

# Evaluating the stability of colour slides: 30 years of natural ageing at the National Museum of Denmark

Joana Silva<sup>1</sup>, Sille Juline Høgly Petersen<sup>1</sup>, Morten Ryhl-Svendsen<sup>1</sup>, Jesper Stub Johnsen<sup>2</sup>, Karen Brynjolf Pedersen<sup>3</sup>

<sup>1</sup> Royal Danish Academy - Conservation, Copenhagen, Denmark. [jsil@kglakademi.dk](mailto:jsil@kglakademi.dk),

<sup>2</sup> Viking Ship Museum, Roskilde, Denmark.

<sup>3</sup> National Museum of Denmark, Copenhagen, Denmark

Corresponding author: Joana Silva ([jsil@kglakademi.dk](mailto:jsil@kglakademi.dk))

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## ABSTRACT

In the 1990s, chromogenic reversal films (also known as colour slides) were a widespread medium to document objects from museum collections. At the same time, there was a growing awareness about the poor long-term stability of these materials due to the vulnerability of chromogenic dyes to relative humidity, temperature and light, as well as to other factors such as the quality of processing.

In this context, a study collection was created in 1992 at the National Museum of Denmark, with the aim of evaluating the stability of different brands and models of 35 mm colour slides used at that time. Six films were selected: i) Kodak Kodachrome (ISO 64); ii) Kodak Ektachrome (ISO 100); iii) Fuji Fujichrome Velvia (ISO 50); iv) Agfa Agfachrome RS 100 (ISO 100); v) Agfa Agfachrome 1000 RS (ISO 1000); vi) Polaroid Presentation Chrome (ISO 100). Different colour and neutral patches were exposed in the test slides to allow a proper understanding of the fading of the different dyes. After processing, the films were contaminated with three concentrations of fixer to simulate improper processing. A set of films was maintained untreated for comparison. The films (treated and untreated) were framed, stored in plastic folders, and placed in eight different locations at room temperature. A reference set was kept in a freezer at -21°C. To assess the fading and production of yellow stain in the samples, density measurements were carried out before ageing.

More than thirty years after the production of the study collection, the overall test slides were assessed once again, following the same methodology. Also, the climate of the locations where the slides have been kept was monitored. Despite the locations have presented some differences in temperature and relative humidity conditions, only two led to notable distinctive results: the reference set, with samples showing almost no changes, and location 6 (an office room) with high frequency fluctuations of relative humidity and slight exposure to light, leading to serious changes in the samples. From all chromogenic reversal films tested, Ektachrome was the most stable. No significant yellow stain was measured in any of the samples, and residual fixer did not prove to be an alarming problem in most cases. In general, some discrepancies were found between the present study (natural ageing test) and the literature (based on artificial ageing tests).

**KEYWORDS** colour slide; chromogenic reversal film; densitometry; natural ageing; colour change; fading

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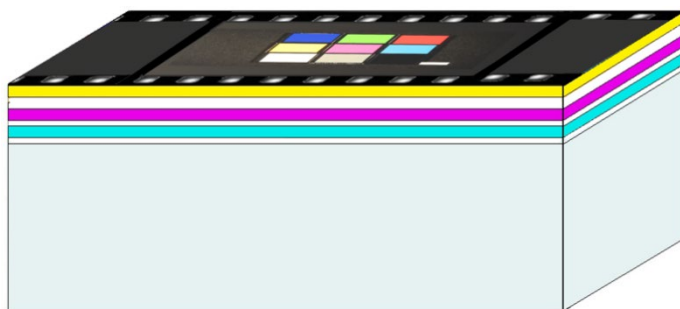
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## 1. Introduction

The first chromogenic photograph, Kodachrome, was launched in the 1935 by Kodak, and was a chromogenic reversal film (CRF). The process was based on colour couplers, molecules able to produce dyes during chemical processing. Colour couplers were gradually introduced during the development in separate baths (added colour couplers type), in a very complex and long processing. In 1936, Agfa disclosed Agfacolor Neu, another type of chromogenic material, also a CRF, with a similar but much simpler chemistry. The colour couplers were introduced in the emulsion during manufacture (integrated colour couplers type), and therefore, only one colour developing bath was needed. After Agfa's patents expired, other photographic industries (including Kodak, with the introduction of Ektachrome), started manufacturing this type of products. Therefore, most chromogenic materials are based on this technology (Pénichon, 2013).

CRFs are colour transparencies with a direct positive image. When mounted in a frame, prepared to be projected in a slide projector, they are commonly called colour slides. These materials were widely used in photojournalism, academia, art and had a variety of commercial applications (Weidner, 2013).

CRFs are complex multi-layered materials. After processing, they are composed of overlapping emulsion layers containing yellow (Y), magenta (M), and cyan (C) dye clouds in suspension in gelatine, supported by a plastic base (Fig. 1). In the integrated colour coupler type materials, the couplers that were not converted into dyes remain in the emulsion layer (Pénichon, 2013).



- yellow dye (blue sensitive layer)
- gelatine (interlayer)
- magenta dye (green sensitive layer)
- cyan dye (red sensitive layer)
- cellulose triacetate

Fig. 1. Schematic representation (not to scale) of the stratigraphic layers of a typical 35 mm chromogenic reversal film.

Chromogenic dyes, in general, are intrinsically unstable. These are highly susceptible to oxidation and hydrolysis both induced by relative humidity (RH) and temperature (T) - dark fading - and by radiation - light fading (Wilhelm

and Brower, 1993). The continuous contact with environmental agents gradually disrupts the chromophore structures of the dyes, leading to a gradual loss of colour and image detail (Reilly, 1998). Since each dye fades at a specific rate, depending on its molecular structure, these materials are prone to shift the original colour balance of the image. As previously referred, integrated coupler type materials have residual colour couplers in the emulsions that tend to oxidize and create yellowish degradation products, which also contribute to colour change (Bergthaller, 2002). Other factors can influence the ageing course, such as pollutants or residual chemicals from processing (Wilhelm and Brower, 1993). Thus, depending on the film type and on its history (processing, storage, usage, display), different degradation pathways can occur. Due to early signs of degradation, the industry was pressed to improve the stability of chromogenic products. In 1969, the American National Standards Institute (ANSI) started to develop standards for testing the stability of chromogenic materials to dark and light fading, based on artificial ageing tests and following the Arrhenius method. ANSI guidelines, and later those from International Standards Organization (ISO), were widely adopted by manufacturers, independent laboratories, researchers and conservators (Wilhelm and Brower, 1993). The experiments conducted with this method led to a deeper knowledge on chromogenic dyes' deterioration mechanisms, contributing to important improvements in the stability of these materials from the 1980s onwards (Reilly, 1998). Also as a result of these tests, recommendations for the preservation of chromogenic materials were disclosed. In general, these should be kept at very low T and RH conditions (i.e T= -10°C and RH=50%, or T= -3°C and RH=40%, or T=2°C and RH=30%) and in the dark, to extend their lifespan (ISO, 2000).

In the 1990s, while in widespread use, there was a raising awareness of the instability of chromogenic materials inside cultural institutions. In 1992, Jesper Stub Johnsen and Karen Brynjolf Pedersen, both conservators at the National Museum of Denmark (NMD) at that time, created a 35 mm colour slide study collection. In the NMD, colour slides were mostly used to document objects from the collections. Concerned about the permanence of CRFs, they gathered different available film types to study their natural ageing. They also decided to explore the presence of residual fixer, known to be an agent of deterioration. The colour slides were placed in different locations at the NMD. To monitor their degradation, they recorded the initial optical densities (OD) of the samples using a densitometer, as described in ANSI and ISO standards. In 2005, they re-measured some of the samples (Pedersen et al., 2005).

In 2024, the study collection was donated to the Royal Danish Academy - Institute of Conservation (RDA-IC), together with the records of the measurements made in 1992 and the densitometer. This paper presents the results of the colour slides' assessment after more than 30 years of natural ageing. The main goals of the present study were to measure OD variations, identify degradation pathways of the different film types in different storage conditions, check the influence of residual fixer in the degradation of the CRFs, and try to compare the obtained results with the literature.

## 2. Experimental

### 2.1. Samples preparation

The reference collection is composed of 6 different 35 mm CRFs from 1992: i) Kodak Kodachrome ISO 64, ii) Kodak Ektachrome ISO 100, iii) Fuji Fujichrome Velvia ISO 50, iv) Agfa Agfachrome RS 100 ISO 100, v) Agfa Agfachrome 1000 RS ISO 1000, and vi) Polaroid Presentation Chrome ISO 100. With exception of Kodachrome, the CRFs used in this study are from the integrated colour couplers type. The CRFs were gathered and prepared in 1992 as explained hereafter.

All CRFs were exposed to a colour checker. The films were processed in a commercial laboratory using E-6 processing (ColourLab, Copenhagen), except Kodachrome films that were sent to a Kodak laboratory (Dybendal, Taastrup) to be processed with K14.

A part of the samples was left untreated and the other was subjected to one of the following fixer baths with increasing concentration (Ilford F23:H<sub>2</sub>O): i) FIX I - 1:1000, ii) FIX II - 5:1000, iii) FIX III - 10:1000. The films were treated for 1 min in the respective fixer solution and then hung to dry.

Afterwards, the films were cut and framed in plastic mountings. 9 equal sets were prepared. Each set was originally composed of 96 samples, stored in 4 hard plastic folders for 24 slides: 1-untreated, 2-FIX I, 3-FIX II, and 4-FIX III. Each folder contained the 6 CRFs, with quadruplicates of each type of sample. Holes were drilled in the folders in front of each slide to enable direct contact of air with the samples. (Fig. 2).

A reference set was kept in a freezer, and the others were placed in 8 different locations, mainly at the National Museum in Brede and Copenhagen. The 7 sets that could be retrieved in 2024 are presented in Table 1 (section 3). The untreated samples from set 3, as well as 2 entire sets were lost. Set 3 has been in 2 different places.

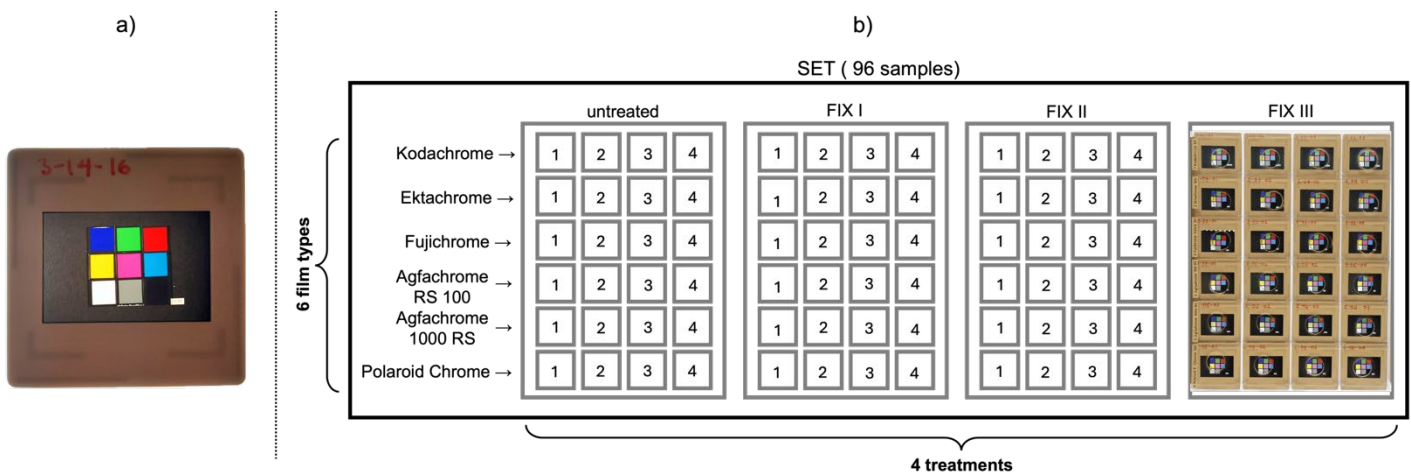


Fig. 2. Example of a colour slide (a) and a set of 96 colour slides (b), from the reference collection.

### 2.2. Photographic documentation

In 2024, the reference collection was documented, using a digital camera Canon EOS R with a Canon lens RF 24-105 mm, mounted on a reproduction column. The folders and colour slides individually were photographed with the same acquisition conditions (aperture and exposure time), over a light table (Kaiser slimlite plano) with T<sub>±</sub>5000 K.

### 2.3. Climate of the locations

Climate conditions of the different locations where the slides have been kept were monitored in 2024. T and RH

measurements were recorded every hour between mid-May and the end of August 2024, using dataloggers Tinytag Ultra 2.

### 2.4. Densitometry

In 2024, the OD of all the samples was registered resorting to the same methodology and densitometer used in 1992, Barbieri Electronic Densy 301 operating in transmittance (status A). The measuring aperture is 3 mm. To follow the fading of the dyes individually, primary colour patches in the colour checker were measured using the complementary coloured filter: Y patch using blue (B) filter,

M patch using green (G) filter, and C patch using red (R) filter. Neutral grey (N) patch, which is theoretically composed of similar proportions of the 3 dyes, was measured with the 3 filters (R, G, B). Finally, the white (W) patch was measured with the B filter, to estimate the production of Y stain. The other patches in the image were not contemplated in this study. Only 1 measurement was recorded for each patch considering that there are quadruplicates of each sample type. To ensure the validity of the measurements performed in 2024, the equipment was calibrated using its reference (standard 420B, status A), and adjusting each filter to the values measured in 1992.

The measured OD were recorded in a Microsoft Excel® datasheet and treated in Python. A Bayesian model was developed that assumes degradation (difference between the OD measured before and after ageing) follows a normal distribution, with a unique mean ( $\mu$ ) for each

patch/treatment/film/location combination and a standard deviation ( $\sigma$ ) that varies only by patch. The values obtained on the Y patch were  $D_{min}$  corrected, i.e. the value of the W patch was subtracted to the value of the Y patch, to discount the Y stain produced in that patch and better assess the Y fading (ISO, 2006).

### 3. Results and Discussion

#### 3.1. Visual observation and photographic documentation

By observing the samples with the naked eye and digital images, slight differences can be seen between the reference samples and those kept in regular climate conditions, for all film types. Figure 3 gathers some close-ups of the colour-checker recorded in the CRFs. Samples in location 6 show clear colour changes, particularly Kodachrome treated with FIX III.

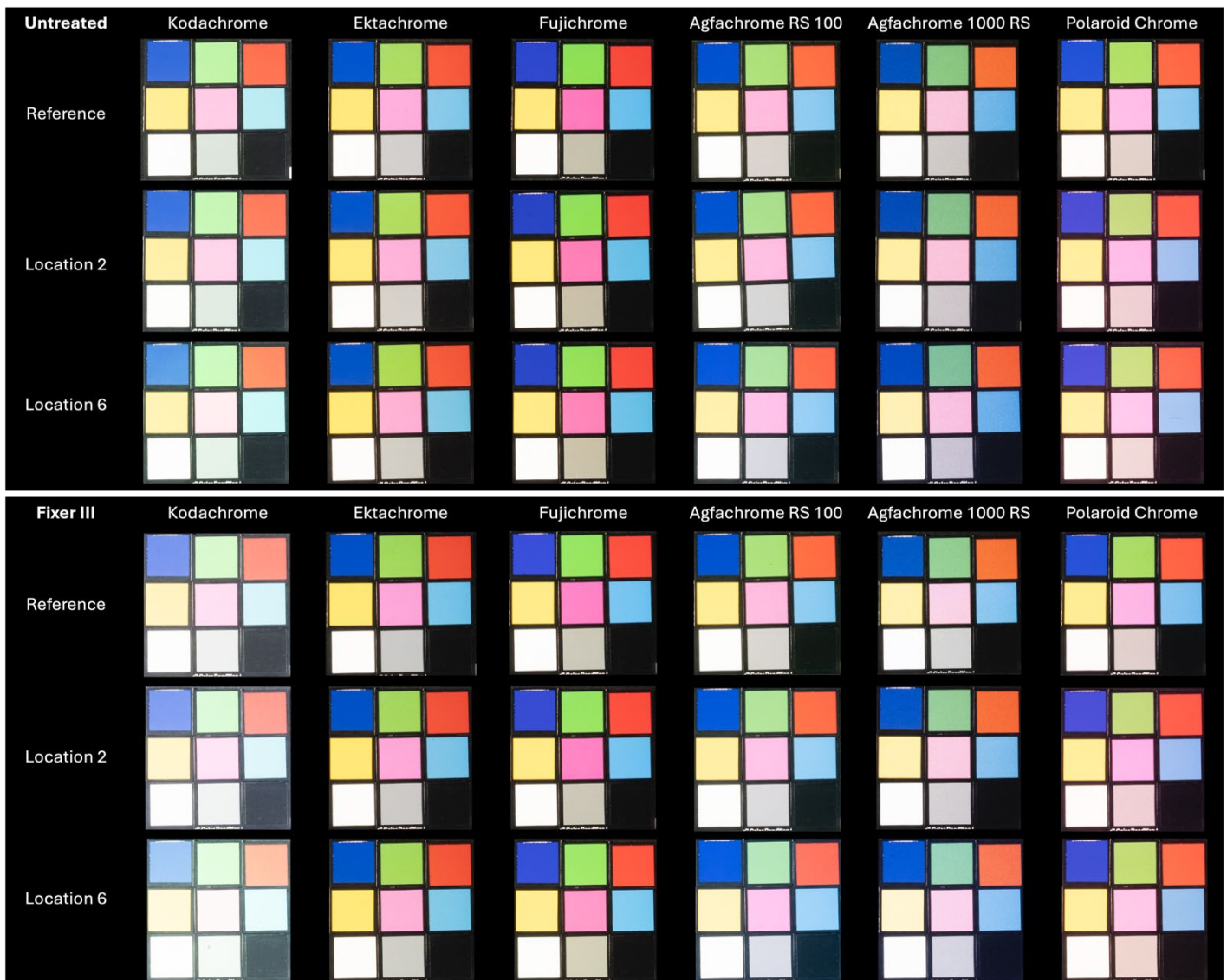


Fig. 3. Details of the colour checker recorded in the samples, for the different film types in the reference set and sets in location 2 and 6. Top: untreated samples; Bottom: treated with FIX III.

With the exception of the reference set, the first sample of each film type in each folder (first row of the folders) shows a more visible degradation than the other samples in the same line. The reason for this phenomenon is still unclear (microclimate, condensation, contamination by the adhesive on the spine of the folder?).

### 3.2. Climate in the different locations

Table 1 shows the T and RH values recorded with the dataloggers. Based on the analysed period, the T and RH values in the different locations were similar on average. The T averages ca. 24°C in most locations, being slightly higher in one of the storages of location 3. Regarding RH, more variation can be seen, ranging the average values

between 40 and 47%. The reference set was kept in a freezer at ca. T=-21°C and RH=46%. A calculation was applied to the data by combining both the amplitude of T and RH changes and their rates, to account for the cumulative stress on the materials. Higher values of this metric indicates more severe cycles of climate change (table 1).

Although these results only represent a small part of the year, it can be said that, in general, the storages present inappropriate T and RH values for this type of materials, that should be kept in a colder and drier climate (ISO, 2010). Nevertheless, it is expected that during the rest of the year, considering the Danish weather, T and RH reach more suitable values, especially during winter.

Location	Description	Temperature (T, °C)				Relative Humidity (RH, %)			
		min	max	average $\mu \pm \sigma$	$\Sigma( \Delta T  \times  \Delta T / \Delta t )$ °C <sup>2</sup> /h	min	max	average $\mu \pm \sigma$	$\Sigma( \Delta RH  \times  \Delta RH / \Delta t )$ % <sup>2</sup> /h
0 Reference (Brede), NMD	freezer	-33.4	-21.6	-21.3 ± 1.7	-	30.6	51.9	45.9 ± 5.3	-
1 Ship History Laboratory (Roskilde)	storage room, inside drawer in a metallic cabinet	21.7	25.7	24.0 ± 0.9	15.8	39.8	56.8	47.2 ± 3.7	82.2
2 Ethnographic Collection (Copenhagen), NMD	storage room, in open shelf	22.2	26.0	24.5 ± 1.0	0.7	42.3	48.4	46.3 ± 2.0	28.3
3 Near-east Antiquities (Copenhagen), NMD	office, in open wooden shelf servers room, inside wooden cabinet	20.8 23.2	27.7 28.8	24.8 ± 1.7 26.5 ± 1.3	21.1 4.3	27.4 28.8	57.5 51.3	42.1 ± 3.6 39.8 ± 4.1	1205.4 1119.1
4 Conservation Department (Brede), NMD	storage, inside drawer in a metallic cabinet	22.1	26.9	24.3 ± 1.1	15.3	28.2	63.0	44.7 ± 6.0	1301.0
5 Modern Times News (Copenhagen), NMD	storage, inside drawer in a metallic cabinet	21.3	26.9	24.7 ± 1.4	0.8	36.0	48.4	43.0 ± 2.9	52.7
6 Photo Conservation Office (Brede), NMD	office, in open wooden shelf	21.0	27.8	24.5 ± 1.4	20.5	38.1	57.3	45.4 ± 2.0	2145.4

Table 1. Temperature and relative humidity values measured between May and August 2024, in the different locations where the sets have been kept since 1992 (minimum, maximum, average and amplitude & rate of variation values)

Based on the thermohygroscopic measurements and data treatment, the locations were divided in 3 major groups with similar characteristics (excluding the reference set):

- 1st group (location 2, 5) in which the T and RH are stable during the overall measured period;
- 2nd group (locations 1, 3, 4) with fluctuations of RH and/or T, with quite high amplitude, sometimes within less than 24 hours;
- 3rd group (location 6) with high frequency oscillations of RH, also reaching high amplitudes within less than 24 hours.

### 3.3. Densitometry

A selection of densitometry results is presented hereafter. According to ISO standards for measuring image stability in colour photographs, ageing studies should be

performed in samples with colour patches having initial OD equal to 1 (ISO, 2006). However, as can be seen in table 2, in the present study different initial OD were obtained depending on the film types. For that reason, the densitometry results presented next are based on the absolute values instead of the percentage, as normally found in the literature.

Figures 4 to 7 show the estimates for  $\mu$  and  $\sigma$ , using the data measured in 1992 and 2024. Each graph represents the different patches measured with the respective filter, as explained in the section 2.4. Considering that the first row of the folders showed abnormally degraded samples, the OD measured on these were not considered. Thus, the OD from 2024 only considered 3 samples of each type. Our statistical model accounts for this limitation by modeling a specific  $\sigma$  for each difference and patch combination.

	Initial Optical Densities (average)				
	B filter	G filter	R filter	B filter	B filter G filter R filter
Kodachrome	1.12	0.94	1.47	0.26	0.68 0.68 0.86
Ektachrome	1.45	1.11	1.28	0.31	0.85 0.86 0.77
Fujichrome	1.56	1.43	1.49	0.30	1.01 0.94 0.88
Agfachrome RS 100	1.24	1.02	1.28	0.22	0.79 0.80 0.72
Agfachrome 1000 RS	1.09	0.94	1.45	0.25	0.88 0.90 0.83
Polaroid Chrome	1.26	0.95	1.22	0.29	0.77 0.96 0.63

Table 2. Initial optical densities of the 6 chromogenic reversal films (average) measured on the colour checker: Y patch with B filter, M patch with G filter, C patch with R filter, N patch with B filter, and W patch with R, G, B filter

As expected, no significant changes were measured in the reference samples kept in the freezer (Fig. 4). Nevertheless, very slight variations can be seen, particularly in Ektachrome, Fujichrome, and Agfachrome 100 films in the Y patch. It seems that T= -21°C was enough to greatly reduce the degradation rate of the dyes, although not completely stopping the chemical reactions (Lavédrine, 2003). No differences can be noted between untreated and treated samples. Considering that the combined permanence of chromogenic materials in controlled and non-controlled storage can drastically reduce their overall life expectancy, and that the samples were removed at least 2 times from the freezer for analysis (in 2005 and 2024), it is possible that the degradation was due to the time out of storage (Reilly, 1998; McCormick-Goodhart 1996).

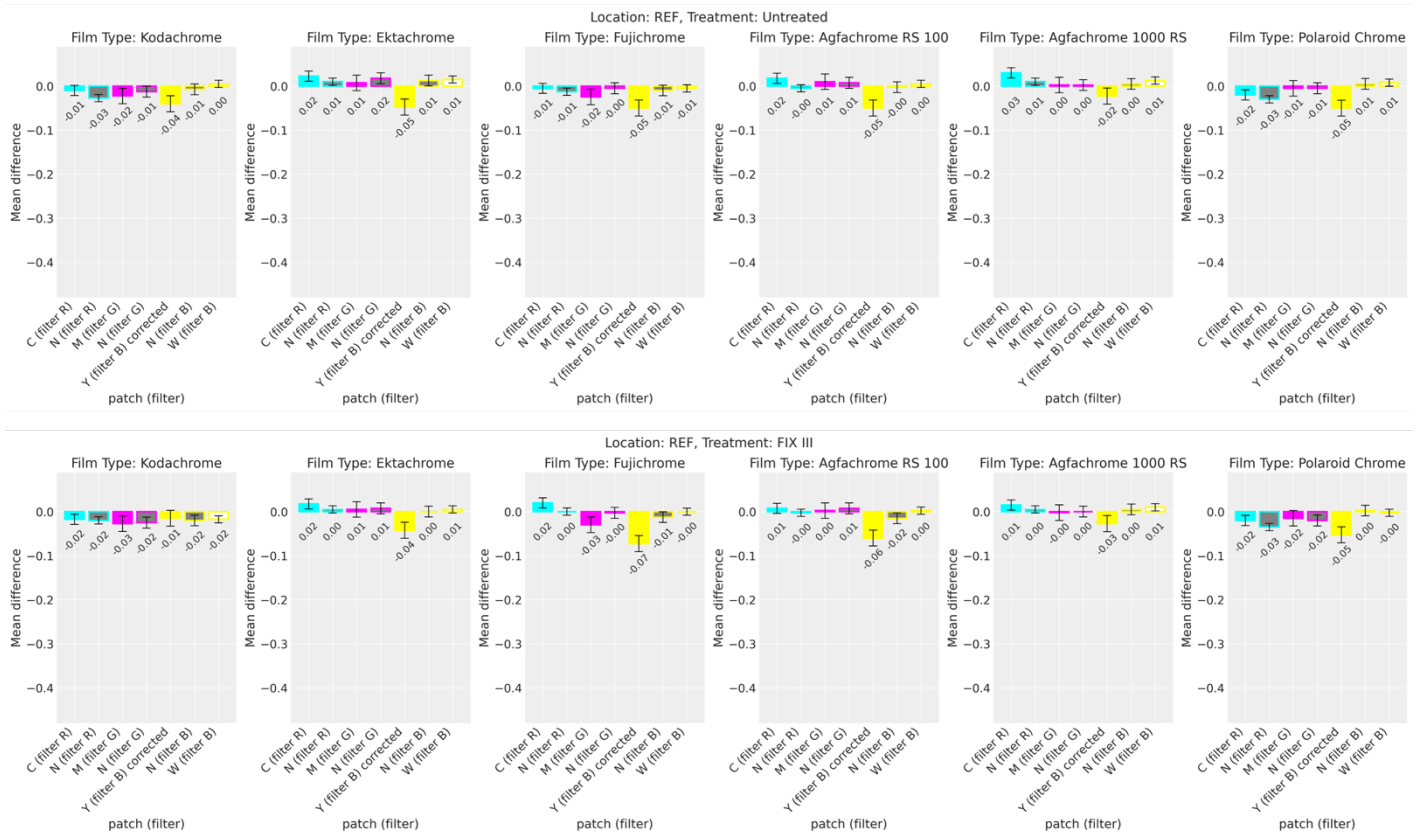


Fig. 4. Mean difference between the optical densities measured in 1992 and in 2024 (absolute values) in reference samples placed in the freezer, calculated in each different patch for each film type. Top: untreated samples; bottom: treated with FIX III.

In location 2, considered the most stable storage (1st group), variations between unaged and aged samples were observed (Fig. 5). Under this climate conditions, it can be stated that Kodachrome and Ektachrome are the most stable films. Depending on the film type, different degradation pathways are visible. In Kodachrome, M is the dye fading faster. In Ektachrome, Fujichrome and both Agfachrome, the limiting dye is Y. Polaroid Chrome shows the highest variations, being C the least stable dye, immediately followed by Y. It can also be noted that the dyes degraded faster in pure colour patches than in N patches. According to Wilhelm & Brower (1993), this could be due to the protective effect of the top layer, i.e the Y

layer on top could be absorbing some wavelengths that otherwise would be transmitted to the lower layers and degrade the M and C dyes.

Regarding the Y stain, that can be assessed by looking at the W patches, it is basically negligible. As expected, Kodachrome, from the added colour coupler type, does not show any Y stain due to the absence of residual colour couplers responsible for the formation of yellowish degradation products (Wilhelm and Brower, 1993). The samples treated with fixer do not seem to be more degraded than the untreated samples.

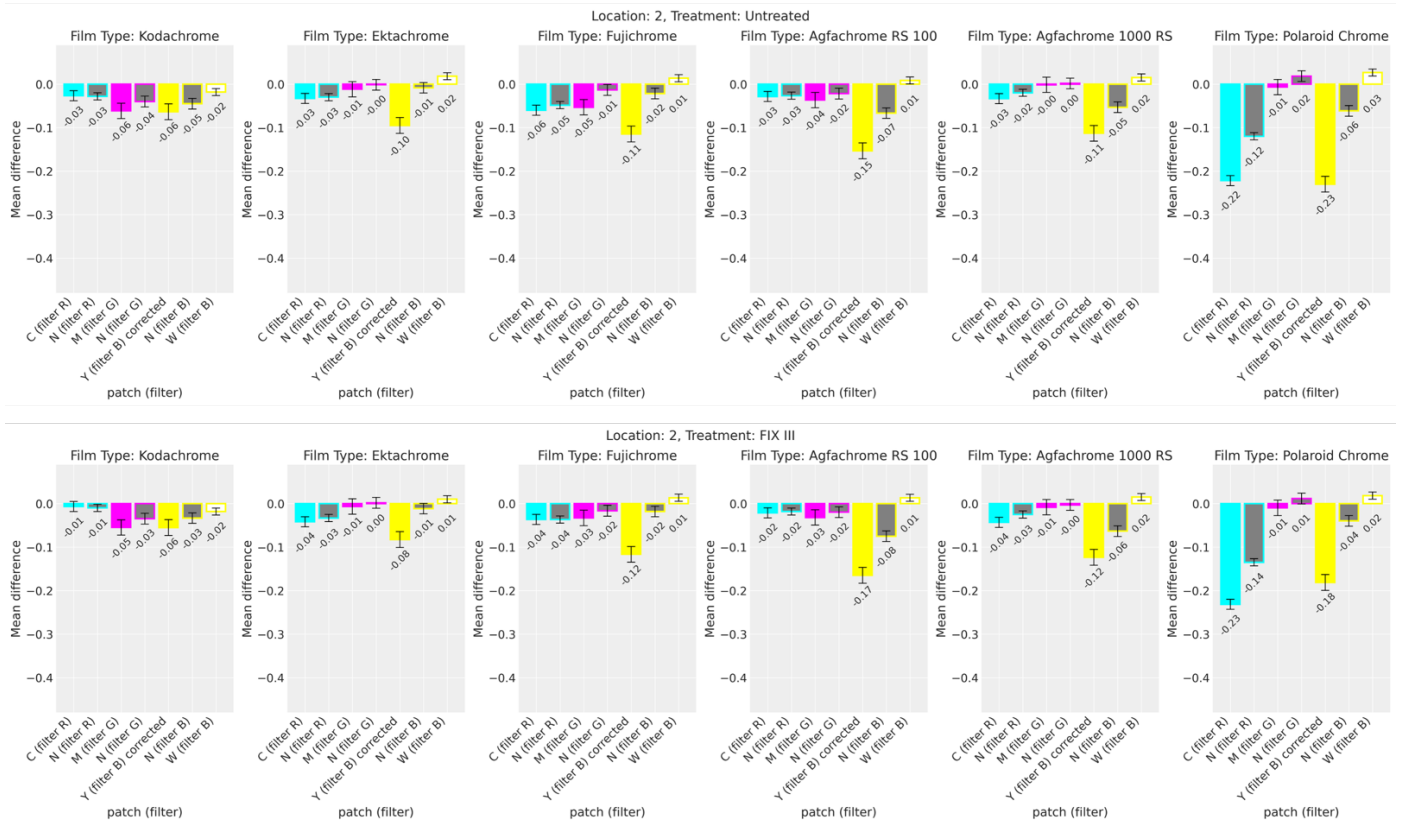


Fig. 5. Mean difference between the optical densities measured in 1992 and in 2024 (absolute values) in samples placed in location 2, calculated in each different patch for each film type. Top: untreated samples; bottom: treated with FIX III.

Figure 6 shows the results from location 4, representing the 2nd group of storages with regular T and RH fluctuations with high amplitude. Curiously, the results are similar to those obtained in location 2, with the same order of values. The same trends can be established, although in these locations Ektachrome can be considered the most stable film type.

Figure 7 shows the results from location 6, the one with high frequency fluctuations of RH (3rd group). In this location, a different tendency can be seen. In general, all the film types are more degraded, sometimes having doubled the levels of fading. Kodachrome clearly becomes

the least stable film type, but Ektachrome maintain its place as the most stable. A clear difference between untreated samples and samples treated with FIX III can also be seen, showing higher levels of degradation, especially for Kodachrome and Agfachrome RS 100. It also seems that for Ektachrome and Fujichrome, FIX III particularly affects the M dye, which turns as the limiting dye under these conditions. This general increase in the degradation of the CRFs can be a consequence of the high frequency of RH oscillations. Frequent cycles of T and RH fluctuations are known to cause physical stress in the materials (McCormick-Goodhart, 1996; Lavédrine, 2003), and this might also have a negative impact on the stability

of chromogenic dyes. Considering that this set was not stored inside any drawer or cabinet, the acclimation of the slides to the environment would be facilitated, thus increasing the number of acclimation cycles (Lavédrine, 2003). Another hypothesis for these results is the contribution of light fading summing to dark fading, considering that this set has been kept in an open shelf close to a window. Although there was no direct sun over the samples, it is possible that some light was reaching the interior of the transparent folders, especially those placed on top, as is the case of Kodachrome. According to Wilhelm and Brower (1993), Kodachrome is by far the least stable CRF in relation to light fading, being M the limiting dye under projector fading conditions.

Although the results obtained for films treated with FIX II were not presented here, in some cases those samples were in better conditions than those treated with FIX I and sometimes even those untreated. For the moment, no plausible explanation was found.

One of the goals of this work was to compare the obtained results with previous studies, all based on artificial ageing tests. The results were mainly compared with the book by the independent researchers Henry Wilhelm and Carol

Brower (1993), since they compiled artificial ageing tests conducted to different CRFs by themselves and by the industry, in the 1990s. This task revealed to be harder than expected, because each author conducted experiments using different ageing conditions and disclosed the results in different formats. Nevertheless, some discrepancies were found. According to Wilhelm and Brower (1993), Kodachrome is the most stable CRF by far in the dark. However, in the present study, Ektachrome was generally the most stable, and Kodachrome was clearly the least stable in location 6. According to the same authors, the stability (and limiting dyes) of the films under study should be: Kodachrome (Y) >>> Ektachrome (C) > Agfachrome 100 (Y) > Fujichrome (Y) > Polaroid Chrome (C); while in the present study, in most locations: Ektachrome (Y) > Kodachrome (M) > Fujichrome (Y) > Agfachrome 1000 RS (Y) > Agfachrome RS 100 (Y) > Polaroid Chrome (C).

Another interesting point is the high concern with Y stain in the book. The authors state that the most significant issue in E-6 films stability is the high levels of Y stain (Wilhelm and Brower, 1993). However, in this study, this clearly seems to be a minor issue.

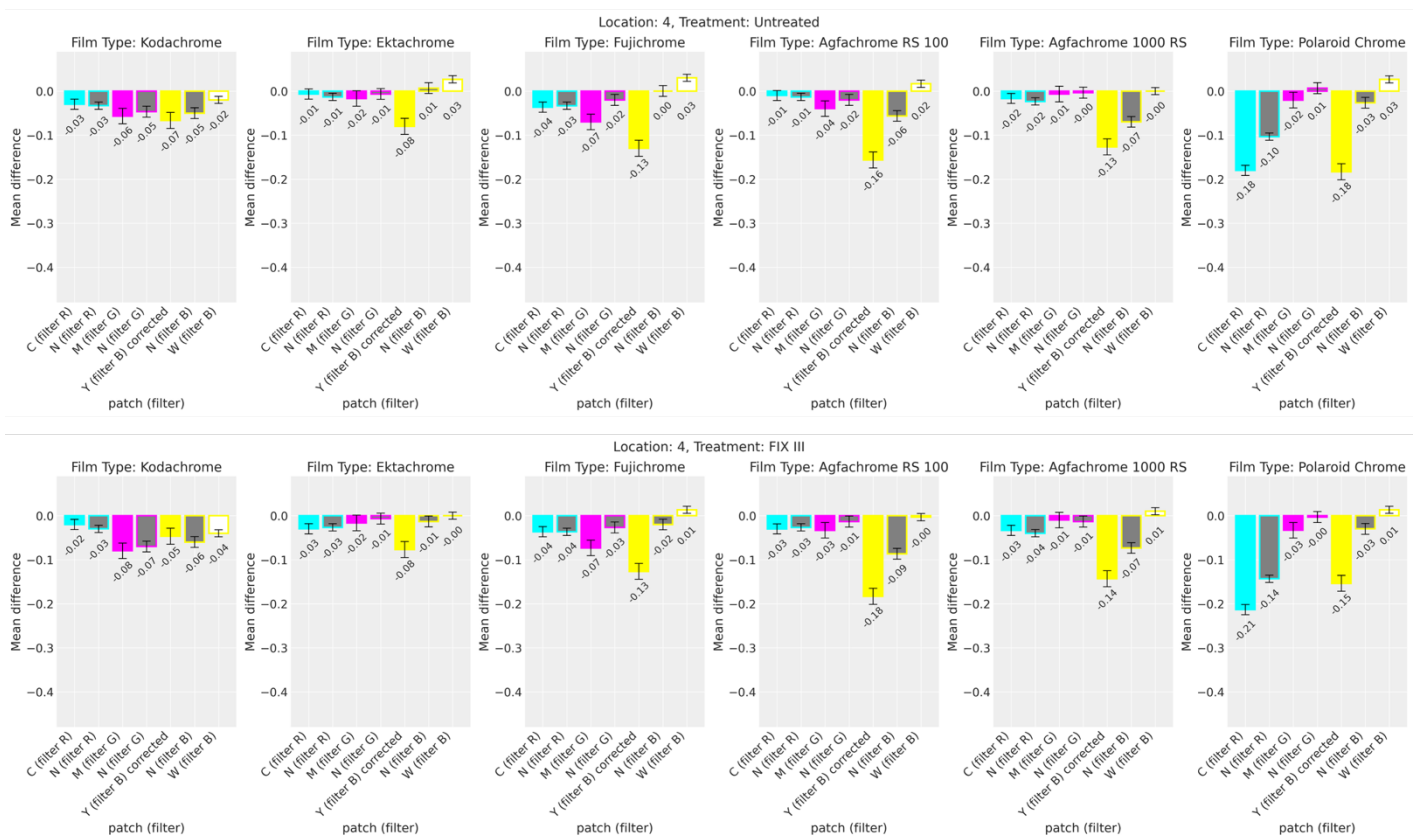


Fig. 6. Mean difference between the optical densities measured in 1992 and in 2024 (absolute values) in samples placed in location 4, calculated in each different patch for each film type. Top: untreated samples; bottom: treated with FIX III.

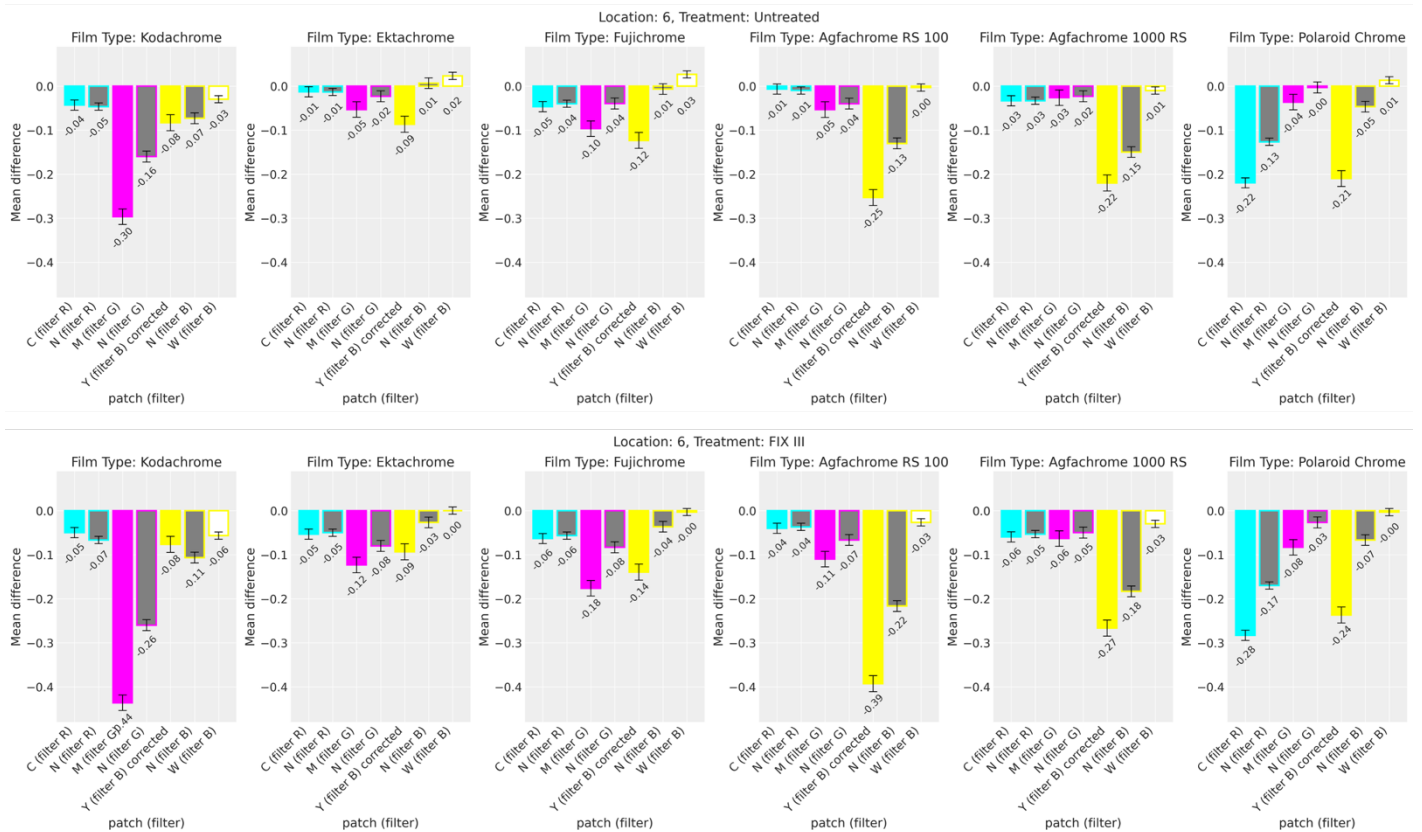


Fig. 7. Mean difference between the optical densities measured in 1992 and in 2024 (absolute values) in samples placed in location 6, calculated in each different patch for each film type. Top: untreated samples; bottom: treated with FIX III.

These discrepancies might be due to the fact that previous studies were based on artificially ageing experiments, while the outcomes of the present study results from naturally aged samples. According to the literature, predictions based on Arrhenius extrapolations can have a margin of error as high as 50% (Wilhelm and Brower, 1993). One possible reason for that error, might be that artificial ageing conditions are frequently conducted above glass transition T of the gelatine emulsion, leading to chemical and physical reactions that would not occur under normal climate conditions, and so, conducting to inaccurate results (McCormick-Goodhart, 1996; Adelstein *et al.*, 1997; Silva 2019).

#### 4. Conclusions

After more than thirty years of natural ageing in different locations, the slide collection was re-assessed using densitometry. Based on this study, the positive influence of freezing the CRFs can be highlighted. On the contrary, location 6 has clearly proved to gather inappropriate environmental conditions. This result can be associated to the high frequency of T and RH fluctuations and/or to light fading summing to dark fading. Interestingly, no significant differences could be established between the other

locations when analysing the densitometry measurements, although some present stable T and RH values while others high fluctuations of these values.

In terms of film type stability, in most locations Ektachrome > Kodachrome > Fujichrome > Agfachrome 1000 RS > Agfachrome RS 100 > Polaroid Chrome. In storage 6, the order changes slightly, being Ektachrome the more stable, and Kodachrome clearly the more unstable.

In most cases, Y dye is the limiting dye, except for Kodachrome (M) and Polaroid Chrome (C, although Y also high).

Another surprising result was the low levels of Y stain measured in all samples. Also, the influence of residual fixer does not seem to be a major problem, except in location 6 and particularly affecting M dye.

When compared with the literature, the obtained results suggest that there may be significant differences between studies carried out with natural or artificial ageing.

In the future, the sets will be placed back in their locations to continue the natural ageing experiment. The environmental conditions of the locations will also be monitored to complete at least a full year of measurements, in order to have a better understanding of the different storage conditions.

## 5. Conflict of interest declaration

The authors declare that no competing interests exist.

## 6. Funding source declaration

This research started in 1992 at the National Museum of Denmark, that founded the initial project. Currently the slide collection is part of the Royal Danish Academy. The present study did not receive any specific grant from funding agencies.

## 7. Acknowledgment

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## 8. Short biography of the author(s)

**Joana Silva** has a BSc and MSc in Conservation and Restauration, with specialization in photography at NOVA. Her PhD (NOVA) was based on the photographic and film collection by the artist Ângelo de Sousa, specifically on the preservation of his slide-based artworks. Ever since, she has been studying colour photographs, especially chromogenic reversal films. She is now Assistant Professor (RDA).

**Sille Juline Høgly Petersen** has a BSc and MSc in Conservation and Restauration at RDA, with specialization in Graphics. She has been working as a freelance conservator in different cultural institutions in Denmark. She also been teaching/research assistant at RDA. Colour photography is one of her main areas of interest.

**Morten Ryhl-Svendsen** has a BSc, MSc, and PhD in Conservation and Restauration, with specialization in preventive conservation. He is Associate Professor and Head of the Master's Program in Conservation at RDA. Main areas of research are the impact of air pollution on heritage materials, and the climate control, energy use, and sustainability of museum buildings.

**Jesper Stub Johnsen** has a BSc and MSc in Conservation and Restauration at RDA, with specialization in Photographs. He has a PhD from Gotenbourg University. He also have a Master of Public Administration from Copenhagen Business School. He has been leading different danish cultural institutions and is currently Head of Research and Collections at the Viking Ship Museum.

**Karen Brynjolf Pedersen** has a Bsc of Paper and Photographic Conservation and 27 years of experience in this field. Simultaneous tasks have been as a project

leader of various exhibitions, conferences, storage of museums objects etc. Since 2019 she has been working as a Registrar with loans in and out of the National Museum of Denmark.

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