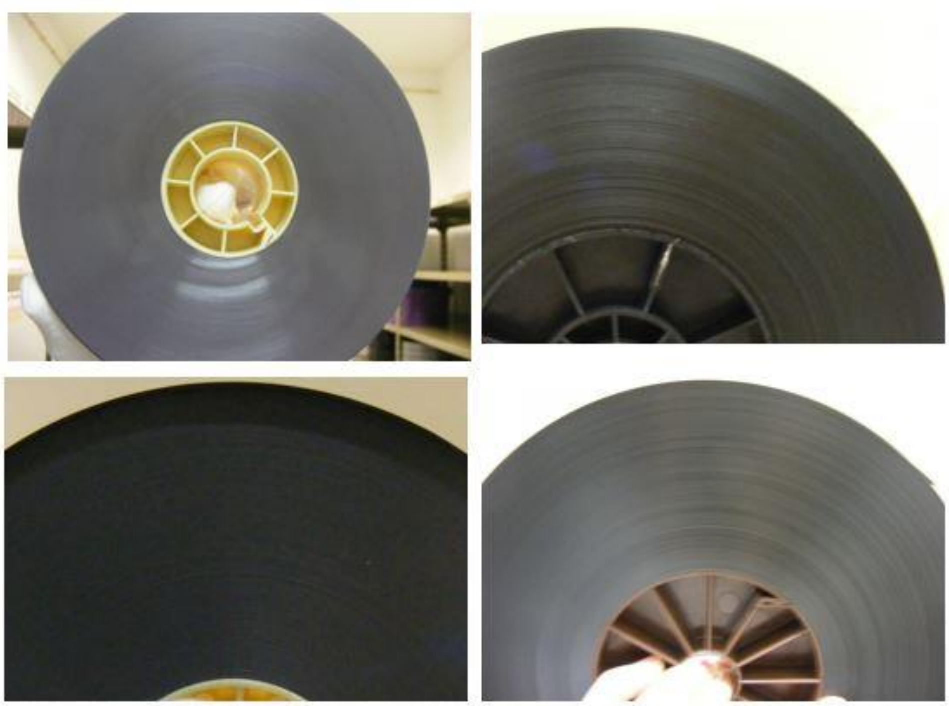

Figure 31 - Light transmission test: MAG on PET support © ANIM/Credits: Teréz Somfai

IV. Important ISO standards concerning Safety films

Table 5 - Most important ISO standards concerning film storage

ISO reference (38)	Title	Scope
ISO 18916:2007	Imaging materials — Processed imaging materials — **Photographic activity test for enclosure materials**	Advised materials for enclosure. Materials should be tested annually. Photographic activity test – the importance to determine chemical interactions between the enclosure and the photographic images.
ISO 18902:2013	Imaging materials — Processed imaging materials — **Albums, framing and storage materials**	"Photo-safe" enclosures are made of components that do not accelerate natural aging and pass criteria of the photographic activity test. Moreover: - Plastic enclosures: should not contain plasticizer, nor chlorine, nitrate or acetate. - Metallic packaging: must be non-corrosive and must not be covered with lacquer or enamel which may result in reactive gaseous products
ISO 18911:2010	Imaging materials — Processed safety photographic films — **Storage practices**	Recommended conditions in storage facilities, suggestions for proper handling and inspection. High temperature and humidity - the most important factors of degradation of support and emulsion. Ideal conditions that decrease degradation speed: - Low temperature - 20-50% RH - Monitored air quality → elimination of acids – with adsorbents Nitrate films should be separated from safety films.

V. AD strip and Danchek strip product information and restrictions

Table 6 - Properties of IPI's and Dancan's acid detector products

Property	**IPI (39)**	**Dancan (40)**
Size	1 x 4 cm	1 x 4 cm
Reference color scale	4 colors	7 colors
Package	Polyethylene bag inside of an aluminum-bag tightly sealed with tape.	Dark PE-LD Minigrip®
Storage conditions	Light sensitive. Must be stored in sealed plastic bags protected from air.	The indicator is expected to fade in an open environment
Expiry	1 year	No information
Required exposure time	Temperature-dependent. (detailed exposure guide in the manual)	24 hours on 20 degrees 2-3 days in cold condition
Placement of the strip	Direct contact with the films.	Direct contact with the films.

According to IPI, on room temperature, the response time is just 24 hours, whilst at a lower temperature more time is required. The color of the strip is homogeneous when the color change is complete. Strips are light-sensitive; therefore, a proper package is necessary to protect them from color fading. IPI sets up expiry date in 1 year, and brings attention to the following conditions that can influence results:[12]

- Strips must be used in a closed space
- Strips should be placed on the top of the film and not on the core (to ensure faster results)
- Appropriate both for picture and magnetic tracks, as far as the support is acetate
- The film mass (length of film) has very little influence on the results, response time might be slower in case of a smaller amount of sample
- The colored strip quickly regains blue color in a non-acidic environment, therefore, reading must be done immediately
- Although color pencil scale has 4 colors on it, IPI recommends the usage of 7 levels, counting intermediate levels as well (suggested levels of assessment: 0, 0.5, 1, 1.5, 2, 2.5, 3)
- Level 1.5 is the "autocatalytic" point, that indicates a seriously degrading film
- In cool storage conditions, assessments should be repeated in every 5 years

Special attention to the environment must be taken to prevent the volatile nature of acidity influencing results. In an open environment, if highly degraded films are present, stable films can show severe results.

[12] AD strips users manual, 1998.

Figure 32 - Placement of AD strips on a film reel © Teréz Somfai

Figure 33 - Packaging of Danchek strips (left) and IPI's AD strips (right) © Teréz Somfai

VI. Plan of ANIM's main building and the location of storage rooms

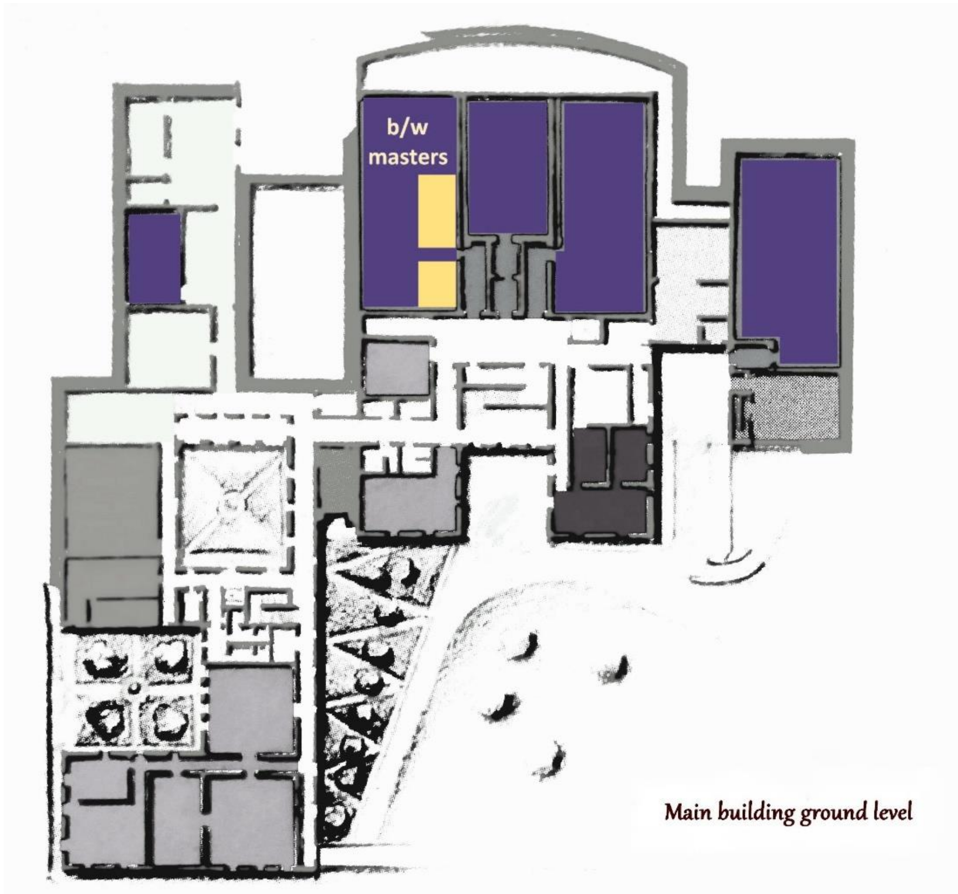

Figure 34 - Plan of ANIM's main building (Edited from Cinemateca Portuguesa, 1995. p.9.)

VII. Sample selection; distribution of the film stock regarding age and brand

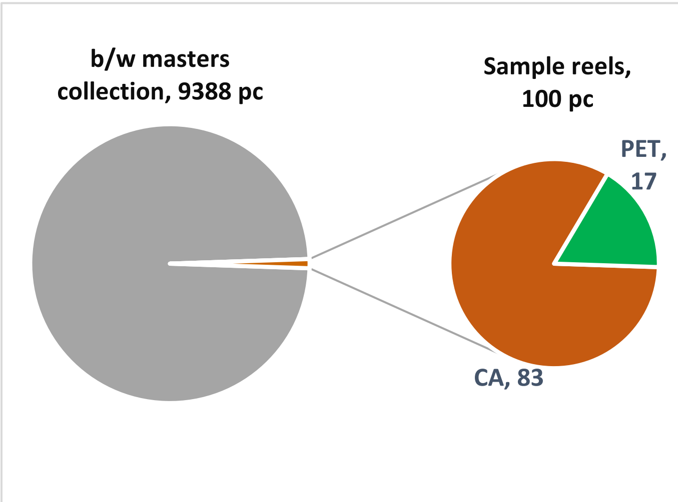

Figure 36 - Film supports present in the collection

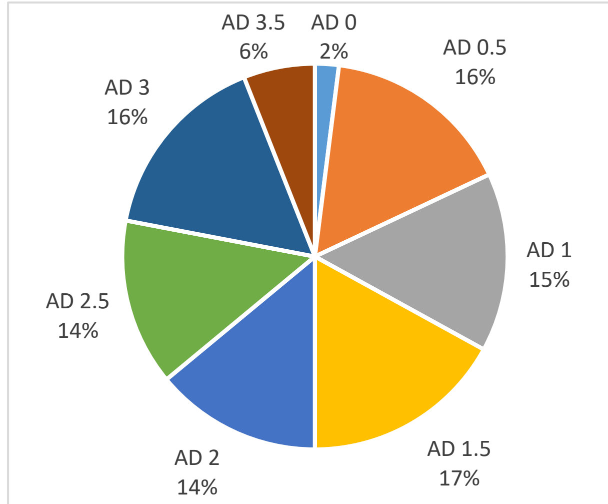

Figure 35 - Sample selection; Distribution of AD levels measured in 2014

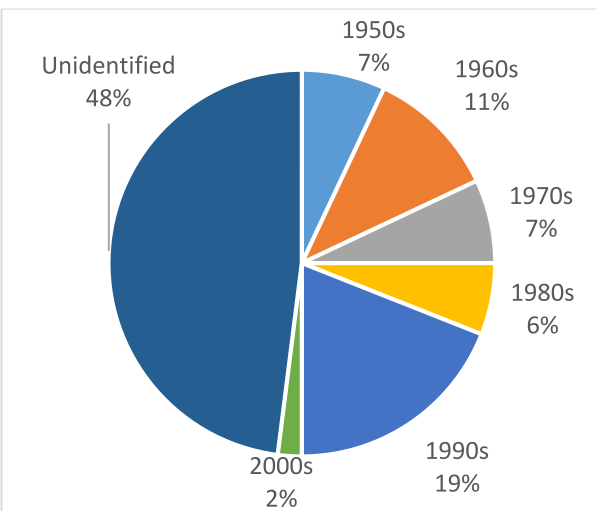

Figure 38 - Age distribution of the sample reels

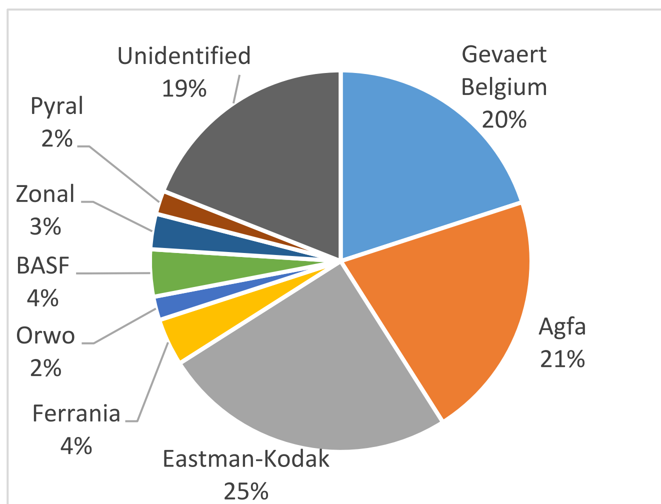

Figure 37 - Brand distribution of the samples

VIII. Assessment of film cans

Figure 39 – Overall view of film cans of the analyzed reels © Teréz Somfai

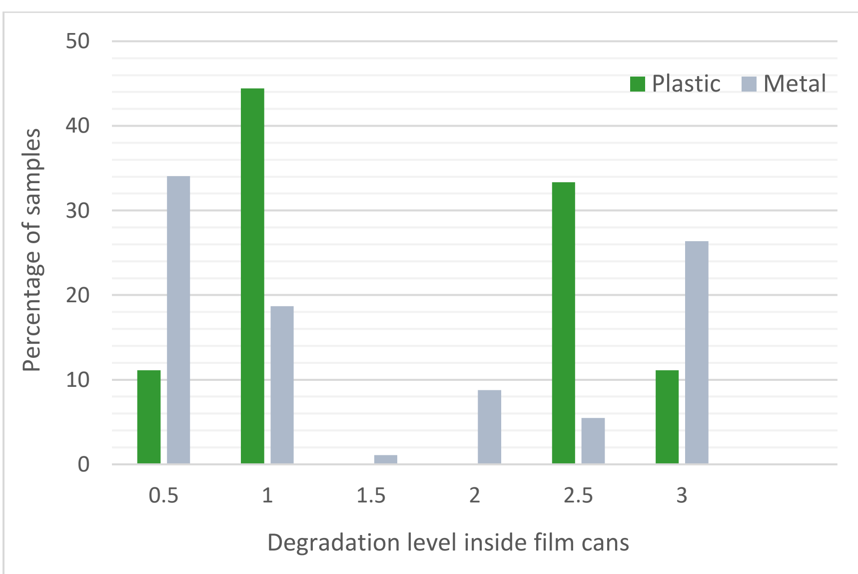

Figure 40 - Effect of the composition of film cans