A New Color Negative Film for the Digital Future

By David Long, Mike Ryan, and Roger Morton


David Long


Mike Ryan


Roger Morton

With the design of the Kodak Vision2 500T/5218 color negative film, a new film technology optimized for both the conventional optical and digital post-production worlds, has been introduced. Though resolution and grain improvements comprise a large part of the advances offered by this new technology, film sensitometry and color reproduction have also been carefully engineered to facilitate improvements in neutral scale control and digital post-production productivity. All of this is made possible by silver halide technologies that significantly reduce grain, and film-building technologies that shape a new standard of photographic performance in a world of digital applications.

There is no argument that motion imaging capture technologies of the present and the future must provide consideration for a wide variety of conventional optical and digital application compatibility. Consider the theatrical feature paradigm. Although digital post-production, digital intermediate, and digital special effects converge with their optical counterparts in the image creation stage, classic film projection, while currently the norm for image distribution and display, must share some of the spotlight with newer digital projection technologies. In the television world, image transfer has migrated from analog video to digital data streams (although the electronic image capture process does continue to depend on analog technologies) and will likely continue to employ more and more complex scanning and processing techniques. A constant in this story of progression and advancement is a reliance on high-quality capture media that can enable the very best of all the imaging production paths available. In this vein, several new technologies encompassing material research and film-building techniques have been introduced into the Vision2 500T/5218 color negative film platform to enhance the capability of silver halide-based image capture to offer high-quality results.

Materials Research: Image Structure Technologies

As silver halide technology continues to advance, one of the major concentrations continues to be maximizing the efficiency of light capture and amplification photophysics. The reasoning is classic. More efficient light capture leads to faster emulsions, smaller grains, and greater sharpness. This, likewise, leads to cleaner printed images and less noisy, higher resolution scans. With the introduction of these new technologies into the 5218 color negative film, significant improvements in image structure are realized.

A presentation of these technologies is best organized in order of the classic image capture chain. Summarized in simple terms, the silver halide image chain comprises, in sequence: incident photon capture, latent image formation, latent image identification, latent image amplification, and dye (or density) formation. Fundamental to the understanding of this chain is knowing that each step is characterized by its own set of efficiencies and distinct mechanisms. Also important to remember is that several of these steps include degradation modes that inhibit or reverse progress. Jones[1] introduced the concept of detective quantum efficiency (DQE) to summarize the overall capture quality of a dye-based imaging material in terms of signal-to-noise ratios at the input (incident photons) and output (optical density). Each of the steps in the image capture chain contributes to DQE by means of a rule of products and, thus, an improvement in the efficiency of any particular step in the chain will lead to an improved overall DQE. In other words, new technologies can be tackled at any one level of the image chain and real results in overall photographic performance can be expected.

In the context of incident photon capture, the first technology introduced into the 5218 color negative film was new advanced tabular grains in each color-sensitive layer of the film. In the blue layer (classically requiring the most speed in tungsten balanced films), high-speed image capture has traditionally relied on more conventional (3-D) emulsions to achieve the desired photographic performance. This follows from some very practical limitations of geometry. Silver halide crystals possess an intrinsic sensitivity to blue light. Because of this, blue photographic speed can generally be gained by simply including more silver mass in each blue emulsion crystal (of course, big crystals lead to big grain).

Tabular grain capture in the blue, on the other hand, must rely heavily on absorbed sensitizing dye technology, and this equates to a surface-area proportionality with speed. Surface sensitizing dyes are the same mechanism by which photographic grains with no inherent sensitivity to red or green light are able to absorb these particular photons. Classically, blue sensitizing dye technology has not offered sufficient efficiency to work in conjunction with tabular grains of a reasonable size, and the granularity advantages offered by the thin grain geometry in slower emulsions has not been fully realized. Consequently, high-speed tungsten films have relied upon the volume benefits of large 3-D grains to achieve proper speed, but with grain penalty. By blending conventional emulsions with the newer, more efficient tabular grain emulsions in the fastest blue layer, the true speed needed for EI500 is achieved, but with vastly improved granularity and less noise in the blue color record.

In the red and green sensitive layers, new tabular grains with an enhanced utilization of light have also been used to lower granularity. As in the blue tabular grains, iodide architecture and dopant level have been optimized to achieve this efficiency, essentially by preventing destructive recombination events that limit the number of electrons available for latent image formation. In each color record, the advantages offered by the tabular grain premise are fundamental. The flat twinned crystal structure classic to the tabular grain still provides maximum surface area (for dye absorption and speed) with minimum volume and offers the benefit of reduced crystal mass, smaller grain size, and increased number of image centers (which is indirectly proportional to granularity by way of the random dot model). The difference is that new advances in photon capture efficiency enable the tabular grain's structural superiority to be fully exploited.

Having an impact on both the photon capture and latent image formation stages of the image chain are 2-electron sensitizers.[2] These consist of fragmentable electron donor compounds that have been designed to work with sensitizing dyes to offer the potential of delivering two electrons for every absorbed photon of light. The classic mechanism has always been one for one. In modern color photography (as alluded to previously), light energy is absorbed by a sensitizing dye physically bonded via dipole and Van der Waal's attraction to the silver halide surface. The excited dye then transfers an electron to the silver halide crystal in an energetically favorable reaction, and that electron goes on to create the latent image upon reaction with lattice edge or interstitial silver ions.

Of native importance to the efficiency of the latent image formation step is the number of electron transfer reactions that must occur for the latent image site to

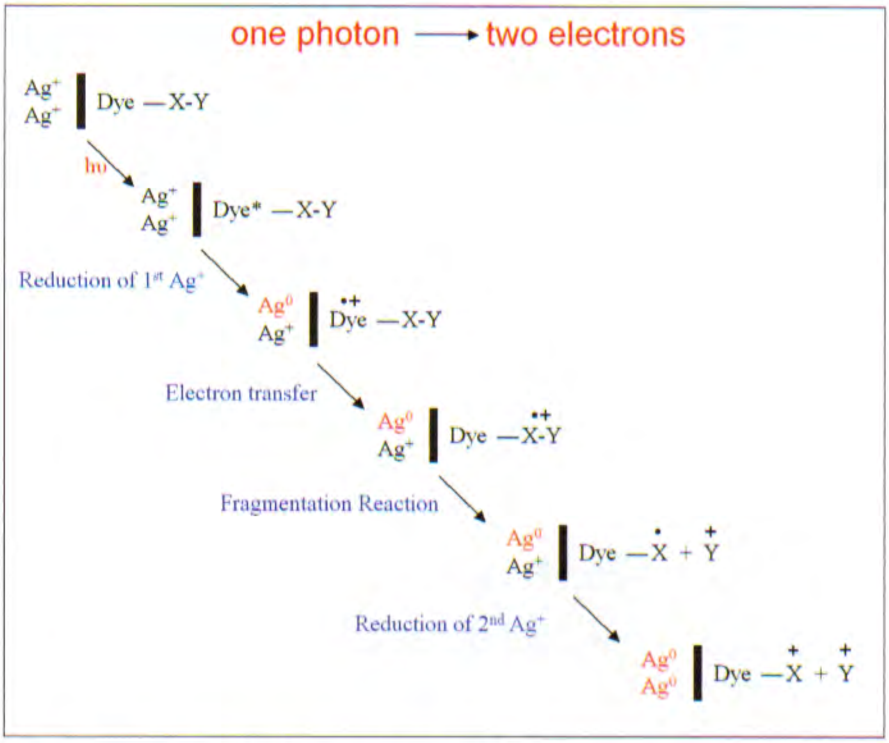

Figure 1. Illustration of the two-electron sensitizer mechanism.

grow large enough and to survive on the crystal until it gets to the development process. Most destructive to the success of this event are the electron-hole recombinations, which can occur before the ejected electron has a chance to find a new home with a silver ion. By designing these new compounds to have an affinity for the silver halide surface and to work in concert with the oxidized form of the sensitizing dye, the potential is created for both stabilizing the new latent image and yielding an additional electron suitable for reaction. Figure 1 illustrates how one mechanism for this concept works. Here, X-Y represents the high-potential electron donor compound.

Upon reduction of the first silver ion, the oxidized sensitizing dye is left to live an unstable existence. Normally, this situation would be perfect for recombination; but X-Y is designed to donate an electron of its own to the oxidized dye. This is the mode by which the 2-electron sensitizer can serve to stabilize existing latent image. The newly oxidized form of X-Y undergoes a fast fragmentation reaction splitting off a strong reductant X• radical from a stable Y+ cation. The X• radical is then further oxidized as it injects an electron into the conduction band of the silver halide crystal. This increase in the generation of electrons can improve the speed performance of the film or reduce the silver halide crystal grain size, thus lowering the granularity of a film already performing at the intended exposure index. In any event, it certainly contributes to cleaner images for printing and scanning.

For the latent image identification stage, the 5218 film technology incorporates advanced development accelerators.[3] These materials improve the probability of developer molecules finding latent image sites in the amplification phase. The job of ECN2 color developer (or developer in any other photofinishing process) is to provide a steady stream of electrons to the silver halide so that it may continue the reduction reactions begun by the energy of the incident photons. The developer is ideally intended to only continue these reactions at sites where latent image already exists (hence the term, exposure "amplification"). Advanced development accelerators better prepare the latent image centers to be identified when developer reacts with exposed silver halide.

Beyond latent image identification and amplification comes dye formation. Dye formation follows from the reaction of oxidized developer molecules and anionic color coupler species at the site where the developer has reacted with the latent image. The colored species known as photographic dye is the molecule that results from this particular reaction. Of course, the color of the dye is dependent on the chemical properties of both the developer and the coupler. For the 5218 color negative film, high-activity couplers have been included to effectively produce two molecules of dye for every molecule of oxidized developer.[4] The concept is quite simple. Colored couplers are introduced to the film with an additional dye moiety attached. The coupler is still colorless in an unprocessed film, but upon reaction with oxidized developer, the moiety is released and becomes colored. In this manner, two colored species are created. Figure 2 offers an illustration of the mechanism.

In addition to the new "two-for-one" couplers, more classic "one-for-one" couplers with higher chemical activity than older designs have also been added to the film pack.[5] By effectively improving dye yield, high-activity couplers allow for an optimization of both coupler and silver load in the film design. This in turn, allows for smaller, faster emulsions and a lower silver level. With fewer scattering sites present in the film, the optical efficiency of the formulation can also be optimized, and sharpness can be enhanced. Again, this translates to less noise and higher resolution for subsequent printing or scanning steps.

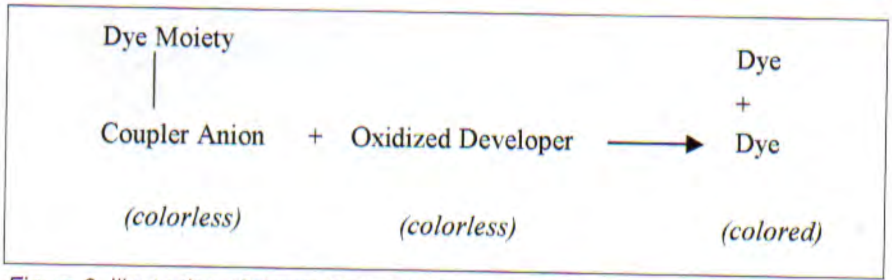

Figure 2. Illustration of simple high-activity coupler reaction.

Following from the combination of technologies here, Fig. 3 summarizes the rms granularity of color negative film 5218 versus that of Vision 500T color negative film 5279. The results achieved are well shared across all three color records and a wide range of exposure space.

Film-Building Strategies

Beyond chemical technology innovation in the 5218 film, a great deal of effort has also been put into film-building techniques that enhance photographic quality for optical and digital post-production. It is not enough to minimize noise and maximize resolution when designing a film for the future, as image reproduction quality plays an integral part in downstream processes. If film color and tone reproduction are not properly managed in either the classic printing paradigms or the newer digital intermediate applications, the result will be completely unacceptable, no matter how clean or sharp the image. With this thought in mind, several design strategies have been incorporated into the 5218 film technology set in order to account for the currently accepted standards of color and tone quality; keeping in mind that the classic "look" offered by film system is a standard that most digital systems are also currently attempting to emulate.

The first strategy to be discussed is triple coating. By subdividing the individual color records in a film into three distinct emulsion layers, a greater control over color, tone reproduction, and grain structure can be achieved. Though Vision film stocks were developed with the green-sensitive record having three distinct dye forming layers, this concept has been extended to the red sensitive record in the 5218 color negative film (Fig. 4).

The next feature of interest is tonescale linearity. With this film, great care has been taken to ensure a consistent, linear tonescale in the middle portions of the sensitometric curves. This feature is particularly useful when film is being scanned or telecined for manipulation in the digital realm.

The historical justification for the negative capture format is the tremendous exposure latitude it affords, providing for the creation of a wide range of looks and

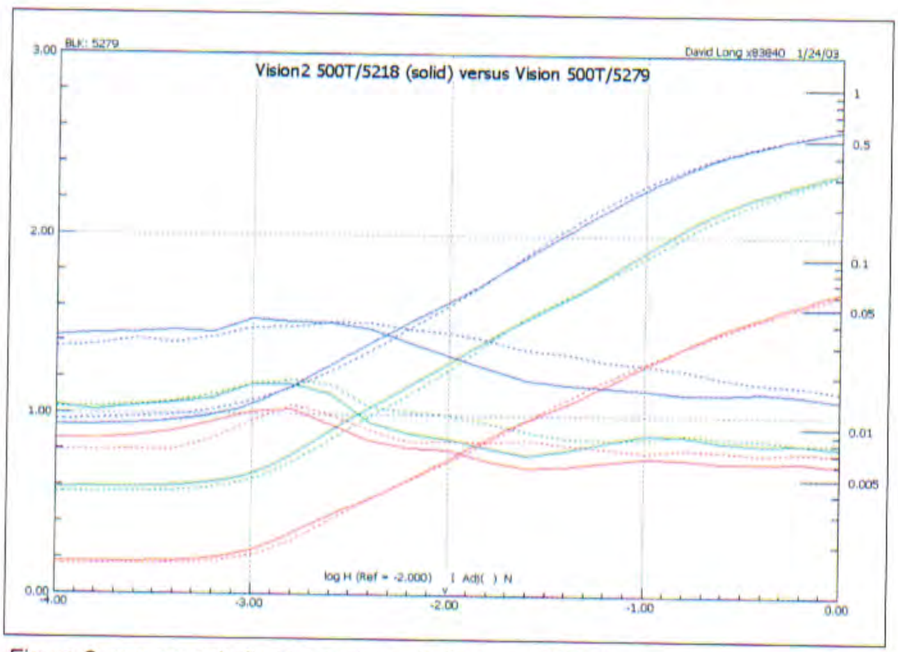

Figure 3. rms granularity comparison of 5218 and 5279 films.

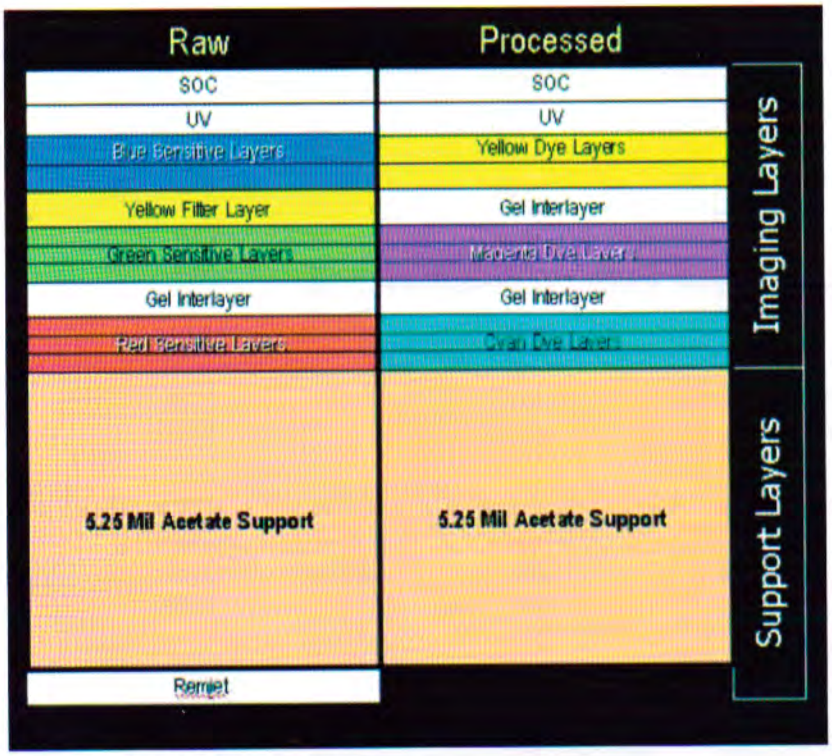

Figure 4. The 5218 film structure.

protection in extreme lighting conditions. This is one of the primary areas in which film is far superior to either analog or digital video formats. Negative film capture allows the opportunity to deal with the image in the printing stage or transfer and turn it from a negative back into a positive. And in the telecine or digital scanning realms specifically, a linear curve shape offers a tremendous advantage to those trying to manipulate the signal. A linear curve shape is more predictable in the digital environment, and a film with a well-designed tonescale offers the perfect mix of smooth, clean response in the mid-tones and natural, opened transitions in the highlights and shadows. Figure 5 summarizes the linearity of 5218 versus 5279, complete with first derivative curves to relay point-slope characteristics.

In addition to controlled linearity, accurate speed performance in each of the three color records of the film is crucial to shadow neutrality, consistency, and predictability. In the 5218, a new concept of speed control is implemented to ensure that the red, green, and blue color-sensitive layers respond to the lowest levels of light in a uniform manner. This response enables a much cleaner scanning position where little to no color correction is required to clean up shadow detail or shadow tonality. Figure 6 outlines the toe sensitometry of 5218 versus 5279. The curves have been shifted to show off the speed match of 5218 versus 5279 and to reveal the benefits offered by the better-controlled film building in the 5218 film.

Finally, color reproduction is also optimized to offer more natural hue reproduction. The overall color balance is cooler than the Vision film family, de-emphasizing a non-ideal warmth in flesh tones with the older technology and providing a better starting place for printing and scanning. Color saturation is also reduced, along with color contrast, in order to facilitate a more responsive image scan (as well as to better reflect cinematographer preferences for color and tone in optical prints). In most digital or telecine post-production schemes, a lower color saturation and contrast

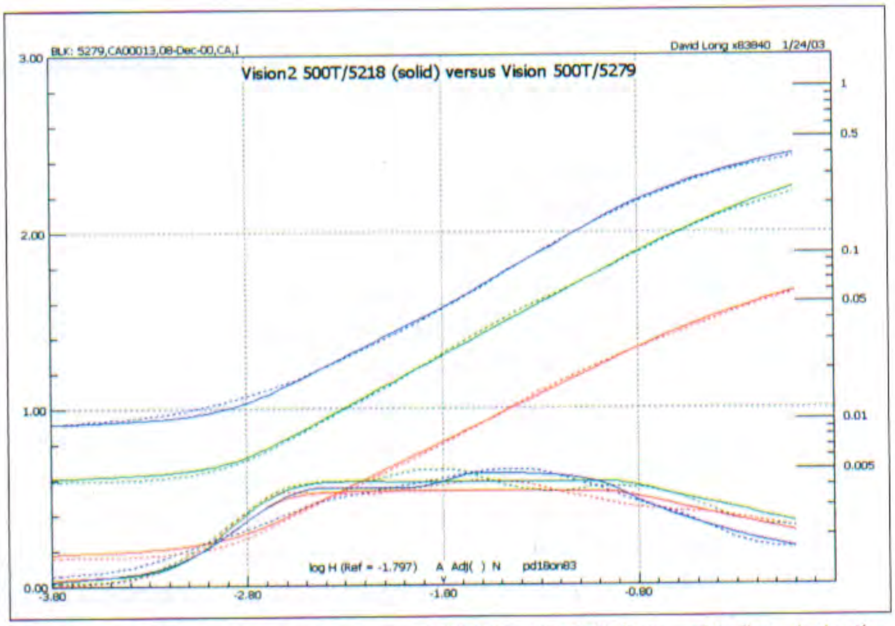

Figure 5. Sensitometry comparison of 5218 and 5279 films, with first derivative curves included to illustrate linearity.

provides for a more controllable color management following the scan stage. When combined with better-controlled neutrality across gray tones, the overall image is optimized for a more natural feel.

For digital compositing work, hue reproduction in the 5218 film technology set is also designed to reduce color contamination and fringing. By adjusting blue rendition, slightly less magenta, and green rendition, slightly less yellow, colored fringe intensity in blue and green screen work is better controlled and hue purity for digital matte work is improved. Additionally, the 5218 film technology also yields much more consistent hue reproductions across different exposures. With a more linear tone and color response, color shifting is not a problem in uniform reflectors struck by variable illuminance (like in a blue or green special effects screen, which must be carefully lit to ensure consistency in exposure across the frame). These results translate into cleaner effects work in post-production.

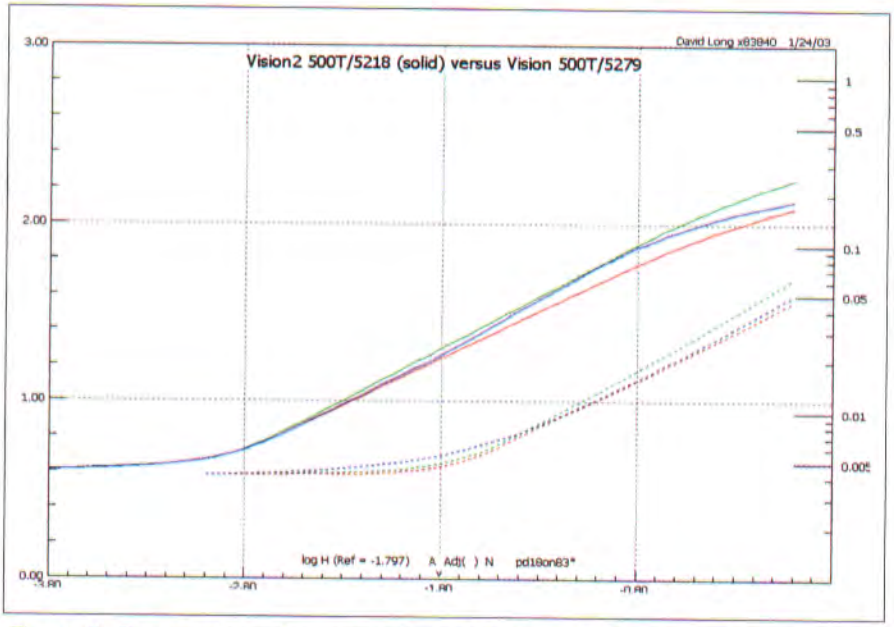

Figure 6. Toe sensitometry comparison of 5218 and 5279 films. Curves shifted vertically and horizontally to illustrate toe speed and sensitometry matches.

Practical Testing—Digital Post-Production

With the technology base established, the 5218 film has been extensively tested in real post-production settings to show credible benefits in digital pathways. Through a series of advanced analysis tools and models, extensive picture testing, and real-world treatments, a more conclusive practical basis for improvement is recognized.

Blue and Green Screen Testing

In order to assess blue and green screen compositing capabilities, facilities at Cinesite in London were used. For a fair comparison, Vision2 500T/5218 was tested against Vision 500T/5279, Vision 200T/5274, and SFX 200T/SO-214 color negative films. The 5218 version performed extremely well for blue and green grain noise versus the 5279, though not quite as well as the 5274 and SFX 200T, which each appear almost grainless in the Cineon and Ultimatte compositing software set. Still, comments from the effects artists at Cinesite suggest the noise level of 5218 is finally at a reasonable level for compositing work at 500-speed. For edge definition in matte work, this film actually performs better than any of the other three films, with SFX 200T a close second. With respect to colored fringing, 5218 does exhibit a fringe width comparable to 5279 and notably worse than 5274 or SFX 200T, but the fringe color saturation is much less intense, thus allowing for easier post fixes. Finally, the color reproduction in the 5218 film is advantaged over each of the other three films. With less yellow contamination in greens and less magenta contamination in blues, the FX software is able to separate background screen from foreground subject more cleanly. Additionally, 5218 hue reproduction is consistent across exposures and serves to effectively hide nonuniformities in screen illumination on set, making it easier to account for any lighting variability introduced during capture.

Digital Intermediate—Scan and Record

The 5218 color negative film was also compared to 5279 for quality and efficiency improvements in the scanning and recording production path for digital intermediate. Though there are less quantifiable results associated with this test, general impressions from the production team validate the design objectives of the new technology. Color and tone linearity and neutrality allow for much easier grading in software with less intervention on the part of colorists.

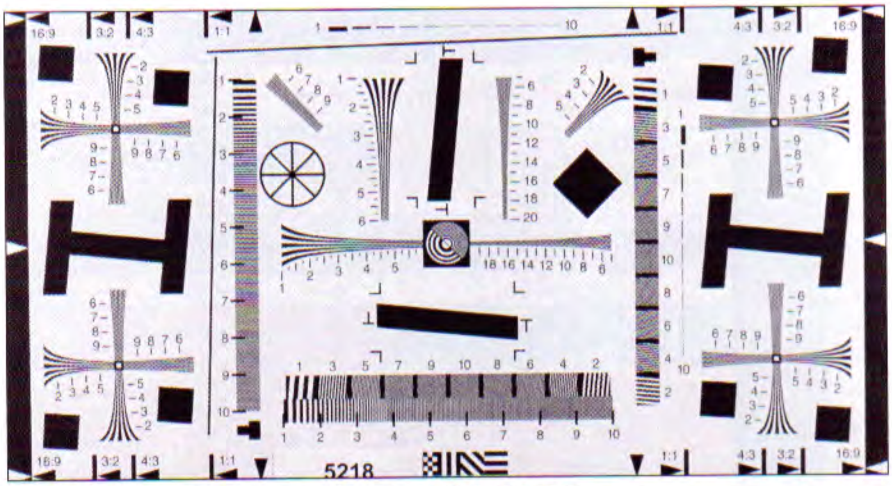

Figure 7. Low-resolution rendition of the ISO 12233 target.

done in the native HDCAM format with sharpening controls set to the null position and image processing performed in the camera. The second analysis comprises a 35mm theatrical feature film example using the same HDCAM content slightly cropped to a 1.85:1 aspect ratio and 35mm 5218 film scanned at 4K, again on the Genesis scanner with no digital sharpening. For each comparison, film and electronic systems were analyzed in a common data space extendable to similar downstream processing and post-production paths.

Exposing the ISO12233 target onto each imaging system produced a majority of the measurements calculated for this evaluation. (Fig. 7 shows this target.) Additional data was collected from other charts and sources to be discussed shortly.

For this comparison, all measurements were run in projection screen space with the viewer assumed to be two picture heights away. Further, it was assumed that no data or quality loss is incurred from processing or projection downstream of the digital data creation. This is, of course, not a realistic situation because even the perfect case of no quality loss from image processing, compression, or transmission would be subject to electronic projection hardware and lens MTF losses. However, this does provide a fair way to isolate a quality comparison between the capture systems. Further, as film and electronic projection improve, downstream quality losses will continue to diminish. Table 1 offers the digital data geometries used.

Tables 2 and 3 summarize the results gathered from the battery of measurements performed on the two imaging systems. Further, the arrows in each category

Reduced noise levels clearly translate into higher quality images and provide a stronger base for new grain reduction and sharpening algorithms in cases where such image processing is desired. This further supports the notion that 70mm release print quality can be generated from 35mm origination and advanced scanning and image processing techniques.

Super 16mm and 35mm Capture Comparisons to 24P HDTV

Based on research undertaken in preparation for the paper entitled, "Assessing The Quality Of Motion Picture Systems from Scene-to-Digital Data,"[6] a great amount has been learned in improving film capture and scanning for digital post-production. Many of these opportunities have been realized in the 5218 film. When scanned in either Super 16, 35mm, or Super 35 format, results show that with a scanner that does not include digital sharpening, film can provide superior digital data compared to 24P cameras in which digital sharpening is disabled.

All of the following analyses can be broken down into two general comparisons based on currently popular, high-quality, post-production workflows. The first concentrates on a television example and utilizes a 2K scan of Super 16mm film in the 16:9 aspect ratio using the Cineon Genesis digital film scanner with no digital sharpening. The Sony FDW900 is chosen for the electronic capture comparison with all work

Table 1—Summary of Scanned System Geometries

	Television (16:9)		Feature (1.85:1)	
	5218/S16	24P	5218/35	24P
Scan Format	2K	HD	4K	HD
Scan Width (pixels)	2048	1920	3656	1920
Scan Height (pixels)	1152	1080	1976	1038

Table 2—Summary of Television System Measurements (with advantaged system highlighted)

		5218 Film/S16	24P Camera
Limiting Resolution (line widths/picture height)	↑	1030	800
Maximum MTF Slope (relative to 5218)	↓	Reference	17% less
SQRI Sharpness (relative to 5218)	↑	Reference 0 JNDs	2 JND lower
Average Aliasing Ratio to 770 line widths/picture height	↓	7.5%	25%
Depth of Field (based on magnification squared)	↑	+55%	Reference
Depth of Field Sharpness (change for 33 in. shift at 20ft—f2)	↑	9 JNDs	6 JNDs
Dynamic Range	↑	~20 stops (with excellent highlights)	9-10 stops (with excellent shadows)
Archivability		• human readable signal • format independent • chemistry stable to 60-70 years	• binary signal • tied to legacy hardware • tape stable to 20-25 years

heading are a quick reference of whether higher quality results from the value of the metric being high or low. For all categories except one below, 5218 is the advantaged system. This summary is followed by a more in-depth explanation of each metric.

Limiting Resolution refers to the highest spatial frequency of information, which is maintained with at least 5% MTF in image data. This reflects the highest amount of scene detail the imaging system can capture, but is not a measure of perceived sharpness. In Super 16mm format, the 5218 color negative film scanned at 2K resolution is able to reproduce at least 5% modulation out to 1030 line widths per picture height (LW/PH) compared to only 800 LW/PH for a 24P camera. 35mm scanned at 4K is even better with performance out to 1450 LW/PH. In the theatrical release example, a small fraction of the 24P camera resolution loss arises from the crop to 1.85:1.

Maximum MTF Slope impacts the perception of motion reality in high frequency scenes. In almost every imaging system (including the human eye), the quality of response declines as the frequency of image detail increases. This essentially means that scene detail of increasingly smaller scale becomes increasingly blurred or confused in a typical reproduction. For moving pictures, this has added impact on the rendition of scene textures that are moving or rotating away from the observer. The trick is to keep the change in MTF, as a function of frequency, slow and gradual. Further, it is undesirable to have excessive peaking of the frequency response as this adds artifacts to a quick camera move. The slope or rate of change of MTF with frequency thus provides an indication of the reality of motion one can expect from moving textured objects in a scene. In this analysis, the 24P camera actually offers a lower maximum MTF slope versus the 5218 Super 16mm film, but it is higher than the 35mm system. Although at a disadvantage, the Super 16mm film data can be corrected downstream by employing sharpening algorithms.

The SQRI Sharpness metric was developed by Barten[7] to relate analytical modulation and acutance data to the subjective perception of sharpness. Unlike limiting resolution that concentrates on an imaging system's ability to discern increasingly fine detail, sharpness metrics concentrate on the overall observation of quality at all frequencies. In this analysis, the Super 16mm 5218 color negative film is advantaged over the 24P system by two just noticeable differences (JNDs) and 35mm is advantaged by 10 JNDs.

Aliasing Ratio is a characterization of the harmonic artifacts created when you try to image very fine detail on a device with limited spatial resolution. For images, the aliasing ratio is defined as the magnitude of the reproduction's false harmonic pattern relative to the

Table 3—Summary of Theatrical Release System Measurements (with advantaged system highlighted)

		5218 Film/35	24P Camera
Limiting Resolution (line widths/picture height)	↑	1450	770
Maximum MTF Slope (relative to 5218)	↓	Reference	28% higher
SQRI Sharpness (relative to 5218)	↑	Reference 0 JNDs	10 JND lower
Average Aliasing Ratio to 770 line widths/picture height	↓	3.8%	25%
Depth of Field (based on magnification squared)	↑	+516%	Reference
Depth of Field Sharpness (change for 33 in. shift at 20ft - f2)	↑	59 JNDs	6 JNDs
Dynamic Range	↑	~20 stops (with excellent highlights)	9-10 stops (with excellent shadows)
Archivability		• human readable signal • format independent • chemistry stable to 60-70 years	• binary signal • tied to legacy hardware • tape stable to 20-25 years

magnitude of the scene incident sinusoid modulation. At a frequency of 770 LW/PH, the 2K Super 16mm 5218 film data has a small 7.5% aliasing ratio, while the 24P system has a 25% ratio. The 35mm version of the 5218 film performs better, with an aliasing ratio of only 3.8%.

Depth-of-Field analyses determine the control cinematographers have in drawing a viewer's interest to a specific area of a scene. Generically, conclusions drawn can be described as mostly independent of film or camera manufacturer. They rely rather on simple geometrical comparisons of camera optical paths and sensor formats combined with measurements of camera and lens MTF signatures. That being said, the results presented here would be similar, no matter what film or 2/3 in. CCD HD camera is used, as long as each conformed to the standard format geometries.

Both of the depth-of-field metrics recognize that a smaller depth of field is preferred in order to allow maximum creative flexibility in scene composition. In the first measurement, the amount of magnification from scene to sensor is squared as lateral optical magnification varies, because the square of the image magnification and lateral optical magnification is directly related to depth-of-field performance. By this logic, the Super 16mm format affords 55% less depth of field than the 2/3 in. CCD HD format, therefore giving the cinematographer greater control. The 35mm format offers 516% less depth of field giving even greater control.

A more easily understood concept of depth-of-field comes from calculating the sharpness difference between a scene element precisely focused at 20 ft from the image plane through an f2 lens and an element 33 in. further away under the same focus. In the Super 16mm format, the sharpness in the out-of-focus element is 9 JNDs less than the one in focus, where the same comparison yields only 6 JNDs of difference for the 2/3 in. CCD chip. The 35mm format offers a 59 JND drop in sharpness in this geometry.

Dynamic Range refers to the total exposure range over which an imaging system is able to offer a unique recorded signal—all the way from the deepest shadows to the brightest highlights. For film, this is essentially the total exposure range from absolute D-min to absolute D-max. For HD, this is the range of exposure from dark current noise to sensor saturation. The performance of both systems is, of course, further subject to the limitations of lens flare. By estimation, the 5218 color negative film offers around 20 stops of exposure differentiation where the 24P format provides only 10.

Issues around archivability are fairly straightforward. Essentially, all film technologies benefit in this regard from offering a human readable storage that is mostly

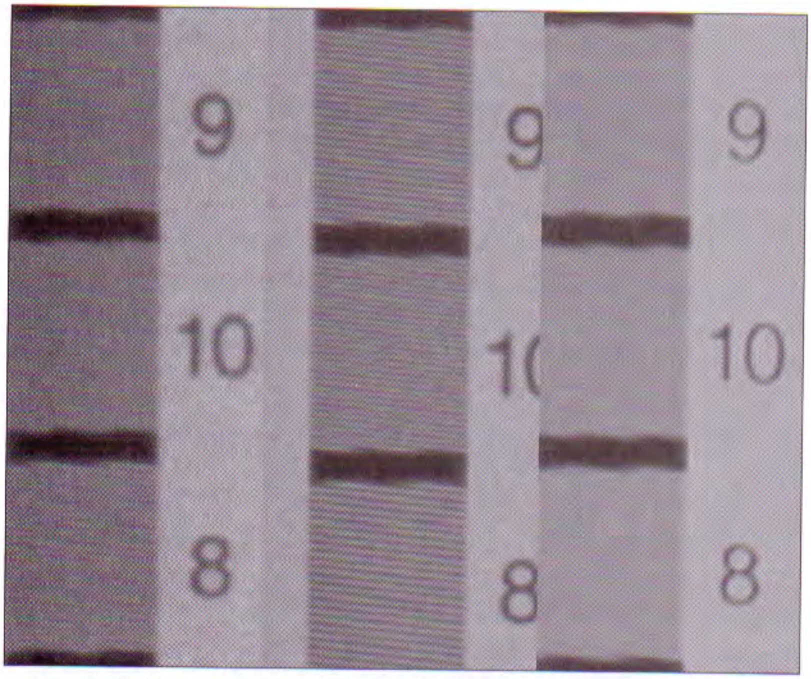

Figure 8. Enlarged view of portion of the ISO 12233 target—5218 Super 16mm (l) versus 35mm (c) and 24P (r).

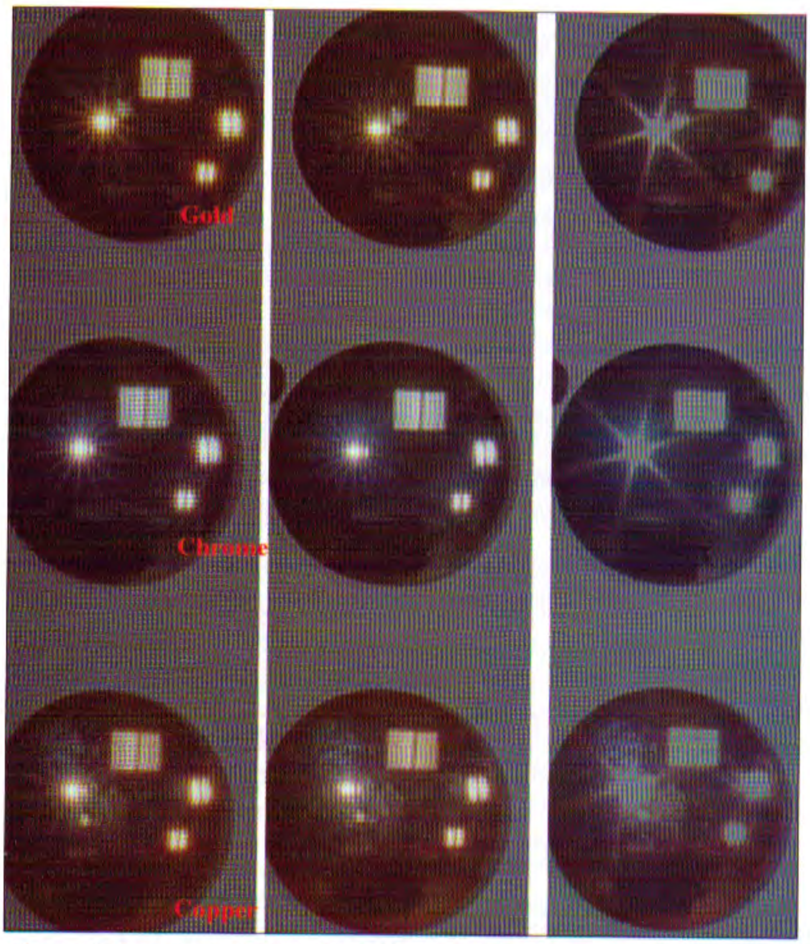

Figure 9. Dome target with 5218 Super 16mm (l) versus 35mm (c) and 24P (r).

format independent and will last when properly stored for 60 to 70 years. 24P images, on the other hand, are stored in a binary encoded signal usually on magnetic tape that potentially lasts only 20 to 25 years, even under optimum conditions. Additionally, tape formats are extremely dependent on legacy hardware being preserved to play back recorded data signals for the lifetime of the storage media.

To further illustrate the results shared thus far, Figure 8 shows a comparison of the 5218 film in Super 16mm and 35mm, and a 24P camera, captured from a portion of the ISO12233 target. The numbers on these images refer to the number of line widths per picture height imaged (in hundreds). Each of these images was produced as digital data and rendered to display at 16 bits per pixel.

The 5218 film in Super 16mm format shows clear imaged line structure still present at 800 and 900 LW/PH, and some detail is still visible at 1000 LW/PH. The 35mm format provides clear detail at all three resolutions. The Sony HD image shows no resolved detail at even 800 LW/PH, although some vertical detail can be recovered if on-camera sharpness algorithms are employed.

To summarize exposure latitude differences, Fig. 9 illustrates the results of exposing the 5218 film in Super in 16mm and 35mm formats, and the 24P system using highly specular reflective surfaces and extremely intense incident sources. The advantages of the film system in overexposure latitude for both color quality and tonal separation are clearly evident from this test. For reference, the incident source reflected in the left portion of each dome is approximately 16 stops above the gray background behind each dome. As this test serves to re-visit a previous analysis technique, Morton's paper[6] should be consulted for additional details behind the standardized exposure conditions employed.

Based on the data presented here, plus other considerations such as capture color gamut and accuracy, the 5218 color negative film in Super 16mm and 35mm is better for generating source digital data. Although none of these images were retouched with image processing to further enhance image quality, the film system would surely be more amenable to additional manipulation, as it contains fewer native aliasing artifacts. Additionally, it possesses no compression or color sub-sampling artifacts in the first generation stage. By co-optimizing image reproduction attributes for both traditional and digital systems, this new film system is well positioned to accommodate the flexibility required in modern digital applications.

Conclusion

Using advanced chemical and film-building technologies, the 5218 color negative film delivers vastly improved image quality to both optical and digital post-production processes. Because of a continued dedication to silver halide research, all of the inherent benefits of film-based image capture are further accentuated by these technology developments, which continue to propagate at an extremely quick pace. Certainly, further developments will follow.

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THE AUTHORS

David Long joined Kodak in 1997 as a member of the Manufacturing Research and Engineering Organization. In 1998, he moved into his current role as product development engineer with the Entertainment Imaging Division. His primary responsibilities with Kodak include new product development and image science and systems integration for the motion picture product platform.

Long joined Kodak after graduating from the University of Texas at Austin with a B.S. in chemical engineering and a M.S. in materials science from the University of Rochester. He is also a graduate of Kodak's Image Science Training Program.

Mike Ryan has been involved in research and development of silver halide technologies for consumer, professional, and motion imaging applications at Kodak. He is currently a senior principal scientist with the media and materials platform, coordinating the development of new color negative film products. Prior to his current assignment, Ryan's responsibilities included emulsion research and project management for the EXR, Vision, and Vision2 family of origination films. He joined Kodak in 1986, after graduating from the University of Rochester with a B.S. in chemical engineering.

Roger R. A. Morton has for many years enjoyed developing electronic and digital image processing technologies. He is currently a Research Fellow at Eastman Kodak, and works on measurement and optimization of cinema and television systems.

Morton's Ph.D. in electrical engineering involved some of the earliest research into digital imaging. During his career, he has developed numerous new digital concepts and brought them to market. Recently, he developed new measurements and new measurements tools for the motion picture analysis and has also created and worked on new systems approaches and understandings of motion picture system optimization, including Super 2K. Morton is experienced in digital imaging techniques, noise reduction, compression, and 3-D imaging.

In recognition of his pioneering and innovative work, Morton has received 69 U.S. patents, and corresponding foreign patents. He is a SMPTE Fellow and has authored 22 published scientific works, including those in the 2002 and 2003 *SMPTE Journal*. He was a 2003 SMPTE Journal Award recipient.

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