Presented at the Electronic Media Group Session, AIC 40th Annual Meeting, May 8–11, 2012, Albuquerque, NM.

FADING OUT: THE END OF 35 MM SLIDE TRANSPARENCIES

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ABSTRACT

This paper reflects on the challenges facing conservators dealing with the preservation and display of slide-based works in fine art collections following the discontinuation of the last remaining slide duplicating stock, Kodak Edupe, in March 2010, and the imminent demise of this analog technology. This paper explores the strategies currently available to conservators and the rapidly decreasing timeframe in which action will need to be taken.

INTRODUCTION

There are moments in the history of conservation when objects are radically altered in order to preserve what was most valued at that time. For example painted surfaces from panel paintings have in the past been stripped from their wooden support and re-adhered to canvas. The arguments justifying these decisions undoubtedly appeared compelling at the time, only to become highly controversial centuries later.

Within time-based media conservation, we are faced with a radical shift in technology as commercial support for 35 mm slides ceases. In this paper I explore how, as conservators, we might respond to, and plan for, this significant change in the technology underpinning slide-based artworks in our collections. Unlike the decisions made to remove painted surfaces from panel paintings, the decision to change the underlying technological support of 35 mm slide-based artworks is not motivated by the desire to prevent damage, but rather has become the only way in which we can continue to display these works. Of course, it is hard not to wonder if the decisions we make now about this body of work will in hindsight seem as contentious and misguided as those who feel passionately about the decisions made in the past about the treatment of panel paintings. However, at this time as we live on the cusp of this shift to the digital, we are fortunate in be able to work with the artists involved, to explore ways of managing these changes in order to attempt to secure the continued display of these works whilst we understand both analog and digital technologies. In this emerging territory the conservator's role is to function as a diplomat: mediating between the museum, the artwork, the artist, and a distributed network of experts. The most important aspect of this role is to help build understanding and trust.

This paper follows the journey within time-based media conservation at Tate from 2007 to the present day. Recognizing the slow demise of slide technology, during this period we have

1. learned how to duplicate analog slides ourselves;
2. explored the possibility of producing slide duplicating stock as a niche product;
3. reached out to a broader community to identify centers of excellence in the field of slide digitization outside the field of fine art conservation; and
4. developed a course of action for the preservation of slide-based artworks in our care.

THE 35 MM SLIDE MEDIUM

"Slide" commonly refers to a 35 mm photographic positive image comprising chromogenic dyes on a transparent base held inside a plastic or card mount. Without this mount, the transparent film material would not be able to "slide" from one image to another inside a carousel or magazine when projected. In contrast to negative-based film, reversal film is photo-chemically processed as a positive image. In most Romance languages *slide* is translated as *diapositive: dia* [Gr.] (through, between). *Transparent* breaks down into *trans* [Lat.] (beyond, across) and *parere* [Lat.] (to appear, be visible, be seen, etc.). All three terms: *slide*, *transparency* and *dia* describe an ephemeral presence, a state in which a picture is formed, lasts, and disappears (Bauer 2000).

The 35 mm slide transparency is a hybrid medium that belongs on a continuum between still photography and motion-picture film and combines qualities of both technologies. A slide is a high-resolution positive photograph that is exemplary in its accurate color reproduction and versatility. A 35 mm slide can be magnified by a factor of 100 (from 35 mm to 3,500 mm) and still maintain a crisp and detailed projected image.

Kodak's commercial slogan during the 1950s was: "For sparkling pictures big as life. . . . Kodak 35 mm color slides" (Life 1958, 68) (fig. 1). During the 35 years of their popularity, from 1960s to the mid-1990s, 35 mm slides were a cheap and easy way to create high-quality projected images in a technological environment that offered few, if any, viable alternatives. Even if money were no object, no other medium could compete with the ability of slides to produce large-scale projected images of comparable excellence. Video technology, for example, could only produce a fraction of the quality. Alternative technologies such as 16 mm film involved a far more elaborate production process. The only other format that was readily available on a similar budget, without the need of professional post-production, was 8 mm film

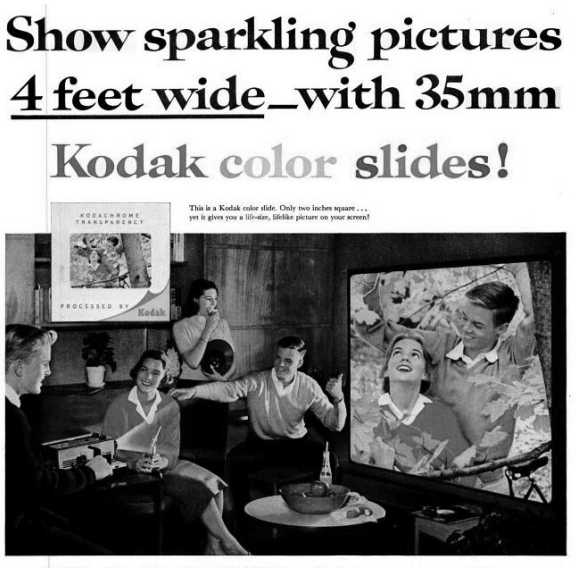

Fig. 1. Kodak Advertisement in *LIFE*, October 5, 1959, p. 68.

produced for the home movie market. Both 16 mm and 8 mm film are moving image media and hence produce a very different quality of image.

In its heyday, processing costs for slides were relatively low and they were widely used in contexts ranging from domestic to commercial applications such as advertising, fashion, and industry as well as academia and the arts.

Many art historians still refer to slide-based artworks as *slide-tape*. This term dates from the 1970s when magnetic audio tapes in cassette format were used to store a tone that cued slide changes alongside the audio track or spoken word accompanying the images.

Artists began to explore media technologies in the early 1960s, a period which coincided with a radical shift in artist practice. Artists have both exploited slide technologies as a precise aesthetic medium and as a means of documenting more conceptual practice. C Harrison, in his paper, Saving Images, has also argued that slides suited the artistic debates of the period because they provided a means of creating sequences of images that were not object-based.

> Slides, of course, offered a virtually infinite range of cheap pictures, easily accumulated. Their small size meant that they could be readily manipulated, while their transparency meant that they could be enlarged to the typical scale of paintings without the imposition of a lot of physical material. (Harrison 2005, 35–48)

Slides had a "technical innocence," having little history as an artistic medium but instead a practical association with documentation (Harrison 2005, 39).

Slides were used to capture performances, journeys, and the lives of artists, as evidenced in works created by Nan Goldin (b. 1953), Robert Smithson (1936–1973), Lothar Baumgarten (b. 1944), David Tremlett (b. 1945) or Paul McCarthy (b. 1945). Artists such as Dan Graham (b. 1942) and Robert Smithson freely worked across media using the same set of images in slide projections, printed photographs that were framed and hung on a gallery wall, and print media in catalogs or magazines.

The use of slides to tell stories, in both simple and technically sophisticated, straightforward, and ambiguous ways, has been exploited in the works of David Lamelas (b. 1946) and James Coleman (b. 1941) either in creating simple sequences of images or complex dissolves with audio accompaniment. Many of these early adopters and also a later generation of artists such as Armando Andrade Tudela (b. 1975) and Hilary Lloyd (b. 1964) used slides to create and display visually rich and beautiful images, exploiting the high-resolution photographic quality offered by the medium.

It may also be the case that in recent years artists have been drawn to this technology for the very reason that it is on the brink of obsolescence:

> Today, no exhibition is complete without some form of bulky, obsolete technol-

> ogy—the gently clunking carousel of a slide projector or the whirring of an 8 mm or 16 mm film reel. The sudden attraction of "old media" for contemporary artists in the late 1990s coincided with the rise of "new media," particularly the introduction of the DVD in 1997. (Bishop 2012, 2)

While artists value the experience of the apparatus of slide technology to a greater or lesser degree, the position of the slide projector on a pedestal and the sound it creates when the slides change is tightly interwoven with our experience of these works. Though we appreciate that the equipment associated with slide technology possesses a sculptural presence, this is often entirely unintended and is simply a consequence of using this technology. Nevertheless, the carousel slide projector has become an iconic object and the distinction between the apparatus of 35 mm slide projection and a digital projection is therefore significant (fig. 2).

Fig. 2. Installation view of Ceal Floyer, *Light Switch*, 1992–9, 35 mm projected color slide, acc. no. T11811. © Ceal Floyer. Courtesy of Lisson Gallery, London.

MANAGING THE REALITY OF OBSOLESCENCE

The history of artists using 35 mm slide technology as an integral part of their artworks is relatively recent and as with all technology-based works these works face significant problems related to the obsolescence of the technology upon which they depend. Whilst this may have been understood, the significance of this fact was largely theoretical until recently, whereas artists, curators, and conservators are now facing this as a stark reality. Despite the significance of the original technology to the this body of work, it is clear that in the future alternative modes of display will have to be found and agreed upon between the artists and curators involved.

There might be artworks for which these alternatives fall short of the artist's conception, in which case these artworks will no longer be displayable either temporarily or permanently. How to negotiate the future of these works in cases where no satisfactory alternative means of display can be found is largely unknown territory. One alternative may be to explore the representation of these artworks by documentation, a strategy not without its own challenges and complications.

There is little precedent for this situation within conservation and hence a lack of practical experience in planning for substantial shifts between technologies. There is little to guide us in how to judge the time available to lay the foundation for the necessary decisions and subsequent actions as these technologies fade. Technological obsolescence progresses in an irregular manner over many years and attempts to model this must take into consideration a combination of factors:

- The ability to duplicate 35 mm slides
- The availability of spare parts and consumables such as projector lamps and slide mounts
- The availability of equipment on the second-hand market once fabrication has stopped
- The availability of specialist knowledge to install, maintain, and repair the equipment involved
- The availability of a budget to pay for these services

There is a relatively short period of time available during which old and new technologies can be compared in

order to be able to make informed decisions about the best possible options for specific artworks. This window represents a time when the old technology is not yet entirely obsolete and the new one is already mature enough to provide a stable alternative. However, even if we recognize that now is the time to make these decisions, do we as a profession have a good enough understanding of 35 mm slide technology to make these judgments?

When slide technology was in vogue, conservators had only marginal dealings with these artworks as artists often directly oversaw the production of slide duplicates for the display of their works. While it may have been recognized that this situation was not ideal, conservators often did not have enough works in their care to have the opportunity to develop the expertise needed to be able to judge the quality of slide duplicates. Furthermore, access to the in-camera master is not usually available to the conservator for direct comparison between this and duplicate copies.

COLLECTING SLIDE-BASED WORKS

It is rare that the acquisition of a slide-based artwork into a fine art museum collection consists of unique in-camera originals as these works are usually sold as editions and the artist will typically retain the master slides. A common scenario is that museums will obtain a number of sets of slides that are first-generation duplicates from the in-camera original, with an additional clause in the artist's certificate that future copies should be requested from the artist. There is often an assumption that the museum will use the duplicates provided for display.

The quality of the slides that a museum receives varies. An artist such as James Coleman employs an archivist and his slides are tightly managed and kept under controlled environmental conditions. All of his images have been shot on identical slide stock using the same camera. The slide duplicates that form part of the acquisition are produced as three identical sets made at the same time, using the same stock and the same duplicating machine.

Works by other artists may be produced in a more ad hoc fashion and be created and stored under less strictly controlled conditions. It is not unknown for slides that form the artist's master set to have been used for display and to have faded or suffered damage. Duplicates taken from these for subsequent exhibitions are produced by different labs on different stock and it is from these slides that a selection is often made and given to the museum as part of the acquisition.

These very different scenarios may be indicative of the failings of a commercial gallery to understand what is involved in managing these works or the different artistic context in which these artworks were created. As touched upon earlier in this paper, in some cases slides may have been chosen by the artist as a precise aesthetic visual medium whereas in other cases they may have been used more as a tool for documentation, as in, for example, the context of conceptual art practices. When slides have been used more as a tool for documentation than as a precise aesthetic medium it is perhaps more common that the production and management of both the original master slides and their duplication has been less precisely managed.

Artist interviews are a standard tool of contemporary conservation practice. These interviews are formal moments in an ongoing dialogue between the artist and the museum that often continues for many years. The first interview is commonly conducted between conservators and the artist when a work comes into the collection, followed by the second interview at the point when the work is requested for display. During these interviews it is essential that the demise of 35 mm technology be discussed so that it is possible for conservators to work with these artists to understand more clearly the significance of slide technology to their works and to plan for the future of the work.

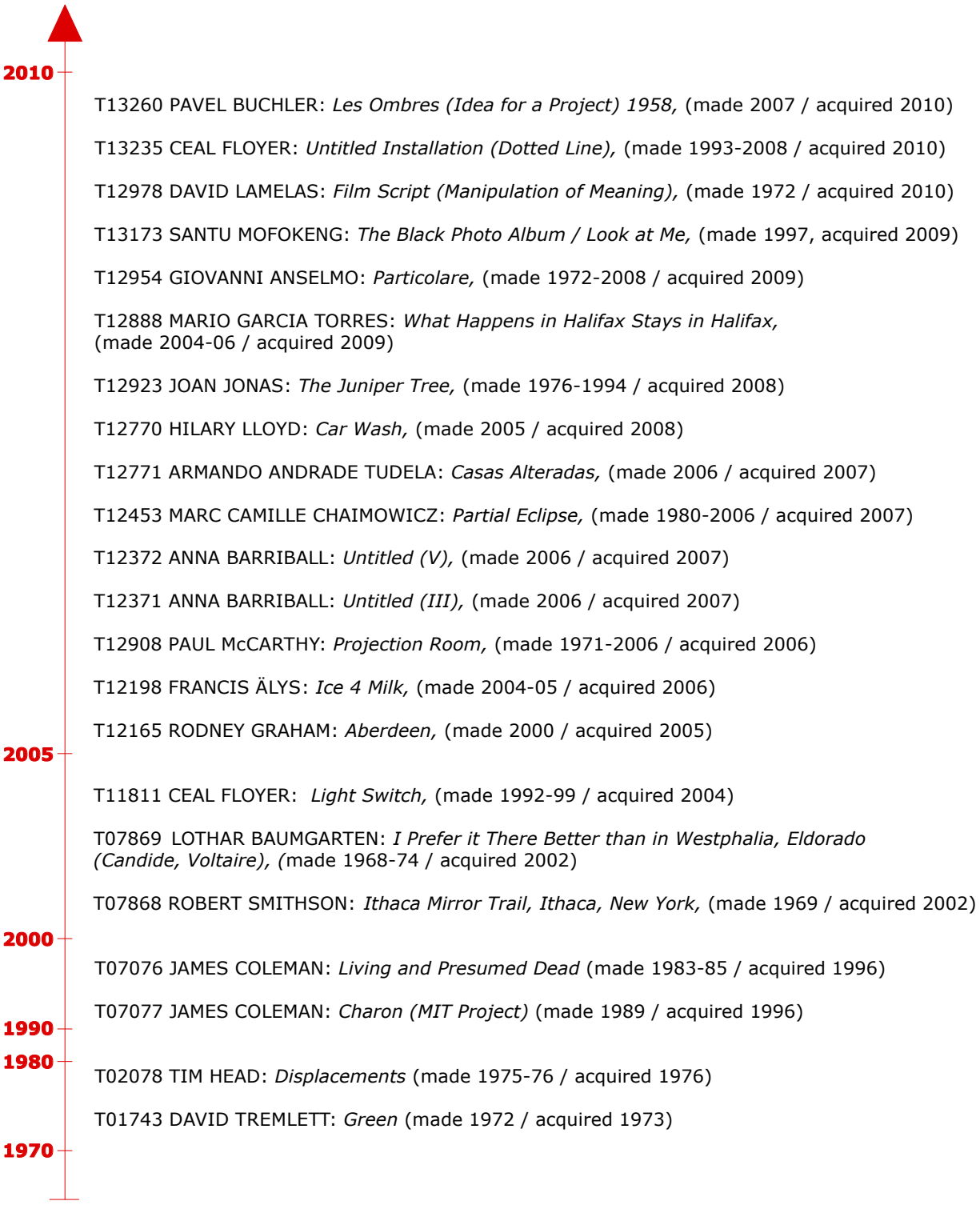

Fig. 3. Slide-based artworks in Tate's collection by the year of acquisition.

SLIDE-BASED ARTWORKS IN TATE'S COLLECTION

The challenges associated with acquiring slide-based works came to a head in 2007 when there was a significant increase in slide-based works coming into Tate's collection. Until 2004 Tate held six slide-based works in its collection. The earliest work was David Tremlett's *Green*, 1972, eighty-one 35 mm projected color slides, acc. no. T01743, acquired in 1973. From 2004 until the end of 2010 the total number of works increased to 22 (fig. 3). These incorporated a wide spectrum of works including multi-channel installations consisting of more than 160 slides each, and projections using a single slide. Newly acquired works included those recently made, as well as older works that had only recently entered the market or works that were produced over many years.

This rapid expansion of Tate's collection coincided with the demise of analog photography and its replacement by digital imaging, a development that started gradually at the end of the twentieth century with the full impact being felt by 2006. It was established practice at Tate to work with the artist when a new slide work was acquired to create a set of slides that would act as the museum's archival master set. Within a couple of years, Tate was faced with a backlog of work relating to the creation of archival master copies for these newly acquired artworks. It was also becoming increasingly apparent that artists, galleries, and museums were all beginning to struggle to obtain good quality slide duplicates.

ANALOG SLIDE DUPLICATION

Even in the heyday of slide technology it was a challenge to produce good quality and accurate slide duplicates, a task that demanded both patience and skill. This was due to the following four factors:

1. The importance, where possible, of matching the stock used in duplication to the original stock manufacturer
    a. Because of the difference in color gamut and spectral sensitivity between slide stocks made by different manufacturers
    b. Because of the differences created by moving between developing processes. K-14 is the process used for Kodachrome stock and E-6 is the process used for Ektachrome or Fujichrome duplicating stock.
2. The variation in the emulsion of different production batches of one and the same slide duplicating stock
3. Instability of the chemicals inside the processing bath and the regularity with which this is monitored, adjusted and renewed
4. The time and knowledge required to improve color filtration settings to adjust for these factors

Owing to the commercial demise of analog photography and specifically 35 mm slide transparencies, the majority of photographic laboratories are no longer producing slide duplicates nor processing 35 mm slide film, and those few laboratories that continue to offer this service are now only dealing with small quantities of material. These commercial drivers often mean that quality control is less stringent. In 2007, in response to this rapidly changing situation, time-based media conservation set out to re-evaluate which photographic laboratory in London was able to produce the best analog duplicates. We restricted our search to London in order to avoid the risk of having to ship the master slides and also because we felt that is was highly desirable to build a professional relationship with a local laboratory that would help us to understand how the difficulties involved could be resolved.

Our assessment of these laboratories was based on the following factors:

- How well the color filtration and exposure time was chosen

- How much cropping of the margins of the image occurred. Cropping is always present when duplicating from an in-camera original but not when using first-generation duplicates slides. Evaluating the amount of cropping would show whether the set-up of the slide in the duplicating machine was rushed, as it is less time-consuming to zoom in rather than to precisely capture the correct dimensions.
- Whether the duplicating camera transported the film using pin-registration. This means that the width of each slide exactly matches the distance of eight perforation holes from outer edge to outer edge. The black bar between each image should be of equal width of about 2 mm and be centered between two perforations.
- Whether there were any blemishes or micro-scratches. Drying marks are indicative of how the film has been attached to the hanger and micro-scratches can occur when the film is sleeved.
- The degree of variation that occurred in the processing bath over the duration of two weeks

The outcome of our test was disappointing and despite concerted attempts to challenge the laboratories to improve the precision of their color accuracy, the results remained below acceptable standards for these most basic measures. It was as if the highly trained analog eyes that once oversaw this process were no longer available; or perhaps morale was low as many experienced staff faced redundancy given the reduced demand for analog photographic processes.

As part of a new approach it was decided that a time-based media conservator would need to learn how to operate a slide duplicator in order to gain first-hand experience of the challenges involved in producing accurate color-matched slide duplicates. It was also considered valuable for conservation to regain some control of this task, given that the standards we were trying to attain did not sit well with the commercial constraints that governed what was possible within a photographic laboratory. In consultation with Tate's photography department, which owned a Firenze ChromaPro 45 slide duplicator, Tate begun to duplicate the slides in-house and then send the exposed strip of slide film to an external photographic laboratory to be developed.

Rod Tidnam, a Tate photographer with more than 40 years of experience, provided training on how to operate the ChromaPro. Rod taught me how to judge which filters to use depending on the stock of the slides being duplicated, how color correction filters would cancel each other out and what this means in relation to lens stops and exposure time. Within a short period of time, I felt that I understood this process and I began to see a clear improvement in the quality of the duplicates. This workflow served to minimize variation. Variability in the results cannot be completely eliminated as the color processing of the slide film remains a significant factor due to the change in the processing bath from week to week. In order to minimize the impact of changing processing baths, the workflow was adjusted and the filtration tests were repeated weekly. It was clear at this point why the initial laboratory tests were unsatisfactory; this systematic workflow is extremely time-consuming and would be difficult to achieve within a commercial environment. However, although time-consuming, it was encouraging to have established a successful method of producing duplicate slide sets for the purposes of archiving and display.

Towards the end of 2009, the situation changed once again when Fujifilm discontinued its range of CDU type II slide duplicating stock. This was rapidly followed by Kodak's announcement that it would be ending the production of its entire range of Edupe duplicating stock in March 2010. This was not completely unforeseen as the price of the duplicating stock had steadily increased and its availability had become increasingly scarce. Noting these indicators, Tate had begun to create a small stockpile of Kodak Edupe, Fujifilm CDU II and Agfa Scala

black and white negative film that can also be developed as reversal. Despite my initial success in mastering the slide duplication in-house, I was still an amateur and needed to use large amounts of this stock as part of the testing process. This was no longer viable, given the finite amount of duplicating stock now available. What followed was a year in which slide duplication came to a halt. This meant that there were no slide-based artworks available for display at Tate whilst alternative methods of slide duplication were sought.

At the beginning of 2011, Tate established a new collaboration with Activity Studios, a small slide laboratory in south-west Germany, which is able to control the production processes much more tightly, and also understood the needs for accurate duplication when working with artworks (www.activity-studios.de).

In the past, when a film stock has been discontinued, it would be phased out over a number of years, while the manufacturer established whether a market remained. However because analog photography is no longer commercially supported, the discontinuation of specific stocks is no longer due to the launch of new products. Kodak Edupe Slide Duplication Film was always a professional specialist product hence was one of the first stocks to go. This was rapidly followed by in-camera stocks, marking the effective end of commercial support for 35 mm slide technology. In March 2012, the last three professional Kodak slide stocks E100G, E100VS and Elite Chrome Extra Color 100 were discontinued with immediate effect as part of a direct response to Kodak's filing for bankruptcy protection at the beginning of year (fig. 4).

It remains unclear how long the analog photographic negative stocks for prints will remain in production but there is a suggestion that as long as the motion picture industry is shooting on film, there will be enough revenue to allow the continued production of a small range of still photographic films. However, it is notable that


Kodak

KODAK PROFESSIONAL Color Reversal Films Print | Close

— DISCONTINUATION NOTICE —
March 1, 2012

Due to a steady decrease in sales and customer usage, combined with highly complex product formulation and manufacturing processes, Kodak is discontinuing three EKTACHROME (color reversal) Films:

KODAK PROFESSIONAL EKTACHROME E100G Film
KODAK PROFESSIONAL EKTACHROME E100VS Film
KODAK PROFESSIONAL ELITE Chrome Extra Color 100 Film

We estimate that, based on current sales pace, supplies of these films are expected to be available in the market for the next six to nine months; however, inventories may run out before then, depending on demand.

This does not affect KODAK PROFESSIONAL Color Negative Films or KODAK PROFESSIONAL Black and White Films which remain a viable part of the KODAK PROFESSIONAL Film portfolio.

Please note: E-6 Chemicals will also continue to be available.

KODAK PROFESSIONAL EKTACHROME Film E100G
— for natural skin tones and virtually grainless images

KODAK PROFESSIONAL EKTACHROME Film E100VS
— for vivid, saturated color

Fig. 4. Discontinuation notice of all remaining slide stocks by Kodak (2012).

the industry is not making any clear public statements regarding its commitment to analog still photography.

THE FEASIBILITY OF SMALL-SCALE PRODUCTION OF SLIDE STOCK

The small-scale production of batches of fluorescent tubes used in Dan Flavin's (1933–1996) light-based artworks provides an example within contemporary fine art conservation of now obsolete commercially produced components being re-fabricated in small-scale production. For the last ten years, Dan Flavin's studio has organized the production of specially pigmented fluorescent tubes that are no longer available off the shelf, for a consortium of museums and collectors. Closer to slide technology, there is also an example of the reintroduction of a once legendry analog film process provided by the Impossible Project. Here, ten former Polaroid employees took over the last production plant of integral instant film in Enschede, in the Netherlands, shortly after Polaroid shut down in 2008 (www.the-impossible-project.com). Since then, they have launched at least four different instant films and are supported by enthusiasts around the globe.

Both of these initiatives prompted me to investigate whether it would also be possible to produce small-scale slide duplicating stock independent of Kodak and Fujif-

ilm. To explore this option, I visited Filmotech ORWO in Germany. ORWO was originally AGFA and was renamed after the latter was re-established in West Germany at the end of the Second World War. ORWO produced most analog film materials for the communist world under the brand Original Wolfen. This included the production of slide film until 1990. Today they manufacture black and white motion picture film stock for a specialist market and this stock is considered superior to the quality of equivalent stock produced by Kodak (www.filmotec.de). In talking to ORWO it became clear that producing color film stock is a far more complex industrial process than the production of black and white stock, given the multilayered photographic emulsion and the chromogenic dyes involved. The staff at ORWO explained that it would only be cost effective to produce a slide duplicating stock if the stock were produced in very large quantities; their direct reply humorously indicated the difficulty of the task:

> If you are able to produce an order for an amount over the size of two football fields (120 m long and 90 m wide) and have 2 Million Euros to spare for testing and are able to give us 2 years' notice, we could look into this further. (ORWO 2011)

It became clear that it would be extremely difficult to launch a project to produce the amounts of slide duplication stock needed to keep artists' slide installations displayable, largely because the industrial infrastructure needed and the complexity of the process cannot be compared with that used to produce fluorescent tubes or Polaroid instant film.

ALTERNATIVE MATERIALS FOR PRINTING TRANSPARENCIES

In addition to standard analog production routes, I have also explored the production of slide duplicates using digital intermediates which were created using light valve technology (LVT) film recorders onto sheet film, cathode ray tube (CRT) film recorders printing onto in-camera slide stock and motion picture reversal stock, laser film recorders printing onto microfilm, and inter-negative 35 mm motion picture stock to produce slide duplicates as film prints. The results are summarized in table 1.

Light valve technology film recorders

Light valve technology (LVT) film recorders, such as the Durst Rhino II, are able to produce very accurate duplicates. As with all of these technologies, these film recorders depend upon the expertise of those able to maintain and calibrate them; an expert knowledge that is increasingly rare. The recorders that are still in service

Technology	Film used	Perforation holes	Cost	Color stability when projected
LVT film recorder	Sheet film	No	Medium	Medium
CRT film recorder	– In-camera stock – Motion picture reversal stock – Sheet film	– Yes – Different style (BH) – No	Medium / High	Medium
Laser film recorder	Microfilm	No	Medium	Good
Laser film recorder	35 mm motion picture print stock	Different style (BH)	Lowest	Poor

Table 1. Summary of alternative production routes.

have been purchased second-hand long after commercial support has come to an end. I have witnessed problems in the sharpness of the image caused by the misalignment of the light beam; this is particularly visible when the sheet film chosen lies at the limits of the device.

The potential disadvantage of this method for the purposes of duplicating slides is that sheet film does not have perforation holes; hence the exact registration between the slide image and the perforation holes is lost. This is a particular problem for slide works that require exact positioning of the slide inside the mount for their playback—for example, in a work which incorporates dissolves and cross-fading where images are overlaid on each other using a number of synchronized projectors. Cutting out the individual 35 mm slides from a sheet of film can become laborious. However, there is also great practical advantage as one 5 x 7 in. sheet can produce up to fifteen 35 mm slide exposures and an 8 x 10 in. sheet can hold thirty-five 35 mm exposures. Doug Munson at Albumen Works, Massachusetts, has achieved great results with this method and is the only professional photography conservation laboratory that offers in-house slide duplication (www.albumenworks.com).

Cathode ray tube film recorders

Cathode ray tube (CRT) film recorders, such as the Agfa PCR II Plus, support a larger variety of stocks owing to the variety of interchangeable fittings that are called camera movements. These include 35 mm, 70 mm, and medium format film of different length rolls, as well as sheet film in different sizes. CRT recorders are an older technology than LVT, however if properly maintained and calibrated they can achieve equally good results. The main advantage of CRT recorders for slide duplication is that 35 mm perforated film can be used.

Despite earlier discontinuation notices in July 2012, the remaining slide stocks that are still available are Fujichrome Velvia 50, 100, and 100F ISO (in 35 mm, 120, 4 x 5, and 8 x 10 formats), Fujichrome Provia 100F ISO (in 35 mm, 120, 4 x 5, and 8 x 10 formats) and Fujichrome Provia 400X ISO (in 35 mm and 120 formats). Especially without Fujichrome Velvia 100F the future use of film recorders for slide duplication will be jeopardized. In the tests that Tate conducted with Activity slide laboratory, we also explored using a motion picture reversal stock in a CRT recorder in order to see if Kodak E100D stock, which at the time of writing is still being made, could be used as an alternative to the discontinued slide stock Kodak E100G. In evaluating the results, the similarities between the slide stock Kodak E100G and its motion picture equivalent Kodak E100D was striking. The results of these tests showed that the emulsion of both stocks is very similar and that Kodak E100D could be used instead of slide stock. However, motion picture stocks have Bell & Howell (BH) perforation holes, which are a different shape than photographic stocks that have Kodak Standard (KS) perforations. In order to transport films with BH perforations, a camera movement that supports this type of hole is needed.

Laser film recorders

At the time of writing, laser film recorders and microfilm continue to be commercially supported technologies and are continuing to be developed, for example the Arche laser recording system for color microfilm that was developed by the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg, Germany (www.ipm.fraunhofer.de).

Ilfochrome Micrographic is a high-resolution direct positive color film whose processing is based on silver-dye bleach technology (P-5 process). Though in principle microfilm should not be capable of getting even close to the dynamic range of slide film, tests that I carried out at Mikrosave in Switzerland showed surprisingly good results (www.swiss-mikrosave.ch). One significant advantage of microfilm is that it is designed to have outstanding ageing properties. To test the dye fading properties of microfilm inside a slide projector, I projected two slides for three continuous days, exposing only part

of the image to light. One slide was made using Kodak Edupe and the other was made using Ilfochrome Micrographic Type P. The results were evaluated by eye and the microfilm appeared to be approximately five times more light stable than slide duplication film. Microfilm is produced as sheet film and roll film but does not have perforation holes.

Inter-negative film

The final alternative production route tested is directly based on that of motion picture print films. Here the tonal values of the digital file need to be reversed to produce an inter-negative from which slides can be made. This method is not new and has been used as a low-cost means to produce duplicates since the 1960s. However, in 1993.Wilhelm stated that this method of duplication was considered low quality due to the low resolution of print stock, which matters less in moving image, and also the color instability of certain print stocks (Wilhelm 631–32). Given that film production methods and the quality of stock has improved since the tests referenced by Wilhelm, this method of producing slide duplicates has recently been re-examined by Maurice Schechter of DuArt Media lab, New York, (discussed at TechFocus II: Caring for Film and Slide Art, April 2012, organized by the Electronic Media Group of The American Institute for Conservation of Historic and Artistic Works (AIC) and hosted by the Hirshhorn Museum and Sculpture Garden) and also at the National Gallery of Canada where Ainsley Walton has investigated this as an archiving strategy for slide-based artworks as part of the DOCAM project (Walton 2007).

All four of these production methods require the original 35 mm slide to be digitized. This means that initial costs are significantly higher when compared to the analog production methods. However, once digitization has been carried out, the long-term costs of producing slides are comparable to analog duplication.

DIGITIZATION

Since time-based media conservation at Tate first started to look into digitization as a means of preservation in 2001, best practice for digitally capturing analog slide transparencies has progressed.

Scanners and Digital Camera Backs

The introduction of digital camera backs as a means of digitization have been more recently introduced in addition to flatbed and drum scanning technologies. Though at present, these three scanning technologies coexist, the industry is signaling that only digital camera back technology will be developed further. Servicing support especially for drum scanning has already become scarce. Each technology has its individual advantages and disadvantages, but in many cases, quality control is only as good as the eyes of its human operator. The main differences between these three technologies is the scanning or digitization time per slide, its optical system, and at which point corrections will be carried out as part of profiling the scanner or the camera according to the slide stock.

Checking the Color of a Digital File

When comparing a 35 mm analog slide with a digital file, it is essential to have a set-up with a calibrated high-resolution monitor, placed in a neutral environment with grey walls and diffused light. Recommended models are EIZO ColorEdge and NEC SpectraView series.

It is essential to calibrate the monitor at regular intervals. For this, a separate calibration device such as an X-Rite i1Display Pro is required. A variety of test targets for the image capture or validation process are also recommended. These include the X-Rite ColorChecker Digital SG and the Applied Image QA-62 Test Target. Dietmar Wüller at Image Engineering in Germany (www.image-engineering.de) and Don Williams at Image Science Associates, New York (www.imagescienceassociates.com), currently offer targets and validation software to evaluate

your imaging system and can advise clients. Amongst other criteria, these tools determine the actual resolution, possible distortion and the dynamic range of the system.

An analog 35 mm slide is best looked at with a professional 10X loupe on top of a light box with a black card mount blocking any excess light. Describing subtle differences in visual appearance is difficult and perceptions are highly subjective. To judge the sensitivity of the optical system used in scanning the slides, one should focus on the fine details in the dark areas and detail in the highlights, to check that information has not been lost.

Color Management

Given the lack of knowledge of color management within conservation at Tate, a collaboration was sought between conservation scientists, scanning operators, and the bench conservator.

Color management provides a workflow and a framework; however it is wrong to assume that digitization makes it possible to leave the inaccurate world of analog duplication and achieve objective precision. Instead, color management is still a very young science and the task of translating between the analog and digital color spaces is extremely complex. Each component in a workflow interprets and displays color differently; hence calibration and color management are key in the communication of color information between different devices and their human operators.

CIELAB is a color space that encompasses all colors that the average human eye is responsive to; this is a device-independent reference. The CIELAB, when looking at it as a three-dimensional ball is built around three axes which are expressed in the three values L* a* b*. L* is the luminance from black to white, a* is expressing the shift from green to magenta, and b* indicates values between blue and yellow.

However, devices can only display color in a fraction of the ranges available within the CIELAB color space. This restricted range is called gamut and differs from device to device and between film stocks. In order to interpret the closest equivalent of natural color falling within the gamut of the device, a color model is applied. For devices that use in-built luminance this is RGB and for printing this is CMYK. In professional photography, the most widely used color profile for RGB devices is Adobe RGB (1998). Though an image has its three RGB values assigned to it without specifying the profile (full scope of color), the computer would not know how to encode it properly and would open and or import it in the default color space instead. RGB values alone will result in deviation when crossing between different RGB-based color profiles (e.g. sRGB, Apple RGB, or ProPhoto RGB), but will preserve it and more accurately describe the same color in another color environment when a profile has been assigned.

Color scientists within the International Color Consortium (ICC) continue to establish new color profiles, progressively trying to map color that is specific to a certain device more accurately (www.color.org). New profiles are also created for new devices and technologies as they are introduced into the market. Color profiles that are independent from ICC and often specific to certain makes and models should be avoided.

One of the early tools adopted for this was the Kodak Q-60 input color target, which maps the dyes in Kodak's Ektachrome and Kodachrome transparencies and reflection materials (Kodak 2003). Q-60 targets are produced based on the ANSI IT8.7/1 guidelines from 1993. These were intended to define a standard for an input test target that would allow any color input scanner to be calibrated with any film dye set used to create the target. The color space chosen for the design of the target is the CIELAB color space and for this Agfa, Kodak, Fujifilm,

and Konica provided data to map the color gamut of the different film stocks. The colored batches of the target are measured and the data particular to the production date is kept as a rich text document, which is referred to as batch data. This can be downloaded from ftp://ftp.kodak.com/gastds/Q60DATA (the directory "E3-Data" includes the files for 35mm Ektachrome stock).

The batch data of each color square on the target is made up of three colorimetric readings in two color spaces XYZ and Lab. When creating a scanner profile, the target is scanned without any correction and in a second step the correction is carried out by a software application that automatically uploads the batch data and corrects the color as needed. The difference between how the scanner has first read the color and what it was corrected to, by applying the batch data, is what is referred to as a scanner profile.

These values, used to correct the color in a scanner profile, are captured in look-up tables: algorithms that determine which color batches should be corrected and which should remain without change after the initial calibration set up. This is basically a method to gather data, similar to a reference library needed for infrared spectroscopy when identifying color pigments or binding mediums. The truth, however, is that these color profiles are only partially successful, as the correction of one dye can result in the deviation of another for which the color difference is expressed in Delta E (ΔE). This is essentially where color management reaches its limitations. The automated setup for scanning therefore becomes semi-automated as the operator may then rectify the errors by tweaking the color by hand. Any adjustments will always be a question of prioritizing the accuracy of one area of color rendition over another. This additional time to rectify color is costly.

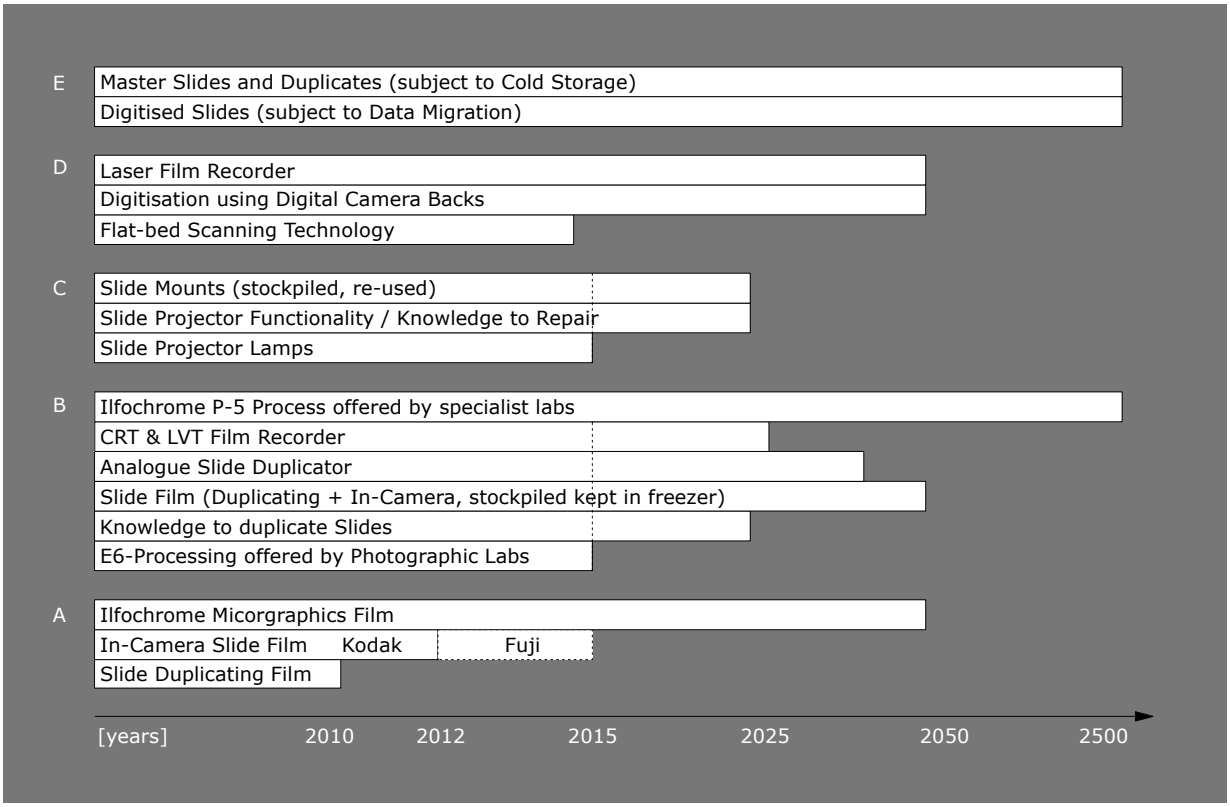

Fig. 5. Expected decline of slide technology related services.

Digital camera backs can capture the slide as a RAW file and a color profile is only assigned once the RAW file is opened and processed as a rendered image (e.g., to the TIF, JPG, or PSD formats). Hence, it is crucial to assign the appropriate color profile and the desired correction in a standardized fashion before the file is rendered. This can be done using a color target chart such as an X-Rite ColorChecker Digital SG that replaces the Q-60 input color target used for transparencies, but also follows the ANSI IT8.7/1 guidelines. The *AIC Guide to Digital Photography and Conservation Documentation*, recommends retaining the RAW file as DNG as well as the processed TIF for long term preservation (Warda et al. 2011, 81–82). The unprocessed RAW file is heavily depended on the camera manufacturer's proprietary code that is not openly accessible to developers, so there are potential long-term preservation and accessibility issues.

Digitizing Artists' Slides

As a result of this research project Tate has decided to create digital images of roughly 2000 slides that make up the current collection of slide-based artworks. Where possible Tate will work with the artist to digitize the in-camera original transparencies where they exist and where they represent the best available master set. Tate is currently conducting tests using the digital back system established by Picturae, a Dutch company specializing in the digitization of cultural heritage such as photographs, transparencies, negatives, books and large scale maps (http://picturae.com). Picturae is using a calibration process, which incorporates a combination of color, sharpness and distortion targets whereby any unacceptable deviations are detected during the warm-up of the system every day. In the tests that have been conducted to date, the tonal rendition of the digital scans could be directly compared to the 35 mm original slide without any additional correction.

THE WAY FORWARD

The diagram in figure 5 is a visualization of the three factors affecting our ability to continue to show 35 mm slide-based artworks as slide projections as well as current options for digitization and storage. Some questions to guide the reader through each section of this chart include the following:

- (A) Can I purchase slide stock?
- (B) Can I duplicate slides after slide stock has discontinued?
- (C) Are there slide projectors, spare parts and accessories available?
- (D) What technologies are available for digitization?
- (E) What is the predicted longevity in storage?

Technological environments are like ecosystems with multiple dependencies. The constituent with the shortest life expectancy limits the availability of the associated activity. While stockpiling slide film and slide projector lamps is recommended, it must be seen in the context of the other parts of the technological environment. For example, if a digital scan is available, this also enables the use of film recorders (LVT, CRT) to create slides from the digital scan onto slide stock as long as the E-6 developing process remains available.

In figure 5 I have tried to estimate the life expectancy of the significant components of the technological infrastructure upon which 35 mm slide-based artworks depend; predicting the future, however, is never an exact science.

A course of action that maximizes options over time is prudent. In my opinion, based on the research carried out in this project, the best use of resources is to split the available budget between creating analog duplicates, digitizing the collection and locating projector parts. In our situation, analog duplication remains a viable option given access to the generous amount of slide duplication film that Activity, the slide lab with whom Tate is collaborating, has stockpiled over recent years.

Different collections, however, will have different local circumstances, which make different courses of action both feasible and recommended. For example, the Solomon R. Guggenheim Museum in New York has digitized some of the slide works through a partnership with Chicago Albumen Works, and they are achieving great results by creating duplicates via LVT film recorders; whereas the Kunsthaus Zürich in Switzerland has been duplicating slides on microfilm, in close collaboration with Mikrosave.

The relationships one builds are essential to the success of any of these methods. Every method has its particular advantages and disadvantages and as long as conservators can rely on experts who have perfectly mastered the chosen technology, there is great value in this pluralism of approaches.

BUILDING BROADER NETWORKS

Conservators of contemporary art are connected worldwide through INCCA (International Network for the Conservation of Contemporary Art) (www.incca.org), but there are only a few conservators specializing in this relatively new area of time-based media conservation within fine art museums. In contrast, the library and archive community has a far larger and more developed professional network of librarians and archivists, image scientists, programmers and photographers who are engaged in the challenges of slide preservation and digitization. Although there may be a need to distinguish between the difference in approach when digitizing archival material and artists' slides, there is much that time-based media conservation can draw upon. Technical expertise is also available through the Society of Image Sciences and Technology (IS&T) (www.imaging.org) which encompasses all aspects of imaging science and functions as a consultancy to mediate between the trained practitioner rich in bench skills and the latest research in the field of electronic imaging, color science, and image preservation and its subsequent product development.

There is also a greater need for museums to form partnerships so that they become visible as potential clients for the industry. To this end, it would be highly desirable to gauge the number of slide-based artworks that are currently held by private or public collections so that services related to their preservation and digitization could be shared.

As I embarked on this research, I thought that Tate would need to invest in specialist equipment and software to undertake the digitization of its collection in-house. However it is clear given the cost of purchasing this equipment and specialist skill needed in its maintenance and operation that it makes much more sense to work closely with a company which can offer this expertise.

CONCLUSION

Given the importance of working with the artist to arrive at alternative display scenarios whilst it remains possible to still compare this to the original analog slide projection, there is real urgency in moving forward with the digitization of these works. Clearly to be successful in this, conservators need to understand both the analog processes and those associated with the digital, and our challenge is not simply in learning a new language but in translating between the two. We have learned that there is value in ensuring that we can compare the impact of shifts in technology for specific works in Tate's collection by being able to see the analog next to the digital allowing us to move back and forth between these worlds for a little bit longer.

As museums enter into this difficult phase, between the end of a technology and its complete disappearance, there is real advantage in partnerships being formed to share the costs of digitization, negotiate access to master sets, and where possible take advantage of economies of scale.

ACKNOWLEDGEMENTS

This research has been made possible by the generous support of a research grant from the Esmée Fairbairn Foundation. Further information about Tate's slide project, the tests conducted and lessons learnt can be found at www.tate.org.uk/about/projects/dying-technologies-end-35-mm-slide-transparencies.

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