KODAK PROFESSIONAL ENDURA Premier Paper: Still the Digital Imaging Media of Choice

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Abstract

There are a wide range of digital print technologies available today, including Silver halide, Inkjet, Electrophotographic, and Dye Sublimation. However, only one, silver halide paper, specifically KODAK PROFESSIONAL ENDURA Premier Paper, incorporates imaging technology that provides an optimal balance of lab-preferred and consumer-preferred characteristics regarding image quality, high productivity, low cost and long-term permanence. This paper will discuss those technologies and how they enable KODAK PROFESSIONAL ENDURA Premier Paper to meet the needs of the critical portrait/social market. In addition, there is a general lack of awareness of the long-term storage and accessibility issues associated with digital files for which printing can fill a significant need. The optimal performance of KODAK PROFESSIONAL ENDURA Premier Paper provides the easiest, most economical solution for multi-generation preservation through hard copy printing of digital files. A print made on KODAK PROFESSIONAL ENDURA Premier Paper is a human-readable technology-independent record that will provide long-term access for multiple generations and provides a solution to the needs of long-term preservation of digital files by the consumer.

Introduction

Professional print labs and consumers alike have a wide choice of digital print technologies available today. For the consumer, this includes inkjet as well as thermal dye transfer media. For the high volume pro lab this includes silver halide and electrophotographic (EP) technologies. It is true that each technology has its own specific benefits, for example instant prints from thermal media at retail kiosks and photo books from EP, but silver halide paper provides the broadest range of benefits over the widest range of applications. Specifically KODAK PROFESSIONAL ENDURA Premier Paper incorporates imaging technology that provides an optimal balance of lab- and consumer-preferred characteristics regarding image quality, high productivity, low cost and long-term permanence. This paper will discuss those technologies and how they allow KODAK PROFESSIONAL ENDURA Premier Paper to meet the critical needs of the portrait/social market. In addition, the tremendous growth in digital photography by both consumer and professional photographers is accompanied by a general lack of awareness of the long-term image storage and accessibility limitations associated with digital files. The paper will also discuss how the optimal performance of KODAK PROFESSIONAL ENDURA Premier Paper provides a solution for consumer preservation of digital files for multiple generations.

Advantages of Silver Halide and Endura Premier Paper

Being a silver halide paper, KODAK PROFESSIONAL ENDURA Premier Paper provides the general advantages of silver halide papers for the professional and commercial finishing labs. These characteristics and those specific to ENDURA Premier Paper are discussed in detail below.

Gelatin and the Emulsions

The entire emulsion package is embedded in gelatin, providing several unique benefits to silver halide papers. 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 imbedded within and surrounded by the gelatin, the dyes are further protected from adverse chemical reactions such as attack by atmospheric pollutants such as ozone. Unlike other 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.

Paper Support

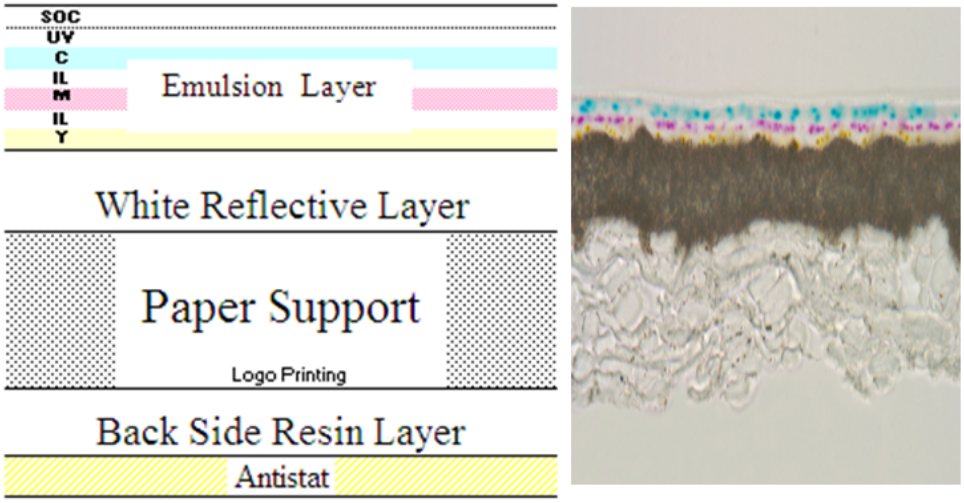

Figure 1 – Illustrated layers and corresponding photomicrograph cross section of KODAK PROFESSIONAL ENDURA Premier Paper

KODAK PROFESSIONAL ENDURA Premier Paper uses a specialty paper core, surrounded by a plastic, polyethylene resin-coating on both sides of the paper (a white reflective layer above and a clear resin back side layer below). See Figure 1. The paper core 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 surrounding plastic resin makes the paper core essentially waterproof, blocking any absorption of processing chemicals from the top or bottom of the paper sheet. The white resin layer not only provides for bright whites, but acts as a reflector to bounce the light back through the imaging dyes, effectively providing double the impact from the dyes. This means greater color saturation and color reproduction benefits.

In KODAK PROFESSIONAL ENDURA Premier Paper, the support, gelatin, and emulsions form an integrated package to provide high quality, long lasting images. Designed and built specifically for photographic imaging, clearly this is a specialty paper with many unique qualities that function together to optimize the photographic performance and maximize the enjoyment and longevity of an image. This is true whether captured as an analog image with film, or as a digital image.

High Image Quality, High Productivity, Low Cost, High Longevity

Usually it's a trade-off. In the world of digital printing with the available printing technologies, you can choose two of the four attributes of image quality, cost, longevity, and speed/productivity. With KODAK PROFESSIONAL ENDURA Premier Paper and its silver halide technology, however, you get all four attributes without compromising on any one. The extremely high resolution of a continuous tone print is just the start. While newer digital (non-silver halide) printing technologies may have an advantage in one or two of these four attributes, when taken as a whole, KODAK PROFESSIONAL ENDURA Premier Paper cannot be beaten.

Image Quality

A key attribute contributing to pleasing image quality in silver halide papers is the "smooth continuous tone" pleasing print from dye clouds as opposed half-tone dots. This makes silver halide technology the gold standard for professional portraiture, where the imaging science technology is delivered within the paper, not applied to the top of the paper support.

Flesh Reproduction

Kodak Professional color photographic papers set the standard long ago and continue to lead in overall image quality today. Two key attributes to this claim are flesh reproduction and the flesh to neutral relationship. Kodak scientists long ago, in conjunction with key professional labs and photographers, recognized the importance of 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 of colors in 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.

Highlight and Shadow Detail

Details in both highlights and shadows are also critical for professional photographers, both in the image capture as well as the output print. Consider capturing the intricate details in the bride's wedding gown in the same photograph as the groom's black tuxedo. With digital capture the photography has to be good but the output medium must also have the necessary dynamic range to reproduce the details. The special curve shape of KODAK PROFESSIONAL ENDURA Premier Paper provides a softer, lower contrast lower scale to preserve

highlight details combined with a higher contrast upper scale and maximum density (D-max) to provide the digital printer with the ability to reproduce subtle details in the shadow areas.

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 subtle pastel colors of subject elements such as bridesmaids' gowns are the correct color. Commercial labs need accurate color reproduction to accurately reproduce their clients' trade mark colors and the saturated colors of their clients' products. KODAK PROFESSIONAL ENDURA Premier Paper features a 5% increase in color gamut when compared with the previous generation of professional color paper, KODAK PROFESSIONAL SUPRA VC Paper. Yet the lower scale allows for the subtle as well. See Figure 2.

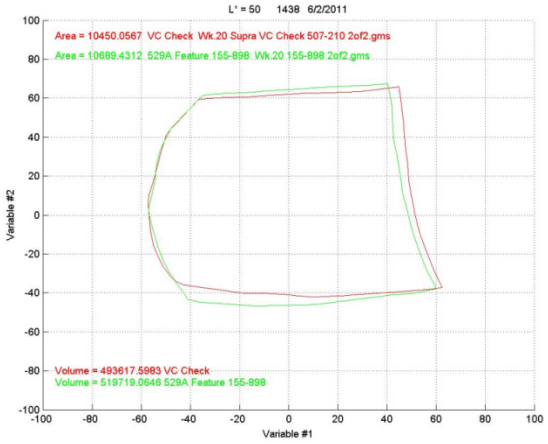

Figure 2 – Color gamut comparison of ENDURA Premier Paper compared to SUPRA ENDURA VC Paper

Illuminant Insensitivity

Depending on the colorants used in various technologies, sensitivity to viewing illuminants, for example, daylight, tungsten, or fluorescent, can be quite high. That is, a print may have excellent color reproduction and flesh tone characteristics under daylight illumination, but look quite different when viewed under tungsten illumination. 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 have minimal sensitivity to viewing illumination. See Figure 3. Prints on ENDURA Premier Paper will look great regardless if they are viewed under daylight conditions at a family picnic, or while relaxing in the home under tungsten or fluorescent illumination.

Figure 3 also shows the benefit of the new cyan dye in expanding the color gamut. The new cyan dye peak has a bathochromic shift compared to the previous cyan dye delivering 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.

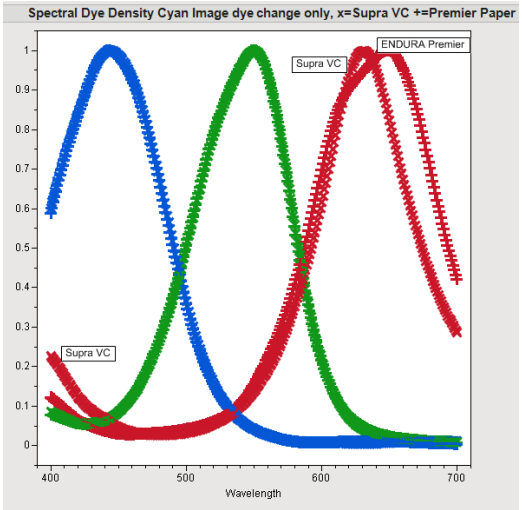

Figure 3 – Spectral dye density comparison of ENDURA Premier Paper compared to SUPRA ENDURA VC Paper, showing improved color reproduction and color gamut

Sharpness

Sharpness is an important image quality attribute that must be properly tuned for optimal performance. The extremely high resolution of a continuous tone printing system like silver halide color paper can actually be counter to high sharpness. Development of the silver halide grain can be controlled to produce "edge effects", which enhance the sharpness to a degree. In digital photography, sharpness can be enhanced by the image processing during the capture of the image and also during the editing the image after capture. Too much sharpness can be a negative attribute. This is especially true in portrait social applications where smooth flesh rendition, without enhancing wrinkles or blemishes, is very important. Other digital printing technologies, because they are not continuous tone, will also have a sharpening effect that can be very undesirable for professional and commercial photographic applications. With the long history of Kodak Professional color papers and Kodak's multiple decades of historical knowledge gained through listening to professional labs and photographers, it is easy to understand how optimized sharpness contributes strongly to the overall image quality advantage of silver halide printing technology.

Productivity

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 only Kodak Professional offers the continuous tone image quality with digital laser printing out to widths as large as six feet! See Table I for productivity rates in wide format printing. For medium format printing using 10-inch rolls of paper, print speeds of 1200 to over 1750 8x10 prints per hour can be achieved, depending on the printer.

Table I: 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

Low Cost: Silver is Expensive – But it is Very Cost-Efficient

Yes, silver is a precious metal, is expensive, and the price fluctuates in the commodities markets. But this has little bearing on its use as a light sensitive component in photographic paper. After acting as the light sensor and then directing the development of the image dyes, the silver is recovered from the processing solutions to minimize environmental impact and provide money back to the lab. The lab owns this recovered silver and typically sends it to a refiner where the metal is purified. With high efficiency electrolytic silver recovery systems, recovery efficiency of between 90 and 95% is typical. Said in a different way, for every dollar of the value of silver in the paper purchased by the lab, between 90 and 95 cents 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 the value to the lab as they receive a check for the recovered silver.

Image Permanence – Image Quality Today AND Tomorrow

Three key and fundamental design criteria for color paper that have been in place for decades at Eastman Kodak Company, and now Kodak Alaris, are (1) image quality, (2) ease of use for the labs (including environmental benefits) and (3) image permanence. Image quality, of course, is important because the photographer and end consumer want their images to look their best. But image permanence is also important because they want their images to continue to look their best well into the future.

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 stability to all factors except light, and includes heat, ozone, and humidity. Dark stability is critical because over the long term, over 90% of all professional and consumer prints are stored in the dark. Dark stability testing, otherwise known as thermal testing because higher temperatures are used, is performed according to the Arrhenius methodology as detailed in ISO 18924 and the methods of the newly published ISO 18936 on thermal testing [1, 2].

Properly stored in the dark in typical consumer home environments, ENDURA Premier Paper will last over 200 years before showing a noticeable change. In typical consumer home display 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. Because of its relevance to the consumer home, Kodak has run tests with xenon light for over forty years. This xenon test protocol will eventually become an ISO standard.

For the remaining critical environmental factors of ozone and humidity, the ENDURA family of papers is bulletproof, showing virtually no change to these factors. 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 the test [3, 4]. For a more detailed discussion on the importance and intricacies of image permanence testing and including all four environmental factors, see Kodak's White Paper on image permanence testing of ENDURA papers [5] and the consumer guide on image permanence testing from the Image Permanence Institute at Rochester Institute of Technology [6].

It is important to recognize that image permanence is not just about the dyes and the image, but also about the paper support the images are printed on. As mentioned earlier the resin coated support is made up of specialty paper and high quality resins specifically designed for photographic applications. Part of this design is to insure longevity of the support. It makes no sense to have high permanence levels in the dyes if the support can't match that performance. To prevent degradation caused by physical change such as crazing and cracking Kodak Alaris uses special resin stabilizers in the ENDURA Papers to provide stability that equals or exceeds that of the image dyes.

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 [7]. These independent tests are used to validate the testing done internally and verify our published claims.

Making Prints is Very Important

There are two strongly compelling reasons consumers will make prints of the best of the best of their digital collections: 1) tangible, physical reality; 2) long-term preservation.

There is a tangible, physical reality to holding, passing and sharing a hard copy print or photo book. Prints provide an

emotional connection that viewing on a computer screen or smart phone cannot achieve. Studies done at the College of Imaging Arts and Sciences at Rochester Institute of Technology have shown that people look longer and pick up more information from a hard copy print than in looking at the same image on a screen [8, 9].

For long-term preservation, a hard copy photograph has no equal. A hard copy print is the best way to insure that important pictures will be accessible and viewable well into the future. Digital files can be copied perfectly but if a flaw develops in the file, the image is gone forever. More likely, a digital file can easily be lost in the huge sea of a consumer's digital collection. Over the longer term, digital formats will change, both hardware and software, rendering a digital file virtually useless. Consider the difficulty in reading a file from a 3.5 inch floppy disk, or a ZIP drive containing photographic images. A hard copy print, however, is "future proof", that is, not dependent on some current state of digital technology that will change with time and this avoids the issues caused by the always-advancing digital technology. To access and view a print or photo book requires no digital device or software – just your eyes and a light source. [10, 11].

We take pictures to capture and preserve special moments in time. In the days of film and analog photography, we reserved taking pictures for the most special moments because film and its associated processing was expensive. This included vacations, birthdays, reunions, weddings and school photography, to name a few. Today with digital photography we shoot away without regard to the "costs" because it seems like digital photography is "free". Of course it is not in reality.

One of the costs we don't think about is the management and long term preservation of the images capturing these special moments. With digital photography we take pictures of much more than just the special moments of our lives; but of course all of the special moments mentioned above are still happening. In the days of film photography, a print was the only way to "retrieve", view and share those moments. Today, prints, pages and screens are all excellent options. However, the best way to preserve those special moments for the long term is to use the material that has proven itself over the long term – silver halide photographic paper.

Conclusion

KODAK PROFESSIONAL ENDURA Premier Paper comes from a very long silver halide lineage. ENDURA Premier Paper makes use of state-of-the-art imaging technologies to provide a host of benefits to both the professional lab producing the print and to the end consumer as this silver halide paper has evolved into the world of digital printing. This includes meeting a broad set of laboratory and end user needs from 4x6 prints to large posters up to 72-inches wide, and to photo books, the photo album of the 21st century. For the lab this includes ease of use technology to provide a wide range of digital exposure capabilities, process capabilities that minimize cost and environmental impact, high productivity and low cost. Unlike many of the other digital printing technologies there is no need to compromise on these characteristics. For the end consumer the paper provides excellent image quality for pleasing prints, both today and far into the future. And with its state-of-the-art image permanence and stability, ENDURA Premier Paper gives the end consumer the easiest, most economical solution for multi-generation preservation through hard copy printing of digital files. Just as printing did through the history of analog photography, a print made today on KODAK PROFESSIONAL ENDURA Premier Paper is a technology-independent record that will provide long-term access for multiple generations. There is no better way to safely preserve those precious memories than with a print or photo book made with ENDURA Premier Paper. Not only do you get all the image quality benefits that Endura Premier Paper is well known for, you also get the assurance of long term, technology independent permanence for generations to come. And, when stored in typical consumer home conditions, a print on ENDURA Premier Paper can be expected to last over 200 years. Clearly the evolution of Kodak technology in KODAK PROFESSIONAL ENDURA Premier Paper positions the product at the pinnacle of development of silver halide media and your customers' photographic images deserve all these unique advantages.

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Author Biography

Patrick Webber is a principal scientist at Eastman Kodak Company. He has worked there for over 35 years and has held a variety

of positions in silver halide manufacturing, and research and development. His primary focus for the last 25 years has been the development and commercialization of professional silver halide media products both for optical and digital use. Pat was the systems team leader for the ENDURA Premier Paper design team.