Silver Halide Photographic Paper:

It still makes sense in the digital age

White Paper

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Table of Contents

Introduction

Rapid advances in digital capture technology and the widespread availability of capture devices at every price point makes it important to understand the continued relevance of silver halide paper in digital photographic workflows. Kodak Alaris is taking a leadership role in the research and technology innovations that keep silver halide at the forefront of photographic printing for film and digital images.

The intent of this comprehensive technical white paper is to demonstrate why Color Negative Paper (CNP) or silver halide photographic printing paper makes sense — and helps to position your lab as offering the highest quality output for the digital age. KODAK PROFESSIONAL ENDURA Premier Paper provides the best printing media available to photographers today.

Listening to the Customer

Kodak's philosophy of continuous improvement and listening to the customer is a part of who we are. First as Eastman Kodak Company and now as Kodak Alaris, George Eastman built this company on that founding principle. Ongoing trade trials with selected customers ensure that experimental prototype paper, enhancements, or changes to our current silver halide offerings meet our customers' needs. We listen to customers about what they like, what works, what we can improve and we pay careful attention to your ideas and recommendations.

We keep a close eye on industry trends. We understand what drives growth in alternative capture and print technologies. We're active participants in technological and market thought-leadership. We depend on feedback from consumers, photographers, labs, user groups and trade associations. These include:

- The Association of Professional Color Labs (Association of Professional Color Imagers)
- International Imaging Industry Association (I3A)
- The Photo Marketing Association International (PMAI)
- The Professional School Photographers Association (PSPA)
- Sports Photographers Association of America (SPAA)
- Society for Imaging Science & Technology (imaging.org)
- Wedding & Portrait Photographers International (WPPI)
- Attendees at the annual KODAK PROFESSIONAL ProLab Workshop

The Importance of Making Prints

Why make prints when we have computers, tablets and smartphones? There are two compelling reasons we make prints of the best images in our digital collections. First, because sharing a tangible print with friends and family creates a durable bond through instant and shared communication. Prints allow us to Re-live and Preserve these moments well into the future.

The tangible reality of holding, viewing and sharing a hard-copy print or photo book cannot be duplicated electronically. Prints provide an emotional connection that viewing an image on a computer screen or smartphone simply cannot achieve. Studies done at the College of Imaging Arts and Sciences at Rochester Institute of Technology in 2009 and in 2012 demonstrate that people look longer and pick up more information from a hard-copy print than when they view the same image on a screen[1, 2]. In these studies, participants received a gift for participating. They had the choice of a hard-copy photographic booklet or a PDF version of the images they had just viewed. Overall, 74% of the subjects chose the hard copy over the digital file. Of the subjects that were shown the hard-copy book, 91% chose the hard copy over the PDF. Of those that saw the PDF on the screen, the majority chose the hard copy over the PDF.

Sharing a printed photograph with friends or family results in a durable bond — a result of instant communication and the subsequent feedback loop. Direct communication and face-to-face sharing drives emotional attachment and involvement with the image and with the photographer. This type of interaction does not occur to this extent when images are viewed apart from the giver/sharer, such as in an email or on social media.

Second, a high-quality photographic print is the best way to ensure that important images are easily accessible well into the future. Digital files can be shared and copied easily, but if a flaw develops in the file, or in the drive on which it is stored, or perhaps the formats become obsolete, the image is gone forever. **For long-term preservation, a hard-copy photograph has no equal.**

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[1] Tsai, Ya-Fang; "An experimental study of differences in reading photo books by presentation media: Print vs. screen"; RIT College of Imaging Arts and Science research monograph, 2009; ISBN 1109508271

[2] Proceedings of the IS&T 3rd Symposium on Technologies for Digital Photo Fulfillment; "Review of Research at RIT Comparing the Print Value and Permanence of Digital Prints vs. Offset Lithography and Silver-Halide Prints"; Daniel Burge, Susan Farnand, and Franziska Frey, Rochester Institute of Technology (USA); pages 39-43; Las Vegas, Nevada; January 2012

Over the longer term, digital formats change (both hardware and software), potentially rendering a digital file virtually useless. Consider the difficulty today in reading a file from a 3.5-inch floppy disk or a ZIP drive, or the inability to open old or obsolete versions of MICROSOFT Office files. Although we've done a better job of ensuring that digital image files do not become obsolete, a high quality photographic print avoids these issues. To access and view a photographic print requires no digital device or software — just your eyes and a light source. Simple and foolproof! You might even say "future-proof"[3, 4].

At a recent American Association for the Advancement of Science conference in San Jose, Vint Cerf — one of the "fathers of the Internet" — warned that a second dark age may be looming on the horizon, due to the fact that so much of our data these days is kept in digital formats. As Cerf says, one of the best options you may have right now for ensuring the long term survival of important photos is to print them out physically (with materials designed for longevity) and to keep the prints in a safe place.[5]

In addition to file obsolescence or catastrophic failure, deferring the curation and selection process can be a much bigger issue for digital files. As our digital collections grow, a digital file can easily be lost or buried in the huge sea of images we store on multiple drives, on CDs/DVDs, or other removable storage devices including the "cloud". We intend to organize our pictures and image files. We intend to spend all those hours deleting what we don't want. The reality is that the majority of us just don't.

At Kodak Alaris, our intent is to provide permanent, high quality images that last more than a lifetime — on **KODAK PROFESSIONAL Endura Premier Papers**.

[3] Proceedings of the IS&T Archiving Conference; "Preservation of Documents and Photographic Images: Long Term Strategies for Future Generations"; Joseph E. LaBarca, JEL Imaging Services, LLC (USA); pages 136-143; Salt Lake City, Utah; May 2011

[4] Proceedings of the AIC & ICOM-CC Photographs Conservation Joint Meeting; "Preservation of Photographs for Future Generations: New Opportunities for Prints and Photo Books"; Joseph E. LaBarca, JEL Imaging Services/Pixel Preservation International (USA); pages 68-69; Wellington, New Zealand; February 2013

[5] PetaPixel, by Michael Zhang; February 17, 2015

Printing is Alive and Well — Industry Trends

If you look at the statistics for the billions of images printed and compare that to the hundreds of billions of images captured, it's logical to assume that printing is essentially passé. The number of images printed today is a small percentage of the total images captured. It's important to understand why printing in general, and printing on silver halide photographic paper in particular, still makes so much sense. The use of color negative film requires a print to see the image, ensuring a 1:1 capture-to-print ratio. At the height of film usage, nearly 100 billion images were captured each year, resulting in over 100-150 billion photographic prints being sold. With double printing of consumer film images, the percentage of prints made, versus images shot, approached 120%.

As digital capture swept through the photo industry, film usage declined directly. As a result, so did the number of prints. While prints from film were declining, the number of prints from digitally captured images exploded. That trend continues, largely unabated and amplified by the addition of high-quality lenses and sensors to cell phones. Printing from digital files has grown significantly due to the proliferation of capture devices and the connectivity that provides the ability to share images instantly.

Consumers still want prints — certainly not of every shot they take, but of the best ones, the "keepers" that they want to have around for months, years, and generations. This includes all types; consumer snapshots and professionally captured images from important milestones such as weddings and school photography. While the sheer number of prints from digital have not yet made up for the gap when compared to film capture days, the number of prints being made from digital continues to grow. Moreover, that growth is accelerating.

Acceleration is happening for two reasons: first is the simple fact that the decline in prints from film is stabilizing, meaning that declines in film capture no longer influence the total number of prints made. Second is the extremely rapid increase in the number of images captured digitally, combined with significant improvements in image quality. In effect, consumers almost always have a decent quality camera with them. The industry predicted this would happen — Kodak included — it just required some time for mobile phone camera quality to reach the point of broad adoption and penetration. In fact, an industry consortium, the International Imaging Industry Association, also known as I3A, created the Camera Phone Image Quality Initiative to help set quality standards and metrics to ensure this would happen. Eastman Kodak Company was a strong participant in this initiative — Kodak Alaris continues to be.

Some final thoughts on photographic printing trends: InfoTrends, in their January 2013 Consumer and Professional Imaging Analysis titled "Road Map 2013: Photo Printing Trends", sees significant growth areas in printing[6]. They cite trends driving this growth, including: significant growth in smartphone camera usage, growth in printing in emerging markets, especially the Asia-Pacific and Latin American regions, and growth in on-line print orders. InfoTrends believes this growth "will shape the digital photo printing market for years to come." InfoTrends also continues to "...firmly believe that a photo print is still the best way to ensure that important photos will be easily accessible and viewable well into the future." This sentiment continues in "Road Map 2014", where InfoTrends expects to see the percentage of images printed from smartphones and tablets continue to grow. They believe that the best way to save the most important photos and ensure that they will be easily accessible in the future is by printing them, and says, "Photo prints will continue to be an important and very relevant segment of the digital imaging ecosystem."[7]. The InfoTrends "Road Map 2015" report again emphasizes the potential growth trends and the importance of printing by saying, "...[prints] are the best way to ensure that important photos will be easily accessible and viewable years into the future and have an intrinsic, emotional value that electronic viewing does not.[8]

This growth means that in the not-too-distant future, prints from digital have the potential to meet or exceed the number of images printed during film's peak. And while only a small portion of the digitally captured images will ever be printed, even a small percentage of a very large number is a very large number of prints. That is a very large opportunity for Kodak Alaris and the photo printing industry. The key for Professional Labs and Photographers will be in understanding the importance of long-term image quality and what this means to the consumer. It will be important to differentiate between prints created on desktop printers or using dry media and images printed on true professional photographic paper. Image quality and image permanence need to continue to be part of the dialogue with photographers and consumers.

[6] InfoTrends Consumer and Professional Imaging Analysis, "Road Map 2013:Photo Printing Trends"; January 2013

[7] InfoTrends Consumer and Professional Imaging Analysis, "Road Map 2014:Photo Printing Trends"; January 2014

[8] InfoTrends Consumer and Professional Imaging Analysis, "Road Map 2015:Photo Printing Trends"; February 2015

Image quality and permanence are critical factors in why Kodak Alaris remains at the forefront of providing breathtaking printed images. Silver halide technology is over 100 years old. Kodak Professional photographic image quality and permanence are a result of experience, testing and retesting to ensure optimum results. On the following pages we've set out to provide you with the technical tools and resources that will allow you to have an in depth conversation with your customers about why silver halide, specifically KODAK PROFESSIONAL Endura Premier Paper, makes sense in the digital age.

Three key and fundamental design criteria for color paper have been in place for decades at Eastman Kodak Company, and now at Kodak Alaris. These are; first Image Quality, second, Image Permanence, and last but not least, Ease of Use or productivity for the labs (including environmental benefits).

The remainder of this white paper is divided into four sections. Section one includes an overview of the physical properties of the paper, substrate and emulsion — from the ground up, so to speak. Section two of the technology review focuses on the attributes of KODAK PROFESSIONAL ENDURA Premier Paper that contribute to image quality and permanence — the part that consumers care about. We've followed this with section three, insights into methodology, the ecology and economics of silver recovery and the production process designed to make KODAK PROFESSIONAL ENDURA Premier Paper easy and economical for Professional Labs to use. Finally, in section four we've given you some history and answered detailed questions such as, "Why did imaging industry experts need to understand and manage reciprocity failure?"

Section One: Paper & Emulsion

Paper Support – A Specialty Product for Photographs

KODAK PROFESSIONAL ENDURA Premier Paper uses a specialty paper core, surrounded by a plastic, polyethylene resin coating on both sides of the paper. See Figure 1. The resin makes the paper core essentially waterproof, blocking any absorption of processing chemicals from the top or bottom of the sheet.

The backside (non-image) resin is clear and contains an anti-static ("antistat") layer to reduce the propensity for static buildup and discharge from the plastic. This layer also provides "tooth" for back-printing for recording information during printing, and for information written by the end user. It may also contain Brand identity and copyright information to protect the image owner or the image rights.

The paper core layer is a highly refined specialty paper designed specifically for photographic applications. This includes neutral sizing to provide longevity and durability over time, as well as resistance to penetration by the processing chemicals. The paper fibers are derived from renewable eucalyptus pulp and also contribute to the thickness, stiffness, and curl resistance of the package, providing the proper "feel" of a high-quality professional photograph.

The resin layer above the paper core includes titanium dioxide and optical brighteners, to optimize the "package". The total system of emulsions, surface coatings and films that absorb and reflect light gives our paper its characteristic look for whiteness and provides a light, bright D-min. It also provides enhanced image sharpness. This white resin layer provides for bright whites, and acts as a reflector to bounce the light back through the translucent imaging dyes, effectively doubling the impact of the dyes. This means greater color saturation and color reproduction benefits.

A critical goal is to ensure that the longevity of the support is as good as the performance of the imaging dyes. After all, what good is it to have accurate colors and high permanence levels in the dyes if the support can't match that performance? Design parameters for the paper support include small details such as the paper core size and composition to prevent yellowing or core set (curling) as well as resin formulations with stabilizers to prevent crazing and cracking.

Crazing is the localized breakdown of the long-chain polymers making up the resin to form micro voids that can eventually form fine, visible lines. Crazing can be heat induced over time but is more typically a photo oxidation reaction caused by UV light. Crazing is typically not seen on the surface of the print, as the image dyes will hide the lines. However, over time, stresses can concentrate in the craze line of an inferior paper, which can eventually break the surface of the resin, forming a crack. If not addressed, these defects can eventually cause flaking and loss of pieces of the resin, and along with it the image. To prevent this we use special resin stabilizers in ENDURA Papers to provide stability to equal or exceed that of the image dyes.

Layer Illustration/Photomicrograph

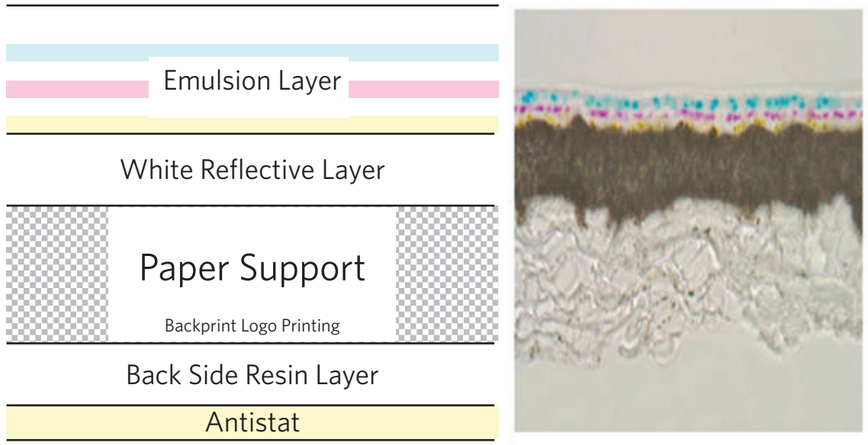


Figure 1: Illustrated layers and corresponding full photomicrograph cross section of KODAK PROFESSIONAL ENDURA Premier Paper showing emulsion and paper support layers.

A modification to this resin package is used in KODAK PROFESSIONAL ENDURA Metallic Paper. Here the white resin layer is replaced with a specialty thin-film layer. This film layer also contains titanium dioxide and tints, but includes microscopic air voids as well. The combination of the air voids and titanium dioxide particles create a special reflective action that produces the distinctive metallic effect that gives ENDURA Metallic Paper its unique look.

Emulsions and Dispersions

The "emulsion package" of KODAK PROFESSIONAL ENDURA Premier Paper consists of seven layers stacked on top of each other. See the "Emulsion & Dispersion Layers" in the upper left portion of Figure 2. The three main red, green and blue layers contain light-sensitive emulsions along with corresponding dispersions containing the dye-forming couplers. Through the science (some may also call it magic) of laminar flow, these seven layers are coated simultaneously at very high coating speeds, without any intermixing between the layers. The full seven-layer package is thinner than a human hair — laid down on the base in a single pass. Laminar flow describes a physical state in which a fluid, in this case the liquid emulsions, have no turbulence that can create intermixing; the flow is smooth and uniform.

From top to bottom, sitting on top of the resin-coated paper support, the layers are as follows:

- Overcoat — protective layer with UV absorbers
- UV layer with additional UV absorbers
- Red sensitive cyan-forming layer — contains red sensitive silver halide and cyan-forming couplers, as well as tints to improve whiteness and provide a light, bright minimum density (D-min)
- Interlayer — a scavenger layer to separate the red from the green and prevent developer cross talk to maintain pure magenta colors; also contains UV absorbers
- Green sensitive magenta-forming layer — contains green sensitive silver halide and magenta-forming couplers
- Interlayer — a scavenger layer to separate the green from the blue and prevent developer cross talk to maintain pure yellow colors
- Blue sensitive yellow-forming layer — contains blue sensitive silver halide and yellow-forming couplers

The seven layers together are approximately 7 microns wide (about 0.0003 inches or 3 ten-thousandths of an inch). For comparison, a human hair is 50 to 100 microns in diameter (about 0.002 to 0.004 inches). These thin layers of chemicals are coated at very high speeds and have no intermixing whatsoever. This maintains their separate, distinct position in the emulsion/dispersion package, which is critical to the color fidelity and performance of the paper.

The overcoat layer serves many purposes. It provides physical protection for the imaging layers below. This gives the paper extra durability from scratches and abrasions in production and in handling of prints by consumers. The overcoat layer, as well as several other layers, also contains UV absorbers, which serve two purposes. In the unprocessed light-sensitive state, the absorbers provide protection against exposure from static discharges, both during manufacturing/finishing and during imaging exposure through digital printers — especially in dry conditions. After processing, the UV absorbers filter UV light during display to protect the color dyes from fading. This provides enhanced light stability performance and contributes to the print's longevity on display.

The entire emulsion package is embedded in gelatin, providing several more unique benefits to ENDURA Premier Paper. Physically, gelatin provides overall durability and further protection to the imaging layers. Structurally, the gelatin holds the dye molecules in place to prevent wandering or "bleeding," which can occur with other digital printing technologies, for example certain inkjet systems in high-humidity environments. And because the dye molecules are embedded within and surrounded by the gelatin, the dyes are further protected from adverse chemical reactions such as degradation by atmospheric pollutants such as ozone. Unlike printing technologies where the colorant lies on top of the media, where they could be prone to physical abuse and chemical attack such as degradation by pollutants, the gelatin provides a virtual "safe haven" against image degradation from most pollutants. See additional details in the image permanence section below.

Layer Illustration/Photomicrograph

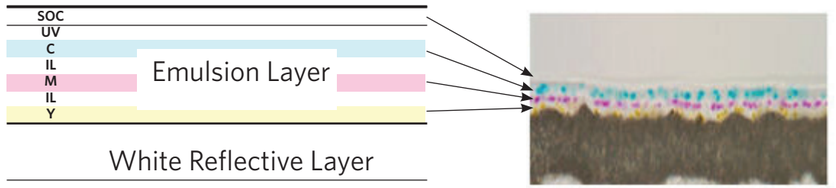


Figure 2: Illustrated layers and corresponding photomicrograph cross section of KODAK PROFESSIONAL ENDURA Premier Paper

Section Two: Image Quality & Image Permanence

Image Quality

A key attribute in image quality in consumer and professional grades of silver halide photographic papers is the "smooth continuous tone" of the image. This is a result of the precise layering of photo responsive chemicals, which deliver accurate color and extraordinary detail. This makes silver halide the gold standard for professional portraiture, where quality counts and where the precisely controlled imaging technology is consistently delivered by the paper.

In digital printing systems, when printers are properly calibrated and color-managed using color profiles that conform to the standards of the International Color Consortium (ICC) — of which Kodak is a founding member — silver halide photographic paper will produce the appearance of a continuous tone image. ICC color profiles, specific to the combination of the digital printer and the paper, are used in the processing of digital images to establish and maintain a consistent relationship amongst all colors in an image. This is accomplished by delivering an accurate neutral tone scale response and color reproduction that is true to the original scene. Furthermore, the use of ICC profiles in the digital imaging workflow helps to maintain consistency of results between different types of photographic paper printers in the lab.

Flesh Reproduction

Flesh tone reproduction and the flesh-to-neutral relationship are two key attributes of image quality in a professional silver halide paper. Long ago, in conjunction with key professional labs and photographers, we recognized the importance of accurate flesh reproduction. Flesh-to-neutral defines the relationship between flesh tone and the neutrality of highlights, midtones, and shadows. When balanced for pleasing flesh, the proper ratio and colors of the highlights and shadows must be balanced and optimized. Doing so will keep flesh tones, highlights, and shadows looking natural, without too much "ruddiness" or "beefiness" in the flesh, while maintaining a natural look in facial highlights.

The correct tone scale positioning of the red, green, and blue layers to provide the proper flesh-to-neutral relationship is critical. With digital color management systems, the tone scale can be retained, while optimizing for other characteristics such as color saturation. This is enabled by the use of ICC color profiles in conjunction with a photographic paper properly optimized for digital exposing systems, such as KODAK PROFESSIONAL ENDURA Premier Paper. Many types of "looks" are possible, but having the right ICC compliant color management profiles in place is critical to achieving the proper flesh-to-neutral relationship. For example, in KODAK PROFESSIONAL Digital Print Production Software / DP2, abstract profiles can be applied that will change flesh hue without affecting other colors or neutrals. Likewise, saturation can be boosted on all colors without changing the flesh tone. These and other profiles are provided through the KODAK PROFESSSIONAL Pro Lab Resource Center website to allow Pro Labs to "tune" the look of finished prints that deliver the KODAK PROFESSIONAL flesh reproduction advantage.

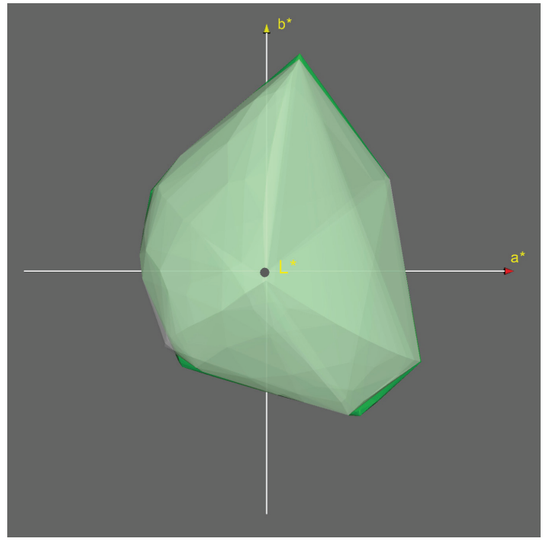
ENDURA Premier Paper offers labs the latest in efficiencies for high speed digital printing while providing the end consumers with higher color gamut and image quality — all while maintaining the critical characteristics of excellent flesh tone and all-around image longevity unmatched by any of the other digital print technologies available today.

Highlight and Shadow Detail

Also critical for Professional Photographers and labs is the ability to maintain detail in both highlights and shadows areas of the image. This is true for both image capture and the output print. Consider capturing the intricate details in a bride's white wedding gown and the groom's black tuxedo as he stands next to her. The output medium must have the necessary dynamic range to reproduce all of the captured detail. The special curve shape of KODAK PROFESSIONAL ENDURA Premier Paper provides a softer, lower contrast, lower scale to preserve highlight details along with a higher contrast upper scale and maximum density (D-max) to enable the digital printer to reproduce subtle details in the shadow areas, in order to get the most out of an image.

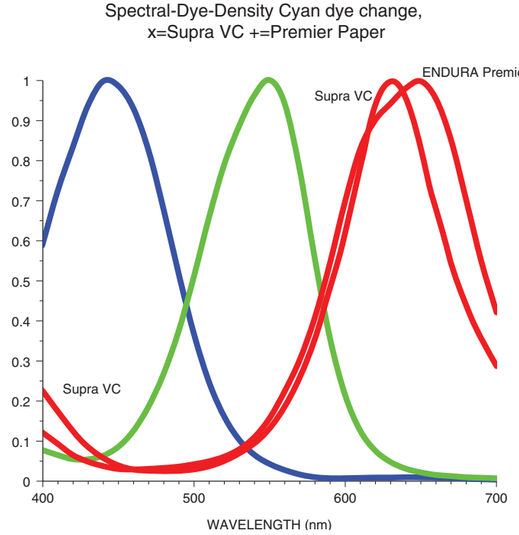
Color Reproduction

Accurate color reproduction with a large color gamut provides important benefits to both commercial and portrait/social labs. Portrait/social labs need accurate color reproduction so that, for example, the subtle pastel colors of bridesmaids' gowns are the correct color. Commercial labs need accurate color reproduction so that they can correctly reproduce client critical trademark/brand colors; they also need a wide color gamut to be able to reproduce the saturated colors featured in many of their clients' products. At the same time, flesh tones in models must look realistic. The higher upper scale of ENDURA Premier Paper delivers a 5% increase in color gamut. Yet the lower scale, in conjunction with Kodak profiles and proper printer calibration, allows for good reproduction of accurate flesh tones, and the subtle and saturated colors all within the same image. Our latest advances in color reproduction (ENDURA Premier) enabled the approximate increase in color gamut of 5%, shown here in Figure 3.



- The technology changes have improved and increased the total color gamut capabilities
- When color gamut is measured through commercial digital printers the increase in total color gamut is approximately +5% with our latest product

Figure 3: 3D Color Gamut comparison of ENDURA Premier Paper to SUPRA ENDURA VC Digital Paper. The light and dark green surface shows the full color gamut; the dark green areas indicate the color gamut increase of ENDURA Premier Paper.



- The new cyan dye delivers significantly improved color reproduction
- Especially in cyans, greens, blues and cleaner yellows
- The cleaner yellow color reproduction is a result of lower unwanted absorption below 440nm

Figure 4: The spectral dye density comparison of ENDURA Premier Paper compared to SUPRA ENDURA VC Paper, shows improved color reproduction and color gamut as well.

Illuminant Insensitivity

Depending on the colorants used in the various digital printing technologies, sensitivity to viewing illuminants — e.g. daylight, tungsten, or fluorescent — can be quite high. That is, a print may have excellent color reproduction and flesh tone characteristics when viewed under daylight illumination, but look quite different when viewed under indoor tungsten or fluorescent illumination. This is especially important when images are viewed in a variety of environments and light sources.

The dyes used in KODAK PROFESSIONAL ENDURA Premier Paper meet the needs of high color saturation and excellent color and flesh reproduction while at the same time having minimal sensitivity to differences in viewing illumination. Prints on ENDURA Premier Paper look great regardless of where they are viewed — in daylight conditions at the family picnic, while relaxing in the home, even under tungsten or fluorescent conditions in a retail environment.

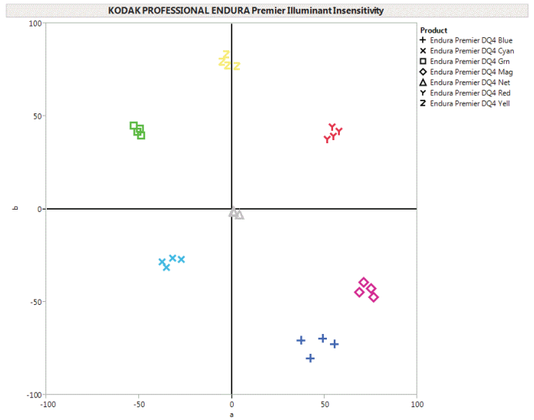


Figure 5: CIELAB plot of one neutral and six color patches showing the small perceived color change with four different light sources.

Sharpness

Sharpness is another important image quality attribute that must be fine-tuned for optimal performance. The "near infinite resolution" of a continuous tone printing system such as silver halide color paper can actually run counter to the desired perception of sharpness. Development of the silver halide grain can be controlled to produce "edge effects," which enhance the sharpness to a degree. Traditionally this happened during film development.

In digital photography, sharpness can be managed in the camera when the photograph is taken, and in editing software after capture. Too much sharpness can produce an unnatural look and lead to unsatisfying results. This is especially true in portraiture, where smooth flesh rendition, without emphasizing wrinkles or blemishes, is very important. Other digital printing technologies, which are not continuous tone, can also have a sharpening effect that adds harshness to an image, resulting in a less pleasing final print.

Figure 6: Oversharpened image

Image Permanence – Image Quality Today AND Tomorrow

KODAK PROFESSIONAL ENDURA Papers have held leadership positions in image permanence since their introduction in 2002. Among all silver halide color papers, ENDURA Premier Paper has double the dark stability performance of its next best competitor. "Dark" stability is the stability, or resistance to change, due to all environmental factors except light, and includes heat, ozone and humidity. Dark stability is critical because in the long term, over 90% of all professional and consumer prints are stored in the dark (albums). Dark stability testing, otherwise known as thermal testing(because higher temperatures are used to accelerate the testing), is performed according to the Arrhenius methodology as detailed in ISO 18924 and the methods of the newly published ISO 18936 on thermal testing[9, 10]. Based upon this testing, an image produced on ENDURA Premier Paper properly stored in the dark in a typical consumer home environment, will last over 200 years before showing a noticeable change.

In typical consumer home display or lit environments, ENDURA Premier Paper will last over 100 years before a noticeable change occurs. Light stability testing is done in accordance with ISO 18909, using multiple high intensity fluorescent light sources. Because the consumer home display environment is typically dominated by daylight, Kodak performs additional testing using high intensity xenon light sources. Xenon light is a much closer representation of the dominant light in consumer homes compared to tungsten or fluorescent light sources. Because of its relevance to the consumer home, we've been running tests with xenon light for over forty years. A new international standard, ISO 18937, was published in the spring of 2014 and closely follows the test protocols that Kodak and Kodak Alaris have been using for decades[11]. For the remaining critical environmental factors of ozone and humidity, the ENDURA Paper family is extremely robust. When tested following the protocols of the newly published standards on gas fading, ISO 18941, and humidity degradation, ISO 18946, ENDURA Papers show essentially zero change during the course of these tests[12, 13]. Testing by Torrey Pines Research, an independent testing lab, was conducted and looked at all four environmental factors. These test results provided an independent verification of the Kodak permanence estimates[14]. For a more detailed discussion on the importance and intricacies of image permanence testing, including all four environmental factors, see Kodak's White Paper on image permanence testing of ENDURA Papers[15] and the consumer guide on image permanence testing from the Image Permanence Institute at Rochester Institute of Technology[16].

Kodak Alaris performs image permanence testing in its own specialized lab but also does verification testing at independent outside labs. Testing has been done at both the Image Permanence Institute at Rochester Institute of Technology, and at Torrey Pines Research as mentioned above. These independent, third party tests are used to validate the testing done internally and to verify our published claims. When ENDURA Papers were first launched in 2002, the Image Permanence Institute performed comparison testing of the new papers with the previous generation of Kodak color papers. KODAK PROFESSIONAL ENDURA Media was found to exhibit significantly improved image stability in terms of color balance and dye fade compared to the older generation paper. These independent results confirmed our internal testing and, in fact, indicated that our published estimates concerning image longevity were actually conservative.

KODAK PROFESSIONAL ENDURA Premier Paper comes from a very solid foundation, to which we expanded the color gamut and increased the accuracy of the flesh tones. Along with all the changes made to move silver halide paper into the digital world, changes to improve its long-term image stability have been made as well. ENDURA Premier Paper represents the state of the art in image stability and when properly stored in dark conditions such as an album or a photo book, will last for over 200 years.

[9] ISO 18924:2013 – Test Methods for Arrhenius-Type Predictions
[10] ISO 18936:2012 – Imaging Materials - Processed Colour Photographs -- Methods for Measuring Thermal Stability
[11] ISO 18937:2014 – Imaging Materials –Photographic Reflection Prints -- Methods for Measuring Indoor Light Stability
[12] ISO 18941:2011– Imaging Materials -- Colour Reflection Prints -- Test Method for Ozone Gas Fading Stability
[13] ISO 18946:2011 – Imaging Materials -- Reflection Colour Photographic Prints -- Method for Testing Humidity Fastness
[14] Research report by Torrey Pines Research: "Image Stability Test for Eastman Kodak"; September 2010
[15] Eastman Kodak Company White Paper: "KODAK PROFESSIONAL ENDURA Papers: Defining Print Life: the Critical Balance of Light and Thermal Stability"; revised March 2013
[16] Image Permanence Institute at the Rochester Institute of Technology: "A Consumer Guide to Understanding Permanence Testing"; December 2009

Section Three: Ease of Use — For Labs

Manufacturing and Production

As with all our photographic papers, KODAK PROFESSIONAL ENDURA Premier Paper, is manufactured using highly developed coating technologies. These technologies allow the coating of extremely thin layers of light sensitive and color forming chemicals (the emulsion and dispersion packages discussed earlier) onto the specially designed and formulated photographic paper base we discussed above. At the same time, the manufacturing process is highly developed and closely monitored to provide very large quantities of product that are highly consistent in performance within a coating run and across manufacturing events from coating to coating. The product sensitometry is tested and highly controlled for photographic speed and contrast throughout the manufacturing and coating processes providing extremely long runs of product with uniform sensitometry. This means that within a given "date code" a lab can count on consistent results in their own production, and as a lab moves from one batch of paper to the next, they will see minimal differences in the quality and sensitivity of the product. That translates to a high level of efficiency, productivity and ease of use for the lab, and removes one of the many variables that labs need to account for in managing their quality. Fewer remakes and greater print yields in the lab can be directly tied to this attention to detail and manufacturing performance by Kodak Alaris.

In addition to sensitometric testing, the physical quality of the product is tightly controlled. The coating process includes in-line continuous laser scanning that is looking for lines, streaks and other types of spot defects. The resulting rate of finished product defects is extremely low and falls well into the Six Sigma level of quality. If a defect is found, it is mapped and stored by the computer and later removed in the finishing operation, so even in the rare case where this occurs, an end user will never see it.

After coating, the "master rolls" move from the coating operation to the finishing operation. Here, using highly automated operations, the product is slit into more manageable roll sizes able to be more easily used by labs. As noted above, at this point in the process any defects found by the scanner in the coating operation are blocked and removed. Master rolls as wide as 72 inches and up to several miles long are slit down to finished roll sizes, packaged in light tight bags, and placed in secondary packaging for shipment and storage. As if this was not challenging enough, it should be noted that from emulsion mixing/manufacturing to coating and final finishing/packaging, all of these complex operations are done in total darkness.

One final note about manufacturing and production; the entire process is flexible and robust enough to allow for a variety of papers to be produced from a common manufacturing platform to match the unique regional preferences and requirements of markets around the world. This is not a "one size fits all" operation. A large benefit of our highly tuned manufacturing process is the flexibility to ensure that the world's unique markets get the individual Kodak branded products that they need, while leveraging the processes and quality control capabilities they've come to expect.

Wet Chemistry — Environmentally Sustainable

Clearly, any product offering today needs to meet the challenges of minimizing environmental impact. Color photographic paper is one element of the overall imaging chain and relies on a sophisticated chemical and mechanical infrastructure to process it and produce final prints. KODAK PROFESSIONAL ENDURA Premier Paper is part of a complete imaging system, including:

- The digital printers to expose and handle photographic paper
- The chemical/mechanical processors to process and fix images to the media
- The associated chemicals of Process RA-4 to convert latent images into long-lasting prints
- Chemical Process Control
  - Developer Regeneration
  - Silver Recovery
  - Effluent Management

Chemical and silver recovery systems, along with the use of paper pulp from renewable sources, help minimize ENDURA Premier Paper's environmental footprint and reduce overall operating costs.

In high-volume applications, where the maximum value of color photographic paper in general and ENDURA Premier Paper in particular shines brightly, the environmental impact is extremely low. The developer for Process RA-4 is designed for a very low replenishment rate, as low as 11 ml/ft2. In high-volume applications, this already low effluent volume is even more significantly reduced by the use of developer regeneration. There are regeneration options that allow for the recycling and reuse of nearly 100% of the available developer effluent back into the process. The bleach-fix is designed for an extremely low replenishment rate of 5 ml/ft2, and silver from this solution is recovered before the effluent is discharged. The wash rate for ENDURA Premier Paper can be as low as 200 ml/ft2, and the water wash for these high volume processors is staged with counter-current flow, which effectively concentrates the chemical effluents (bleach-fix components and silver) into the first wash tank. In a counter-current flow scheme, only the overflow from this first wash is ever discharged. Before discharge, the wash water is treated for silver recovery just like the bleach-fix. With high efficiency electrolytic silver recovery systems, silver recovery efficiencies of 90 to 95% are typical. High volume, centralized labs can achieve even greater results with suitable investments and operation focus on silver recovery efforts, and Kodak Alaris offers consulting services in support of these initiatives.

In lower volume applications, such as minilabs in distributed retail applications, the environmental impact is also quite low due to minimal throughput volume per location and the very efficient design of the minilab processor. The developer and bleach-fix replenishment rates are as low as above, making the effluent volume low enough that it can be collected in the unit and sent off site for treatment where economies can be leveraged for efficient silver recovery and effluent management of a large number of distributed sites. In virtually all minilab operations today, a washless option is used in place of a fresh water wash, further reducing effluent volume and further helping to minimize the environmental impact.

Any environmental assessment must also include a look at energy consumption. Here again, energy consumption has been minimized through efficiencies designed into the processors for either large high-volume processors or low-volume minilabs in retail locations. Efficient processor design means that process solution volumes have been optimized so that only the minimal amount of solution volume is utilized for a given level of throughput. Minimizing solution volumes also minimizes the energy required to maintain these solutions at a specified operating temperature. With the paper designed for low wash rates, the energy required to heat the reduced volume of wash water is lower, and no ongoing heating of water is needed if the washless option is used in the very low volume applications. The energy impact of Process RA-4 for ENDURA Premier Paper is low. The energy investment is well worth the return in terms of the previously noted throughput and productivity benefits of this photographic paper.

For additional information on improvements to the environmental impact of KODAK PROFESSIONAL ENDURA Media, see Table I.

Table I: Environmental Improvements and Benefits of KODAK PROFESSIONAL Media

Improvement	Environmental Benefit
Product Design & Manufacturing	
Reduced Silver (Ag) in the media (up to 75%)	Source reduction-less silver required reduces demand on mining operations
Eliminated use of Mercury (Hq) in media	In alignment with our commitment to reducing the use of substances that may pose risks to human health or the environment
Paper media support changes	Supplier derives pulp from renewable sources, accredited forest management scheme-PEFC* (Eucalyptus Pulp)
Packaging	Packaging cardboards can be recycled, packaging contains recycled content, processing solutions provided in recyclable plastic containers Cartons designed/engineered to offer appropriate protection in transit with minimal use of materials.
Customer Use	
Shortened processing cycle	Energy conservation Reduction in electricity consumption and associated GHG emissions
Lowered replenishment rates	Water conservation Less effluent for treatment and disposal
Digital workflow-ability to design and optimize images digitally	Eliminated printed media waste, proofing/reprinting
Easily implemented Silver (Aq) recovery techniques	Preserves a precious resource and reduces demand on mining operations Recovers and reuses silver. One third of the silver used to manufacture KODAK Products is derived from recycled/recovered system Customer realizes financial gain on recovered Silver (Ag) sold back to refiners

* Program for the Endorsement of Forest Certification (PEFC)

Low Cost: Silver is Expensive — But it Doesn't Matter

Yes, silver is an expensive precious metal, and the price fluctuates in the commodities markets. But this has little bearing on its use as a light-sensitive component in photographic paper. As mentioned above in the Wet Chemistry section, after acting as the light sensor and then directing the development of the image dyes, the vast majority of the silver is removed from the product and recovered from processing solutions. This serves to minimize both costs and environmental impact. More detail is needed about this because there are "myths" being promoted in the industry that the price of silver is directly linked to the cost of using a photographic color paper like KODAK PROFESSIONAL ENDURA Premier Paper. The "myths" go on to say that because of the high cost of silver, the cost to the processing lab (and ultimately the end consumer) must be higher than using other technologies. This is simply not true. Silver is merely an intermediate step in the process of making a print. While the unexposed and unprocessed photographic paper does contain silver in the form a silver halide crystal, this silver is removed in the process as follows.

- After exposure by the digital photographic printer, silver halide crystals form a latent image site
- Once in the developer solution, the latent image site is developed, converting the silver halide molecule into a grain of metallic silver
- At the same time a coupler molecule contained in the same layer as the silver grain forms a cyan, magenta or yellow dye molecule

Areas of the image that do not receive light exposure remain in the silver halide state. The next step in the process is a bleach-fix.

- The bleach part of the bleach-fix solution converts the metallic silver grain back into silver halide
- In the bleach, all metallic silver that was formed in the developer step is converted back to silver halide
- The fixer part of the bleach-fix solution now takes over and removes all the silver halide from the paper, dissolving the molecules into the bleach-fix solution
- The paper meanwhile continues to the wash and dryer resulting in the picture you hold in your hand
- The bleach-fix solution flows from the processor to a silver recovery unit, usually electrochemical, where the silver halide is converted to metallic silver
- The lab owns this silver and typically sends/sells it to a refiner where the metal is purified and the lab is paid the market rate for the recovered silver, less a modest refining fee

With high-efficiency electrolytic silver recovery systems, typical recovery efficiency is between 90% and 95%. Which means that, for every dollar of the value of silver in the paper purchased by the lab, between $0.90 and $0.95 is recovered. The refiner sends a check to the lab for the value of the silver, less a refining charge, and the refiner puts the silver back in the market perhaps to be used again in photographic color paper. This entire process illustrates the sustainable nature of silver halide photographic paper and how silver is used as an intermediary in the overall photographic printing process.

So, what is the value of the silver in a print or photo book produced with silver halide photographic paper like ENDURA Premier Paper? Essentially, zero — all the silver originally in the paper when the lab purchased it, is removed during the production process and the lab receives a check from the refiner for the value of the recovered silver, often at rates of 95% or higher.

Section Four: Eastman Kodak Company, Kodak Alaris — Silver Halide Technology Engineered for Digital Imaging

Kodak Professional — Advancing Photographic Paper for Over 60 Years

Our ongoing support to the photo printing industry through innovative advances in silver halide printing technology started in the mid-50s and continues to this day with the latest paper, KODAK PROFESSIONAL ENDURA Premier Paper. We want you to understand how and why Kodak Alaris continues to invest in this industry.

Industry Participation

We've had a long history of strategic participation in the consumer and professional printing industry, which has been ongoing for nearly 60 years. Eastman Kodak Company promoted and supported technological and industry innovation in part to grow sales of photographic paper and chemicals in the analog years, and with those same products along with thermal dye transfer, inkjet, and electrophotographic technologies in the digital years. We pioneered the industry's move from black and white to color and from manual analog printing (enlargers) to semi-automated and fully automated machine printing (still analog). Through the 70s, 80s, and 90s, we continued to advance the state of the art in color image quality, image longevity, and photo lab efficiency, making photography more appealing and less costly for the consumer.

Tracking the Progress of Digital Printing

In the early 90s when digital printing was in its infancy (making a single 8x10 print digitally from a laser enlarger took nearly ten minutes), our strategic planners began tracking and in many cases driving advances in digital printing. When digital printing became fast enough to be commercially viable in the mid-90s, we introduced silver halide papers for digital printing to complement the analog papers[17, 18]. Digital printing was still a small percentage and the technologies of the two papers were quite different out of necessity; from a practical standpoint the analog paper could not easily be printed digitally and vice-versa[19]. In reality, printing the analog paper with digital exposing devices resulted in very low contrast due to the very short exposure times. See Figure 7.

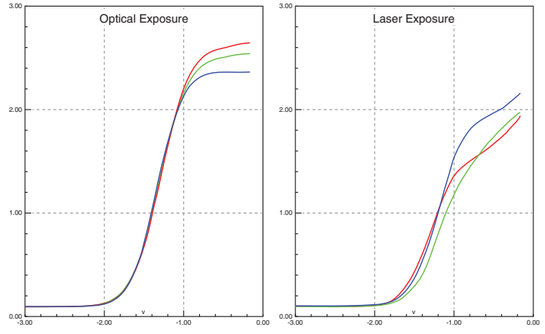


Figure 7: Comparing optical and digital exposures on a paper designed only for optical printing. Note the lower maximum-density and low upper-scale contrast of the results from the digital/laser exposure.

The strategic thinkers knew that digital would grow, so the early 2000s featured photographic papers developed to be more cross compatible between digital and analog printing. By the early 2000s, we offered labs common papers that could be used successfully for both types of printing. This required extensive development of new emulsion technologies, especially in the area of media reciprocity technology, to ensure satisfactory quality and the ability to successfully blend products produced optically (enlargements) with digital print packages in the same order.

[17] Proceedings of the IS&T 10th International Symposium on Photofinishing; "The Continuing Efforts of Eastman Kodak Company to Produce Direct Digital Output Silver Halide Color Media", John F. Bacilek; Eastman Kodak Company (USA) pages 36-40; New Orleans, Louisiana; February 1998

[18] Proceedings of the IS&T PICS 1998: Image Processing, Image Quality, Image Capture, Systems Conference; "Direct Digital Output Silver Halide Color Media and the Market Response to this New Capability", John Bacilek and Charles Whitfield; Eastman Kodak Company (USA) pages 15-20; Portland, Oregon; May, 1998

[19] Proceedings of the IS&T 12th International Symposium on Photofinishing; "Guidelines for Digital AgX Writing Systems", John Bacilek, Timothy Ciranni, William Rochford and Walter Sherwood; Eastman Kodak Company (USA) pages 77-80; Fort Lauderdale, Florida; February 2002

New Hi-Tech Emulsions

Reciprocity is the ability of a silver halide grain to respond to a very short, high intensity exposure in the same way to the same exposure but at a longer time and lower intensity. In effect, we needed to develop a fixed response to a given amount of light energy delivered; low intensity/long duration needed to match results from high intensity/short duration. Reciprocity failure occurs when the response at the two equal exposures is not the same. This was a big issue when an analog paper, designed for seconds of exposure, was subjected to the high intensity, extremely short exposure times of a digital printer. Scientists spent several years developing a solution to the issue of reciprocity failure. The resulting proprietary technology was a breakthrough in improved reciprocity performance, allowing labs to move to a single paper and eliminating an inherent source of variability; saving them time, materials and money. Prior to the new reciprocity technology, two papers — one for analog exposures and one for digital — were needed because there were significant gaps in product performance (reciprocity failure) at the micro and nanosecond exposure times of digital printers. The new proprietary technology allowed for excellent performance at both the nanosecond exposures of lasers to the multiple-second exposures of optical enlargers[20]. See Figure 8.

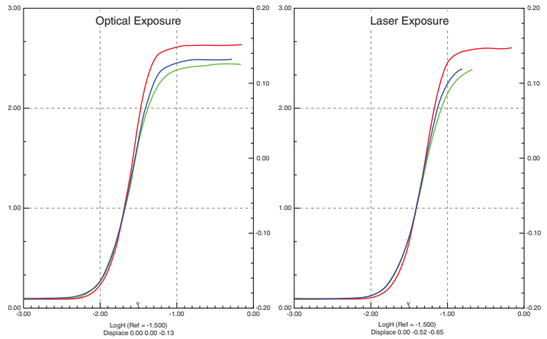


Figure 8: Comparing optical and digital exposures on a paper utilizing Kodak proprietary technology for controlling reciprocity failure and optimized for both optical and digital exposures. Result: significantly improved digital performance.

To be sensitive at both a 100-nanosecond exposure of a laser printer and a 100-second optical exposure of an analog enlarger covers 30 stops of exposure time! Said in a different way, 100 seconds is a billion times longer than 100 nanoseconds (0.000 000 100 seconds)! See Figure 9.

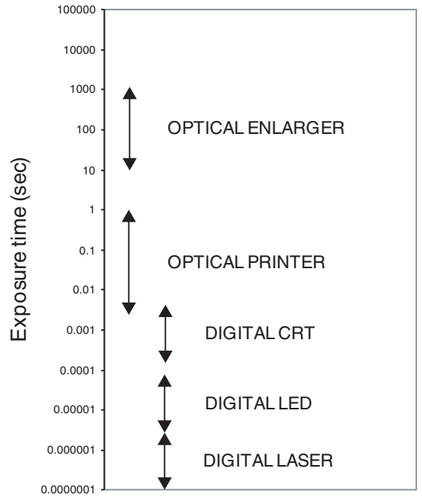


Figure 9: Comparison of the typical optical and digital exposure range for silver halide papers.

[ii] Proceedings of the IS&T Symposium on Technologies for Digital Fulfillment; "Silver Halide Color Paper – the Preferred Digital Print Media"; Stuart Gordon, Eastman Kodak Company (USA); pages 70-72; Las Vegas, Nevada; March 2007

Productivity

Higher speed lasers supported the continued and expanded use of silver halide, or AgX, in commercial applications as well. Print speeds and yields were dramatically improved by these developments as evidenced by the results below.

Whether the discussion is about wide format printing measured in square feet per hour or smaller format printing with units of 8x10s per hour, silver halide technology is the media of choice for mid- to high-volume printing operations of photographic quality prints. And no other digital printing technology offers continuous tone image quality with digital laser printing out to widths as large as six feet! Only Kodak Professional offers digital silver halide media that wide. See the productivity rates in Tables II and III below for typical wide format square feet per hour and smaller format 8x10s.

Table II: Wide Format Productivity

ENDURA Premier Paper Roll Width, inches	Printing Speed, ft2/hour *
20	Up to 110
50	Up to 500
72	Up to 485

* Depending on printer

Table III: Medium Format Productivity

Printer	8x10 Prints per Hour
Kodak RR30 Printer, 10-inch roll	1180
Kodak RP and SRP30 Printer, 10-inch roll	500
Durst Zeta Plus, 10-inch roll	1770

Moving Towards Digital

The industry has migrated almost exclusively to digital printing. Kodak Alaris scientists have continued to adjust and re-optimize the emulsion technology for pure digital applications. Shifting spectral sensitization to be on-peak with the very narrow bandwidth laser light was one important change/improvement that has been made. See Figure 10. Optimizing the speed of each layer to be more in tune with the power output capabilities of the red, green and blue lasers was another development effort undertaken to further improve performance.

Consider an optical paper exposed through a negative with its classic orange mask. The speed relationship between the red, green and blue layers of the optical paper needed high blue speed, moderate green speed, and lower red speed to compensate for the orange mask of typical color negatives. Absorber dyes in the paper were used to achieve the proper speed balance, resulting in some green speed and some red speed being thrown away through the absorber dyes.

Now consider the same optical paper being exposed by red, green and blue LEDs or lasers. While the blue exposing engine encountered the high blue speed of the optical paper, the red engine had to work hard to compensate for the lower red speed. Because there was extra red speed available in the emulsions and with a paper not slaved to optical printing through negatives, the red speed of a digital paper could be increased by removing absorber dye. This is one example of the continuous improvements engineered into our photographic media.

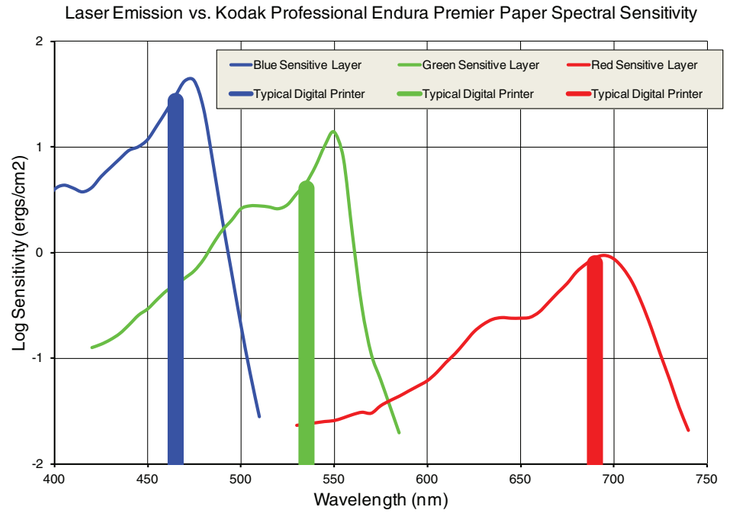


Figure 10: Paper spectral sensitization compared to laser output.

The ongoing evolution of emulsion technology with continually improving reciprocity provided both a productivity benefit as well as an economic/capital equipment benefit to the labs. The new technology allowed the paper to work across a wider variety of print engines, giving labs the flexibility to maximize their capital investments in exposure equipment. This included continuing use of analog/optical equipment (primarily for enlargements), as well as use of early digital technology CRT (cathode ray tube) printers (many of which are still in use today), along with modern LED and laser printers. Even on different surfaces and substrates, nearly identical results were achievable due to the reciprocity and color management profiles generated for each media and device.By the late 2000s, digital printing was predominant and our strategy reflected that with the KODAK PROFESSIONAL ENDURA Paper family that was optimized for digital printing, although they could still be used in optical applications. By the early 2010s, the industry was printing virtually 100% of their work digitally and we launched a new optimized product, KODAK PROFESSIONAL SUPRA ENDURA VC Paper, to reflect this[21]. Unlike earlier papers, SUPRA ENDURA VC Paper was optimized exclusively for digital printing.

ENDURA Premier Paper — Latest Technology for Today

Our latest introduction, KODAK PROFESSIONAL ENDURA Premier Paper, is also optimized specifically for digital printing and reflects the latest emulsion and dispersion/dye technologies to provide further improvements in color gamut/saturation while maintaining pleasing flesh tones. It delivers all of the operational benefits derived from consistent quality roll-to-roll and batch-to-batch. We support KODAK PROFESSIONAL ENDURA Premier Paper by providing updated profiles for many digital printers and other color management capabilities that allow labs and photographers to tune the paper to achieve a range of desired "looks", satisfying a broad range of customer or end-user requirements. This is the most recent example of an ongoing stream of benefits to the labs, their customers, and the end consumers[21, 22] delivered by KODAK PROFESSIONAL Media. Based on our history, continued innovation and demonstrated performance, investing in a new paper should be no surprise at all. It is a logical extension of the successes that have led us to this point and a sure signal of our ongoing commitment to excellence and the professional photography markets around the globe.

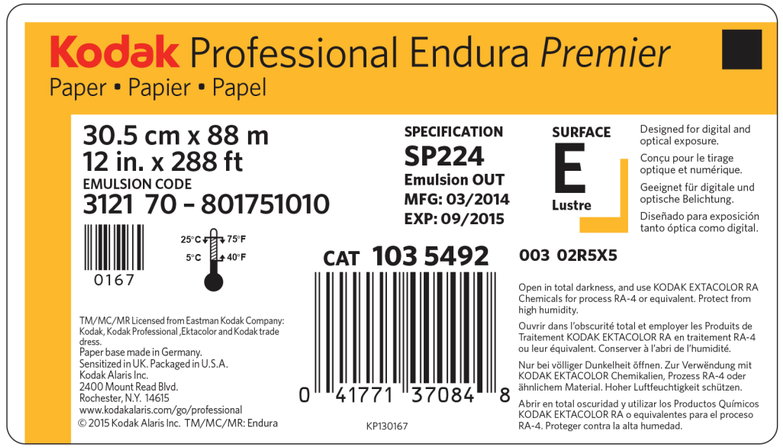


Figure 11: KODAK PROFESSIONAL ENDURA Premier Paper, E Surface

Bottom Line

While the fundamentals of this technology are over 125 years old, our current offerings leverage over a century of continuous improvement. These investments have brought us to the current state — and with these continued efforts, the best technology in digital printing just keeps getting better!

Continuous tone or silver halide images are still the standard against which all other imaging technologies are measured. Productivity in the printing, processing and finishing of CNP also make it one of the most economical ways to put images onto a substrate. The proven performance of silver halide in print life, image quality and protection from obsolescence of digital files, continue to keep it in the forefront of the photo imaging market, while leveraging the significant capital investments made by our customers in printing equipment. So it's no surprise that by 2018, silver halide is still projected to be the most popular way to put images on media; exceeding the volume of prints produced by all other technologies combined — electrophotographic, inkjet, and dye sub/thermal.

Considering the four primary performance vectors for Color Negative Paper — image quality, cost, longevity and speed or productivity — KODAK PROFESSIONAL ENDURA Papers excel. It doesn't have to be a choice between image quality or cost, longevity or speed/productivity. KODAK PROFESSIONAL ENDURA Papers are without compromise — the one to beat. We provide the widest range of applications and usability that covers an expansive set of lab and end-user needs, from 4x6 prints, to large format display images up to 72 inches wide, and now to double-sided photo books, the photo album of the 21st century.

If photographic paper were introduced today, it would be heralded as the highest quality, infinite resolution, lowest cost, and fastest, most productive way to print an image. It would be "an overnight success" in digital imaging that's been over a hundred years in the making. We owe it to our customers, and to their customers, to fully embrace the wonder that is the photographic print. There's only one original and this one looks better than the day it was born and launched.

[21] Proceedings of the IS&T 2nd Symposium on Technologies for Digital Fulfillment; "KODAK PROFESSIONAL SUPRA ENDURA VC Digital Paper – A New Silver Halide Paper Optimized for Color Managed Professional Digital Labs"; Patrick Webber, Eastman Kodak Company (USA); pages 63-65; Las Vegas, Nevada; February 2009

[22] Proceedings of the IS&T 4th Symposium on Technologies for Digital Fulfillment; "KODAK PROFESSIONAL ENDURA Premier Paper – A New Silver Halide Paper with Improved Color Gamut for both Portrait Social and Commercial Applications"; Patrick Webber, Eastman Kodak Company (USA); Las Vegas, Nevada; January 2013

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