MEMORIAV, Bümplizstrasse 192, CH-3018 Bern, www.memoriav.ch
Tel. +41 (0)31 380 10 80, Fax +41 (0)31 380 10 81, info@memoriav.ch

MEMORIAV
DOSSIER

DIGITISATION OF SMALL GAUGE FILM TO HD

Characteristics of 16 mm reversal film stock during transfer to high definition

IMPRINT

Memoriav Dossier
Digitisation small gauge film to HD
April 2011
This study was commissioned by Memoriav

Author
David Pfluger, Basel

Editor / Production
Laurent Baumann, Memoriav
Yves Niederhäuser, Memoriav

Design
Martin Schori, Biel

Proofreader
Markus Schütz, Bern

Translator
Katrin Gygax, gygatext, Zurich

Publisher
Memoriav
Bümplizstr. 192, 3018 Bern
Tel. 031 380 10 80
info@memoriav.ch
www.memoriav.ch

Title photograph: Film still from the RTS test reel; enlarged, cropped. Photo: RTS

CONTENTS

1. Preface

16 mm films are an important part of our audiovisual cultural heritage. There are numerous collections stored not only in television archives, but also at a wide variety of other locations, whose images are of great contextual value. All these films are endangered to one degree or another, especially the so-called reversal film, be it due to the inevitable chemical deterioration process, or simply because the technical knowledge of how to show such movies is disappearing.

For various reasons, today only a small portion of these treasures can be protected and saved in the traditional manner by transferring them to new film material.

The great hopes of preserving at least a part of this valuable cultural heritage for future generations therefore lie in digitisation technology.

Although this technology is generally well-established in the areas of text documents and still photographs, there is still much to do in the field of film. This study, which David Pfluger carried out as commissioned by Memoriav, reveals the entire complexity of the undertaking and the many issues tied to it.

As is so often the case in this field, there is no one right solution. Many parameters, decisions and objectives ultimately determine which method offers the best results. A distinction must especially be made between the physical preservation of information stored in images and their reuse – for example in the area of audiovisual media, where accelerated technical developments, and the instability that comes with them in terms of formats and standards, can call today's solution into question already by tomorrow.

With that in mind, this paper should be considered a contribution to a discussion that must be ongoing if we want to preserve part of this cultural heritage for coming generations.

Kurt Deggeller, Director of Memoriav

2. Summary and Editorial Notes

This paper deals with the question of which differences in quality arise in transfers of 16 mm reversal film in standard definition (SD) and high definition (HD) video. A test series was made using a reel of 16 mm reversal film specially assembled from the archives of the Swiss public broadcasting station RTS **(REF1)**. The focus of the study lay in the quality of reproduction of image characteristics such as resolution and image structure. Through tests using various scanner and telecine models, it was analysed which characteristics were a result of the film's actual image and which could be traced back to the machines that were used. Workflows were examined and problematic steps identified.

The studies showed that there are no simple answers to the questions posed. The resolution of 16 mm reversal film can often be sufficiently represented in SD, but the images' characteristics, which result from the film's grain, can only be sufficiently reproduced in HD. It therefore depends on the transfers's objective as to which level of quality is sufficient. During the transfer step, which also includes grading, the quality of the result is significantly influenced by the expertise of the operator. The available know-how and the time dedicated to each setting are just as important for the end result as the general technical conditions. This makes automating the process more difficult. The tests were carried out using only 16 mm reversal film, but the findings make it possible to extrapolate this conclusion onto other small gauge film formats.

The process and the results of the test series are comprehensively documented in this PDF paper, which includes illustrations. Attached are TIFF files which include 1:1 stills of the digitised film clips. These image files are linked to the illustrations or notes in the text. They can be opened by clicking on them for close study of the described findings. This way, readers are free to draw their own conclusions as well.

The tests for this study were carried out during 2009. All information about the existence, services and equipment of providers in Switzerland are in reference to the status quo of that time. Schwarz Film AG, which then still existed, has meanwhile been taken over by Egli Film. Two of the providers had scanners that were still in the testing phase, which influenced the timing and the results. This was taken into consideration during the evaluation of the test results.

3. Acknowledgements

Thanks go to the following people, institutions and companies, which offered support during the execution of this project:

Memoriav:	Kurt Deggeller, Felix Rauh, Yves Niederhäuser, Laurent Baumann
RTS:	Patricia Herold, Didier Bufflier, Jean-Michel Schluchter
SRF:	Jürg Hut
RSI:	Theo Mäusli, Siro Boffa
HKB:	Manuel Schüpfer
Egli Film:	Michael Egli, Sabine Strastil, Timo Inderfurth, Ivo Bischof, Norbert Dziambor
Swiss Effects:	Ruedi Schick, Rocco Schult, Ian Matthis
reto.ch:	Reto Kromer
Image & Media Lab Universität Basel:	Ruedi Gschwind, Peter Fornaro
Kodak:	Felix Berger
Lichtspiel:	David Landolf
Nofilm:	Ueli Nüesch

4. Objectives

The objective of this project was to create a series of tests to help critically evaluate the quality of 16 mm reversal film. The influences of outside factors were kept as low as possible – where they could not be avoided, we ensured there was an option of evaluating their influence. The aim was to clarify which factors are important for the various quality criteria during a transfer. Of interest was also to find out where the conditions for archiving 16 mm reversal film overlapped with those of its repurposing in broadcast, and where they contradicted one another.

5. Initial position

Work on transferring 16 mm reversal film had already begun years earlier at RTS **(REF1)** and SRF **(REF2)**. The target formats chosen at that time were Beta SP and later IMX (RTS) or Digital Betacam (SRF) video (see **Appendix 11.1**). This already created a certain standard, but with the introduction of high definition TV and the establishment of tape-free, digital production archives, several issues have again been raised.
The work was not carried out under “laboratory conditions”. The steps were carried out in the same way they would be in an archive. This working method led to several important insights into certain work steps. Mistakes and doubts about results will not go unmentioned in this paper – they should offer the possibility for readers to evaluate results individually and apply conclusions to their own projects.

The reproduction of the colours of analogue colour film in digital space is a very imortant and complex issue, especially when the aim is archiving. However, colour grading and reproduction were not a central theme of this project. It does not specifically relate to reversal film and the large part of Swiss television’s reversal material is black and white.

The question is, which level of quality is sufficient for this type of film stock, so that the digital product can be labelled a digital archive master. The arguments are not the same for the different goals of repurposing and long term digital archiving.

5.1 Quality characteristics of digitised motion picture film and digitisation purposes

The fundamental issue in transfers of film stock is wether an analogue medium can be digitally transferred at all in a way that the results could be called an original digital copy. “Though it is possible to calculate the resolution potential of film, comparisons of electronic and film quality are difficult to make without practical experiments. The amplitude/detail roll-off characteristics of the two media are different, and other differences in quality factors such as contrast linearity and noise level and structure, which are difficult to quantify numerically, affect the final perceived quality.”
EBU Tech 3315 **(REF3)**.

In addition to the purely technical values, the questions about quality of digital copies are also philosophical ones. Is the objective to take an image that has incorporated the characteristics of the technology with which it was made and reproduce an image that only renders the original content? Or is it acceptable – or even obligatory – to ensure the characteristics of the selected filming medium are transported along with it? What is seen as good or good enough also depends on the objectives foreseen for the digital product. Depending on its purpose, the required level of quality of the resulting digital master will differ. The archives of TV stations serve various purposes and those responsible are therefore faced with a variety of challenges. Especially for very large collections, it is the cost factors that dominate any action.

The central quality factors in transferring an analogue image to the digital domain:
– spatial resolution
– resolution of hues of colour or grey
– colour space
– temporal resolution
– degree of data compression of the above characteristics

Quality can be divided into the following categories:
Depending on requirements, quality factors are of varying degrees of significance in each area of use. The areas of use can therefore be roughly divided into categories of quality (see table below).
No general statement can be made for the use in research activities, because depending on the subject, either content or technical aspects may be of importance and the material’s quality must meet those specific requirements.
In the field of broadcasting, it is clear that digitisation is imperative if footage is to be rebroadcast. However, digitisation of film footage is becoming an issue for many archives that have been purely analogue until now, because the choice of technical options are rapidly disappearing especially in the area of small gauge formats. This effects the number of available emulsions just as much as the services offered by the laboratories. At the same time, costs are rising. The result of all this is also that a loss of technical expertise is taking place in these areas. Sooner or later there will be no option other than the digitisation of collections in their entirety.

5.2 Aspect ratios 4:3 and 16:9

16 mm film offers two standard aspect ratios. The classic 4:3 aspect ratio (1:1.33) and the Super-16 format (1:1.67). Super-16 was introduced in the early 1970’s. All the 16 mm footage produced before that time had a ratio of 4:3. At the time when motion picture film was the dominating recording medium, both 16 mm and TV images had a ratio of 4:3. Therefore, all reversal material has an aspect ratio of 4:3. We are currently still in a transition phase towards 16:9.
How TV stations are dealing with the issue of the older 4:3 formats will not be discussed here in detail. However, the results of the test series indicate which of the options make the most sense from a technical point of view.

Purpose	Spat. Res.	Bit depth	Compression	Medium
Information/communication, education	< SD, SD	8 bit lin	very heavily compressed > 4:2:0	file/internet
Private and business commercial use	SD, HD	8 bit lin	heavily compressed 4:2:0, > 4:2:0	DVD, Blu-ray
TV/broadcasting	SD, HD	8 bit lin, 10 bit log	compressed 4:2:2, 4:2:0	Master tape or file
Commercial use for screening	HD, 2k	8 bit lin, 10 bit log	slightly compressed 4:2:2, 4:4:4	DCP
Archival copy	2k, > 2k	10 bit–16 bit linear or log	uncompressed or lossless compression 4:4:4	uncompressed file formats, MJ2K

A 4:3 image can be displayed with a 16:9 aspect ratio in various ways:
- By inserting the 4:3 image onto the 16:9 frame whilst retaining the full 4:3 image. This results in two black spaces on either side of the image (curtains, pillar box). With an HD format of 1920×1080 pixels, the image area within the screen only has 1440×1080 pixels.
- By zooming the 4:3 image out to fill the entire 16:9 frame. The 4:3 image is cut off at the top and the bottom. 25% of the image's surface area is lost.
- The pan & scan method, which uses variable segments of the original format. 25% or more of the image's surface area is lost.
- Techniques have been developed in which the 4:3 image is stretched horizontally to completely fill the 16:9 format. The important centre of the image remains unstretched and the less important edges are stretched more strongly. The image information is completely retained, but is displayed at various degrees of stretching.

See also: EBU Tech 3289, 3289s1, EBU R86-2000 **(REF4)**.

5.3 Film stock

This study tested only 16 mm reversal film stock. Expanding the study to a comparison with other 16 mm film stock, (negatives, copies, intermediates) or even other sizes (35 mm, 8 mm) would have burst the limits of the study or forced us to go into less detail. Various existing test reports on comparisons are useless, because the different formats were tested so superficially that the results are not convincing (**REF5**). 16 mm negative film was not included in the test series as an element for comparison, because a direct comparison is difficult. Negatives must be handled completely differently during the transfer process and the image is then digitally reversed. Scanning a positive copy made from a 16 mm negative has the disadvantage that the analogue copying process lies in between, which brings along its own quality factors. To make this kind of comparison representative, the test series would have to have been expanded by several elements. It would also have been very difficult to find negative material that would include about the same requirements – as far as content and recording technology are concerned – as the reversal material.

The most important facts about the use of reversal film at Swiss television:
Film stock used was almost exclusively from Kodak. The majority of the collection is in black and white (emulsions Plus-X, Tri-X and sometimes 4-X).
The black and white emulsions Plus-X and Tri-X have not significantly changed since their introduction.
After the introduction of colour emulsions in the 1950's, footage was also shot in colour. There is a larger variety of colour emulsions than black and white emulsions. Their quality has changed significantly over the years.
Film footage was often underexposed and the film "pushed" during development so that cameramen could shoot under bad lighting conditions. This technique has a stronger effect on reversal material than negative film.
Kodachrome stock, which was very popular with amateurs, was not used.

A detailed list of emulsions is included in **Appendix 11.2**

The most important differences between negative and reversal film:
Negative material offers an aperture range of ca. 10 apertures, whereas reversal film provides only about 6.
A negative must be copied to positive, i. e. from a dynamic range of exposure of ca. 10 usable apertures to about 6. In this process, there is still enough room to manipulate the image. Not so in the case of reversal film.
At the same film speed, reversal film has more intense grain than negative film.
Reversal film reacts more sensitively to film manipulation, like "pushing" the film during development. The image becomes strong in contrast and its grain increases.
When transferring negative film, it is advantageous to to use a logarithmic colour space (e. g. 10-bit log). 10-bit linear is more suitable for reversal film.

5.4 Image sharpness and grain

In the evaluation of film images, the sharpness of the image is often considered the most important quality characteristic. Reversal film stock especially is frequently discounted as weak in this aspect – the strong grain is identified as the reason for this. However, the sharpness of a film depends on a range of factors: **Appendix 11.3** attempts to offer an overview that is as complete as possible for this test series. There are factors influencing the quality of the 16 mm reversal film which are linked to its fields of application:
- Used by reporters pressed for time;
- in small or cheap cameras that compromise on quality;
- under difficult conditions (handheld camera, no artificial light);
- with deliberately incorrect exposure (usually underexposure), with film "pushed" in the lab;
- processing under time pressure;
- use by amateurs with limited technical knowledge.

Characteristics of film grain
Often it is misunderstood what film grain really is. Grain is not equal to the silver crystals which result from exposure and development. "Resolution is independent of film grain, but resolution is harmed by the presence of film grain because it is image noise." (Tim Vitale, **REF6**).

The crystals themselves are 0.2–2.0 micrometres in size and are too small to be seen by humans as discrete points **(REF7)**. They are distributed in clusters within the gelatine.
And not just on one level, but in all three dimensions. This means that clusters overlap as the layer is viewed. The eye sees a chaotic pattern of various densities: noise. This noise is superimposed onto the actual image, which is defined by the size of the silver crystals. An identical structure is formed in colour film, since colour dyes group around the silver crystals. If the silver is washed out, the "clouds" of colour dyes are left behind. Their dimensions are inevitably somewhat larger than those of the silver crystals. Certain techniques in film digitisation reduce the impression of grain. This is the case with diffuse background lighting, as well as with transfers under liquid.
The essay "Film Grain, Resolution and Fundamental Film Particles" by Tim Vitale offers a good overview on the subject of film grain **(REF6)**.
For us, the following questions are of main relevance:
– How are images and grains optically displayed in digital form with the devices used and in various resolutions?
– How do compression and grain interact?
– What kind of effect does noise suppression have?

5.5 Transfer machines

During the execution of a test series, attention must be paid to ensure that the characteristics of interest are actually measured. Other parameters should be kept as low and as constant as possible. It is not always possible to execute this thorough and without exceptions, because various influences are strongly interdependent. The aim of this study was to test film emulsions and not specific scanner models. There is an extremely wide variety of devices available on the market and they differ greatly in price and quality. Various reasons limited the selection of transfer machines. For this test series, it was decided to adapt the workflows to post-production options on the Swiss market. Thus it was possible to include and study the external constraints which affect local archives.
Since large numbers of 16 mm reversal film in the archives of Swiss television stations had already been processed, the devices and workflows used were also included in the test series.

Appendix 11.4 lists the post-productions companies in Switzerland that offer HD transfers of film.

Standardising all parameters in the film digitisation process is impossible. There is no "neutral" setting in digitisation to project a "pure" original. The various techniques alone, which are used in the variety of devices, generate raw data that cannot directly be compared with one another. Each machine converts the data before they are available for grading. Nonetheless, the objective was to find settings that are as transparent as possible for each transfer, with reference to the following image characteristics:
– detail enhancement;
– black and white values;
– noise reduction;
– colour grading.

The operator's level of experience is essential in the process. He must have a good eye in order to exactly determine the characteristics of film and the opportunities offered by the transfer machine.

5.6 Target format

Similar to the issue of hardware, the abundance of digital formats poses a challenge. The aim of the test was to compare the performance of the film stock and not that of different codecs in SD and HD. Issues about digital archiving are closely tied with those of compression and codecs, because the wealth of data from uncompressed transfers is usually too high and too hard to deal with to be used in digital archiving. Despite this, this study only touches on these issues. An in-depth study dedicated to the quality of various codecs and their suitability for archiving would offer fodder for many separate studies. We worked around the issue of codecs by focusing only on uncompressed data. An attempt was made to achieve consistency in generating images to find the constants regarding the film material. Using uncompressed HD files was the best solution for this study, but this does not mean it is the best solution for digital archiving.

5.7 Image content of the test reel

The test roll was put together especially for this project using footage from RTS' archives. It combines as many aspects as possible that typically characterise film in their and many other television archives.
These characteristics are the following:
– black & white and colour film stock;
– wide shots and close-ups;
– structures rich in detail for the analysis of resolution levels;
– contrasty material aswell as such with balanced exposure;
– over and underexposed material;
– various emulsions with various grain and colour rendering;
– skin tones in colour film;
– test pattern for image sharpness.

Details are listed in **Appendix 11.5**

6. Test Series and Workflow

6.1 Preliminary remarks

It is difficult to test the quality of transfers avoiding influence by other factors. The technical processes are complex and in many cases they are not accessible in detail. The most important principles for the best possible consistency within a test series are:

- keep workflows simple and short;
- switch off all device "extras";
- consistency in format and operating software;
- clearly communicate prerequisites and objectives to technicians carrying out the tests;
- accompany the grading process in person if possible.

The following main factors played a role in this study:

1) Workflow

How the work steps are chained up has an important influence on the quality of the product. The chain is as strong as its weakest link. Quality lost at some point during the process cannot be restored down the line.
The exact workflow of the test series is discussed later in this chapter.

2) Quality of the scanner model

Various film transfer machines were used for the test series to get an impression of their level of performance and to compare them with one another. Their technical difference is tied to the performance of the operator.

3) The human factor

The experience and know-how of the technician operating the device plays a key role. If this person is unknown to the customer, this point is likely to be the most difficult to evaluate and control. It would have been ideal for the test series to have the same operator for all transfers. However, this was not possible for logistical and financial reasons. In addition, grading technicians are generally practised at one specific system.

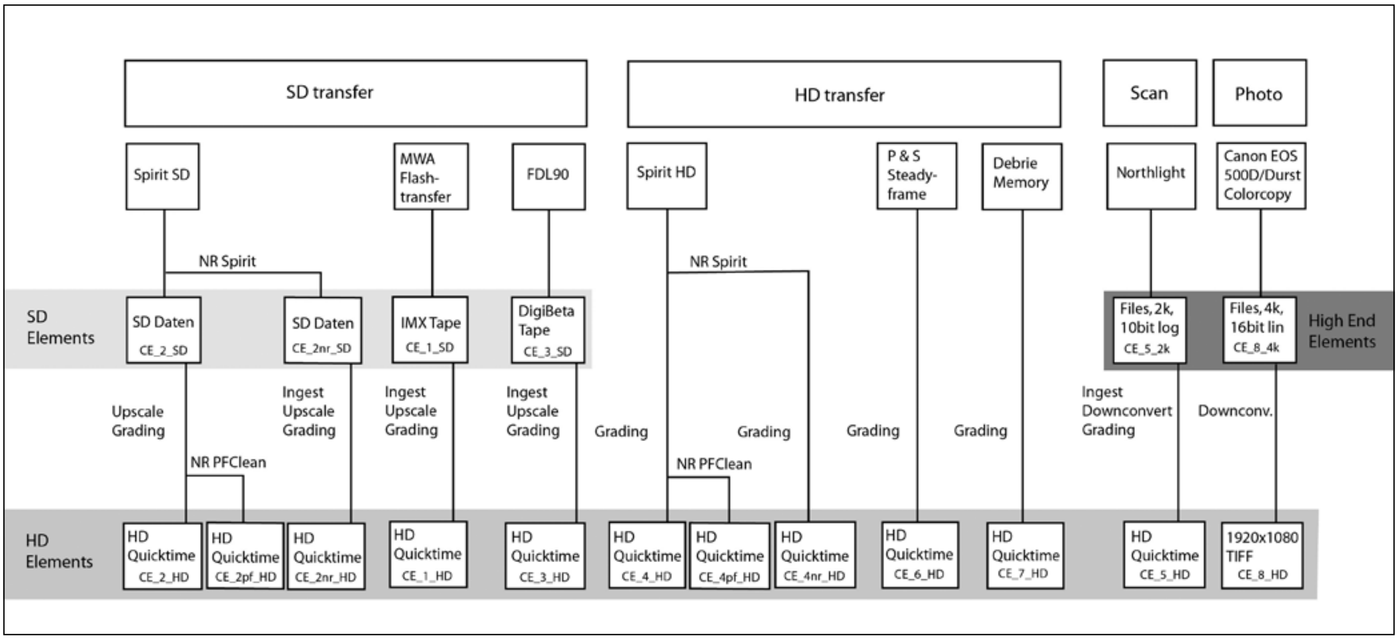
4) Quality of signal processing

There are important quality differences in signal processing procedures like upscaling the resolution (also called upres) or noise reduction. In the test series always the same algorithm was used for upscaling the SD transfers to HD. This made it possible to compare the test results. One single cross-comparison test was made using a different algorithm in order to illustrate the influence of quality differences here as well.
Noise reduction: the differences in quality of tools on the market are enormous. During the test series, we used only two options in order to get a slight impression of what the effect of these differences could be.

5) Grading after transfer

During the test series, corrections after transfer were made to reduce visual factors that have nothing to do with the quality of the digitisation, but which strongly affect how the image is perceived. In concrete terms: the black & white values of the individual test sequences were matched with each other. Colour grading was left in the hands of the machine operators and not touched further.

Figure 1: Overview of the test series



6) Displaying transfers for evaluation
The market for monitors and screens is very confusing and exceptionally competitive. Manufacturers use technical tricks to be able to offer as flexible devices as possible, but this makes the devices' electronics complex and obscure for the observer.
A monitor that can be calibrated is necessary for a good presentation; it must offer a resolution that corresponds to that of the test sequence – in this case a pixel-by-pixel representation.

How data processing works inside the transfer equipment remains unknown. Processes carried out internally are difficult to investigate. Manufacturers use various tricks to achieve the desired results in terms of price and speed, which can have disadvantages for image quality.

Scan logs are listed in **Appendix 11.6.**
Technical datasheets for the transfer machines are in **Appendix 11.7.**

6.2 Test series

Transfers were made of the 16 mm test real in SD, HD and 2 k. Individual images with a resolution of ca. 4 k were also recorded. **Figure 1** offers an overview of the test series (page 10). The comparison elements CE_1_HD to CE_8_HD served as a starting point for the analysis of the results.
The machines used offers a good cross section of the equipment available in Switzerland, whereat the Spirit can be seen as a kind of industry standard. For this reason, the transfer made using the Spirit were selected as a reference for the comparison between SD and HD.
Because workflows used at Swiss TV stations were also included in our choice of workflows, the compressions they use are an inherent part of the corresponding test examples (CE_1_HD and CE_3_HD).

6.3 Workflow

Figure 2 (page 12) shows the workflows used for the test series. For comparison, all results were converted into Quicktime files at 1920×1080, 8-bit lin, uncompressed.
The upscaling of the SD resolution into HD was carried out identically in all cases.

The transfer workflows for the TV stations SRF and RTS include digital Betacam and IMX tapes. They were carried out in exactly this way. All resulting HD files were collected on a Quantel system and exemplary clips were taken for comparison. In certain cases, conforming was necessary, because not all files were delivered in the same format. In addition, the black levels were matched to make the visual comparison of the tests more easy.

Characteristics of comparison elements:

Element	Device	Resolution, pixel	Tape/File	Bit depth	Compression	Colour channels
CE_1	FDL90	SD, 720×576	DigiBeta	10bit log	4:2:2, uncompressed	YPbPr
CE_3	MWA	SD, 720×576	IMX	8bit lin	4:2:2, compressed	YPbPr
CE_2	Spirit	SD, 720×576	File-based	8bit lin	4:4:4, uncompressed	RGB
CE_4	Spirit	HD, 1920×1080	File-based	8bit lin	4:4:4, uncompressed	RGB
CE_6	Steadyframe	HD, 1920×1080	File-based	8bit lin	4:4:4, uncompressed	RGB
CE_7	Memory	HD, 1920×1080	File-based	8bit lin	4:4:4, uncompressed	RGB
CE_5	Northlight	2k, 2048×1536	Single Frame	10bit log	4:4:4, uncompressed	RGB
CE_8	Medialab	4k, ca. 4000×3000	Single Frame	16bit lin	4:4:4, uncompressed	RGB

Machine characteristics:

Device	Chip	Light source	max. resolution (16 mm)	max. bit depth	Run
Bosch, FDL90	CCD	Halogen	SD, 720×576	8bit lin	Continuous
MWA, Flashtransfer	CCD	LED	SD, 720×576	8bit lin	Continuous
Thomson GV, Spirit	CCD	Xenon	2k, 2048×1536	10bit log	Continuous
P & S, Steadyframe	CMOS	LED, diffuse	2k, 1728×1240	10bit log	Continuous
Debrie, Memory	CCD	diffuse	2k, 2048×1536	10bit log	Continuous
Filmlight, Northlight	CCD	Metal Halide, diffuse	4k, 4096×3072	10bit log, 16bit lin	Intermittent
Canon EOS 500D / Durst Colorcopy 350	CMOS	diffuse	4k, ca. 4000×3000	16bit lin	–

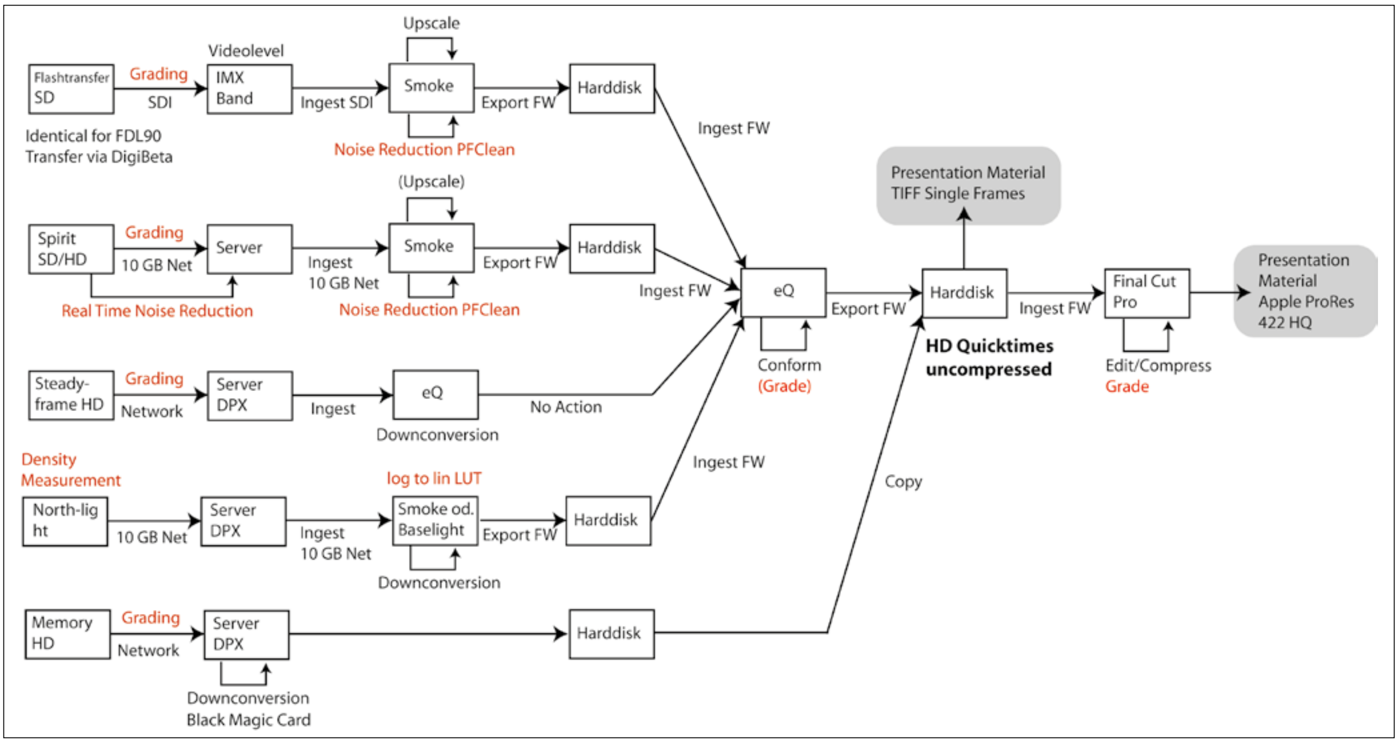
Even if the workflows are adhered to in a straightforward manner, they are complex and entail many steps until the end result. There is always a danger of unnecessarily trimming the quality somewhere along the process. The problem is aggravated by the fact that post-production companies tend towards taking short cuts or speeding up the workflow in attempt to be more efficient. Files are compressed to reduce data size without telling the client in which form and during which step. Although all postproduction companies involved in this test series were clearly told what it was about, in various cases it was suggested that files be generated in compressed codecs because "one couldn't see the difference" between the result and an uncompressed file.
The 4k, 16-bit single images were taken using a Durst Colorcopy 350 with a digital Canon EOS 500D still camera. The diffuse background lighting used to do so resulted in a grain that is less intensive in appearance. Not all images are equally sharp throughout the entire image. Only equipment for holding 35 mm film was available and thus it was difficult to clamp the 16 mm film into it completely in plane.
It is not possible to play back uncompressed HD files on a regular computer without jerky movement, therefore once postproduction was completed, the files were converted to the Apple Pro Res 422 HQ codec and grouped meaningfully for a presentation. For the presentation of stills, individual images were taken from uncompressed Quicktime clips and saved as TIFF files.

Adjustments made to the digital image structure during the test series

– Upscale/down-conversion (for SD, 2k and 4k files)
– IMX compression (only for MWA workflow)
– Conversion from logarithmic to linear colour space using an LUT (for down-conversion of 2k scan)
– Grading (during transfer and postproduction to create demo clips)
– Noise suppression in real-time (Spirit) and by rendering with PFClean **(REF8)** (additional tests only)
– Conversion to Apple ProRes codec (for the presentation)

Figure 2: Workflow overview

Steps where technicians took decisions that affected image quality are marked in red.
The data of the Memory transfers were not channelled past the eQ for technical reasons, but rather arrived last when this step had already been carried out



7. Results

The analysis of the test sequences were carried out using uncompressed and compressed (Apple ProRes codec) Quicktime films, as well as TIFF files of stills. Documenting all characteristics is not possible by just using frame shots, because certain features can only be seen in the moving image. Therefore, not all observations and comments described below are obvious in the images presented here.

7.1. Preliminary remarks regarding images in this document

Controlling the quality of print documents is difficult and the characteristics of the video images can be represented only marginally in printed stills. The images inserted into these chapters have been selected and prepared so that the observed effects are obvious.
Separate images in TIFF format may be consulted for images that match the results of the transfer 1:1. They are linked to this document and can be opened by clicking on the link in the text. All TIFF images were taken directly from the uncompressed Quicktime clips delivered by the postproduction companies. The TIFF files are in the original resolution of 1920×1080 pixels and were saved in 300 dpi. Image clips were enlarged in Photoshop **(REF9)** with "Pixel repetition". For the adjustment of black and white values, the lightest point in the image was set to 255 and the darkest to 0, without losing image information in light or dark areas. In combination with the facts in the text, the image information is meant to be sufficient for observers to come to their own conclusions.

7.2 Cross-comparison of all test segments (Fig. 3)

Comparison elements: CE_1_HD, CE_2_HD, CE_3_HD, CE_4_HD, CE_5_HD, CE_6_HD, CE_7_HD, CE_8_HD

An initial visual cross-comparison of all test segments, without grading adjustments, offer the following observations. Most obvious in the colour tests are the extreme differences in colour (intensity and hues). There are also strong differences in the grading of all segments (black and white values, clipped highights, etc.) The grain is represented very differently in the various transfers.
There is a difference in sharpness between SD and HD, but that is not the first thing that meets the eye. Digital artefacts are also very different. They are especially obvious in the result of the MWA flash-transfer, which is probably mainly an effect of the IMX format used. The analogue artefacts (scratches in the film, dirt, etc.) are apparent to varying degrees: more strongly in softer images, less strongly in contrasty images.

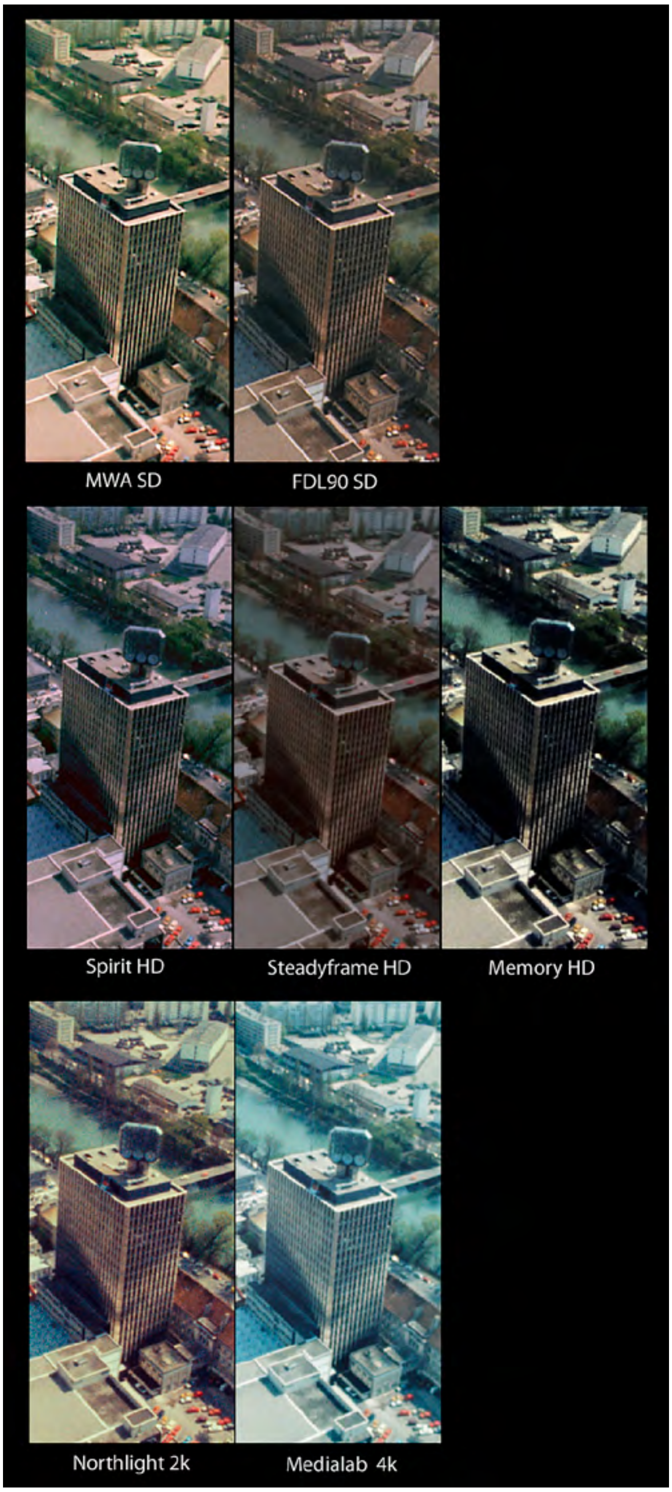


Figure 3 Overview of cross-comparison of all test segments. (Click on the image to open the TIFF file.)

7.3 The Spirit transfer in SD and HD (Fig. 4a/4b)

The Spirit transfers in SD and HD were used as a reference, because Spirit is a widely used model in Switzerland as well as a high-end machine that offers top quality when used properly.
Comparing an SD transfer with an HD transfer made on the same device brings with it the following limitation: the chip used for the transfer is the same in both cases. This means that the SD transfer was also done with the HD chip, but the data were subsequently reduced by the machine to deliver an SD resolution. The data reduced to SD by the device was then upscaled by us back to HD with a Smoke system.
The whole exercise therefore becomes a down/up conversion. However, since there is no way to control the machine's internal processes, we ignore this fact and consider the SD transfers to be just that.

Results

The HD transfer has more definition. The difference in sharpness is not marked. The grain appears acute in the HD transfer and therefore more intensive.
With coarse-grained film stock (e. g. 7250 VNX 400 ASA, Fig. 4b), the difference between SD and HD is clearer, especially due to the more marked changes in the rendering of the grain.

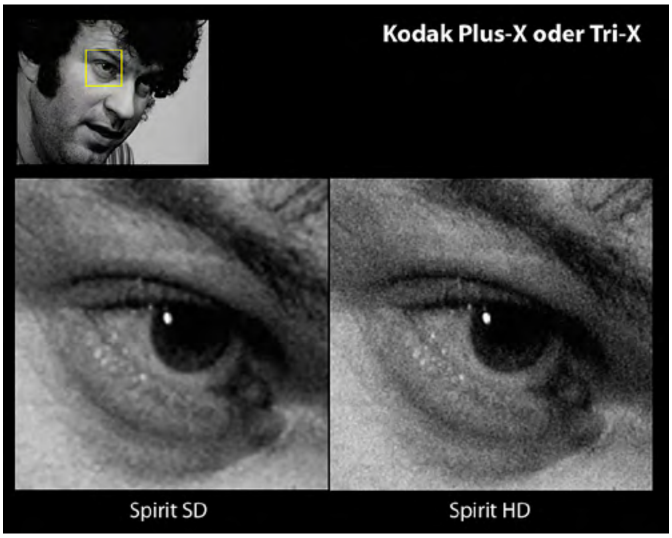


Figure 4a The Spirit scan in SD and HD.
(Click on the image to open the TIFF file).

Figure 4b The Spirit transfer in SD and HD.
(Click on the image to open the TIFF file).

7.4 Comparison of the SD transfers with one another and with HD (Fig. 5)

Comparison elements: CE_1_HD, CE_2_HD, CE_3_HD, CE_4_HD, CE_8_HD

In this case, two different factors were studied: the results of the SD tape workflows of the TV stations was compared with the Spirit reference transfers. In addition, the characteristics of the various transfer machines became apparent.
MWA and FDL90 were created with the tape workflow, therefore all the black areas are lifted and the light areas are lowered (video level: 16–235, graphics level: 0–255). These differences were balanced out as much as possible in the subsequent grading to improve visual comparison.

Results

MWA flash scan: the results of the MWA are significantly worse than those of the Spirit model. There are clear digital artefacts and strong border effects. The grain seems “ironed out” and overlaid by the digital structure. Colours are dull. The issue of to which extent the IMX format is responsible for these characteristics cannot be clarified conclusively.
FDL90: the image of the FDL90 from the tape workflow via Digital Betacam has significantly more video characteristics and they are more consistent with analogue video technology. The pattern of lines is very soft. The quality is very different in comparison to the MWA, but not significantly better or worse. The image is slightly stretched vertically. Among the SD transfers, the Spirit model offers by far the best results in terms of sharpness, artifacts and colour saturation. The most striking thing about the Spirit transfer in HD is the intensity of the grain.

Figure 5 Comparison of SD transfers.
(Click on the image to open the TIFF file).

7.5 Comparison of HD transfers (Fig. 6)

Comparison elements: CE_2_HD, CE_4_HD, CE_5_HD, CE_6_HD, CE_8_HD

In the past few years, many new scanner models have come onto the market, which offer HD transfers at a relatively low price. Until now, high-resolution conversions were possible only using the most expensive models. With falling prices, they are now available for large-scale archive transfers. Some providers have recognised archives as a worthwhile market segment.
We attempted to include this development for the test series in HD. P&S Technik's Steadyframe model had only just been upgraded to 16 mm by the manufacturer at the time the test series was carried out. The results of the transfer were produced during a beta test phase. Conditions were similar for the Debrie Memory model, which had been installed at the provider for only a short time and whose infrastructure for transfers was still being built up.
The results of the Northlight 2k scan are also in this series of comparisons, however they are quite unsatisfying. This will be dealt with later in the chapter.

Results

The reference transfer of the Spirit model is relatively contrasty in grading and the values drop steeply at one point. The detail in dark areas of the image is therefore bad. The grain is slightly "coloured". The results of the Steadyframe seem to be the least sharp of the HD transfers. The detail in the light and dark areas of the image is very good, however. The light areas are relatively low. The least amount of grain is to be seen in the enlargement. According to the Medialab stills, Steadyframe works with diffuse background lighting. Images in black and white have a slightly green tinge. The images from Debrie Memory are relatively contrasty in grading, but offer more detail in black areas than the Spirit. The colour is not very intensive. In the enlargement especially, one can see that the image structure has the strongest digital character of all the HD transfers. The brightness is pumping, which later turned out to result from a wrong setting in one of the device's optical elements. As already mentioned, the down-conversion of the Northlight scan is somewhat problematic and cannot be compared in all points. There was no observable advantage over the Spirit HD transfer in terms of image sharpness.

Figure 6 Comparison of the HD transfers.
(Click on the image to open the TIFF file).

7.6 Contrast behaviour, grading and the results of over and underexposures (Fig. 7/8)

Depending on the workflow, the transfers delivered files in RGB with graphics levels (0–255) or component YPbPr with video levels (16–235). This led to the fact that the test segments visually differ very strongly. The differences could lead to incorrect conclusions with regard to quality. For this reason, the black and white values were adjusted during subsequent grading so that the visual comparison was easier. At the same time, the detail in dark and light areas of the image were not altered.

Underexposures

Comparison elements: CE_1_HD, CE_3_HD, CE_4_HD, CE_5_HD, CE_6_HD, CE_7_HD, CE_8_HD

Results

For the Spirit transfer, the grading was identical for both the SD and HD versions. Although the detail is good in the light areas, there is practically none in the dark areas. This has a dramatic effect in underexposures. SD or HD made no difference. The lost image information couldn't be retrieved with subsequent grading either.
Due to the combination of an economical model with the IMX format, which includes an Mpeg-2 compression, the results of the MWA transfer were technically the weakest. However, the grading was done well by the technician, so that there is detail in the light and dark areas of the image. In the underexposures, the black areas were lifted strongly as an experiment in a second grading process. This resulted in artefacts appearing on the shaded areas. Blocks and banding were formed through the limited resolution of the shades of grey. The levels of grey shading are quite limited already at the highest level of quality when using at 8 bit. This shows that compression or a transfer on qualitatively limited equipment can further limit options for later grading. For the FDL90 results, we managed to bring out many details with adjustments to the black and white values. Increasing the contrast also increased the perception of sharpness. However, the image is hardly better than the MWA transfer. The Northlight scan was generally too light. Much image information was lost in highlights of normally exposed shots. In underexposed shots, however, all the information in the film thought lost in the dark comes out. Most of it had been lost in other transfers. This shows how much image information is in a film, even if it is incorrectly exposed. A comparison with results from the Spirit model, which are low in detail in underexposed regions, expressively demonstrates how important grading is during a transfer. As much image information as possible should be brought into the digital space.

In the transfers made by the MWA and Steadyframe, a slightly flickering structure of horizontal lines was observed, for which no explanation was found. It is possible that these systems came up against their performance limitations during the processing of underexposures.

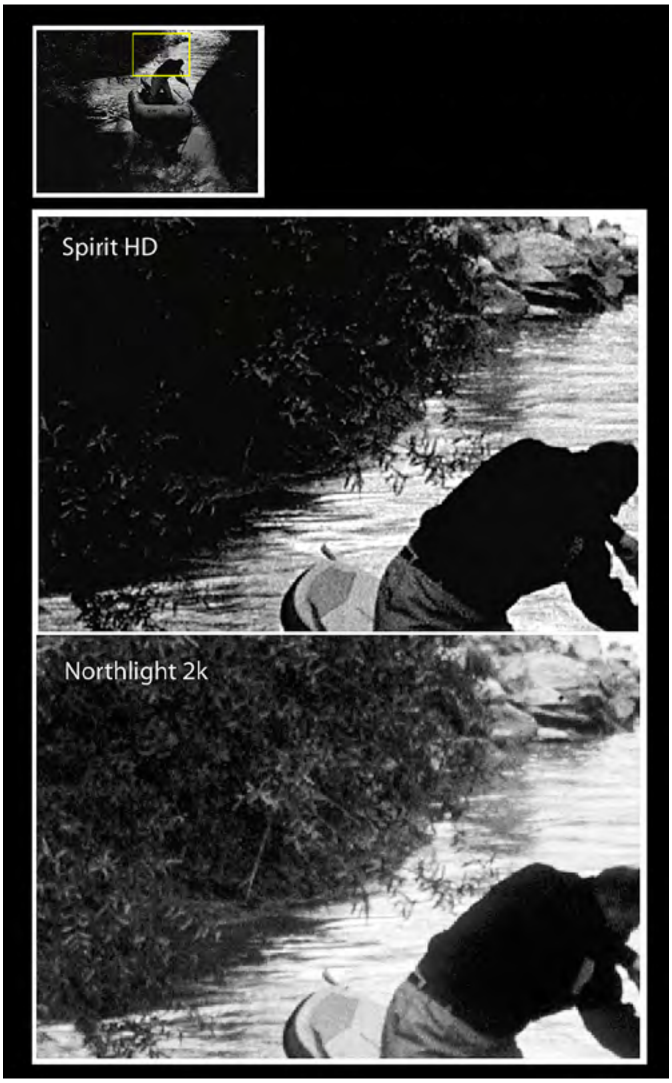


Figure 7a Underexposed original images.
(Click on the image to open the TIFF file).

Overexposures

Comparison elements: CE_1_HD, CE_3_HD, CE_4_HD, CE_5_HD, CE_6_HD, CE_7_HD, CE_8_HD

Various examples from the test series show that the technical conditions that provide bad results for the dark image areas offer better results for lighter parts, and vice versa.
When compromises are made in quality, good results can be achieved for unproblematic images with skill and experience, but difficult original material results in overproportional lower quality and the material is more likely to become unusable.

Results

The Spirit transfers, which are weak in the dark image areas, work better for overexposures. The harsh contrast has a positive influence on the perception of the image. The Northlight scan is completely burnt out and unusable.

Figure 7b Loss of quality in difficult image areas.
(Click on the image to open the TIFF file.)

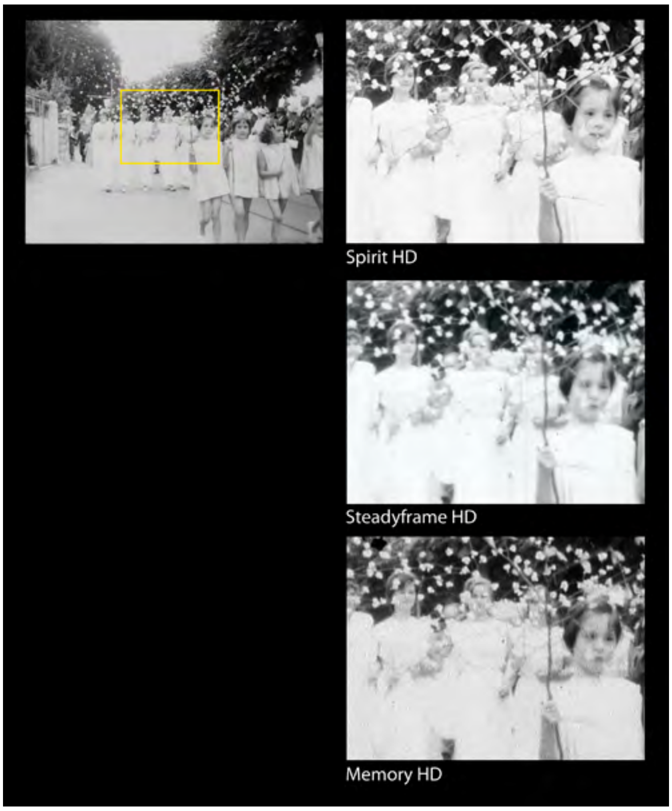


Figure 8 Overexposed original images.
(Click on the image to open the TIFF file.)

The images of Steadyframe are especially blurry in this case, with many scratches and dust. Most likely, the focal point was on the level of the scratches and not in the optimum image plane during transfer.

7.7 Test patterns (Fig. 9)

Comparison elements: CE_1_HD, CE_2_HD, CE_3_HD, CE_4_HD, CE_5_HD, CE_6_HD, CE_8_HD

The results from the comparison of test patterns more or less met the expectations. All HD transfers offered a higher level of definition than the SD transfers. An astonishing fact is that the results of the Steadyframe were better than the other HD machines, even though the film images generally made a weaker impression in terms of sharpness. The Debrie Memory model provided the worst sharpness among the HD devices. The 4k scan is no better than the HD transfers. The focus may not have been set properly.
It becomes clear that the impression of sharpness is not only affected by actual sharpness.

7.8 Image geometry and cropping

Depending on the film camera used shooting the original footage, the 16 mm format did not give an image that fully corresponded to the 4:3 aspect ratio. We repeatedly observed that one of the borders of the image, for example, was curved or its edges were rounded due to the special shape of the gate in the camera. Form an archival point of view, this is also image information that must be transferred. An impossible task with some of the transfer machines.

The transfers do not all show the same image area. In the TIFF file linked to Figure 3 a yellow frame is shown which marks a surface area of 1440×1080 pixels. This frame is also overlaid on all images coming from the transfers of different machines involved. All devices generally have an image area setting. Some of them are more flexible than others. The exact choice of the image area in the transfer must therefore be discussed with the technician. In this series, the original geometry of the film image was respected only in the 2k scan and in the transfer of the Debrie-Memory.
In the case of the FDL90, a slight vertical distortion of the image was observed. Limited image distortion is hard to recognise.
Test images with clear geometrical forms (circular or grid) help to identify deviations.

7.9 Upscaling of SD with Smoke and eQ (Fig. 10)

Comparison elements: CE_2_HD, CE_2eQ_HD

Testing the quality of various upscaling tools was not the intention of the test series. Upscaling was carried out identically for all SD test elements on a Smoke system. To nevertheless receive an idea of the difference between such processes, the SD Spirit transfer was additionally processed with another algorithm on a Quantel eQ system.

Results

The Quantel version is of lower quality as far as sharpness is concerned. In the Quantel version, strong aliasing can be observed in fine horizontal structures. There are differences in image geometry between the two results.

7.10 Grain and noise reduction (Fig. 11)

Comparison elements: CE_1_HD, CE_2_HD, CE_2nr_HD, CE_2pf_HD, CE_3_HD, CE_4_HD, CE_4nr_HD, CE_4pf_HD, CE_5_HD, CE_6_HD, CE_7_HD, CE_8_HD

Suppressing the noise of the emulsion is very important for the relatively coarse grain of reversal film. It is an important step on the way to the improvement of broadcast suitability in HD. At the same time, it represents significant intervention into the image structure, which affects every point of the image. Noise reduction also results in the loss of image sharpness. Setting its intensity means looking for a compromise between noise reduction and limiting the loss of sharpness and other unwanted effects.
A lot of applications for noise reduction are available on the market. In terms of their workflows, they can be divided into two groups:

1) Systems that work in real-time and which can be set at various intensities during transfer.
2) Systems that need more computation time. The digitised material is rendered using more than real time.

In general, rendering systems are of high quality, because there is more processing time for each image. The comparison of various noise reduction algorithms is not part of this study. Nevertheless, additional SD and HD samples were chosen, for which the real-time process included in the Spirit system was used. Noise reduction was applied with limited intensity (see Scan logs in Appendix 11.6). In addition, a test segment was treated with PFClean. The grain structure of the unprocessed segments were compared with each other and with the ones processed

Results

The comparison of the transfers shows that the grain is represented in very different ways, depending both on resolution and on the machine used. The Northlight scan shows a strikingly colourful noise.

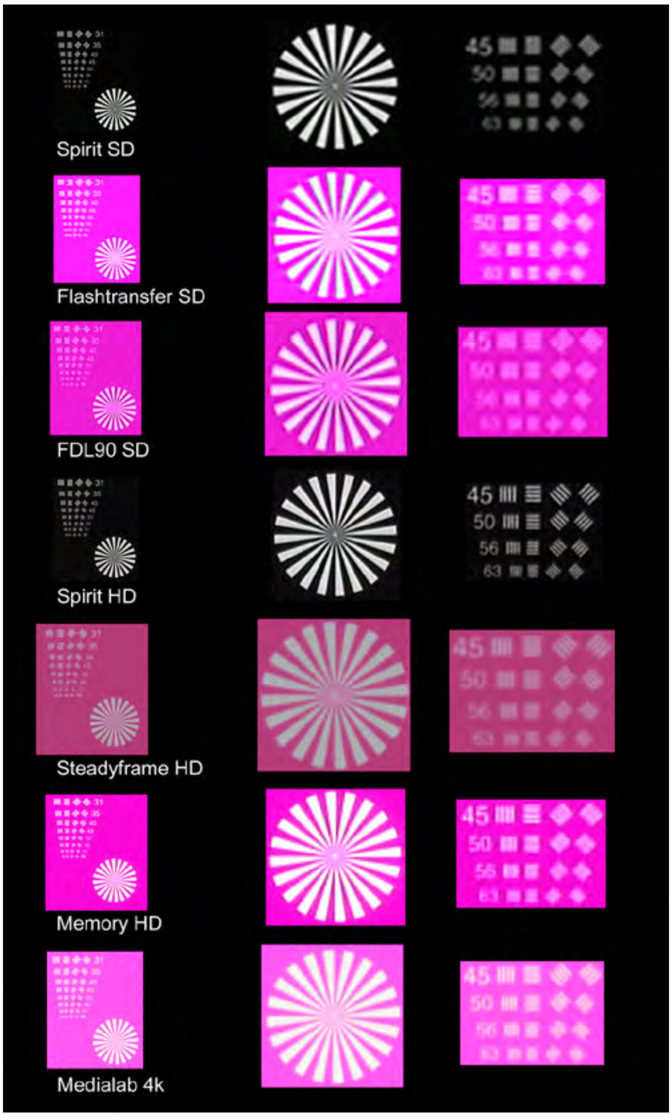


Figure 9 Test patterns.
(Click on the image to open the TIFF file).

Figure 10 Upscaling differences.
(Click on the image to open the TIFF file).

In the HD segment of the Debrie Memory model, we observed a regular arrest of the grain's motion. This later turned out to be a problem through an error in the setup (see also remarks in "Comparison of HD transfers", Page 17). The enlargement showed a stronger block structure in comparison with the other transfers.

Digital characteristics and artefacts interact with grain. This has a greater effect in SD, because at this resolution, the dimensions of grain and pixel size are similar. The results of the Steadyframe as well as the Medialab 4k stills show subdued grain. This is due to the diffuse background lighting, which was used in both cases.
The real-time noise reduction of the Spirit model delivers good results with few artefacts, although the remaining grain changes slightly over time. The results are good if the grain is weak.
If the grain is strong, any change is hardly noticeable. This depends on the level of noise reduction, which was left the same for all shots in this test, but would have to be adjusted according to the situation.
The PFClean rendering system reduces noise but makes the image blotchy, which is especially visible if the image is moving. This characteristic is less visible in stills, where the results look best. However, it produces the most significant loss of sharpness.
The superiority of rendering systems could not be confirmed by these tests.

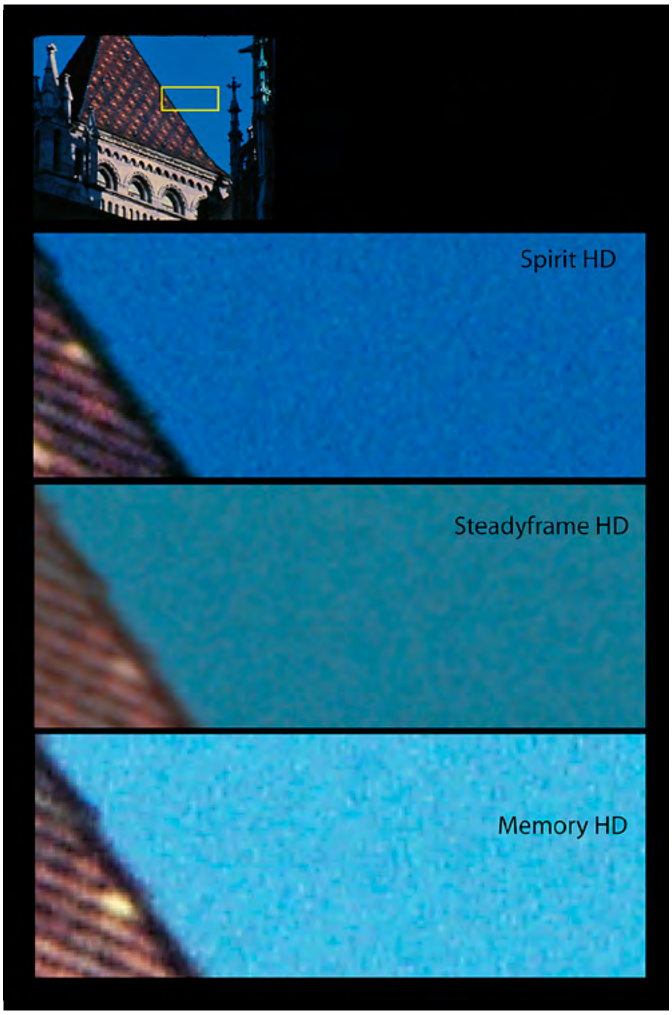


Figure 11a Grain and noise comparison.
(Click on the image to open the TIFF file).

7.11 Bit depth

Reversal film is less tolerant with regard to differences in image brightness than negative film. Negative film tolerates a range of up to ca. 10 apertures, reversal film only 6 apertures. The difference between a 10-bit scan and an 8-bit scan is therefore accordingly smaller with reversal film. The actual difference between 10-bit and 8-bit colour depth is difficult to visualise. The results of this study offer no information that could be implemented in a useful evaluation.

7.12 Problems with scanning

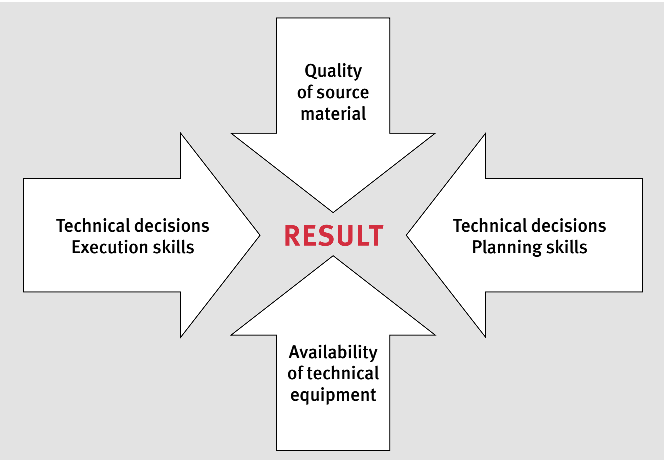
The results of the Northlight scan have a strange quality. They lie generally in the upper third of the brightness scale and have remarkably colourful grain. It is hard to retrace where the problem lies. In the workflow used, the quality of the scan is sustainably influenced in two points:
Prior to the scan, the machine is calibrated by measuring the densest and the most transparent part of the emulsion. If these values are incorrect, it will affect the grey scale of the entire scan. In carrying out the measurement, it is assumed that the film stock is constant for the entire reel. However, our test reel was edited together out of films of various emulsions. It is quite possible that the choice of calibration points was unfavourable for most of the reel's settings and that the scans were therefore not representative.
A further step during which the grey values are changed is the conversion from the 10-bit logarithmic colour space to the 8-bit linear one. There is no mathematically clear, single correct method for conversions from logarithmic to linear space. The process entails using look-up tables (LUT), which are selected based on the character of the image content and the targeted look. High-end scanners are generally geared towards negative film. Scanning reversal film can thus cause problems. This is not a question of hardware, but of software. The needs of reversal film are often not taken into consideration during programming.

Figure 11b Grain and noise comparison.
(Click on the image to open the TIFF file).

8. Conclusion

8.1 General remarks

The question of which level of quality the digitisation of 16 mm reversal film should result in cannot be reduced to the choice of "HD: yes or no?". Many factors play a part in the decision-making process, based on the four parameters: the quality of the original material, the skill in executing the process and, not least, the availability of the desired equipment (cost factor!).



Commercial institutions like TV stations use digital footage mainly for repurposing, for which it must be suitable and easy to use. The archival point of view is of less importance. From a purely archival viewpoint though a digital conversion must take place in such a way that the image is transferred with its inherent media characteristics in place to retain its authenticity.
When digitising a handwritten document on parchment to archive it, one would never think of removing the structure of the parchment and displaying the writing on a white background, even if this would improve its readability. In a modern document written with a mechanical typewriter on grey environmentally friendly paper, however, the characteristics of the material play a smaller role. If we transfer this idea over to film as a medium, the significance of its characteristics probably lie somewhere in between. Because the characteristics of analogue film as a medium are based on a structure whose size lies in micrometres, the resolution of a transfer can never be good enough. Aiming for a resolution on the level of the medium's silver grain would be absurd and completely unrealistic, especially because it involves a three-dimensional structure.
A further fact is that a transfer that contains as much image information as possible is not necessarily the most visually attractive option. Its strength lies in the fact that various visual results can be achieved through further processes like grading. This however, requires further, more or less expensive and seldom automatable work steps. A highest quality transfer for archiving would again incur costs aftewards, since for use in a broadcast the data would first need to be converted, re-graded and possibly processed in some other way.
This results in more effort:

– in digitisation;
– in storage (larger data volume);
– in the preparation for repurposing.

8.2 Image characteristics

Despite limiting the test series to reversal film, we had to deal with a group of film emulsions that differed greatly in characteristics.

Workflow

Signal processing must be discussed with the posthouse in charge of the transfer and set in a way that is binding. Even if the transfer process is relatively straightforward, the image information goes through several additional processes until it is presented. This is generally the case with postproduction. The probability that a reduction in quality is created somewhere along the line is quite high. The steps must therefore be well thought through to prevent this.
Even if simple, a workflow consists of a series of many small steps that can be of better choice or worse. A compromise that reduces the quality can be acceptable in one step, but if always the inferior option is selected in the decision-making process, the result will be much inferior accordingly.
Bottlenecks reducing quality irretrievably, must be avoided. It is advisable to understand the whole process as far as possible. If that is not possible, an external expert should be included for a neutral evaluation.

Equipment

The machines differ greatly in terms of transfer quality and image characteristics. More expensive devices generally still perform better than cheaper ones.

Image sharpness and grain

The gain in additional sharpness of the image content delivered by an HD transfer is not particularly large. Emulsions with various grain levels react differently when transferred to SD and HD. The overall appearance of the image changes greatly through the different representations of the grain. This effect is more marked for coarse-grained images than for fine-grained images.
In an SD transfer, the grain is not resolved and is therefore seemingly flattened and in some cases suppressed.

An SD transfer combined with a compressed target format is not recommended. Some sources argue that, with the increased performance of algorithms for upscaling from SD to HD, the upscaled results will in future correspond with HD transfers. This may more or less be the case for the image content. However, the grain structure is affected to such an extent during the SD transfer that it cannot be reproduced in its original form by upscaling. Too much information about its structure is lost through the lack of definition.

Grading
Grading is of great importance. The qualitatively best transfer machine becomes useless if the technician fails to use the device correctly. The technician must be a person of trust. A specific person should be determined together with the postproduction company to carry out the work. You must know what you want and find a technician that understands your ideas and implements them. Setting the parameters once and letting all the material rush through the machine will not lead to satisfactory results (this also applies to 2k scans!). Having to adjust the device's parameters from one shot to another is unavoidable. The more the efforts in transfer are reduced, the greater is the danger of losing image information.
This also means that it will be more difficult (or impossible) to reuse the resulting product. The greater the compromises in effort, the more drasticly the results will lack quality for shots which are already more problematic in the original. Film often contains such a richness of information that the final look of a shot can be determined in the post production process (analogue or digital post production). The greater the technical compromises in a transfer, the narrower this flexibility becomes. This has negative effects on the reusability of the digital products. The problem of inconsistent colour reproduction becomes significant and in many cases almost unsolvable, since colour references (colour charts) are almost always missing from the image and direct comparisons of film colours with those in the transferred images are extremely cumbersome. In addition, the colour space of the film is different from that of the transfer.

Tweaking the image structure
Emulsions with coarser grain react differently to procedures like noise reduction than fine-grained emulsions. The settings must therefore be flexibly tuned. For SD transfers, it makes more sense to carry out noise reduction through rendering after their upscale to HD, because the initial points for calculation become smaller as the resolution increases.
The differences in the quality of upscaling algorithms are significant. It is important to understand at which point in the process which adjustment should be made ideally (up/downscaling, noise reduction, format changes, data format changes). The ideal method can differ according to the type of workflow. Heavy adjustments usually give bad results: The reversal film stock used by reporters was explicitly developed for SD television. It does not make sense to ignore that and to attempt to bring out a quality for which it was not made.

Special challenges for mass processing
Mass processing brings with it the danger of making too many compromises in terms of quality to keep costs down. With the help of prioritizing the original material, the volume of film to be transferred can be reduced. Consequently, there is more money available per metre of film.

Danger also lies in the tendency to rationalise away the above-mentioned quality safeguards and checking procedures in favour of lower prices and faster processing. To keep cost low and save state-of-the-art systems for projects with a higher profit margin, post-production companies generally make older equipment and less qualified personnel available for mass processing projects.
Archiving in large companies also may raise the problem that the digital format declared as standard for post-production is not ideal for archiving purposes.
If a cost estimate is requested from various providers for a mass processing project, the result is a wide variety of prices. A closer look shows that the included services vary greatly. It is therefore important to clearly define, include or exclude the desired services. This may concern:
– prior ultrasonic cleaning;
– physical checking and repairing of splices;
– the level of grading;
– automated or manual "corrections".

Key steps
1) Structure workflow in detail and define guidelines.
2) Carry out tests.
3) Bring in neutral third-party advisor.
4) Establish trusted person for the transfer.
5) Carry out quality controls.

A detailed checklist for outsourcing projects is included in "Project Outsourcing: Navigating Through The Client / Vendor Relationship To Achieve Your Project Goals", by Chris Lacinak **(REF10)**.

9. References

REF1: RTS – Radio Télévision Suisse (www.rts.ch)

REF 2: SRF – Schweizer Radio und Fernsehen (www.srf.ch)

REF 3: EBU – TECH 3315, “Archiving: Experiences with telecine transfer of film to digital formats” (Geneva, April 2006)

REF 4: EBU Tech 3289, 3289S1 “Technical recommendations for scanned image area dimensions from film for TV” EBU Technical Recommendations R86-2000 “Scanned Image Area Dimensions from Film for Television”

REF 5: Revue des Technologies de Radio-Canada “Méthodes de transfert de film en haute définition” (Nr. 3, Januar 2007)

REF 6: Tim Vitale “Film Grain, Resolution and Fundamental Film Particles” (April 2007)

REF 7: Popular Science “Mysteries of Photography” (Dec. 1935)

REF 8: PFClean is a Pixel Farm product (www.thepixelfarm.co.uk)

REF 9: Adobe Photoshop is an Adobe product (www.adobe.com)

REF 10: “Project Outsourcing: Navigating Through The Client / Vendor Relationship To Achieve Your Project Goals” Audiovisual Preservation, Chris Lacinak (www.avpreserve.com)

10. Glossary

The following glossary does not offer general definitions; it describes how each term is used in this paper.

Abtastung	Scan, Telecine	Optical digitisation.
Aliasing	Aliasing	Step structure of curved lines in an image, defined by the pixel structure of the digital image, dependent on the spatial resolution.
Archivkopie	Archival copy	Copy of a work designated for long-term storage.
Archivmaster	Archival master	Master that is a product of restoration and considered a (possibly new) original in the archive.
Artefakte	Artefacts	Technical characteristics such as line structure or compression reflected in the image quality. They are usually seen as a deficit or damage to the image.
Banding	Banding	Step-like structures in the colour hues dependent on the colour resolution, which is determined by the bit depth.
Bildverhältnis	Aspect ratio	Ratio of image width to image height (e. g. 4:3, 16:9 etc.).
Bittiefe	Bit depth	Digital measurement for the resolution of colour hues.
Codec	Codec	Digital code to display images at a reduced amount of data.
Conforming	Conforming	Adaptation of the digital codec to specific technical values or characteristics.
Definition, Detail	Definition, detail	The richness of spatial or colour detail of an image.
Dichtemessung	Density measurement	Measurement of the transparency of a film image after development.
Digitale Kopie	Digital copy	Copy of the digital master.
Digitales Master	Digital master	Product of a digital work process.
Digitalisat	Digitisation product	Result of the transfer of an analogue document (image) to digital space.
Durchzeichnung	Detail	The richness of spatial or colour detail of an image, usually in reference to the darkest or lightest part of the image.
Echtzeit	Real-time	Characteristic of a calculating processes which can take place in the background during playback of a clip at its real speed.
Einlesen	Ingest	Feeding information into a computer. This can include digitisation, conversion or just data entry.
(Farb-)Lichtbestimmung	(Colour) grading	Adjusting the colour of an image according to specific prerequisites.
Farbraum	Colour space	Three dimensionally – as a three gradient colour space – displayed totality of the colours of a colour model that can actually be displayed. Each technical colour display method has its own colour space.
Farbsättigung	Colour saturation	Colour intensity.
Hochrechnung	Upresolution (upres), upscale	Digital scaling to a higher spatial resolution of a digital image with a specific resolution. This can be done using interpolation or through simple nearest neighbour pixel repetition.
Kanteneffekte	Border effects	Visual artifacts based on digital processes; they affect image areas with extreme differences in brightness.
Konversion	Conversion	The conversion of digital data, e. g. from one codec to another.
LUT	LUT	Look-up table: set of values used for complex conversion processes of one colour space to another.
Nachschärfung	Detail enhancement	Artificial post-sharpening of a digital image through calculation processes.
Operateur	Operator	Specialist who operates a digitisation or grading device.
Rauschunterdrückung	Noise reduction	Reduction of noise in an image. This may be the analogue image structure of a scanned original transferred into digital space, or digital noise.

Degrain	Degrain	Suppression of the analogue grain structure of a scanned film transferred into digital space.
Pixel-by-Pixel-Darstellung	Pixel by pixel representation	Displaying a digital image of a specific resolution, in which each pixel of the digital image is assigned a real image pixel on the screen. Not scaled in size.
Pixelwiederholung	Nearest neighbour	A simple way of upscaling the resolution of a digital image by multiplying existing image information, without computational interpolation.
Reale Schärfe	Actual sharpness	Sharpness of an image given by the sharpness of the optical elements of the image itself and not created by digital processing.
Rendering	Rendering	Computer process that prevents the clip being shown in real-time when it is running.
Scan	Scan	High quality optical image by image digitisation technology for motion picture film.
Schärfeeindruck	Perception of sharpness	The subjective level of sharpness perceived by the eye/brain.
Schwarzwert	Black level	Darkest point of an image.
Signalverlauf	Signal processing	The conversions an image signal goes through during processing.
Skalierung	Scaling, upscaling, downscaling	Digital achievement of a higher or lower spatial resolution of a digital image with a specific resolution.
Stossen	To push	Chemical laboratory process used in developing underexposed negative film to achieve normal density values.
Telecine	Telecine	Optical digitisation technology for motion picture film, using a continuous movement of film to be transferred.
Umkehrmaterial	Reversal film stock	Film material which, after exposure, produces a positive original in the development process.
Umkopiermaterial	Intermediate stock	Film stock made especially for analogue copying.
Weiches/härteres Bild	Softer/more contrasty image	Contrast characteristics of an image.
YPbPr/RGB	YPbPr/RGB	Colour signal split into individual colour channels.

11. Appendix

11.1 Status quo of work on collections of Swiss public TV stations:

- Approximately 12,000 hours (almost exclusively 16 mm reversal film), 4000 of which have already been transferred. This comprises programmes in their entirety (news programmes such as Téléjournal, Rundschau, etc.) and selected “gems”.
- The remaining 8000 hours are not being transferred in their entirety, instead the work is being divided by subject into complete programmes or clips.
- The film collections remain accessible even after the work has been completed.
- HD is used for films to be broadcast completely in HD.
- The transfers of the material are being made in SD at Egli Film, Zurich (FDL 90) and at Schwarz Film Ostermundigen (Shadow).
- Because a solution for digital archiving is within reach, workflow attempts for this technology are currently being made.

The transfers to tape are being made using Digital Betacam, but for digital archiving the files will be processed using the IMX codec.

RTS (Radio Télévision Suisse):

- A total of ca. 10,000 hours of material (almost exclusively reversal film). 2000 hours have been transferred to Beta SP, another 4000 hours to IMX tapes.
- Not all material will be transferred.
- The transfers are made in-house. Since 2008 they are executed in SD on an MWA Flashtransfer machine. Prior to that a Rank Cintel telecine was in use.
- Because RTS has had its own infrastructure and transfer experts for years, it was decided to continue to do the transfers in-house.
- Transfers to HD are planned only for fiction films. All fiction films were shot on negative film stock.
- The film collections will remain accessible even after the work has been completed.

RSI (Radiotelevisione svizzera):

- A total of ca. 5000 hours of material on 16 mm.
- Ca. 1600 hours have already been transferred to Digital Betacam.

As of 2009

Information from SRF: Jürg Hut, RTS: Patricia Herold, RSI: Siro Boffa.

11.2 16 mm reversal film used by Swiss public TV stations

Name	Characteristic	Process	Introduced
Kodak PLUS-X 7276 (PXR)	SW, 50D/40T		1955
Kodak TRI-X 7278 (TXR)	SW, 200D/160T		1955
Kodak 4-X 7277 (4XR)	SW, 400D/320T		1967
Kodak 7241 Ektachrome (EF)	Colour, 160D	ME-4	1966
Kodak 7242 Ektachrome (EFB)	Colour, 125T	ME-4	1966
Eastman 7252 Ektachrome (ECO)	Colour, 25T	ECO-3	1970
Eastman 7240 Ektachrome Video News (VNF)	Colour, 160T	VNF-1	1975
Eastman 7239 Ektachrome Video News (VND)	Colour, 160D	VNF-1	1976
Eastman 7250 Ektachrome High Speed Video News (VNX)	Colour, 400T	VNF-1	1977
Eastman 7251 Ektachrome High Speed (VXD)	Colour, 400D	VNF-1/RVNP	1981

The “Video News” series was conceived for reporters. It’s a low-contrast emulsion, because the transfer to video usually increases the contrast. These emulsions have replaced the older 7241 and 7242.

Information from Didier Bufflier (RTS) and Felix Berger (Kodak), see also: http://motion.kodak.com/DE/de/motion/Products/Chronology_Of_Film

11.3 Factors with influence on image sharpness

Image aquisition
- Film format
- Emulsion type
- Focus
- Aperture
- Vibrations during recording
- Optical system of camera*

Storage
- Temperature/humidity (also after development)
- Timeframe between exposure and development
- X-radiation

Development
- Water and chemical quality
- Special processes:
  – Pushing
  – Bleach bypass

Transfer
- Focus
- Resolution of chip
- Internal data processing
- Target format
- Optical system of transfer machine*

Postproduction
- Original and target format
- Internal data processing
- Data compression
- Upscale/down-conversion
- Application of image-processing

Screening
- Focus (only for projection)
- Resolution of chip/screen
- Original format
- Internal data processing
- Upscale/down-conversion
- Optical system (only for projection)

The above refers to the workflows described in the paper.

* This includes:
  – Position of lens axis with regard to film axis
  – Position of film in gate
  – Dirt/scratches on lens
  – Lens quality:
    › Chromatic aberration
    › Spheric aberration
    › Coma (irregular enlargement)
    › Astigmatism (focus not in one plane)
    › Flare/dispersion
    › Misalignment of lens elements

11.4 HD transfer providers in Switzerland

Company	Manufac turer	Scanner model	Remarks	In test series
Bolex Digital Martigny	MWA	Flashscan HD	8 mm, S8, 9.5 mm HD Telecine	No
Egli Film AG Zurich	Thomson Grassvalley	Spirit DataCine	16 mm/35 mm HD Telecine	Yes
	Filmlight	Northlight Scanner	16 mm/35 mm 4k-Scanner Pin Registered	Yes
Online Video AG Zurich	Thomson Grassvalley	Spirit DataCine	16 mm/35 mm HD Telecine	No
reto.ch GmbH Ecublens	Debrie	Memory SD & HD	8 mm, S8, 9.5 mm, 16 mm, 2k Telecine Sprocket Free	Yes
Schwarz Film AG Ostermundigen	Arri	Arri Scan	16 mm/35 mm 4k-Scanner Pin Registered	No
Swiss Effects AG Zurich	P&S Technik	Steadyframe	16 mm/35 mm 2k-Scanner Sprocket Free	Yes
Simano Film Cureglia	–	–	System in development	No
SD Scanners in the test series				
Egli Film AG Zurich	Bosch	FDL 90	16 mm/35 mm SD Telecine	Yes
RTS, Genf	MWA	Flashtransfer	16 mm/35 mm SD Telecine	Ja

As of Summer 2009

11.5 Composition of the 16 mm test reel of reversal film for Memoriav's SD and HD transfers

5 sequences in bw on acetate base
5 sequences in colour on acetate base
1 sequence test pattern on polyester base

Total duration: 3 minutes
Lead in: start at 10 (25i/s) with black during the last 3 seconds

Sequence 1 B&W portrait of a musician with normal lighting and contrast (60 s)
Emulsion: Plus-X or Tri-X.
Description: This sequence is representative of the good bw image quality one can find in the RTS archives: good sharpness, good lighting and well processed. The structure of the skin, the stripes of the shirt and the accessories are elements to observe. In addition, this sequence contains traces of wear and tear: scratches, small scrapes, finger prints

Sequence 2 Bottles + grape; B&W with contrasted lighting (12 s)
Emulsion: Plus-X or Tri-X.
Description: This sequence is made up of 4 shots (medium to very close up). Excellent sharpness with rich grey shading and very dense blacks.

Sequence 3 Couple descending the stairs with good lighting and shaded areas (10 s)
Emulsion: Plus-X or Tri-X. Date code on edge: 1961
Description: This sequence has excellent sharpness, with beautiful lighting, a very large depth of field (entire image). A couple crosses the shaded areas.

Sequence 4 Parade of little girls; B&W, overexposed (16 s)
Emulsion: Plus-X or Tri-X. Date code on edge: 1960
Description: Although the pavement and the white dresses of the girls seem "burnt", the spectators underneath the trees seem to be "correctly" exposed.

Sequence 5 Boat on a river; B&W, underexposed – night ambiance (8 s)
Emulsion: Plus-X or Tri-X
Description: This sequence is interesting because the light reflecting in the river underlines the texture of the surface, the waves and other movement of the water. Leaves on the riverbank are sometime visible.

Sequence 6 Cathedral roof with good exterior lighting and beautiful colours (19 s)
Emulsion: 7242 Ektachrome (EFB, tungsten El 125). Date code on edge: 1975
Description: This is one of the most used emulsions at RTS, with little grain and beautiful colours. There is much detail in the tiles.

Sequence 7 Arial view of a TV tower in colour with good lighting and excellent sharpness.
Emulsion: 7240 Ektachrome Video News (VNF, tungsten El 160). Date code on edge: 1977
Description: This sequence is very sharp with beautiful lighting: a wide-angle shot that offers details in the distance. Some marks and scratches on the film.

Sequence 8 Interview with a man standing, in colour with good lighting (interiour) and good colour
Emulsion:
Description: Colour of skin.

Sequence 9 Interview with a bearded man in an office, with average colours and definition
Emulsion: 7250 VNX, 400 ASA
Description: Badly lit scene.

Sequence 10 Parade with torches at night; underexposed and grainy
Emulsion: 7250 VNX, 400 ASA
Description: Same emulsion as 9, but situation of strong contrast.

Sequence 11 CST (France) test pattern for framing and sharpness
Emulsion: Positive emulsion, polyester
Description: Definition.

Assembled and described by Didier Bufflier (RTS).

11.6 Scan logs

Logs exist only where there was an opportunity to accompany the transfer personally.

Scan log from transfer at Egli Film
Device: Spirit DataCine

Settings used for SD and HD:

General:	Detail enhancer H/V = 0 (area: 0 – 7)

Real-time noise reduction (can be set individually for the colour channels):

without:	filter strength 000 (area: 0 – 15)
with:	filter strength 333 (area: 0 – 15)
	Highlight: flat
	Lowlight: flat
	Sensitivity: normal
	Motion threshold: normal
	Split: off
	Speed: 0

Gamma and contrast settings were part of grading.

Scan log from transfer at RTS
Device: MWA Flashscan

Test tape 1 IMX "Untouched" (CE_SD_2):

Detail enhancer:	Level: 0 (options: –192 – +192)
	H/V Enhancement: 0 (options: –128 – +128)
Contrast:	Off (options: Off/Low/High)
Gamma:	Lin = Off (options: Low/Std./High)

Graded

Test real 2 IMX "RTS Style" (CE_SD_2dg):

Detail enhancer:	Level: +79 (options: –192 – +192)
	H/V Enhancement: +79 (options: –128 – +128)
Contrast:	Low
Gamma:	Std.

Only brightness adjusted

Log from Image & Media Lab University Basel
The images were taken using a Canon EOS 500D on a Durst Colorcopy 350. The images were photographed in diffuse backlight. The light source was filtered. Exposure times and apertures can be taken from the XMP files of the RAW images. The film speed was set to 100 ISO.

Characteristics of the results:
RAW format converted to TIFF
ca. 4400×3100 pixels
16-bit linear

The numbering of the image positions:
Image 0 is the last image of the first shot (Sequence 1, compare with Appendix 11.4).

Sequence 1	–690
	–450
Sequence 2	0002
Sequence 3	0450
Sequence 4	0830
Sequence 5	1070
Sequence 6	1330
Sequence 7	1530
Sequence 8	2135
Sequence 9	2770
Sequence 10	2900
Sequence 11	any

There are no logs for the transfers made using the Steadyframe, the Debrie Memory or the Northlight scanners.

11.7 Technical datasheets of the transfer machines

The PDF documents with the technical specifications for the scanners used (drafted by the manufacturers of the equipment) are included in the attached documentation.