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An Investigation into the application of digital camera created images and their preparation for newspaper lithographic reproduction without a reference analog reflection or transmission original

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An Investigation into the Application of Digital Camera Created Images and their Preparation for Newspaper Lithographic Reproduction without a Reference Analog Reflection or Transmission Original

by
Victoria Arocho

A thesis project submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
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School of Printing Management and Sciences
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Certificate of Approval

Master's Thesis

This is to certify that Master's Thesis of

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With a major in Graphic Arts Publishing
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To

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Table of Contents

List of Plates

List of Tables

Tables Page

List of Figures

Abstract

Looking at the shoes that digital photography has a role in filling we can quickly see performance issues that will undoubtedly affect our final printed reproduction. The resolution provided by a digital image is directly correlated to the CCD size, quality and any associated post-imaging processes provided by camera manufacturers but is only one of quality-limiting factors involved in digital photography.

"Silicon-based CCD's are monochrome in nature."[1] Having the inability to decipher the varying degrees of red, green and blue light presented to the pixels it is necessary to account for RGB light by introducing a color-filtering method. The color-filtering method prevalent in the cameras to be tested are referred to as "integral color filter arrays (CFA)."[2] Integral color filter arrays performs color filtering on the chip with each individual pixel hosting a specific filter color (red, green or blue). This allows for the deciphering of the various light wavelengths presented in a scene to be translated by the CCD into digitized values of color, but because each pixel can only represent one filter color this results in problems including; "the loss of information leading to reduced effective resolution and increased sampling (quantizing) artifacts."[3]

Such color-gathering techniques and various inherent CCD issues account for problems that must be addressed and minimized during post-image processing prepress steps. The following endeavor is to evaluate three types of digital cameras (Minolta RD-175, Fuji 505a, AP NC2000e/Canon DCS EOS3) which can meet the requirements of a photojournalist then identifying the various issues that are inherent to each camera, post processing prepress solutions will be sought through the use of Adobe Photoshop™.

By evaluating the cameras via tests that provide information about resolution, dynamic range, color gamut reproduction abilities and image-to-noise relationships it was possible to assess what camera shortcomings must be addressed during post-image processing. The shortcomings were then individually assessed and, utilizing prepress skills post-processing procedures, were identified to address the specific inherent shortcomings.

Using SNAP (specifications for non-heat advertising printing) specifications, a representative set of images were printed and analyzed. The results from this analysis presents camera performance issues prior to post-image processing optimization and after post-image processing optimization. It will illustrate the initial shortcomings and how well these shortcomings can be de-emphasized in Adobe Photoshop. The printing of test images to SNAP specifications also illustrates if there is any loss of quality due to the reproduction on newsprint.

Based on the test performed it was established that each usable camera ISO has its own specific set of characteristics that effect visual resolution, color gamut, usable range and noise. The method the manufacturer uses to acquire its images, including CCD hardware, camera firmware and pre-acquire processing, also affect visual resolution, color gamut, usable range, noise and aliasing.

Photographic metering techniques and photographer criteria for ISO selection can assist in maintaining the highest level of exposure quality capable for each camera. When the highest level of image quality is achieved with the use of photographic techniques, the highest level of visual resolution, color gamut, usable range and the least noise can be rendered for each camera image.

Knowledge of Adobe Photoshop and offset printing principles, such as memory colors, wanted and unwanted colors, are valuable in enhancing the digital camera's limited color gamut. The nature of the newspaper printing process produces a small color gamut, therefore, the limited gamut inherent in the digital cameras is of less concern than if the digital images were printed using a larger color gamut capable four-color process.

The identification of each camera's tendencies does allow for a greater understanding of applicable procedures within Adobe Photoshop which can reduce and or alleviate the tendencies.

Endnotes Abstract

1. Kodak CCD Primer, #KCP-001, Charge-Coupled Device (CCD) Image Sensors, Eastman Kodak Company–Microelectronics Technology Division, 001-1

2. IBID, 001-9

3. IBID, 001-9

Chapter 1
Introduction

Statement of Project Goals

With the growing inclusion of digital photography in the newspaper reproduction workflow, there are several goals that remain the same and several that are being altered. "The most obvious requirement for an ideal reproduction is that it visually matches the original."[1] Digital photography's most obvious difference is that there is no longer any form of an original. Devoid of a print or a negative we are left with the imagination of the photographer as it was perceived during the actual occurrence of the event and the photo editors' or prepress technicians' perception of how they thought the event may have looked.

If the differences stopped there, it would not be such a traumatic departure from the scanning of negatives, but in actuality digital photography has greater issues to address. Miles Southworth sums up "the difference between a good color reproduction and a poor color reproduction is usually the result of:

- the color scanner chosen by the operator,
- the proper scanner or desktop computer setup for the printing parameters,
- the originals' image and emulsion characteristics, and
- the scanner operators' image adjustment for a good visual reproduction."[2]

When it comes to digital photography, the above differences become altered in role and placement of responsibility. The "color scanner chosen"[3] now becomes the digital camera chosen. The "proper scanner or desktop computer setup for the printing parameters and the originals' image and emulsion characteristics"[4] now become subject to the photographers' exposure control and compression ratio. "The scanner operators' image adjustment for a good visual reproduction"[5] is now complicated by camera tendencies due to technological limitations (artifacting, blue noise) and is often placed in the hand of photographers who are poorly trained in prepress issues or prepress technicians that are unfamiliar with camera limitations.

With the redefinition of color reproduction issues and the loss of control over image acquisition by the prepress technician it is important to identify digital image tendencies and possible solutions for these tendencies. This thesis is being performed under the hypothesis that an identification of digital camera issues can be correlated to identify when they are most likely to occur. Using prepress knowledge,

skills in Adobe Photoshop and photographic recommendations it will be possible to establish a method for optimizing digital images. The optimization of the digital images will then enable the maximum image quality reproduction achievable using SNAP specifications as the printing model.

The goals of this thesis are:

1. Establish digital camera technological limitations.
2. Using good photographic practices, determine if any of these limitations can be eliminated or decreased by changing shooting methodology.
3. Using prepress skills and knowledge of Adobe Photoshop establish a list of solutions or methods for optimization of images which exhibit problems due to camera limitations (excessive blue noise, artifacting, poor color, sharpness).
4. Determine a method that will produce the best possible reproduction of an image shot with any of the four digital cameras used using specifications as outlined by SNAP.

The research was a compilation of qualitative and quantitative analysis of the various test regions. Because the digital images exist in a virtual environment, Abode Photoshop will be used to determine visual test results and digital code values, which are representative of color brightness levels.

Color was evaluated using spectrophotometric readings taken off the newspaper samples along with readings made from the digital-image files using the "Info palette" in Adobe Photoshop. Camera noise will be evaluated visually using the newspaper samples printed and a visual examination of the Adobe Photoshop files viewed on a computer monitor. Aliasing, camera dynamic range and spatial resolution were evaluated visually. "When the scene information, ie. detail, is greater than the spatial detail captured by a CCD, aliasing will occur."[6] Camera dynamic range speaks as to the ability for a camera to record a range of information.

In many of the tests, visual analysis becomes as important if not more important then any quantitative analysis. This visual analysis is of such importance because it is the only method photographers and prepress technicians have in evaluating digital images in an active workflow. Because the thesis is tailored for optimization of digital images, in an active workflow, ISO based definitions were used to define the criteria for visual evaluation.

Reason of Interest

As a photographer, hours of photography are often equated to one photograph that is asked to "establish the truth of events that seem inconceivable."[7] Through the years, photojournalists have been asked to do this job using a variety of tools. The evolution of photography has taken away the cumbersome 4x5 inch, 120 cameras and now opened up opportunities to work with digital camera technology. Each time the tools have evolved or been eliminated, the role of each participant in the process of image reproduction has changed.

Previous to the integration of digital technology and photography, the photographic workflow was a fairly closed loop operation. Photographers produced their images, processing and printing them only to hand a finished print over to an engraver for the engraver to work their printing magic. Technology in recent years and especially digital photography has expanded the previously closed loop of photography, incorporating it into a multidisciplinary workflow. The distinctions between photographer and prepress technician are shadowed with applications such as Adobe Photoshop and the demands of various workflows.

It is incorrect to define digital photography as the making of photographs with a CCD. Digital photography transcends the bounds of a camera, and its success is based on the successful integration of an efficient production workflow that addresses issues from exposure to the printed piece.

Because digital photography is being integrated into the newspaper workflow with such vigor and enthusiasm, it is in the interest of maintaining high levels of image quality for photojournalists and newspapers alike that drives this investigation.

For the same reasons it is important to create successful images it is also necessary to preserve the quality of images and their ability to reach and communicate with the readership. A poor reproduction of a great image diminishes the quality behind the photographer's craft, often demoralizing the photographer, as well as the integrity of the publication. A successful image of strife, joy or hardship elicits human thought and action.

Technology has as much a responsibility for assisting the conveyance of truth as does the photographer in capturing it.

Endnotes Chapter 1

1. Miles Southworth and Donna Southworth, *Quality and Productivity in Graphic arts*,1989, 9-3

2. Miles Southworth and Donna Southworth, *Pocket Guide to Color Reproduction communication and control,* Edition 3.1, 1995, 1

3. IBID

4. IBID

5. IBID

6. Professor Doug Rea,Interview

7. Howard Chapnick, *Truth need no ally*, 1994, 10

Chapter 2
Theoretical Bases of Study

Background and Significance

March 4, 1880 the first U.S illustrated newspaper, the New York Daily Graphic "published the first halftone. . . a picture of Shantytown, a squatter's camp in New York City."[1] It was not till the technological advances of halftoning that there was a "practical way to transfer the photograph directly to the printed page."[2]

Jumping forward a 100 years to the decade of the personal computer, we see a how "printing has been transformed from an art to a science."[3] The growth of electronic technology has lifted printing and photography to a new level. With both industries trying to fulfill the demands of there forefathers, the Penny Press newspapers of the1800's, "fresh news"[4] being the most valued commodity, an expanded effort to make the world events seamless and mass communications more efficient for newspapers has been an ongoing effort since the invention of the telegraph in 1844.

Digital cameras have eclipsed the notion of time constraints previously experienced by photographers. Before digital photography, it was an "arduous process (to put out photographs on the wire) for photographers. Hours are now reduced to minutes,"[5] said Associated Press Vice President and Executive Photo Editor Vincent Alabiso.

With the evolution of digital camera technology beginning with the discovery of the CCD in the 70's, the technology created today is superior to anything we had in the past, but there is still room for advancements. Until the technological hardware can be revamped to address current limitations, it is necessary that meaningful, realistic solutions be sought.

With newspapers buying new, larger, faster, higher-quality presses (For example, Gannett Rochester is spending $65 million on new high-speed web offset presses. Pacific Press in British Columbia, owners of The Vancouver Sun and The Province, also is upgrading from its current letterpress and flexography presses to $150 million high-speed web offset presses), print quality can only get better. If limitations that exist within digital photography are not addressed, these high-quality presses will be producing high-quality reproductions of poor images. It is important that image quality does not fall behind because of the tools in use, digital photography.

The spread of digital photographic technology is inevitable for one reason: cost savings. Robert Galbraith, *Calgery Herald* digital photographer, states "the final selling point was cost, it was believed that there was a lot of money to be saved. Fourteen to fifteen thousand dollars of consumables per photographer,"[6] per year were being spent! "Despite the huge capitol outlay,"[7] it was money that would be paid back in 14 to 18 months said Nick Didlick, (Photo Editor and digital photographer at The Vancouver Sun).

David Rocha, Senior Photo Technology Specialist with The Associated Press, states

> "As much as we would all love to talk about image quality, ease of use, productivity, filing from remote sites and beating deadlines, the driving force that is always behind a digital camera purchase is money. Newspaper publishers love digital photography and in more cases than not it's newspaper management who has wanted to switch to digital cameras, and newspaper photographers who have been resistant. From a newspaper management point of view, digital photography makes a lot of sense. They buy hardware, albeit somewhat expensive, but equipment can be depreciated which gives you tax benefits, but more than that, a huge section of the newsroom budget is spent on consumables, film, paper, chemistry, disposal charges, plumbing all of those things add up to a lot of money. The average newspaper spends $10,000 to $12,000 per photographer per year; some spend less some spend more. If you have the average camera costing $15,000 that is a return on investment in less than 18 months."[8]

The theoretical basis of study is that there is a need and demand for increased quality from digital images. Until these quality issues can be rectified with hardware software, derived solutions must be sought.

Endnotes Chapter 2

1. Kenneth Kobre, *Photojournalism the Professionals' Approach*, Second Edition, 1991, 321

2. IBID, 320

3. International Paper, *Pocket pal, A Graphic Arts Production Handbook*, 8

4. Joseph R. Dominick, *The Dynamics of mass communication*, Fourth Edition, 1993, 92

5. Vincent Alabiso, Vice President and Executive Photo Editor of The Associated Press

6. Robert Galbraith, Calgery Herald Digital Photojournalist

7. Nick Didlick, Vancouver Sun Photo Editor

8. David Rocha, Senior Technology Specialist for the Associated Press, New York, NY

Chapter 3

Review of Literature

Although CCD technology has been around since the 1970s, it has only been since1994 that digital photography has addressed the needs of the photojournalist. The literature reviewed for this thesis project encompasses material that is dated from 1994.

A gap in literature addressing newspapers and digital photography was discovered after a search of traditional written works was performed. Because of the inadequate amount of resources found regarding the topic of investigation, a series of interviews with industry professional was performed.

The common factor found in all the written literature concerning digital cameras was that, whether created by the manufacturer or independently written, digital camera technology was summed up by reiterating the published "tale of the tape" provided by the manufacturers. Article after article addressed digital cameras in the traditional method cameras have always been defined by, with a in-depth descriptions of their features.

A thesis entitled *Evaluation of Digital Cameras' Color Spaces* by Per Aviander addresses issues of digital camera and color space reproduction but makes no correlation to prepress that would affect a newspaper workflow. In 1995, Peter Dyson authored, *Digital Cameras for Studio Photography: Seybold 1995 Shootout*. Though efficient in addressing and defining technological limitations, its focus was studio photography.

The most significant publication addressing digital photography and the photojournalist is entitled *The Digital Photojournalist's Guide version 2.1* by *Calgery Herald* digital photographer Robert Galbraith. *The Digital Photojournalist's Guide version 2.1* addresses many if not all of the issues concerning digital photography for the photojournalist but does not address all the needs of a prepress technician concerning digital photography.

Calgery Herald digital photographer Robert Galbraith discusses digital photography and its evolution through his newspaper the *Calgery Herald*:

> "How anxious bean counters were in getting rid of film and quality was a secondary issue. During the transition phase (to digital photography) we had a lot of digital images that looked like garbage. We felt like we were on our own because no one in the world was facing what we were. "[1]

The *Calgary Herald* was among three Canadian Southam owned papers that went digital shortly after the release of the Associated Press NC2000 in 1994.

Galbraith continues:

> "Kodak hasn't adequately supported the camera with how to make it work...out of desire to help the photographers at the paper" the book, The Digital Photojournalist's Guide, was written. " I think we've been able to make the technology work with everything we do but I think the technology can be made to work better." The "managing editor and publisher are not fans of digital photography and there was talk in the middle of 1996 in switching back to film when image quality was of importance, but digital photography" was given "another year to prove itself. My boss is getting hammered from above to improve the image quality... from the camera's. I think AP and Kodak have failed at supporting the cameras, given (the digital cameras) cost and complexity."[2]

As a part of the post-digital image processing, it is necessary to JPEG images to achieve the highest rates of image transmission via landline modem or cellular modem. Galbraith states:

> "JPEG is not very digital image friendly. The digital camera is only one small cog in the digital wheel. Right now we (the photographers) are doing basic dodging and burning. With production looking to eliminate variables, photographers, we are likely to lose creative control. We will put in two versions of the images (a raw version and an edited image). There were photographers, men and women, simply in tears over this technology, training would have alleviated this."[3]

Vincent Alabiso, Vice President and Executive Photo Editor of The Associated Press states: "this has put the control of the image back in to the photographer."[4] According to Stephan Savoia, Associated Press Digital Photographer from the Boston, Massachusetts bureau, one of the controls at his finger tips is unsharp masking. Stephan also states "prepress issues don't really apply to my situation as a wire service photographer."[5] With the end goal of wire photos being newspapers it seems that this issue needs addressing.

Alabiso also states, "The most difficult part (of digital photography) has nothing to do with photographers; it's image handling and the key is good digital photography. The learning curve, to work with

Photoshop, is different than a darkroom."[6] With the most difficult part of digital photography being the most important part of printing, reproduction prepress issues become very relevant to the digital photographer.

David Rocha, Senior Photo Technology Specialist for The Associated Press, talks about the sate of digital technology and the Associated Press:

> "That's one of our problems. There is not" a set of standards. "We are still a little bit all over the map and, unless your staff is doing everything the same way, your results will be all over the place. Where a lot of people fall down" is that the images "look really pretty on the screen and real lousy in the paper and there are so many issues to that... you get into a whole other ball game when you are dealing with how stuff looks in print."[7]

Clint Reece, Pagination Consultant at Pacific Press:

> "What people have to realize, when you change to digital photography, is that you have to reassess every piece of the process. This isn't photography for the sake of photography, this is newspaper photography. The photographers need to capture the best image."[8]

Nick Didlick, Photo Editor of *The Vancouver Sun* states: "we don't want to do prepress we want to retain the editorial control of crop, burn, dodge."[9] With the tools for prepress and editorial control coming from the same application, Adobe Photoshop, is it possible to take photographer and make them believe that what you see on the screen is not what you get and some controls are left better in the hands of prepress technicians?

Considering digital photography within the newspaper industry it is important to consider it as the multidisciplinary workflow. The following literature search has found that there is no all-encompassing publication or piece of literature addressing prepress concerns. Industry professionals are seeking answers themselves and a balance of time/cost efficiency and image control is constantly being sought.

Endnotes Chapter 3

1. Robert Galbraith, Calgery Herald digital photographer, excerpt from unpublished interview

2. IBID

3. IBID

4. Vincent Alabiso, Vice President and Executive Photo Editor of The Associated Press, excerpt from unpublished interview

5. Stephan Savoia, Digital Photographer with The Associated Press Boston, Massachusetts Bureau. excerpt from answers to questionnaire (see appendix a)

6. Vincent Alabiso, Vice President and Executive Photo Editor of The Associated Press, excerpt from unpublished interview

7. David Rocha, Senior Photo Technology Specialist for The Associated Press, excerpt from unpublished interview

8. Clint Reece, Pagination consultant at Pacific Press, excerpt from unpublished interview

Chapter 4

Statement of the Problem

With the special demands placed on photojournalist, constantly pushing digital technology to its absolute limits, how can newspapers reproduce the highest image quality from digital images which have inherent technological limitations?

Digital photography "is not the future it's today,"[1] said Associated Press Vice President and Executive Photo Editor Vincent Alabiso. It is for this very reason that technological camera limitations must be identified and assessed so that images can be optimized for print reproduction.

A digital camera that meets the needs of the photojournalist must be versatile. The most important issues include the ability to capture an image using full exposure control and a range of selectable ISO's. Of the four digital cameras to be tested, the Minolta RD-175 and Fuji 505a use three chip color area array CCD technology, while the Kodak AP NC2000e and the Kodak DCS EOS3 use the same area array mosaic pattern color CCD M3 chip, designed by Kodak. The area array CCD M3 chip found in the AP and Canon camera captures the entire image "with one exposure eliminating the need for any movement by the detector or scene. . .producing the highest frame rates. . . however, resolution is limited in two directions."[2] Color is captured in the M3 CCD through the use of integral color filters, which place either a red, green or blue filter over each individual pixel. Because each pixel can only represent one-third of the color filtering needed, to determine accurate scene color, a loss of information leads "to reduced effective resolution and increased sampling (quantizing) artifacts."[3] Each of the three chip color CCD's used act as area array CCD's capturing the entire image with one exposure but color is identified with the use of optics, which direct the appropriate color light to its corresponding color filter, possibly resulting in registration and calibration issues.

CCD area array chips have a given sensitivity range that is altered to achieve variable ISO with the use of "gain calibration; turning up the signal processing,"[4] said to Jay Kelbley of Eastman Kodak, Digital Capture Products Sales Development Manager. A by-product of using an ISO higher than the sensitivity of the CCD array (or increasing the gain on the camera) is increased blue noise.

At the conclusion of a day, the responsibility of working with photographs shot digitally remains in the hands of the photographer or gets transferred to a prepress technician for final image toning. At this point the image handler is presented with an image that has:

limited resolution
limited size
exhibits artifacting
altered color
blue noise.

The prepress individual that previously may have been able to resurrect a poorly shot film image is now faced with a slew of issues that in many cases are new and unfamiliar.

The question that remains is "what is the best procedure to handle digital camera images?" This thesis project proposes that the issues specific to the three different types of digital cameras being tested will help in identifying methods to optimize these images for print production using SNAP specifications as the model.

Endnotes Chapter 4

1. Vincent Alabiso, Vice President and Executive Photo Editor of The Associated Press

2. Kodak CCD Primer, #KCP-001, *Charge-Coupled Device (CCD) Image Sensors*, Eastman Kodak Company–Microelectronics Technology Division, 001-3

3. IBID, 001-9

4. Jay Kelbley, Eastman Kodak, Digital Capture Products Sales Development Manager

Chapter 5

Methodology

The following is a detailed outline of the procedures that were used to complete the project goals:

I Determine the criteria a digital camera must meet in order to fulfill the needs of a photojournalist:

- Portability
- Selectable shutter speeds
- High shutter speeds for shooting in low lighting
- Selectable apertures
- Wide apertures for shooting in low light
- Continuous frame shooting
- Removable media for image storage
- Sync for flash photography
- Ability to work under extreme temperatures, hot and cold
- Durability against temperature changes, moisture and bumps

II Determine possible cameras to be tested:

- Minolta RD-175
- Agfa Actioncam
- Fuji 505a
- Nikon E2s
- Canon DCS EOS 3
- Associated Press NC2000e

III Solicit loans/donations from camera manufacturers.

See Appendix B for sample donation letter.

IV Develop a list of industry professionals to interview:

- Vincent Alabiso, Associated Press Vice President and Executive Photo Editor
- Stephan Savoia, Associated Press Digital Photographer
- Santos Chaparro, Associated Press, Senior Photo Editor for Operations

- David Rocha, Associated Press, Senior Photo Technologies Specialist
- Kenneth A. Parluski, Eastman Kodak, Chief Architect Digital Cameras,Digital and Applied Imaging Division
- Jay Kelbley, Eastman Kodak, Digital Capture Products Sales Development Manager
- Nick Didlick, The Vancouver Sun, Photo Editor
- Robert Galbraith, Calgery Herald, Digital Photographer
- Clint Reece, Pagination Consultant at Pacific Press
- Doug Shillington, Pacific Press, Night Production Manager
- Scott Mitnick, The New York Times, Materials Science Engineer
- Scott Cornish, The New York Times, Quality Assurance Director
- Mike Vazquez, The New York Times, Senior Manager Color Services
- David Adermann, Professor at The University of Newcastle Australia
- Chuck Westfall, Canon U.S.A inc., Camera Marketing Group

V Determine test areas to evaluate cameras

Visual spatial resolution

Color space reproduction accuracy

Color gamut

Qualitative analysis of ISO to noise relationship

Tone reproduction

Dynamic range

Imager consistency

Aliasing

Effects of Dichroic Infrared reducing filter (hot mirror filter)

VI Test used to evaluate test objectives:

Imager consistency (x,y) - photograph a large single tone sheet of paper that fills the imager frame. Examine imager consistency by evaluating color and tone consistency in the image using Info box in Adobe Photoshop with Eyedropper set at 3 by 3 pixel radius.

IT-10 chart from ISO/TC42, WG18 Photography-Electronic still picture camera-Resolution measurement test: used to determine visual spatial resolution and aliasing. Photograph IT-10 resolution chart then evaluate it in Adobe Photoshop.

Color reproduction test chart - Photograph a Macbeth Color Checker™, 13 step grayscale, shadow box and gray card. Read all the densitometric and L* a* b* values in Adobe Photoshop using the Info box and Eyedropper tool set to a 3 by 3 pixel radius. Performing the same readings using a spectrophotometer (accessible in the tone and color lab) compare the values, determining color difference. The following readings will also be performed on the proofs used and the final printed piece.

VIII Test Procedures:

1. The test will take place on the 3rd floor of building 7B in the Electronic Still Photography Lab, Studio 11B.
2. All Tests will be performed under 45° even lighting.
3. Broncolor Primo A, studio flash lights, will be used.
4. The Power pack on the lights will be set at full power for all parts of the test.
5. Neutral density filters will be used to alter the illumination provided by the lights.
6. All tests will be performed using ISO's:
   200, 400, 640, 800, 1000, 1200, 1600
7. All tests will be performed using apertures:f/22, f/8, f/2.8
8. All tests will be performed using shutterspeed set 125th of a second.
9. The color temperature of the lights will remain between 5400°K and 5600°K.
10. Only when the camera dictates that the above listed ISO's and apertures can not be used, will any of the above variations not be performed (example: the Minolta RD-175 uses a stationary ISO of 800 and has an effective widest aperture of f/6.7, therefore several ISO's remain untested).
11. In cases where ISO and aperture variations are limited, tests will be performed with all available camera settings and a statement of the limitations will be noted.
12. In the case of the DCS EOS 3 and the NC2000e all above variations will be performed with and without the use of a dichroic infrared reflecting filter manufactured by Tiffen™ here on referred to as a hot mirror filter.
13. All lighting and color temperature readings will be metered in nine quadrants. All nine quadrants should be no more then 1/10th of a stop plus or minus the expo-

sure used to set the camera or 100°K plus or minus the recorded color temperature.

14. All shooting data will have a record kept on studio data sheets. Appendix C
15. If camera allows for the designation of type of light source adjust it to the flash option. If the camera does not provide for light source, as in the Canon DCS EOS 3 and the AP NC2000e, select the light source in the acquire module.
16. All files will be filed under the following format:

    Test name, camera name, HM if hot mirror is used, date of shoot
17. The test names will be as followed:

Imager consistency test	CCDIC
Resolution	IT-10
Color Reproduction	Color

18. Cameras will be identified as:

Canon DCS EOS 3	EOS
Associated Press NC2000e	AP
Minolta RD175	MIN
Fuji 515a	FUJ

19. An example of the file naming format:

    CCDICAPHM3-29

    The above means the labeled folder contains imager consistency tests from the AP NC2000e camera taken with a hot mirror filter on March 29.

IX Image acquire:

All images will be acquired using the latest version of the camera manufacturer's image acquire software and the most recent version of firmware.

AP NC2000e	Kodak NC2000 Driver v.3.4
Canon DCS EOS 3	Kodak EOS • DCSx Driver v.3.4
Minolta RD-175	RD175 control for Macintosh v.1.13
Fuji 515a	Open JPEG images in Adobe Photoshop

X Image Evaluation procedure:

1. Acquire image in the appropriate acquire module.
2. If the acquire module offers an option for selection of light source, as with the Canon DCS EOS 3 and the AP NC2000e, select option CLICK and click on a

white area (for the color test click in the white patch of the MacBeth Color checker).

3. Each image will be acquired individually and immediately named
4. The file naming convention will be as follows:

   Test name,Camera name, HM if hot mirror is used, ISO, Aperture

   Example: IT-10EOSHM16002.8
5. The image information from the acquire module, including ISO, aperture, shutter-speed, exposure compensation, will be copied and pasted into the Info captioning box in Adobe Photoshop.
6. Depending on the test, the appropriate evaluation methods will be performed on the image.

   Example: Color test, L*a*b* and densitometric readings will be made throughout the image.
7. All observations will be recorded on an observation form (see Appendix C) and also in the captioning section of the Info option in Adobe Photoshop.
8. Once all observations are made for each test they will be divided and analyzed on a per-camera basis.
9. For each camera a list of observations will be recorded on a single sheet.
10. Using prepress knowledge and Adobe Photoshop skills brainstorming of possible solutions will be written out.
11. One by one each of the brainstorming ideas will be examined in Adobe Photoshop.
12. As the images are examined in Adobe Photoshop a second list of observations, detailing the results of the brainstorming ideas will be made.
13. A comparison on the original images and varying degrees of possible corrections will be compiled and then proofed to an Iris printer.
14. Images selected to represent various camera limitations and the final corrected images will be tone corrected for output to film according to SNAP specifications.
15. Film assembly and plates will be made.
16. A press run of the images will be printed in the newspaper lab's four-color newspaper press.

XI Adobe Photoshop

1. Adobe Photoshop preferences will be determined based on SNAP recommendations.

Printing Specifications

Press Specifications:

One sided web run.

Color setting manual

Image area 21 3/4 x27 inches.

SNAP Specifications:

Gray color removal - 70% GCR (60-80%) good

Under color addition - UCA- maintain minimum of 220% of ink coverage in shadow area

Max total area 240% or less with one color solid

Total film density 200-240%

Dot gain - 30%

	C	M	Y	K
High	3	2	1	0
25%	19	15	14	0
50%	39	32	31	8
Shadow	80	75	75	70

Equipment, Facilities, Time Table

Cameras:

Kodak DCS EOS 3, provided by a donation from Kodak.

Associated Press NC2000e, provided as a loan from The Associated Press.

Minolta RD-175, provided by a donation from Minolta.

Fuji 505a, provided by a loan from Fuji.

Production equipment:

Selectset 5000, provided by NTID prepress lab with cooperation from Professor Jere Renzel.

Film processor, provided by NTID prepress lab with cooperation from Professor Jere Renzel.

Iris Proofer, provided by NTID prepress lab with cooperation from Professor Jere Renzel.

Newspaper lab four-color press, provided with cooperation from Mr. John Eldridge.

Studio 11B, provided by School of Photography with cooperation from Mrs. Jodie Baker and Mr. Mike Dear.

IT-10 test target and Image analyzer software provided by IT-10 committee with cooperation by Dr. Ken Parluski.

Computer equipment:

Macintosh 7500/100 with 32MB RAM

Epson Photo Stylus printer

Laserwriter Selectset 360

CD Writer

Location interviews:

One-week site visit to The Vancouver Sun and Province, funding by D.A.D inc.

Site visit to New York Times, New York facility and Edison, NJ plant.

Site visit to Associated Press, New York offices.

Facilities:

Electronic Still Photography lab, RIT School of Photography

NTID prepress lab

Newspaper lab, RIT School of Printing

Chapter 6
Results

Hot Mirror Filter:

Due to the infrared light sensitivity of the Kodak CCD solid state sensor the imagers are "prone to producing a hazy bluish cast in images taken in some lighting conditions."[1] The use of the hot mirror filter eliminates this haze producing a "more 'normal' color."[2] The hot mirror filter works by reflecting infrared light in the 800 to 1200 nanometer range. The visible spectrum ranges from 400nm-700nm.

Upon examination of images taken with the three digital cameras the most noticeable variant was between test images photographed with a Tiffen hot mirror filter and without a hot mirror filter. Plate 1-4 illustrate images taken with the AP NC2000e and the EOS DCS3 digital cameras with a hot mirror filter and without a hot mirror filter at ISO 200 and 800 printed to newsprint. In Plates 1-2 the bottom half of the image, taken with a hot mirror filter, was 9-11% darker at ISO 200, when measuring dot area in Adobe Photoshop using the "info Palette", then the image half taken without the hot mirror filter. At ISO 800 Plates 3-4 the bottom half of the image taken with the hot mirror was 30-33% darker then without the hot mirror.

Images taken with the Fuji camera were not tested with the hot mirror filter but recorded a 40% dot area at ISO 800 with at ISO 800 for the AP and EOS cameras values recorded at 57% and 46% respectively. The Minolta photographed at ISO 800 recorded at 58%.

Plate 1

AP NC2000e ISO 200

Tiffen Hot Mirror vs. No Hot Mirror Comparison Newspaper Sample

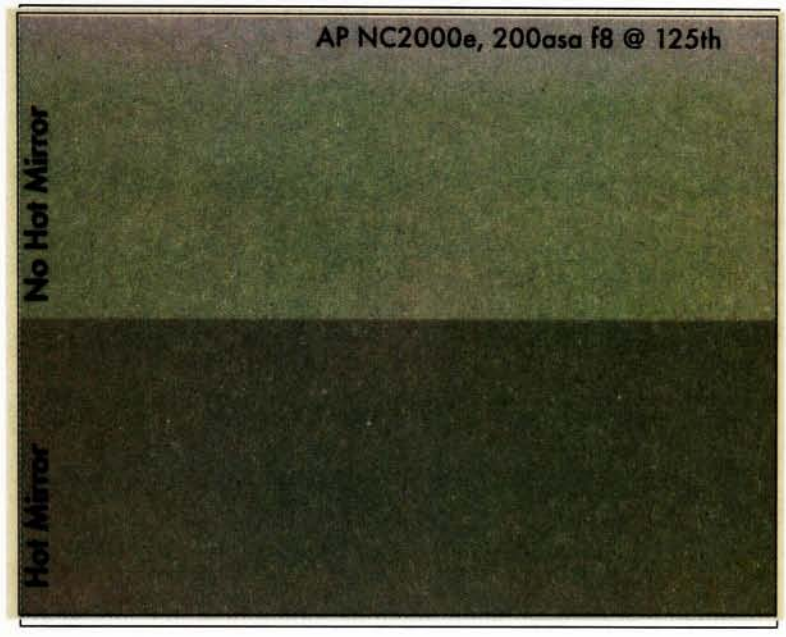


Plate 2

EOS DCS 3 ISO 200

Tiffen Hot Mirror vs. No Hot Mirror Comparison Newspaper Sample

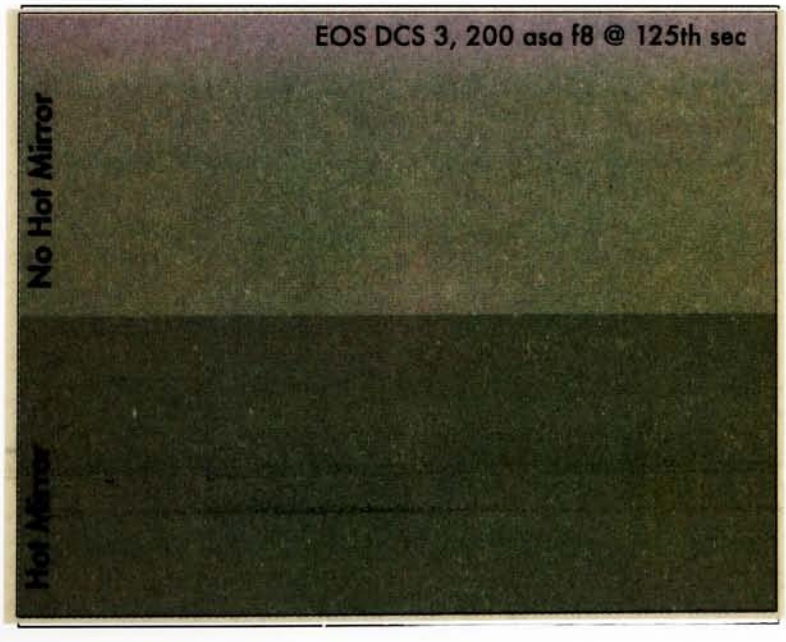


Plate 3

AP NC2000e ISO 800

Tiffen Hot Mirror vs. No Hot Mirror Comparison Newspaper Sample

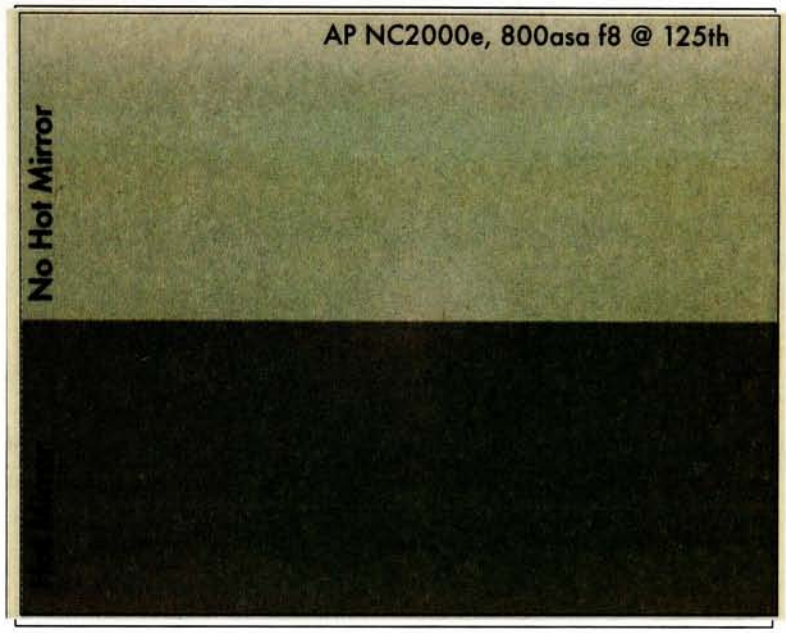
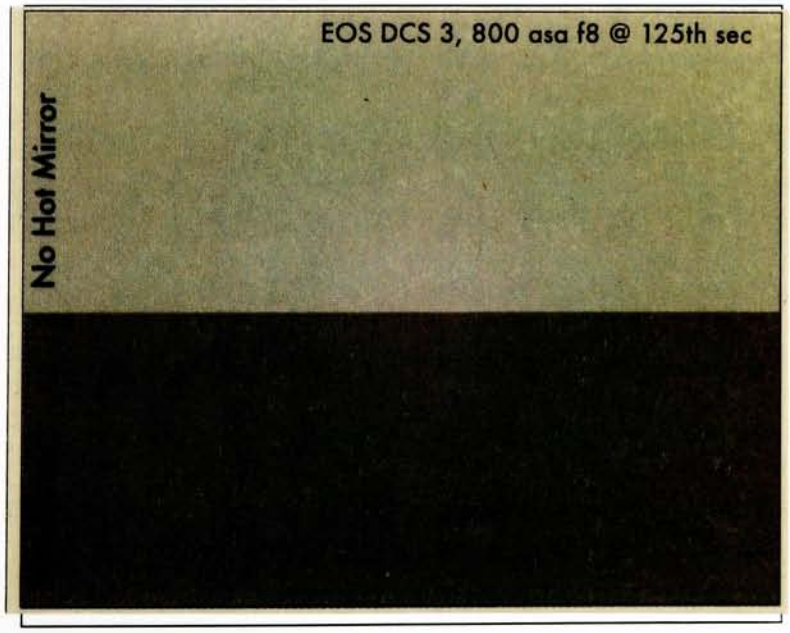


Plate 4

EOS DCS3 ISO 800

Tiffen Hot Mirror vs. No Hot Mirror Comparison Newspaper Sample



Imager Consistency:

Regarding overall tonal image consistency, when photographing a large single tone sheet of paper that fills the imager frame, the AP NC2000e and EOS DCS3 imagers yielded anomalies in regard to change of density and color shift along the image edges and the center point, see Plates 5-10. The change in density and digital color code values from different segments of the imager is charted out in Tables 1-9. All images from the AP NC2000e and EOS DCS3 cameras shot with the hot mirror filter illustrated a difference in color, toward magenta, and a change in density at the center and along the edges of the image. Tests taken without the hot mirror filter yielded less significant density changes and color shifts along the same boundary locations.

The center of the image in the CCDIC test images shot with the hot mirror filter yielded a 3-4% difference from center density to outside area, as seen in Table 2, 4, and 6 while images shot without the hot mirror filter yielded a 2-3% difference in center density to outside density, as seen in Table 1, 3 and 5. At lower ISO's the color shift was present but was less noticeable in the center with increased visibility at the top and bottom edges. At higher ISO's the color shift was greater.

Table 9 illustrates the average of all the image segment percent dot readings for each test image. We can see that the tonal difference between an image shot with and without a hot mirror filter changes with the ISO used. It is also evident that each camera imager interpreted the exact lighting conditions differently giving a range of percent dot areas from 10.8% at AP8008 to 59.4% at Minolta 8008.

Plates 5-12 are reproduced to help the reader visualize issues described above. More precise evaluation of the images can be achieved by looking at the accompanying CD. All images on the CD are identified by plate number.

Table 1

CCDIC AP2008

Center	19-20% dot density		
		Brightness value Range	Brightness value Average
	R	208-211	209.5
	G	202-205	203.5
	B	202-209	205.5
Left	20-22% dot density		
		Brightness value Range	Brightness value Average
	R	199-201	200
	G	201-204	202.5
	B	198-202	200
Right	19-20% dot density		
		Brightness value Range	Brightness value Average
	R	205-210	207.5
	G	202-207	204.5
	B	201-211	206
Top	15-16% dot density		
		Brightness value Range	Brightness value Average
	R	211-214	212.5
	G	209-211	210
	B	218-224	221
Bottom	18-19% dot density		
		Brightness value Range	Brightness value Average
	R	208-212	210
	G	205-208	206.5
	B	215-222	218.5

Results:

Top and bottom edge of the imager consistency test image appears lighter than the overall image and has a magenta cast. The top edge registers an average of 15.5% dot area while the average of the center, left and right sides of the image is 20%. There is a 5% difference between the average of the center, left and right sides of the image and the top of the image. The bottom of the image retains an 18.5% average and is 1.5% lighter.

Plate 5

AP NC2000e ISO 200

Imager Consistency No Hot Mirror

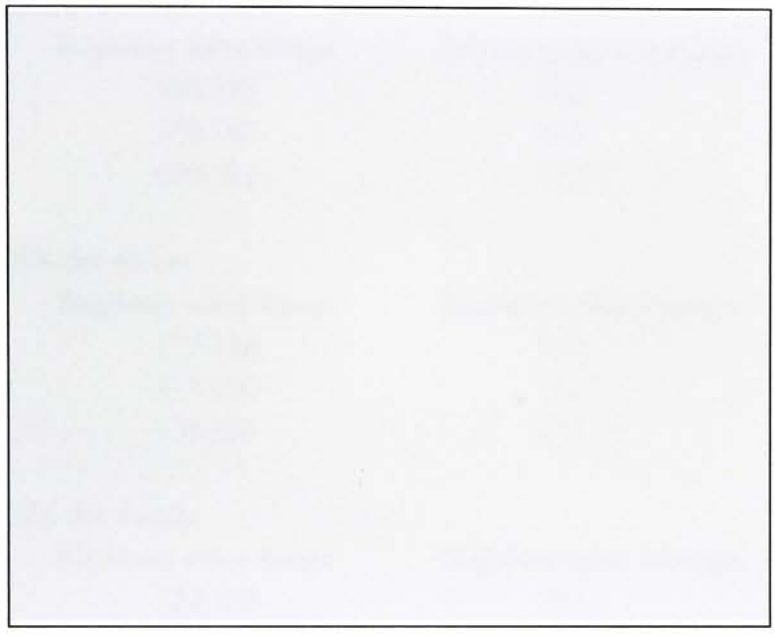


Plate 6

AP NC2000e ISO 200

Imager Consistency Hot Mirror

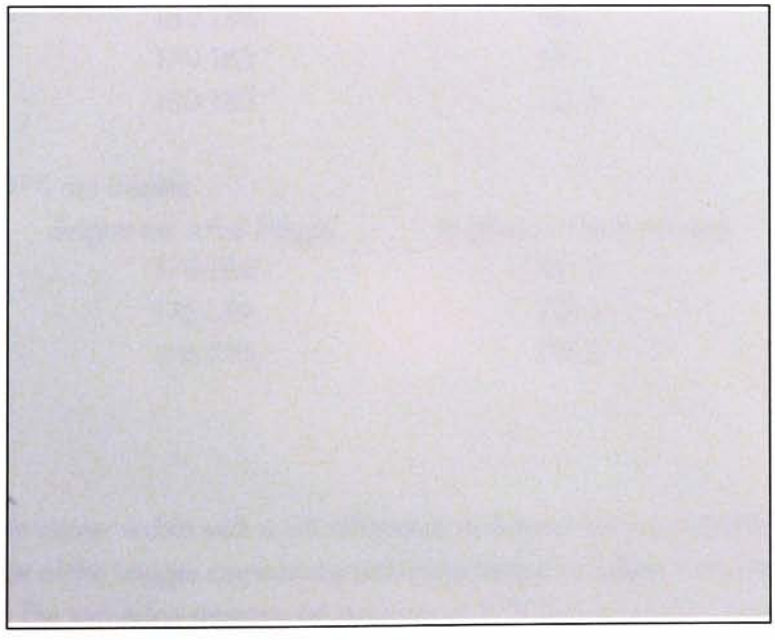


Table 2 CCDIC APHM2008

Center	28-29% dot density		
		Brightness value Range	Brightness value Average
	R	188-192	190
	G	178-180	179
	B	179-182	180.5
Left	30-31% dot density		
		Brightness value Range	Brightness value Average
	R	177-184	180
	G	175-180	177.5
	B	174-180	177
Right	28-30% dot density		
		Brightness value Range	Brightness value Average
	R	182-188	185
	G	178-181	179.5
	B	176-185	180.5
Top	28-29% dot density		
		Brightness value Range	Brightness value Average
	R	182-188	185
	G	179-183	181
	B	180-183	181.5
Bottom	30-31% dot density		
		Brightness value Range	Brightness value Average
	R	179-184	181.5
	G	176-179	177.5
	B	174-179	176.5

Results:

Minor discoloration in center visible with a 3% difference in density from center with magenta cast. Top and bottom edge of the imager consistency test image appears lighter than the overall image and has a magenta cast. The top edge registers an average of 27% dot area while the average of the center, left and right sides of the image is 29.3%. There is a 2.3% difference between the average of the center, left and right sides of the image and the top of the image. The bottom of the image retains an 30.5% average and is 1.2% darker.

Table 3

CCDIC AP8008

Center		13% dot density	
		Brightness value Range	Brightness value Average
	R	209-211	210
	G	206-208	207
	B	210-214	212
Left		14-15% dot density	
		Brightness value Range	Brightness value Average
	R	199-202	201
	G	201-204	202.5
	B	204-207	205.5
Right		13-15% dot density	
		Brightness value Range	Brightness value Average
	R	202-206	204
	G	202-209	205.5
	B	202-209	205.5
Top		5% dot density	
		Brightness value Range	Brightness value Average
	R	235-238	236.5
	G	230-232	231
	B	250-255	252.5
Bottom		18-19% dot density	
		Brightness value Range	Brightness value Average
	R	220-225	222.5
	G	220-224	222
	B	235-240	237.5

Results:

Top and bottom edge imager consistency test image appears lighter than overall image and has a magenta cast. The top edge registers an average of 5% dot area while the average of the center, left and right sides of the image is 13.5%. Outside the center area and within the an inch of the border edges there is a 15% dot area. There is a 2.5% difference between the average of the center, left and right sides of the image and outside the middle of the image.

Plate 7

AP NC2000e ISO 800

Imager Consistency No Hot Mirror

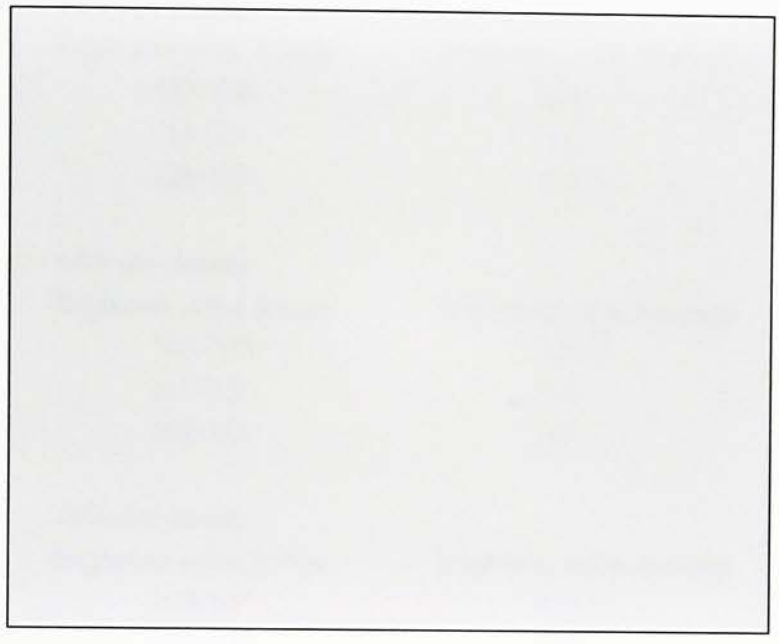


Plate 8

AP NC2000e ISO 800

Imager Consistency Hot Mirror

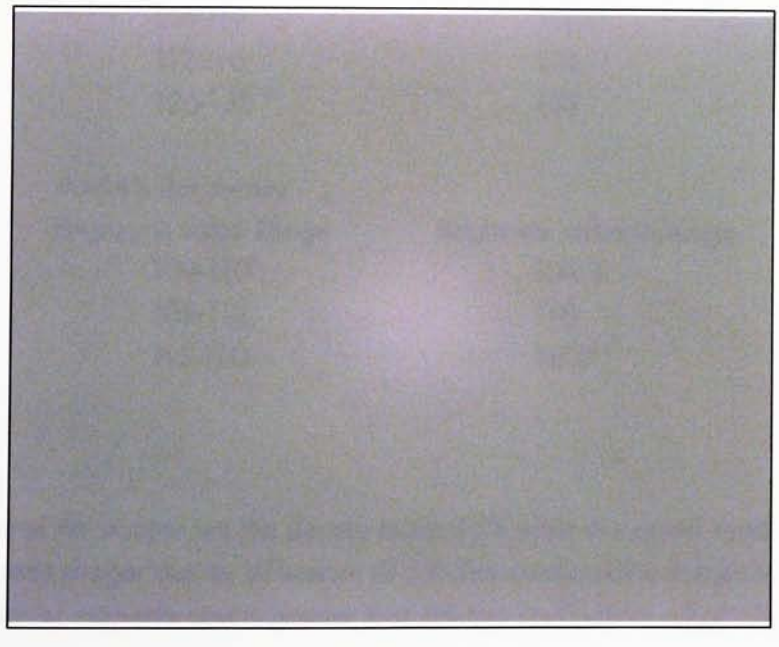


Table 4

CCDIC APHM8008

Center		40% dot density	
		Brightness value Range	Brightness value Average
	R	122-126	124
	G	113-116	114.5
	B	126-131	128.5
Left		44% dot density	
		Brightness value Range	Brightness value Average
	R	105-108	106.5
	G	111-115	113
	B	109-117	113
Right		44% dot density	
		Brightness value Range	Brightness value Average
	R	104-107	105.5
	G	105-107	106
	B	107-111	109
Top		40-41% dot density	
		Brightness value Range	Brightness value Average
	R	116-119	117.5
	G	112-116	114
	B	126-130	128
Bottom		43-44% dot density	
		Brightness value Range	Brightness value Average
	R	109-110	109.5
	G	108-112	110
	B	115-120	117.5

Results:

Outside of the center of the imager test the density reads 45% while the center reads a value of 40% illustrating a center point imager density difference of 5%. The center of the imager test exhibits a magenta cast. The center magenta cast is greater than the top and bottom edge magenta cast visually and also numerically.

Table 5 CCDIC EOS8008

Center	7% dot density		
		Brightness value Range	Brightness value Average
	R	229-231	230
	G	227-229	228
	B	233-234	233.5
Left	8% dot density		
		Brightness value Range	Brightness value Average
	R	224-225	224.5
	G	223-224	223.5
	B	222-223	222.5
Right	7% dot density		
		Brightness value Range	Brightness value Average
	R	227-228	227.5
	G	225-226	225.5
	B	225-226	225.5
Top	5% dot density		
		Brightness value Range	Brightness value Average
	R	236-238	237
	G	235-236	235.5
	B	235-237	236
Bottom	6% dot density		
		Brightness value Range	Brightness value Average
	R	228-232	230
	G	230-233	232
	B	230-235	232.5

Results:

The center of the imager yielded a 7% density with the area surrounding the center of the imager yielding a 9% density. The top of the imager was 2% lighter than the center of the imager and 4% brighter than the area outside the center of the imager. There appeared to be a slight magenta cast in the center and top portion of the image but the image's overall lightness made it difficult to visualize any significant magenta cast.

Plate 9

EOS ISO 800

Imager Consistency No Hot Mirror

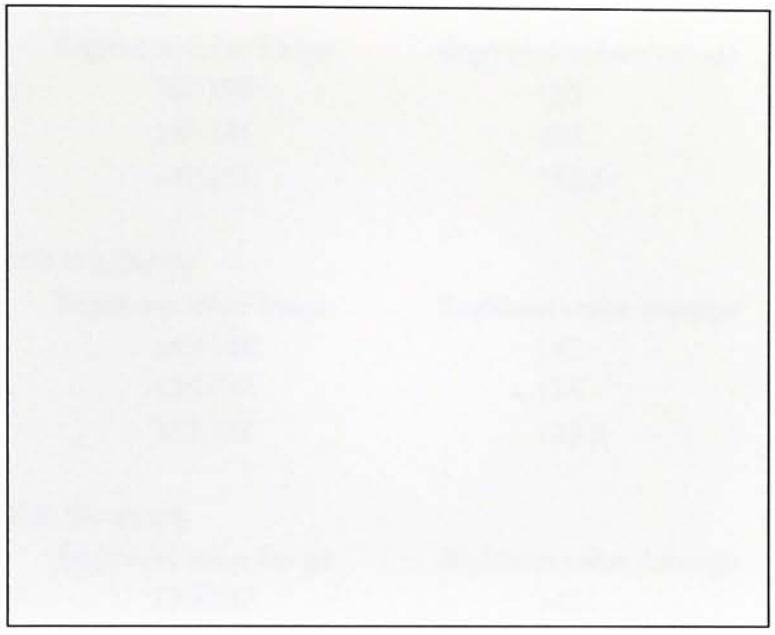


Plate 10

EOS ISO 800

Imager Consistency Hot Mirror

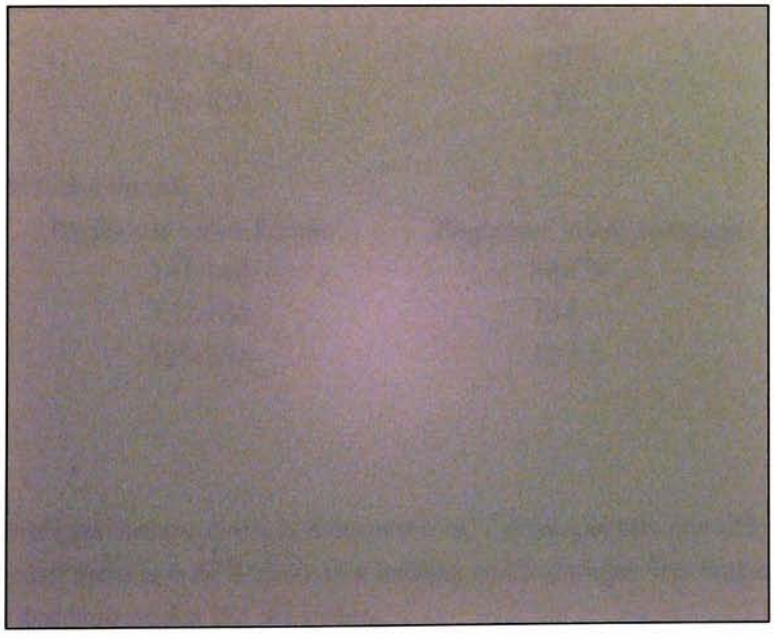


Table 6 CCDIC EOSHM8008

Center	43-44% dot density		
		Brightness value Range	Brightness value Average
	R	151-159	155
	G	137-141	139
	B	140-151	145.5
left	44-46% dot density		
		Brightness value Range	Brightness value Average
	R	142-148	145
	G	135-137	136
	B	133-138	135.5
Right	45-47% dot density		
		Brightness value Range	Brightness value Average
	R	139-147	143
	G	132-140	136
	B	126-136	131
Top	45-46% dot density		
		Brightness value Range	Brightness value Average
	R	145-149	147
	G	137-138	137.5
	B	131-135	133
Bottom	44-47% dot density		
		Brightness value Range	Brightness value Average
	R	141-148	144.5
	G	132-136	134
	B	129-136	132.5

Results:

At center and outside edges there is a visual magenta cast. Center percent dot value is 43% while outside center magenta cast there is a 47% dot value totaling a 4% change. The magenta cast along outside edges is slightly less than center but still visible.

Table 7 CCDIC MIN8008

Center	58% dot density		
		Brightness value Range	Brightness value Average
	R	113-115	114
	G	105-107	106
	B	101-104	102.5
left	59-60% dot density		
		Brightness value Range	Brightness value Average
	R	100-109	104.5
	G	99-105	102
	B	93-101	97
Right	59-61% dot density		
		Brightness value Range	Brightness value Average
	R	105-113	109
	G	99-105	102
	B	93-101	97
Top	57-61% dot density		
		Brightness value Range	Brightness value Average
	R	106-117	111.5
	G	97-107	102
	B	94-104	99
Bottom	59-62% dot density		
		Brightness value Range	Brightness value Average
	R	103-111	107
	G	99-106	102.5
	B	94-102	98

Results:

Visual inspection of the imager consistency test image on screen illustrates no color cast and an overall smooth and even tonality throughout the image. The edges of the image contains a blue/cyan color shift. Images illustrates a approximate tonality difference of 2% with the center of image at 58% and the edges averaging approximately 60%.

Plate 11

Minolta ISO 800

Imager Consistency

Plate 12

Fuji ISO 800

Imager Consistency

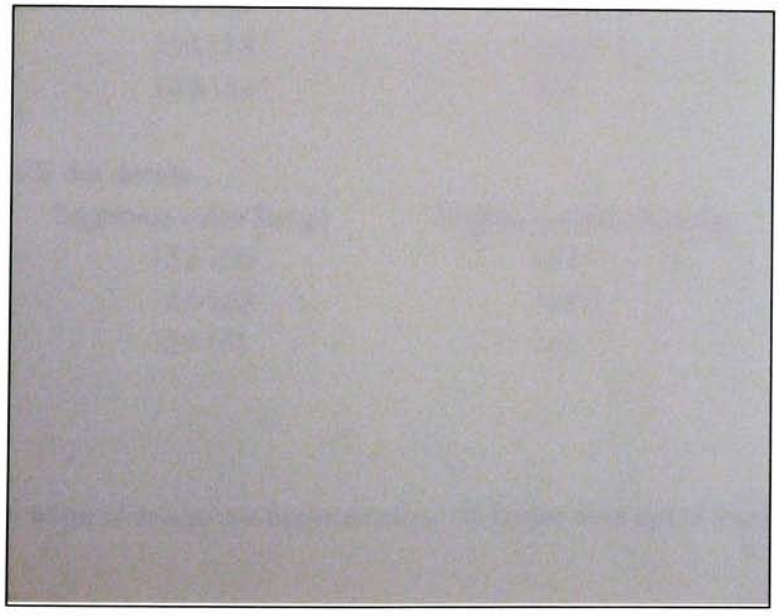


Table 8 CCDIC FUJ8008

Center	39-40% dot density		
		Brightness value Range	Brightness value Average
	R	159-161	160
	G	150-155	152.5
	B	149-150	149.5
left	39-43% dot density		
		Brightness value Range	Brightness value Average
	R	151-160	155.5
	G	143-155	149
	B		
Right	38-40% dot density		
		Brightness value Range	Brightness value Average
	R	155-161	158
	G	151-158	154.5
	B		
Top	38-40% dot density		
		Brightness value Range	Brightness value Average
	R	154-161	157.5
	G	153-158	155.5
	B	148-154	151
Bottom	40-42% dot density		
		Brightness value Range	Brightness value Average
	R	152-156	154
	G	144-153	148.5
	B	139-151	145

Results:

Left edge and bottom edge of image are approximately 1% darker than rest of image. No color cast was present.

Table 9

Imager consistency results:	Average	Δ% HM NOHM
AP2008	19%	Δ10.4%
APHM2008	29.4%	
EOSHM8008	45.2%	Δ34.3%
EOS8008	10.9%	
AP8008	10.8%	Δ31.7%
APHM8008	42.5%	
Minolta 8008	59.4%	
Fuji8008 NC	39.9%	

IT-10 Visual resolution results:

Visual resolution which is identified by the following definition from *ISO 12233, Item [188] Photography- Electronic Still Picture cameras- Resolution Measurements*, states that "the spatial frequency at which the individual black and white lines of a test pattern reproduced on a display or print can no longer be distinguished or are reproduced at a spatial frequency lower than the spatial frequency of the corresponding area of the test target, as a result of aliasing."[3] The visual resolution scale of measurement is defined by the test target line width divided by the pixel height or LW/PH. Simply stated visual resolution is determined by the last level at which the target detail is reproduced.

Table 10 represents the line width location along the vertical hyperbolic wedge used in measuring the horizontal visual resolution for each camera and ISO. Table 11 represents the line width location along the horizontal hyperbolic wedge used in measuring the vertical visual resolution. Table 12 represents a diagonal hyperbolic wedge used in measuring the diagonal visual resolution.

In Tables 10-13 the AP NC2000e line width location is determined by the point where artifacting is evident and there is a loss of detail. Therefore artifacting is a main contributing factor to visual resolution for the AP NC2000e.

Tables 10-12 illustrate that as the ISO used to photograph the IT-10 test target with the AP NC2000e increases, the visual resolution decreases. The visual resolution along the horizontal and vertical plane remains identical at each ISO except in the case of ISO 400 which gives a LW value of 9.5 along the horizontal target and a LW value of 9 along the vertical target.

The difference between the three digital cameras is which part of the definition of visual resolution is used in identifying the camera's resolution. In the AP NC2000e camera, the visual resolution was determined by the reproduction of spatial frequencies lower than the spatial frequency of the target resulting in aliasing. At the LW values identified for each of the ISO's, individual pixel artifacts were noted at the corresponding LW value with the artifacts growing in number and frequency. As the LW value increased, alias resulting color bands appeared in conjunction with the anomaly pixel artifacts. The color bands along the vertical wedge and the horizontal wedge were yellow and blue while the color bands along the diagonal wedge were green and magenta. In the Fuji camera the color band scheme was opposite that of the AP NC2000e. The Fuji camera, yielded yellow and blue bands on the horizontal wedge with magenta and green color bands along the vertical wedge.

The visual resolution in the Minolta RD-175 and the Fuji 505a is dependent on at what LW value the target lines are no longer distinguishable. The Fuji camera exhibits aliasing at high LW values.

Table 10 Horizontal Visual Spatial Resolution LW/PH Locationa

IT-10 Visual Resolution Comparison Chart
Vertical Hyperbolic Wedge

	LW level Artifacting	LW level Loss of Detail	Newspaper Sample LW level Artifacting
AP2008	9.5	9.5	7
APHM2008	9.5	9.5	7
AP4008	9	9	
APHM4008	9	9	
AP6408	9	9	
APHM6408	9	9	
AP8008	9	9	
APHM8008	9	9	
Min8008	None	7.5	6
Fuji8008NC	14	7.5	6
AP10008	8.5	8.5	
APHM1008	8.5	8.5	
AP12508	8.5	8.5	
APHM12508	8.5	8.5	
AP16008	8.5	8.5	
APHM16008	8.5	8.5	
Fuji32008NC	12	6.5	

Table 11 Vertical Visual Spatial Resolution LW/PH Location

IT-10 Visual Resolution Comparison Chart
Horizontal Hyperbolic Wedge

	LW level Artifacting	LW level Loss of Detail	Newspaper Sample LW level Artifacting
AP2008	9.5	9.5	6
APHM2008	9.5	9.5	6
AP4008	9.5	9.5	
APHM4008	9.5	9.5	
AP6408	9	9	
APHM6408	9	9	
AP8008	9	9	
APHM8008	9	9	6
Min8008	None	7	6
Fuji8008NC	12	6	5
AP10008	8.5	8.5	
APHM1008	8.5	8.5	
AP12508	8.5	8.5	
APHM12508	8.5	8.5	
AP16008	8.5	8.5	
APHM16008	8.5	8.5	
Fuji32008NC	12	6	

Table 12 Diagonal Visual Spatial Resolution LW/PH Location

IT-10 Visual Resolution Comparison Chart
Diagonal Hyperbolic Wedge

	LW level Artifacting	LW level Loss of Detail	Newspaper Sample LW level Artifacting
AP2008	9	9	7
APHM2008	9	9	7
AP4008	9	9	
APHM4008	9	9	
AP6408	9	9	
APHM6408	9	9	
AP8008	9	9	
APHM8008	9	9	
Min8008	None	6.5	6.5
Fuji8008NC	None	7.5	6
AP10008	9	9	
APHM1008	9	9	
AP12508	9	9	
APHM12508	9	9	
AP16008	9	9	
APHM16008	9	9	
Fuji32008NC	None	7.5	

Table 13

IT-10 Horizontal and Vertical Visual Resolutions Comparison Digital Files and Newspaper Sample

	LW/PH Horizontal	LW/PH Vertical	LW/PH Newspaper	
			Horizontal	Vertical
AP2008	950/1280 = 0.74	950/1024 = 0.93		
APHM2008	950/1280 = 0.74	950/1024 = 0.93	0.55	0.59
AP4008	900/1280 = 0.70	950/1024 = 0.93	0.55	0.59
APHM4008	900/1280 = 0.70	950/1024= 0.93		
AP6408	900/1280 = 0.70	900/1024 = 0.88		
APHM6408	900/1280 = 0.70	900/1024 = 0.88		
AP8008	900/1280 = 0.70	900/1024 = 0.88		
APHM8008	900/1280 = 0.70	900/1024 = 0.88		
Min8008	750/1528 = 0.49	700/1146 = 0.61	0.39	0.52
Fuji8008NC	750/1280 = 0.59	600/1000 = 0.60	0.47	0.50
AP10008	850/1280 = 0.66	850/1024 = 0.83		
APHM1008	850/1280 = 0.66	850/1024 = 0.83		
AP12508	850/1280 = 0.66	850/1024 = 0.83		
APHM12508	850/1280 = 0.66	850/1024 = 0.83		
AP16008	850/1280 = 0.66	850/1024 = 0.83		
APHM16008	850/1280 = 0.66	850/1024 = 0.83		
Fuji32008NC	650/1280 = 0.51	600/1000 = 0.60		

The aliasing first appears far beyond the point where the target lines are distinguishable. The aliasing exhibited by the Fuji camera was minor compared to the AP NC2000e and did not affect the level of target lines distinguishable.

The Minolta camera exhibits no noticeable aliasing at any portion of the digital test target reproduction upon examination on a monitor, but in the newspaper sample, Plate 15, the Minolta camera appears to have some color aliasing evident. Upon closer examination it can be noted that the artifacts are actually printed dots which have expanded because of dot gain. The aliasing evident in AP NC2000e and the Fuji digital files are reproduced in the newspaper sample, Plates 13-15.

The newspaper images do exhibit significantly less visual resolution than the digital files as seen in Table 13. This decrease in visual resolution can be attributed to several factors having to do with prepress and press methods and devices. Such factors affecting the printed newspaper samples reduced visual resolution include, but are not limited to, the imagesetter, dot gain, paper absorption, press plates and the printing press.

Color aliasing is most evident at the intersection of detail between points of contrast. At higher test target wedge frequencies, aliasing becomes more evident in two forms. The first form is color aliasing and the second is the appearance of aliasing in the form of anomaly pixel artifacts. The anomaly pixel artifacts do occur in conjunction with the color band aliasing but the color band aliasing does not necessarily appear with the pixel anomaly artifacts.

For the AP NC2000e camera aliasing in the form of anomaly pixel artifacts renders detail lost in the target wedge, therefore pinpointing the location were the visual resolution is identified. The color band aliasing does occur at a higher frequency with the use of increased ISO's. At ISO 800, for the AP NC2000e camera test images with and without a hot mirror filter, noise becomes visible in the black portion of the IT-10 target wedge lines in the digital file. At ISO 200 for the AP NC2000e image with a hot mirror filter newspaper sample, there is less noticeable noise.

At ISO 1600 for the AP NC2000e camera test images with and without a hot mirror filter noise is large and contains great color saturation in the black IT-10 target wedge lines. At ISO 200 for the AP NC2000e camera test images with and without a hot mirror filter the noise is nearly imperceptible to the naked eye.

Digital camera resolution is also dependent upon manufacture acquire functions. Acquire functions are procedures programmed by the manufacturer into software that is used in converting the raw digital image into a format recognizable by computer applications such as Adobe Photoshop. Low pass filtering is a function often associated with digital camera acquire software. Low Pass is used to

prevent aliasing by suppressing "high spatial frequencies prior to sampling, but such low pass filtering may cause an undesirable decrease in the sharpness of the image."[4] Although the Minolta RD-175 digital camera has a larger pixel count, 1528 x 1146, than the AP NC2000e and Fuji 505a camera, this is offset by the fact that the type of CCD used, a tri-CCD area array, is used along with low pass filtering to eliminate aliasing. The low pass filtering essentially blurs the image causing the resolution to decrease. The Kodak AP NC2000e camera on the other hand uses no low pass filtering therefore allowing for an overall higher visual resolution.

Plate 13 illustrates the LW/PH (where the pixel height value used was equal to the imager's height in pixels). The AP NC2000e had a varying LW/PH visual resolution depending on the ISO used. The LW/PH resolution varied from ISO 200 LW/PH = 0.74 for the horizontal measurement and LW/PH = 0.93 for the vertical measurement. For ISO 400 - 800 the horizontal resolution measured LW/PH = 0.70. For ISO 1000 - 1600 the horizontal resolution was LW/PH = 0.66. The vertical resolution for ISO 200 and 400 remained the same with a value of LW/PH = 0.93. At ISO 640 - 800 the vertical resolution measured LW/PH = 0.88.

Looking at Plate 13 it is evident that the LW/PH resolution value for the newspaper samples of each camera has decreased. The resolution for all three cameras has decrease when printed on newsprint.

The AP NC2000e and the Minolta cameras had a horizontal LW/PH difference of 0.21 at ISO 800 and a LW/PH difference of 0.25 when comparing ISO 800 for the Minolta camera and ISO 200 for the AP NC2000e camera. The newspaper sample yielded a horizontal LW/PH difference of 0.16 between ISO 200 for the AP NC2000e and ISO 800 for the Minolta camera. The same decrease in resolution is evident when comparing the Fuji camera and the AP NC2000e along both vertical and horizontal axis.

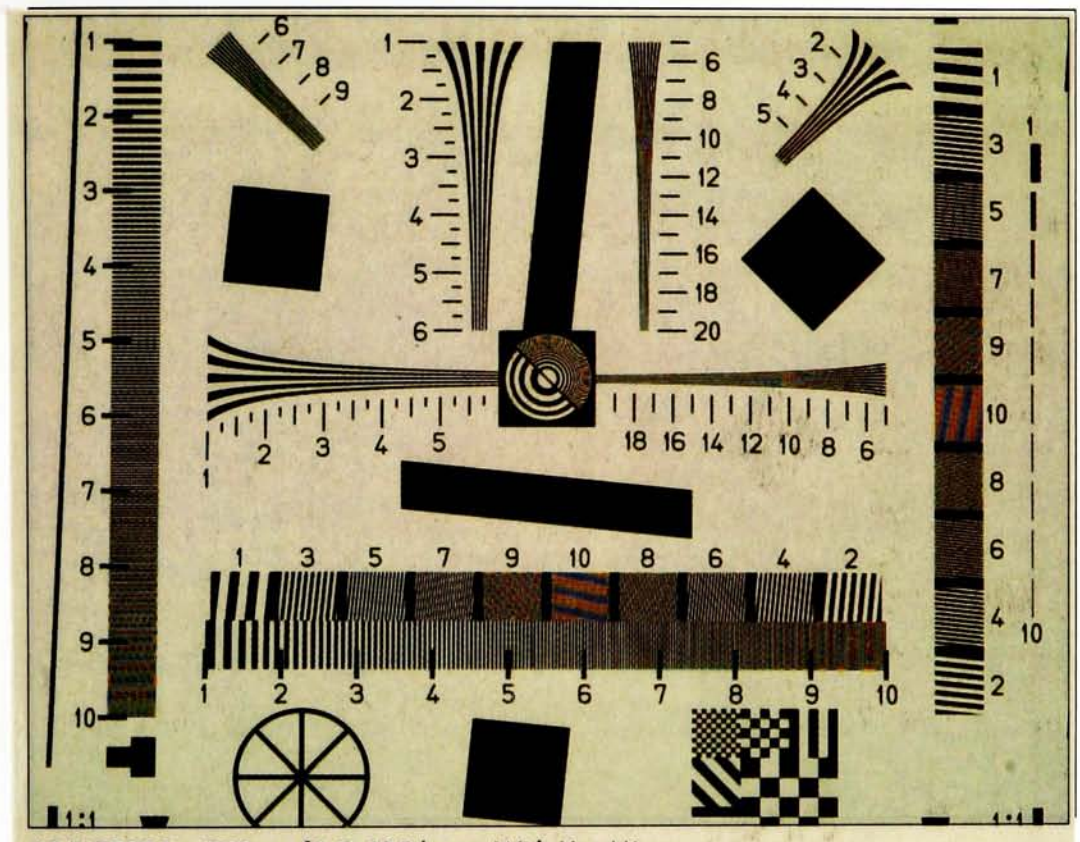
Reproduction of the IT-10 test target to SNAP specifications on newsprint brings the resolution of all the cameras closer together. The AP NC2000e camera containing the highest resolution still has a greater resolution then the Minolta and Fuji camera but losses proportionately a greater amount of resolution. The original resolution for AP NC2000e at ISO 200 was 0.74 and the newspaper reproduction resolution is 0.55 resulting in a resolution difference of 0.19. The Minolta camera at ISO 800 yielded a 0.10 change in resolution while the Fuji camera exhibited a resolution difference of 0.12.

Despite containing less resolution, it was the lower-resolution Fuji and Minolta cameras that proportionately retained more resolution the the higher resolution AP NC2000e.

Plate 13

APHM2008

IT-10 Newspaper Reproduction

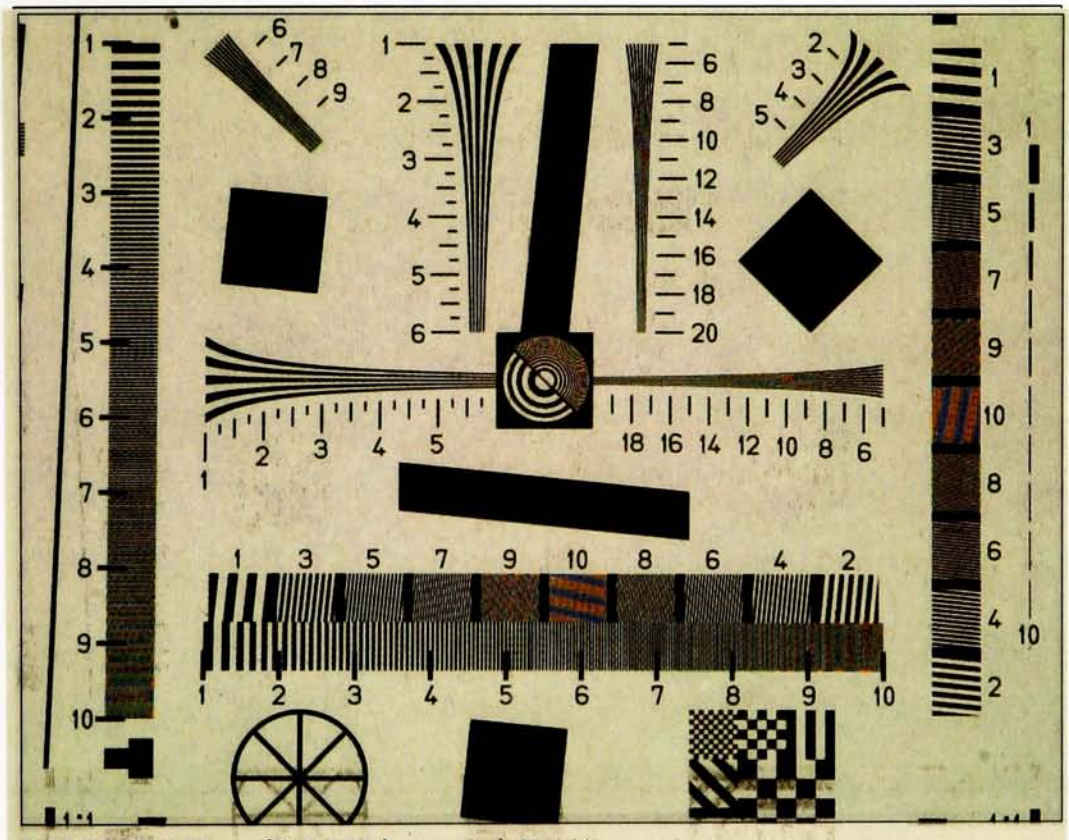


AP NC2000e, 200asa f8 @ 125th sec, With Hot Mirror

Plate 14

EOSHM2008

IT-10 Newspaper Reproduction

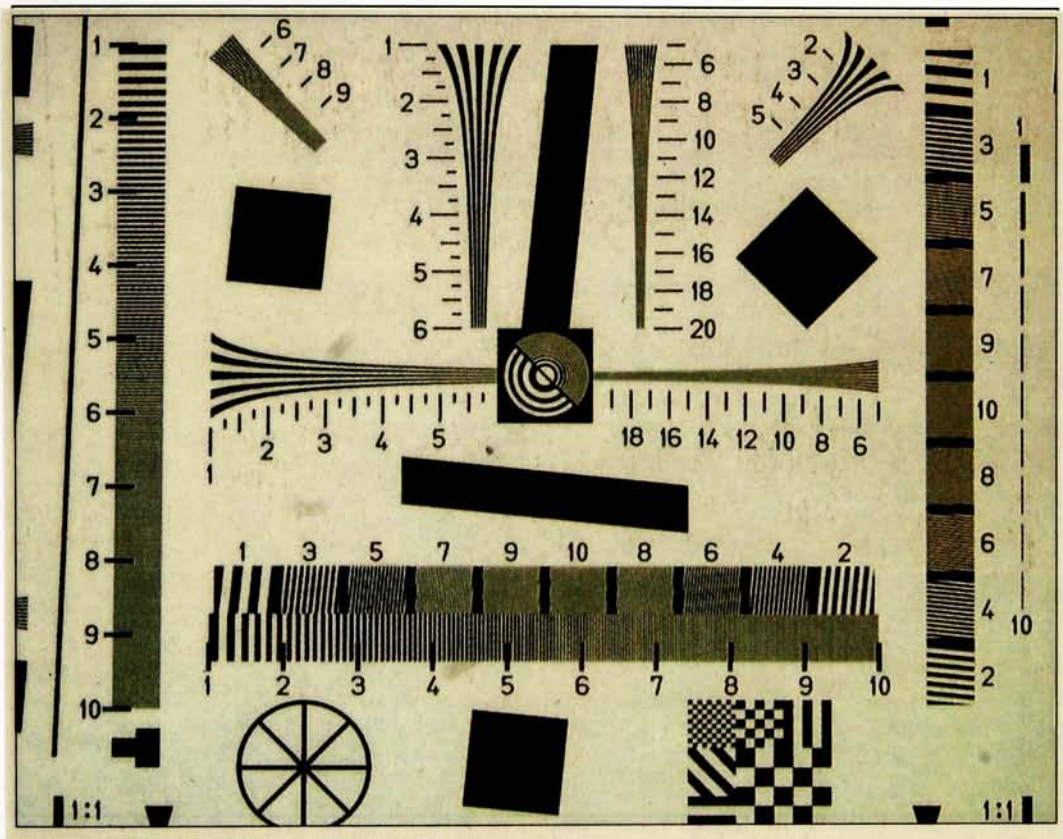


DCS EOS3, 200asa f8 @ 125th sec, With Hot Mirror

Plate 15

Min8008

IT-10 Newspaper Reproduction

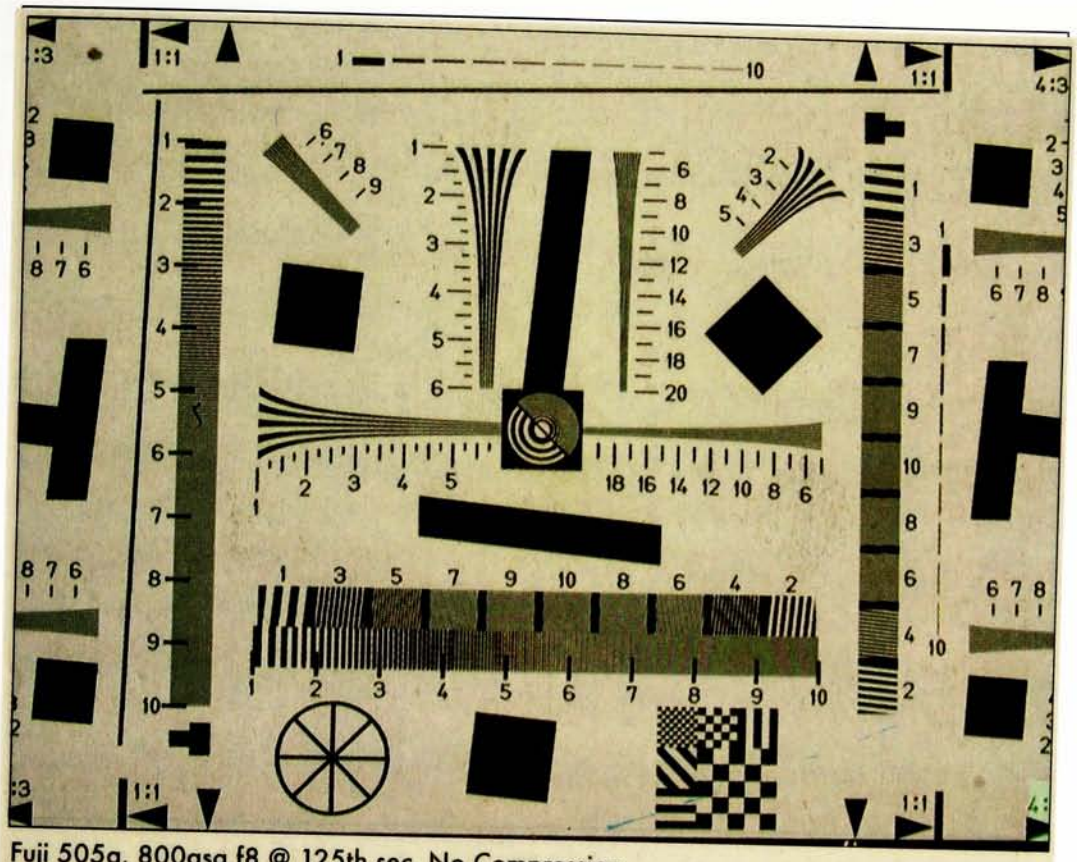


Minolta RD-175, 800asa f8 @ 125th sec

Plate 16

Fuj8008

IT-10 Newspaper Reproduction



Fuji 505a, 800asa f8 @ 125th sec, No Compression

Color Gamut Analysis

Spectophotometric readings were prepared using the XRITE 938. All values of hard copy data such as the original MacBeth color checker, proofs and newspaper samples were read with the XRITE 938. All values taken from the acquired digital image files were read using Adobe Photoshop's "info box" set to read CIE LAB coordinates with the eyedropper set to 5x5 pixel radius. All values were recorded directly to a Microsoft Excel™ spreadsheet or transcribed to a an Excel spreadsheet.
To establish color difference (ΔE^*) the following formula was used:

$$\sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2} = \Delta E^*$$

Digital image CIE LAB coordinates of the MacBeth color checker were read at ISO 200, 400, 640, 800, 1000, 1250, 1600 for the AP NC2000e with and without a Tiffen hot mirror filter, at ISO 800 for the Minolta camera and ISO 800 and 3200 with no compression for the Fuji camera. The coordinates were then compared to the proof CIE LAB coordinates and the newspaper CIE LAB coordinates. All images were photographed at f/8.

Color Difference scale:

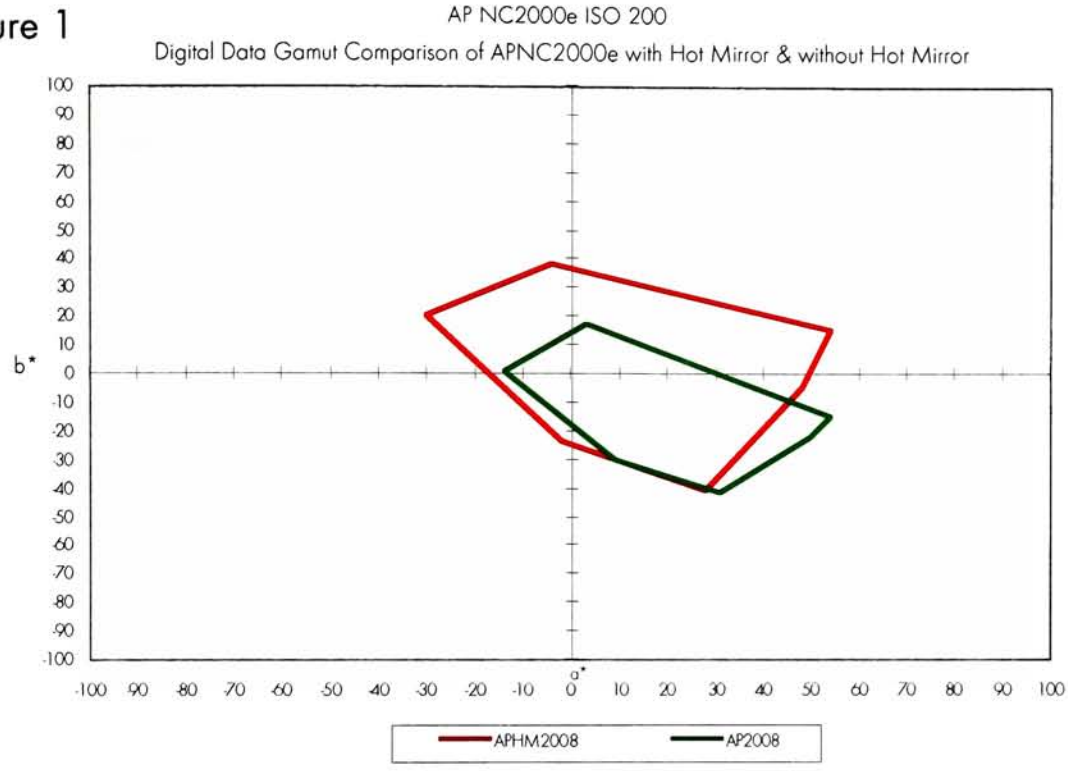
ΔE^*	Perception	Interpretation
<1	No Difference	Excellent match
1-2	Just Noticeable difference	Good Match
4-6	Noticeable	Fair Match
>9	Strong difference	Poor Match

AP NC2000e ISO200 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 200 f/8 without the hot mirror filter in Figure 1 is smaller than the gamut of the test image photographed with a hot mirror filter. The reduction in gamut is most significant in the yellow, green and red region. The blue portion of the gamut shares a border for both test images though the non-hot mirror image gamut reflects an accentuation in the magenta region.

Table 14 and 15 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror. Tables 14 and 15 illustrate the fact that a reproduction varies in color from the original.

Figure 1



If we reference Table 16, we can see the actual CIELAB values and the corresponding ΔE* values for the images shot with and without the hot mirror filter. The only acceptable ΔE* on table 16 is seen in the white and neutral 8 swatch of the Macbeth Color checker. At white, the ΔE*=2.00 and at neutral 8 the ΔE*=2.45. The greatest ΔE* value is illustrated in the red swatch with a ΔE*=33.54. The high ΔE* values in yellow, red and green influenced color swatches mimic the smaller gamut illustrated in Figure 1.

Figure 2 and 3 illustrates the fact that each ISO photographed with or without a hot mirror filter has its own specific color gamut. No two ISO color gamuts were the same. Table 17-22 illustrates the ΔE* between ISO 200 and all other ISO's with the use of a hot mirror filter. Table 23-28 illustrates the ΔE* between ISO 200 and all other ISO's without the use of a hot mirror filter. The ΔE* values comparing ISO to ISO were smaller when comparing different ISO photographed with the hot mirror filter.

Among the comparisons done at ISO 200 with a hot mirror filter, the APHM2008 test image compared to APHM8008 test image exhibited the greatest overall color difference at every color wedge. Among the comparisons done with ISO 200 without the use of a hot mirror filter, the AP6408 test image exhibited the greatest overall color difference at all the color wedges.

Table 14

ISO 200

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

		Orig Mac L*	AP2008 L*	Orig Mac a*	AP2008 a*	Orig Mac b*	AP2008 b*	ΔE
Dark Skin	1	37.86	56	13.84	22	14.83	-13	34.21
Light skin	2	65.57	82	16.91	21	17.79	-5	28.39
Blue sky	3	48.76	60	-4.86	4	-23.14	-17	15.57
Foliage	4	43.1	59	-14.2	7	20.01	-10	40.04
Blue flower	5	54.48	69	8.97	20	-25.04	-21	18.68
Bluish green	6	69.85	81	-32.49	-9	-1.04	-9	27.19
Orange	7	62.1	77	34.86	25	63	8	57.83
Purplish blue	8	38.97	58	9.75	27	-43.64	-37	26.53
Moderate Red	9	50.32	69	48.78	43	16.89	-11	34.06
Purple	10	29.92	60	22.71	40	-21.7	-34	36.81
Yellow green	11	71.67	82	-24.09	-12	59.42	13	49.07
Orange yello\	12	71.66	82	20.07	15	68.48	9	60.58
Blue	13	28.15	47	20.92	31	-56.17	-42	25.65
Green	14	54.11	68	-40.49	-14	33.08	1	43.86
Red	15	41.5	67	58.17	54	29.8	-15	51.72
Yellow	16	81.82	87	3.7	3	80.35	17	63.57
Magenta	17	51.35	73	49.87	50	-14.01	-22	23.08
Cyan	18	48.9	63	-29.14	9	-30.58	-30	40.67
White	19	94.89	92	-0.34	0	-0.18	-1	3.02
Neutral 8	20	80.36	85	-0.11	0	-0.39	-1	4.68
Neutral 6.5	21	64.48	74	-0.01	2	-0.24	-3	10.11
Neutral 5	22	49.48	58	-0.4	5	-0.51	-6	11.48
Neutral 3.5	23	35.11	44	0.02	8	-0.43	-9	14.70
Black	24	20.56	31	0.46	14	-0.18	-15	22.63

Table 15

ISO 200

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM2008 L*	Orig Mac a*	APHM2008 a*	Orig Mac b*	APHM2008 b*	ΔE
Dark Skin	1	37.86	44	13.84	12	14.83	8	9.37
Light skin	2	65.57	73	16.91	15	17.79	8	12.44
Blue sky	3	48.76	53	-4.86	2	-23.14	-17	10.14
Foliage	4	43.1	48	-14.2	-7	20.01	10	13.27
Blue flower	5	54.48	60	8.97	16	-25.04	-16	12.71
Bluish green	6	69.85	74	-32.49	-18	-1.04	-2	15.10
Orange	7	62.1	67	34.86	19	63	30	36.94
Purplish blue	8	38.97	44	9.75	18	-43.64	-31	15.91
Moderate Red	9	50.32	58	48.78	42	16.89	8	13.56
Purple	10	29.92	40	22.71	30	-21.7	-13	15.18
Yellow green	11	71.67	76	-24.09	-24	59.42	32	27.76
Orange yello\	12	71.66	74	20.07	6	68.48	33	38.24
Blue	13	28.15	33	20.92	28	-56.17	-41	17.43
Green	14	54.11	59	-40.49	-30	33.08	20	17.47
Red	15	41.5	52	58.17	54	29.8	15	18.62
Yellow	16	81.82	84	3.7	-4	80.35	38	43.10
Magenta	17	51.35	59	49.87	48	-14.01	-5	11.97
Cyan	18	48.9	52	-29.14	-2	-30.58	-24	28.10
White	19	94.89	90	-0.34	0	-0.18	-1	4.97
Neutral 8	20	80.36	83	-0.11	-1	-0.39	0	2.81
Neutral 6.5	21	64.48	67	-0.01	0	-0.24	-1	2.63
Neutral 5	22	49.48	51	-0.4	0	-0.51	0	1.65
Neutral 3.5	23	35.11	36	0.02	1	-0.43	-1	1.44
Black	24	20.56	21	0.46	3	-0.18	-1	2.71

Table 16

ISO 200

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

		APHM2008 L*	AP2008 L*	APHM2008 a*	AP2008 a*	APHM2008 b*	AP2008 b*	ΔE
Dark Skin	1	44	56	12	22	8	-13	26.17
Light skin	2	73	82	15	21	8	-5	16.91
Blue sky	3	53	60	2	4	-17	-17	7.28
Foliage	4	48	59	-7	7	10	-10	26.78
Blue flower	5	60	69	16	20	-16	-21	11.05
Bluish green	6	74	81	-18	-9	-2	-9	13.38
Orange	7	67	77	19	25	30	8	24.90
Purplish blue	8	44	58	18	27	-31	-37	17.69
Moderate Red	9	58	69	42	43	8	-11	21.98
Purple	10	40	60	30	40	-13	-34	30.68
Yellow green	11	76	82	-24	-12	32	13	23.26
Orange yellow	12	74	82	6	15	33	9	26.85
Blue	13	33	47	28	31	-41	-42	14.35
Green	14	59	68	-30	-14	20	1	26.42
Red	15	52	67	54	54	15	-15	33.54
Yellow	16	84	87	-4	3	38	17	22.34
Magenta	17	59	73	48	50	-5	-22	22.11
Cyan	18	52	63	-2	9	-24	-30	16.67
White	19	90	92	0	0	-1	-1	2.00
Neutral 8	20	83	85	-1	0	0	-1	2.45
Neutral 6.5	21	67	74	0	2	-1	-3	7.55
Neutral 5	22	51	58	0	5	0	-6	10.49
Neutral 3.5	23	36	44	1	8	-1	-9	13.30
Black	24	21	31	3	14	-1	-15	20.42

Figure 2

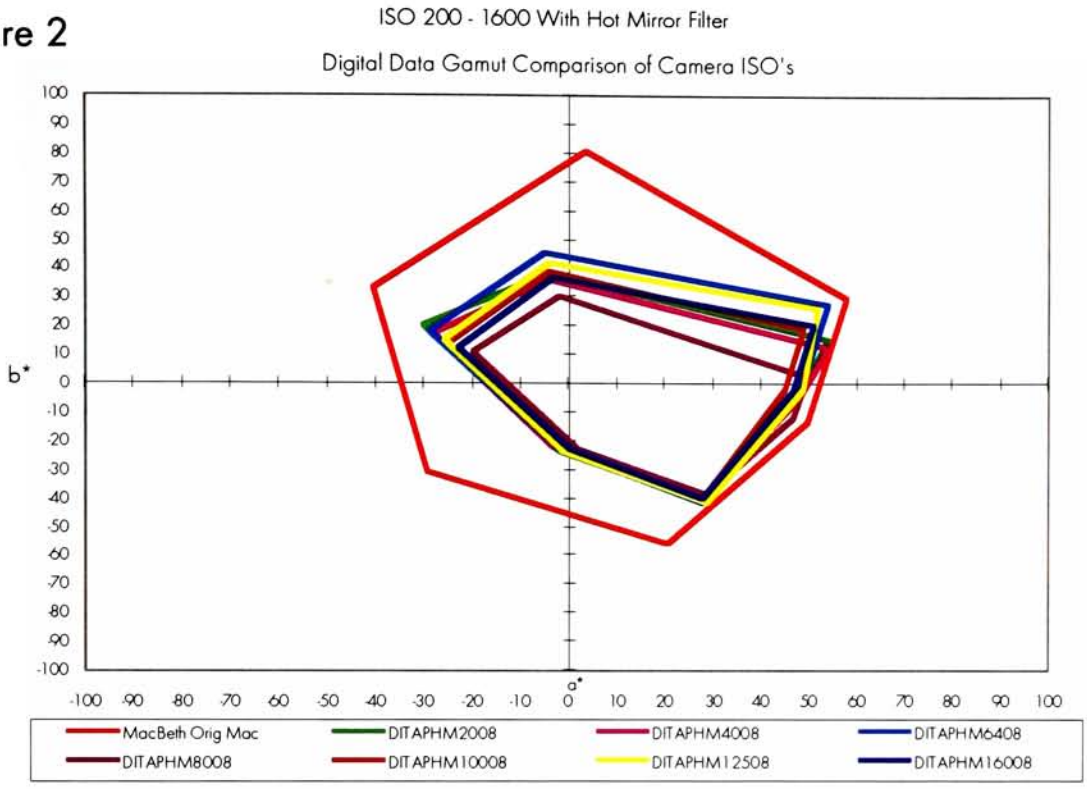


Figure 3

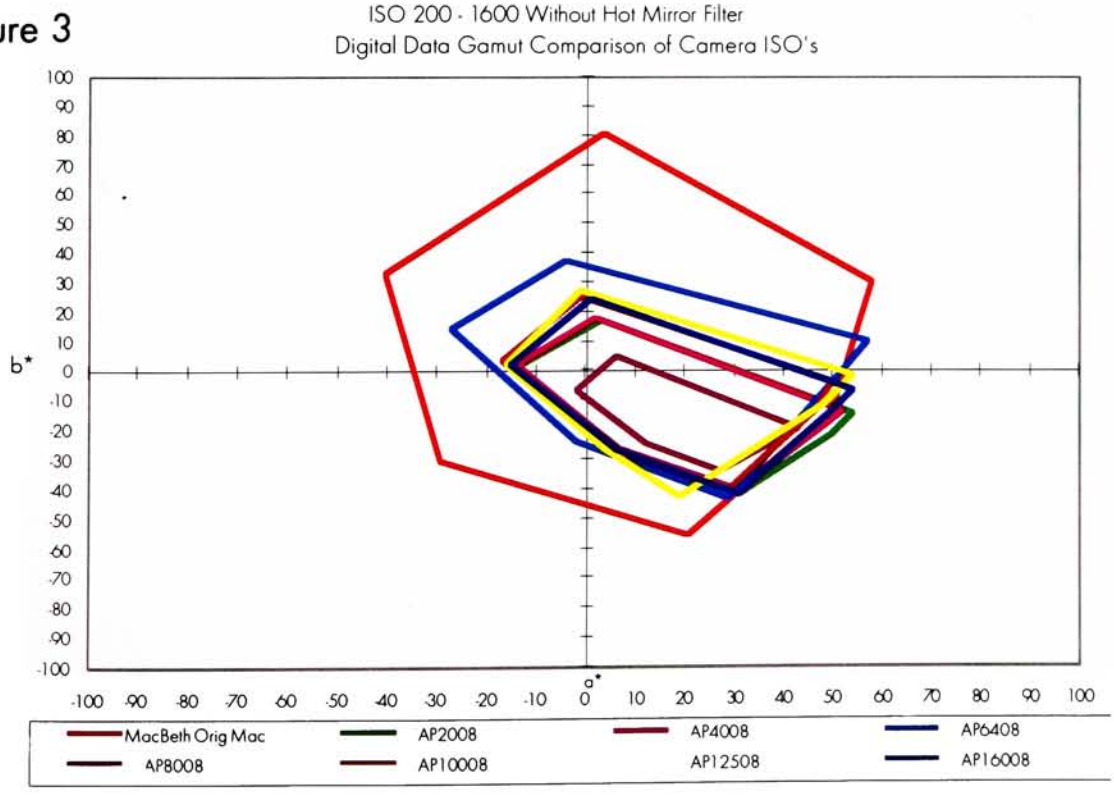


Table 17

ISO 200 & ISO 400

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM2008 L*	APHM4008 L*	APHM2008 a*	APHM4008 a*	APHM2008 b*	APHM4008 b*	ΔE
Dark Skin	1	44	42	12	14	8	5	4.12
Light skin	2	73	71	15	15	8	8	2.00
Blue sky	3	53	52	2	1	-17	-15	2.45
Foliage	4	48	47	-7	-5	10	7	3.74
Blue flower	5	60	60	16	16	-16	-16	0.00
Bluish green	6	74	75	-18	-17	-2	-1	1.73
Orange	7	67	66	19	18	30	29	1.73
Purplish blue	8	44	43	18	20	-31	-31	2.24
Moderate Red	9	58	58	42	42	8	6	2.00
Purple	10	40	40	30	32	-13	-16	3.61
Yellow green	11	76	76	-24	-24	32	32	0.00
Orange yellow	12	74	75	6	5	33	35	2.45
Blue	13	33	31	28	28	-41	-41	2.00
Green	14	59	58	-30	-28	20	17	3.74
Red	15	52	52	54	54	15	12	3.00
Yellow	16	84	84	-4	-4	38	36	2.00
Magenta	17	59	59	48	48	-5	-5	0.00
Cyan	18	52	53	-2	-3	-24	-22	2.45
White	19	90	89	0	0	-1	0	1.41
Neutral 8	20	83	82	-1	0	0	0	1.41
Neutral 6.5	21	67	67	0	-1	-1	1	2.24
Neutral 5	22	51	52	0	-1	0	0	1.41
Neutral 3.5	23	36	36	1	1	-1	-1	0.00
Black	24	21	19	3	5	-1	-4	4.12

Table 18

ISO 200 & ISO 640

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM2008 L*	APHM6408 L*	APHM2008 a*	APHM6408 a*	APHM2008 b*	APHM6408 b*	ΔE
Dark Skin	1	44	43	12	12	8	9	1.41
Light skin	2	73	74	15	14	8	13	5.20
Blue sky	3	53	54	2	1	-17	-15	2.45
Foliage	4	48	48	-7	-9	10	12	2.83
Blue flower	5	60	63	16	15	-16	-15	3.32
Bluish green	6	74	78	-18	-19	-2	-2	4.12
Orange	7	67	68	19	19	30	37	7.07
Purplish blue	8	44	44	18	18	-31	-30	1.00
Moderate Red	9	58	60	42	42	8	15	7.28
Purple	10	40	38	30	28	-13	-8	5.74
Yellow green	11	76	80	-24	-26	32	36	6.00
Orange yellow	12	74	78	6	6	33	41	8.94
Blue	13	33	31	28	28	-41	-42	2.24
Green	14	59	59	-30	-29	20	18	2.24
Red	15	52	53	54	54	15	27	12.04
Yellow	16	84	85	-4	-5	38	45	7.14
Magenta	17	59	61	48	49	-5	1	6.40
Cyan	18	52	56	-2	-2	-24	-23	4.12
White	19	90	90	0	0	-1	0	1.00
Neutral 8	20	83	84	-1	-1	0	1	1.41
Neutral 6.5	21	67	70	0	-1	-1	1	3.74
Neutral 5	22	51	53	0	1	0	-1	2.45
Neutral 3.5	23	36	37	1	3	-1	-2	2.45
Black	24	21	20	3	3	-1	-2	1.41

Table 19

ISO 200 & ISO 800

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM2008 L*	APHM8008 L*	APHM2008 a*	APHM8008 a*	APHM2008 b*	APHM8008 b*	ΔE
Dark Skin	1	44	41	12	17	8	-2	11.58
Light skin	2	73	67	15	18	8	3	8.37
Blue sky	3	53	48	2	6	-17	-16	6.48
Foliage	4	48	45	-7	5	10	-1	16.55
Blue flower	5	60	53	16	19	-16	-18	7.87
Bluish green	6	74	65	-18	-13	-2	-4	10.49
Orange	7	67	62	19	20	30	19	12.12
Purplish blue	8	44	40	18	21	-31	-30	5.10
Moderate Red	9	58	54	42	42	8	-4	12.65
Purple	10	40	42	30	36	-13	-22	11.00
Yellow green	11	76	68	-24	-19	32	24	12.37
Orange yellow	12	74	66	6	8	33	24	12.21
Blue	13	33	29	28	29	-41	-39	4.58
Green	14	59	53	-30	-20	20	11	14.73
Red	15	52	49	54	50	15	2	13.93
Yellow	16	84	80	-4	-2	38	30	9.17
Magenta	17	59	55	48	47	-5	-12	8.12
Cyan	18	52	45	-2	2	-24	-23	8.12
White	19	90	87	0	0	-1	0	3.16
Neutral 8	20	83	77	-1	0	0	-1	6.16
Neutral 6.5	21	67	60	0	1	-1	-2	7.14
Neutral 5	22	51	45	0	3	0	-4	7.81
Neutral 3.5	23	36	31	1	4	-1	-5	7.07
Black	24	21	17	3	6	-1	-3	5.39

Table 20

ISO 200 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM2008 L*	APHM10008 L*	APHM2008 a*	APHM10008 a*	APHM2008 b*	APHM10008 b*	ΔE
Dark Skin	1	44	38	12	13	8	6	6.40
Light skin	2	73	66	15	14	8	9	7.14
Blue sky	3	53	47	2	1	-17	-15	6.40
Foliage	4	48	42	-7	-6	10	8	6.40
Blue flower	5	60	55	16	16	-16	-15	5.10
Bluish green	6	74	69	-18	-16	-2	-3	5.48
Orange	7	67	60	19	19	30	28	7.28
Purplish blue	8	44	38	18	18	-31	-29	6.32
Moderate Red	9	58	53	42	39	8	8	5.83
Purple	10	40	34	30	26	-13	-8	8.77
Yellow green	11	76	70	-24	-22	32	29	7.00
Orange yellow	12	74	69	6	6	33	33	5.00
Blue	13	33	26	28	28	-41	-40	7.07
Green	14	59	51	-30	-25	20	14	11.18
Red	15	52	47	54	49	15	19	8.12
Yellow	16	84	80	-4	-4	38	39	4.12
Magenta	17	59	54	48	45	-5	-2	6.56
Cyan	18	52	48	-2	-1	-24	-22	4.58
White	19	90	86	0	0	-1	0	4.12
Neutral 8	20	83	77	-1	-1	0	0	6.00
Neutral 6.5	21	67	61	0	1	-1	-2	6.16
Neutral 5	22	51	46	0	2	0	-3	6.16
Neutral 3.5	23	36	31	1	4	-1	-3	6.16
Black	24	21	17	3	4	-1	-4	5.10

Table 21

ISO 200 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

	APHM2008 L*		APHM12508 L*		APHM2008 a*		APHM12508 a*		APHM2008 b*		APHM12508 b*		ΔE
Dark Skin	1		44		41		12		14		8		7	3.74
Light skin	2		73		72		15		16		8		10	2.45
Blue sky	3		53		52		2		2		-17		-16	1.41
Foliage	4		48		47		-7		-8		10		12	2.45
Blue flower	5		60		61		16		16		-16		-15	1.41
Bluish green	6		74		76		-18		-18		-2		-3	2.24
Orange	7		67		66		19		21		30		31	2.45
Purplish blue	8		44		42		18		18		-31		-30	2.24
Moderate Red	9		58		58		42		42		8		12	4.00
Purple	10		40		38		30		29		-13		-9	4.58
Yellow green	11		76		77		-24		-25		32		33	1.73
Orange yellow	12		74		76		6		7		33		37	4.58
Blue	13		33		30		28		29		-41		-42	3.32
Green	14		59		57		-30		-26		20		15	6.71
Red	15		52		52		54		52		15		26	11.18
Yellow	16		84		84		-4		-4		38		42	4.00
Magenta	17		59		60		48		49		-5		-2	3.32
Cyan	18		52		53		-2		-1		-24		-24	1.41
White	19		90		89		0		0		-1		0	1.41
Neutral 8	20		83		83		-1		0		0		0	1.00
Neutral 6.5	21		67		67		0		1		-1		-1	1.00
Neutral 5	22		51		51		0		2		0		-2	2.83
Neutral 3.5	23		36		35		1		1		-1		1	2.24
Black	24		21		18		3		6		-1		-3	4.69

Table 22

ISO 200 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM2008 L*	APHM16008 L*	APHM2008 a*	APHM16008 a*	APHM2008 b*	APHM16008 b*	ΔE
Dark Skin	1	44	41	12	14	8	2	7.00
Light skin	2	73	70	15	16	8	7	3.32
Blue sky	3	53	50	2	1	-17	-15	3.74
Foliage	4	48	45	-7	-5	10	6	5.39
Blue flower	5	60	59	16	16	-16	-16	1.00
Bluish green	6	74	74	-18	-16	-2	-3	2.24
Orange	7	67	65	19	21	30	26	4.90
Purplish blue	8	44	42	18	19	-31	-29	3.00
Moderate Red	9	58	56	42	41	8	9	2.45
Purple	10	40	37	30	29	-13	-12	3.32
Yellow green	11	76	75	-24	-23	32	29	3.32
Orange yellow	12	74	74	6	8	33	32	2.24
Blue	13	33	30	28	28	-41	-40	3.16
Green	14	59	56	-30	-23	20	12	11.05
Red	15	52	51	54	51	15	20	5.92
Yellow	16	84	83	-4	-3	38	37	1.73
Magenta	17	59	58	48	47	-5	-3	2.45
Cyan	18	52	52	-2	0	-24	-23	2.24
White	19	90	89	0	0	-1	0	1.41
Neutral 8	20	83	82	-1	0	0	0	1.41
Neutral 6.5	21	67	66	0	1	-1	-1	1.41
Neutral 5	22	51	50	0	3	0	-3	4.36
Neutral 3.5	23	36	35	1	4	-1	-4	4.36
Black	24	21	18	3	7	-1	-8	8.60

Table 23

ISO 200 & ISO 400

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

	AP2008 L*	AP4008 L*	AP2008 a*	AP4008 a*	AP2008 b*	AP4008 b*	ΔE
Dark Skin	1	56	56	22	22	-13	-13	0.00
Light skin	2	82	82	21	20	-5	-6	1.41
Blue sky	3	60	59	4	3	-17	-15	2.45
Foliage	4	59	59	7	5	-10	-7	3.61
Blue flower	5	69	70	20	18	-21	-19	3.00
Bluish green	6	81	82	-9	-13	-9	-4	6.48
Orange	7	77	78	25	24	8	5	3.32
Purplish blue	8	58	59	27	26	-37	-36	1.73
Moderate Red	9	69	71	43	41	-11	-9	3.46
Purple	10	60	61	40	39	-34	-32	2.45
Yellow green	11	82	83	-12	-15	13	17	5.10
Orange yello\	12	82	83	15	11	9	14	6.48
Blue	13	47	48	31	31	-42	-41	1.41
Green	14	68	68	-14	-14	1	2	1.00
Red	15	67	69	54	52	-15	-14	3.00
Yellow	16	87	88	3	2	17	18	1.73
Magenta	17	73	74	50	48	-22	-19	3.74
Cyan	18	63	64	9	6	-30	-26	5.10
White	19	92	92	0	0	-1	0	1.00
Neutral 8	20	85	86	0	0	-1	0	1.41
Neutral 6.5	21	74	75	2	2	-3	-2	1.41
Neutral 5	22	58	60	5	4	-6	-5	2.45
Neutral 3.5	23	44	45	8	8	-9	-10	1.41
Black	24	31	30	14	13	-15	-14	1.73

Table 24

ISO 200 & ISO 640

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

	AP2008 L*	AP6408 L*	AP2008 a*	AP6408 a*	AP2008 b*	AP6408 b*	ΔE	
Dark Skin	1	56	50	22	16	-13	0	15.52
Light skin	2	82	81	21	16	-5	8	13.96
Blue sky	3	60	59	4	1	-17	-17	3.16
Foliage	4	59	55	7	-5	-10	5	19.62
Blue flower	5	69	69	20	15	-21	-15	7.81
Bluish green	6	81	83	-9	-19	-9	-2	12.37
Orange	7	77	75	25	22	8	27	19.34
Purplish blue	8	58	51	27	21	-37	-34	9.70
Moderate Red	9	69	67	43	43	-11	8	19.10
Purple	10	60	48	40	32	-34	-19	20.81
Yellow green	11	82	83	-12	-25	13	32	23.04
Orange yello\	12	82	82	15	8	9	33	25.00
Blue	13	47	39	31	29	-42	-44	8.49
Green	14	68	65	-14	-27	1	14	18.63
Red	15	67	61	54	57	-15	10	25.88
Yellow	16	87	87	3	-4	17	37	21.19
Magenta	17	73	69	50	50	-22	-5	17.46
Cyan	18	63	62	9	-2	-30	-24	12.57
White	19	92	93	0	-1	-1	1	2.45
Neutral 8	20	85	87	0	-1	-1	1	3.00
Neutral 6.5	21	74	75	2	-1	-3	2	5.92
Neutral 5	22	58	58	5	1	-6	-2	5.66
Neutral 3.5	23	44	42	8	4	-9	-4	6.71
Black	24	31	25	14	8	-15	-8	11.00

Table 25

ISO 200 & ISO 800

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP2008 L*	AP8008 L*	AP2008 a*	AP8008 a*	AP2008 b*	AP8008 b*	ΔE
Dark Skin	1	56	68	22	24	-13	-18	13.15
Light skin	2	82	86	21	20	-5	-10	6.48
Blue sky	3	60	64	4	8	-17	-16	5.74
Foliage	4	59	69	7	14	-10	-14	12.85
Blue flower	5	69	75	20	18	-21	-18	7.00
Bluish green	6	81	82	-9	-5	-9	-7	4.58
Orange	7	77	83	25	22	8	-4	13.75
Purplish blue	8	58	72	27	25	-37	-31	15.36
Moderate Red	9	69	80	43	36	-11	-17	14.35
Purple	10	60	78	40	36	-34	-32	18.55
Yellow green	11	82	84	-12	-3	13	3	13.60
Orange yello\	12	82	84	15	15	9	-1	10.20
Blue	13	47	62	31	27	-42	-34	17.46
Green	14	68	75	-14	-2	1	-7	16.03
Red	15	67	80	54	43	-15	-20	17.75
Yellow	16	87	89	3	6	17	5	12.53
Magenta	17	73	82	50	40	-22	-23	13.49
Cyan	18	63	70	9	12	-30	-25	9.11
White	19	92	93	0	0	-1	0	1.41
Neutral 8	20	85	87	0	2	-1	-2	3.00
Neutral 6.5	21	74	78	2	4	-3	-4	4.58
Neutral 5	22	58	64	5	9	-6	-10	8.25
Neutral 3.5	23	44	51	8	12	-9	-14	9.49
Black	24	31	40	14	16	-15	-17	9.43

Table 26

ISO 200 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP2008 L*	AP10008 L*	AP2008 a*	AP10008 a*	AP2008 b*	AP10008 b*	ΔE
Dark Skin	1	56	47	22	19	-13	-10	9.95
Light skin	2	82	75	21	18	-5	1	9.70
Blue sky	3	60	53	4	2	-17	-16	7.35
Foliage	4	59	50	7	2	-10	-4	11.92
Blue flower	5	69	63	20	16	-21	-17	8.25
Bluish green	6	81	76	-9	-15	-9	-4	9.27
Orange	7	77	69	25	22	8	12	9.43
Purplish blue	8	58	49	27	23	-37	-34	10.30
Moderate Red	9	69	62	43	40	-11	-2	11.79
Purple	10	60	48	40	32	-34	-25	17.00
Yellow green	11	82	78	-12	-19	13	21	11.36
Orange yello\	12	82	78	15	8	9	22	15.30
Blue	13	47	38	31	29	-42	-41	9.27
Green	14	68	60	-14	-17	1	3	8.77
Red	15	67	58	54	50	-15	-4	14.76
Yellow	16	87	84	3	-1	17	25	9.43
Magenta	17	73	64	50	47	-22	-13	13.08
Cyan	18	63	56	9	4	-30	-26	9.49
White	19	92	89	0	-1	-1	0	3.32
Neutral 8	20	85	83	0	-1	-1	0	2.45
Neutral 6.5	21	74	67	2	1	-3	-2	7.14
Neutral 5	22	58	52	5	4	-6	-6	6.08
Neutral 3.5	23	44	38	8	7	-9	-9	6.08
Black	24	31	23	14	11	-15	-12	9.06

Table 27

ISO 200 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP2008 L*	AP12508 L*	AP2008 a*	AP12508 a*	AP2008 b*	AP12508 b*	ΔE
Dark Skin	1	56	52	22	19	-13	-9	6.40
Light skin	2	82	81	21	18	-5	1	6.78
Blue sky	3	60	58	4	3	-17	-17	2.24
Foliage	4	59	55	7	1	-10	-3	10.05
Blue flower	5	69	68	20	17	-21	-17	5.10
Bluish green	6	81	82	-9	-17	-9	-2	10.68
Orange	7	77	75	25	24	8	14	6.40
Purplish blue	8	58	54	27	23	-37	-35	6.00
Moderate Red	9	69	67	43	42	-11	-3	8.31
Purple	10	60	52	40	35	-34	-27	11.75
Yellow green	11	82	82	-12	-20	13	22	12.04
Orange yellov	12	82	82	15	9	9	23	15.23
Blue	13	47	43	31	30	-42	-43	4.24
Green	14	68	65	-14	-16	1	2	3.74
Red	15	67	64	54	54	-15	-2	13.34
Yellow	16	87	87	3	-1	17	27	10.77
Magenta	17	73	70	50	48	-22	-12	10.63
Cyan	18	63	61	9	4	-30	-27	6.16
White	19	92	92	0	0	-1	0	1.00
Neutral 8	20	85	86	0	-1	-1	1	2.45
Neutral 6.5	21	74	73	2	2	-3	-4	1.41
Neutral 5	22	58	58	5	4	-6	-6	1.00
Neutral 3.5	23	44	42	8	7	-9	-10	2.45
Black	24	31	27	14	10	-15	-10	7.55

Table 28

ISO 200 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP2008 L*	AP16008 L*	AP2008 a*	AP16008 a*	AP2008 b*	AP16008 b*	ΔE
Dark Skin	1	56	51	22	20	-13	-9	6.71
Light skin	2	82	80	21	20	-5	0	5.48
Blue sky	3	60	56	4	3	-17	-15	4.58
Foliage	4	59	53	7	3	-10	-3	10.05
Blue flower	5	69	67	20	17	-21	-16	6.16
Bluish green	6	81	80	-9	-14	-9	-5	6.48
Orange	7	77	74	25	26	8	11	4.36
Purplish blue	8	58	53	27	26	-37	-35	5.48
Moderate Red	9	69	66	43	42	-11	-4	7.68
Purple	10	60	53	40	36	-34	-27	10.68
Yellow green	11	82	82	-12	-16	13	20	8.06
Orange yellov	12	82	82	15	12	9	21	12.37
Blue	13	47	42	31	31	-42	-42	5.00
Green	14	68	64	-14	-15	1	2	4.24
Red	15	67	64	54	54	-15	-7	8.54
Yellow	16	87	87	3	1	17	24	7.28
Magenta	17	73	69	50	50	-22	-14	8.94
Cyan	18	63	60	9	6	-30	-27	5.20
White	19	92	91	0	1	-1	1	2.45
Neutral 8	20	85	85	0	0	-1	1	2.00
Neutral 6.5	21	74	72	2	3	-3	-2	2.45
Neutral 5	22	58	56	5	5	-6	-5	2.24
Neutral 3.5	23	44	41	8	8	-9	-7	3.61
Black	24	31	25	14	11	-15	-9	9.00

AP NC2000e ISO400 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 400 f/8 without the hot mirror filter in Figure 4 is smaller than the gamut of the test image photographed with the hot mirror filter. The reduction in gamut is most significant in the yellow, green and red regions. The blue portion of the gamut shares a border for both test images though the non-hot mirror test image gamut border reflects an accentuation in the magenta region.

Table 29 and 30 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror filter. Tables 29 and 30 illustrate the fact that a reproduction varies in color from the original.

If we reference Table 31, we can see the actual CIELAB values and the corresponding ΔE* values between the images shot with and without the hot mirror filter. There are no accepTable ΔE* values on Table 31. All ΔE* values fall beyond the range of 4-6ΔE* which depict a "noticeable color difference." The high ΔE* values in the yellow, red and green influenced color swatches mimic the smaller gamut illustrated in Figure 4.

Tables 32-36 illustrate the color difference between different ISO's while using a hot mirror filter. Tables 37-41 illustrate the color difference between different ISO's without using a hot mirror filter. In comparing ISO 400 and ISO 640 with the use of a hot mirror filter only four wedges, blue sky (2.00ΔE**), blue (1.00ΔE*), white (1.00ΔE*) and green (1.73ΔE*) fall at a value less than 2ΔE* denoting a good match. All other wedges fall between 2.45ΔE* and 15.03ΔE*. The red wedge has the greatest color difference with its value of 15.03ΔE*.

Between ISO 200 and 800, Table 33, with hot mirror filter, only one color wedge falls at or below a value of 2ΔE* denoting a "just noticeable difference." A total of ten wedges have a ΔE* of nine or greater denoting a strong color difference.

Table 37, comparing ISO 400 and ISO 640 without a hot mirror filter contains 16 wedges with ΔE*values greater than nine. A ΔE* of nine or greater denotes a "fair match" with noticeable color difference. Table 38, comparing ISO 400 and ISO 800 without a hot mirror filter contains 14 wedges with a ΔE* greater then nine also. Looking a Figure 2 and 3 we can see the trend in color difference. All gamuts regardless of ISO are different with and or without a hot mirror filter.

Figure 4

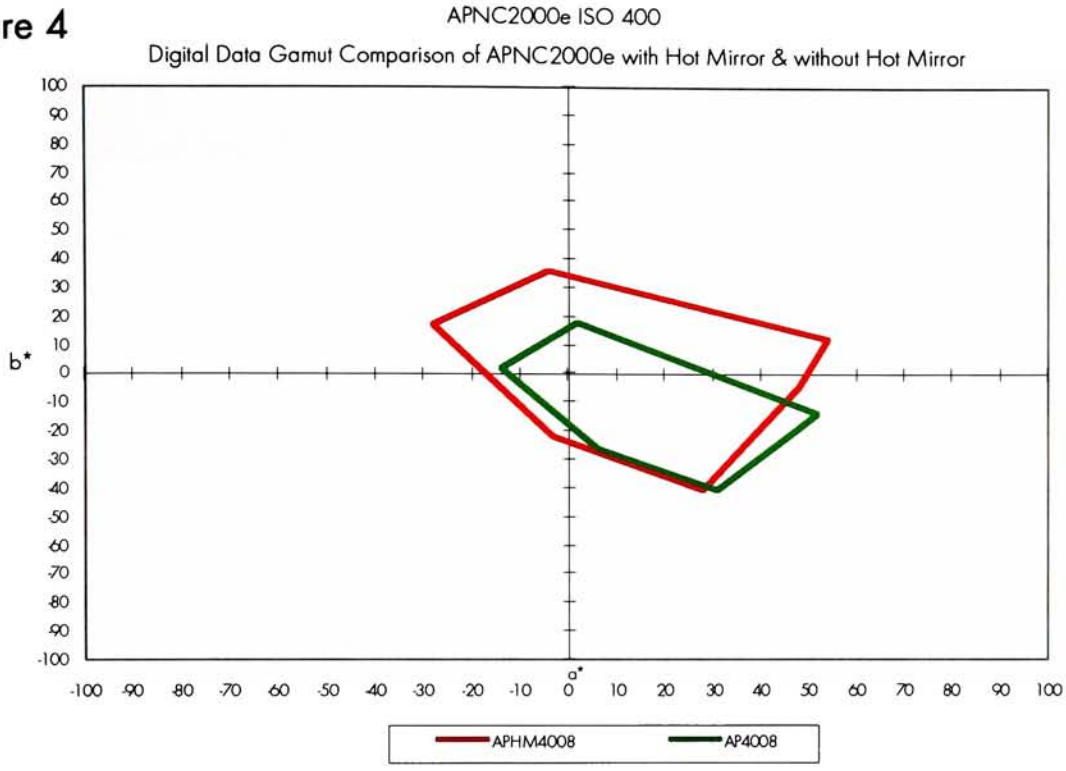

APNC2000e ISO 400
Digital Data Gamut Comparison of APNC2000e with Hot Mirror & without Hot Mirror
b*
a*
APHM4008
AP4008

Table 29

ISO 400

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

		Orig Mac L*	AP4008 L*	Orig Mac a*	AP4008 a*	Orig Mac b*	AP4008 b*	ΔE
Dark Skin	1	37.86	56	13.84	22	14.83	-13	34.21
Light skin	2	65.57	82	16.91	20	17.79	-6	29.08
Blue sky	3	48.76	59	-4.86	3	-23.14	-15	15.26
Foliage	4	43.1	59	-14.2	5	20.01	-7	36.76
Blue flower	5	54.48	70	8.97	18	-25.04	-19	18.94
Bluish green	6	69.85	82	-32.49	-13	-1.04	-4	23.16
Orange	7	62.1	78	34.86	24	63	5	61.11
Purplish blue	8	38.97	59	9.75	26	-43.64	-36	26.90
Moderate Red	9	50.32	71	48.78	41	16.89	-9	34.04
Purple	10	29.92	61	22.71	39	-21.7	-32	36.57
Yellow green	11	71.67	83	-24.09	-15	59.42	17	44.84
Orange yello\	12	71.66	83	20.07	11	68.48	14	56.38
Blue	13	28.15	48	20.92	31	-56.17	-41	26.94
Green	14	54.11	68	-40.49	-14	33.08	2	43.13
Red	15	41.5	69	58.17	52	29.8	-14	52.08
Yellow	16	81.82	88	3.7	2	80.35	18	62.68
Magenta	17	51.35	74	49.87	48	-14.01	-19	23.27
Cyan	18	48.9	64	-29.14	6	-30.58	-26	38.52
White	19	94.89	92	-0.34	0	-0.18	0	2.92
Neutral 8	20	80.36	86	-0.11	0	-0.39	0	5.65
Neutral 6.5	21	64.48	75	-0.01	2	-0.24	-2	10.85
Neutral 5	22	49.48	60	-0.4	4	-0.51	-5	12.26
Neutral 3.5	23	35.11	45	0.02	8	-0.43	-10	15.91
Black	24	20.56	30	0.46	13	-0.18	-14	20.91

Table 30

ISO 400

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM4008 L*	Orig Mac a*	APHM4008 a*	Orig Mac b*	APHM4008 b*	ΔE
Dark Skin	1	37.86	42	13.84	14	14.83	5	10.67
Light skin	2	65.57	71	16.91	15	17.79	8	11.36
Blue sky	3	48.76	52	-4.86	1	-23.14	-15	10.54
Foliage	4	43.1	47	-14.2	-5	20.01	7	16.40
Blue flower	5	54.48	60	8.97	16	-25.04	-16	12.71
Bluish green	6	69.85	75	-32.49	-17	-1.04	-1	16.32
Orange	7	62.1	66	34.86	18	63	29	38.15
Purplish blue	8	38.97	43	9.75	20	-43.64	-31	16.77
Moderate Red	9	50.32	58	48.78	42	16.89	6	14.95
Purple	10	29.92	40	22.71	32	-21.7	-16	14.85
Yellow green	11	71.67	76	-24.09	-24	59.42	32	27.76
Orange yello\	12	71.66	75	20.07	5	68.48	35	36.87
Blue	13	28.15	31	20.92	28	-56.17	-41	16.98
Green	14	54.11	58	-40.49	-28	33.08	17	20.73
Red	15	41.5	52	58.17	54	29.8	12	21.08
Yellow	16	81.82	84	3.7	-4	80.35	36	45.07
Magenta	17	51.35	59	49.87	48	-14.01	-5	11.97
Cyan	18	48.9	53	-29.14	-3	-30.58	-22	27.82
White	19	94.89	89	-0.34	0	-0.18	0	5.90
Neutral 8	20	80.36	82	-0.11	0	-0.39	0	1.69
Neutral 6.5	21	64.48	67	-0.01	-1	-0.24	1	2.98
Neutral 5	22	49.48	52	-0.4	-1	-0.51	0	2.64
Neutral 3.5	23	35.11	36	0.02	1	-0.43	-1	1.44
Black	24	20.56	19	0.46	5	-0.18	-4	6.13

Table 31

ISO 400

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

		APHM4008 L*	AP4008 L*	APHM4008 a*	AP4008 a*	APHM4008 b*	AP4008 b*	ΔE
Dark Skin	1	42	56	14	22	5	-13	24.17
Light skin	2	71	82	15	20	8	-6	18.49
Blue sky	3	52	59	1	3	-15	-15	7.28
Foliage	4	47	59	-5	5	7	-7	20.98
Blue flower	5	60	70	16	18	-16	-19	10.63
Bluish green	6	75	82	-17	-13	-1	-4	8.60
Orange	7	66	78	18	24	29	5	27.50
Purplish blue	8	43	59	20	26	-31	-36	17.80
Moderate Red	9	58	71	42	41	6	-9	19.87
Purple	10	40	61	32	39	-16	-32	27.31
Yellow green	11	76	83	-24	-15	32	17	18.84
Orange yellow	12	75	83	5	11	35	14	23.26
Blue	13	31	48	28	31	-41	-41	17.26
Green	14	58	68	-28	-14	17	2	22.83
Red	15	52	69	54	52	12	-14	31.13
Yellow	16	84	88	-4	2	36	18	19.39
Magenta	17	59	74	48	48	-5	-19	20.52
Cyan	18	53	64	-3	6	-22	-26	14.76
White	19	89	92	0	0	0	0	3.00
Neutral 8	20	82	86	0	0	0	0	4.00
Neutral 6.5	21	67	75	-1	2	1	-2	9.06
Neutral 5	22	52	60	-1	4	0	-5	10.68
Neutral 3.5	23	36	45	1	8	-1	-10	14.53
Black	24	19	30	5	13	-4	-14	16.88

Table 32

ISO 400 & ISO 640

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM4008 L*		APHM6408 L*	APHM4008 a*		APHM6408 a*	APHM4008 b*		APHM6408 b*	ΔE
Dark Skin	1	42	43	14	12	5	9	4.58			
Light skin	2	71	74	15	14	8	13	5.92			
Blue sky	3	52	54	1	1	-15	-15	2.00			
Foliage	4	47	48	-5	-9	7	12	6.48			
Blue flower	5	60	63	16	15	-16	-15	3.32			
Bluish green	6	75	78	-17	-19	-1	-2	3.74			
Orange	7	66	68	18	19	29	37	8.31			
Purplish blue	8	43	44	20	18	-31	-30	2.45			
Moderate Red	9	58	60	42	42	6	15	9.22			
Purple	10	40	38	32	28	-16	-8	9.17			
Yellow green	11	76	80	-24	-26	32	36	6.00			
Orange yellow	12	75	78	5	6	35	41	6.78			
Blue	13	31	31	28	28	-41	-42	1.00			
Green	14	58	59	-28	-29	17	18	1.73			
Red	15	52	53	54	54	12	27	15.03			
Yellow	16	84	85	-4	-5	36	45	9.11			
Magenta	17	59	61	48	49	-5	1	6.40			
Cyan	18	53	56	-3	-2	-22	-23	3.32			
White	19	89	90	0	0	0	0	1.00			
Neutral 8	20	82	84	0	-1	0	1	2.45			
Neutral 6.5	21	67	70	-1	-1	1	1	3.00			
Neutral 5	22	52	53	-1	1	0	-1	2.45			
Neutral 3.5	23	36	37	1	3	-1	-2	2.45			
Black	24	19	20	5	3	-4	-2	3.00			

Table 33

ISO 400 & ISO 800

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM4008 L*	APHM8008 L*	APHM4008 a*	APHM8008 a*	APHM4008 b*	APHM8008 b*	ΔE
Dark Skin	1	42	41	14	17	5	-2	7.68
Light skin	2	71	67	15	18	8	3	7.07
Blue sky	3	52	48	1	6	-15	-16	6.48
Foliage	4	47	45	-5	5	7	-1	12.96
Blue flower	5	60	53	16	19	-16	-18	7.87
Bluish green	6	75	65	-17	-13	-1	-4	11.18
Orange	7	66	62	18	20	29	19	10.95
Purplish blue	8	43	40	20	21	-31	-30	3.32
Moderate Red	9	58	54	42	42	6	-4	10.77
Purple	10	40	42	32	36	-16	-22	7.48
Yellow green	11	76	68	-24	-19	32	24	12.37
Orange yellow	12	75	66	5	8	35	24	14.53
Blue	13	31	29	28	29	-41	-39	3.00
Green	14	58	53	-28	-20	17	11	11.18
Red	15	52	49	54	50	12	2	11.18
Yellow	16	84	80	-4	-2	36	30	7.48
Magenta	17	59	55	48	47	-5	-12	8.12
Cyan	18	53	45	-3	2	-22	-23	9.49
White	19	89	87	0	0	0	0	2.00
Neutral 8	20	82	77	0	0	0	-1	5.10
Neutral 6.5	21	67	60	-1	1	1	-2	7.87
Neutral 5	22	52	45	-1	3	0	-4	9.00
Neutral 3.5	23	36	31	1	4	-1	-5	7.07
Black	24	19	17	5	6	-4	-3	2.45

Table 34

ISO 400 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM4008 L*	APHM10008 L*	APHM4008 a*	APHM10008 a*	APHM4008 b*	APHM10008 b*	ΔE
Dark Skin	1	42	38	14	13	5	6	4.24
Light skin	2	71	66	15	14	8	9	5.20
Blue sky	3	52	47	1	1	-15	-15	5.00
Foliage	4	47	42	-5	-6	7	8	5.20
Blue flower	5	60	55	16	16	-16	-15	5.10
Bluish green	6	75	69	-17	-16	-1	-3	6.40
Orange	7	66	60	18	19	29	28	6.16
Purplish blue	8	43	38	20	18	-31	-29	5.74
Moderate Red	9	58	53	42	39	6	8	6.16
Purple	10	40	34	32	26	-16	-8	11.66
Yellow green	11	76	70	-24	-22	32	29	7.00
Orange yellow	12	75	69	5	6	35	33	6.40
Blue	13	31	26	28	28	-41	-40	5.10
Green	14	58	51	-28	-25	17	14	8.19
Red	15	52	47	54	49	12	19	9.95
Yellow	16	84	80	-4	-4	36	39	5.00
Magenta	17	59	54	48	45	-5	-2	6.56
Cyan	18	53	48	-3	-1	-22	-22	5.39
White	19	89	86	0	0	0	0	3.00
Neutral 8	20	82	77	0	-1	0	0	5.10
Neutral 6.5	21	67	61	-1	1	1	-2	7.00
Neutral 5	22	52	46	-1	2	0	-3	7.35
Neutral 3.5	23	36	31	1	4	-1	-3	6.16
Black	24	19	17	5	4	-4	-4	2.24

Table 35

ISO 400 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM4008 L*	APHM12508 L*	APHM4008 a*	APHM12508 a*	APHM4008 b*	APHM12508 b*	ΔE
Dark Skin	1	42	41	14	14	5	7	2.24
Light skin	2	71	72	15	16	8	10	2.45
Blue sky	3	52	52	1	2	-15	-16	1.41
Foliage	4	47	47	-5	-8	7	12	5.83
Blue flower	5	60	61	16	16	-16	-15	1.41
Bluish green	6	75	76	-17	-18	-1	-3	2.45
Orange	7	66	66	18	21	29	31	3.61
Purplish blue	8	43	42	20	18	-31	-30	2.45
Moderate Red	9	58	58	42	42	6	12	6.00
Purple	10	40	38	32	29	-16	-9	7.87
Yellow green	11	76	77	-24	-25	32	33	1.73
Orange yellow	12	75	76	5	7	35	37	3.00
Blue	13	31	30	28	29	-41	-42	1.73
Green	14	58	57	-28	-26	17	15	3.00
Red	15	52	52	54	52	12	26	14.14
Yellow	16	84	84	-4	-4	36	42	6.00
Magenta	17	59	60	48	49	-5	-2	3.32
Cyan	18	53	53	-3	-1	-22	-24	2.83
White	19	89	89	0	0	0	0	0.00
Neutral 8	20	82	83	0	0	0	0	1.00
Neutral 6.5	21	67	67	-1	1	1	-1	2.83
Neutral 5	22	52	51	-1	2	0	-2	3.74
Neutral 3.5	23	36	35	1	1	-1	1	2.24
Black	24	19	18	5	6	-4	-3	1.73

Table 36

ISO 400 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM4008 L*		APHM16008 L*	APHM4008 a*		APHM16008 a*	APHM4008 b*		APHM16008 b*	ΔE
Dark Skin	1	42		41	14		14	5		2	3.16
Light skin	2	71		70	15		16	8		7	1.73
Blue sky	3	52		50	1		1	-15		-15	2.00
Foliage	4	47		45	-5		-5	7		6	2.24
Blue flower	5	60		59	16		16	-16		-16	1.00
Bluish green	6	75		74	-17		-16	-1		-3	2.45
Orange	7	66		65	18		21	29		26	4.36
Purplish blue	8	43		42	20		19	-31		-29	2.45
Moderate Red	9	58		56	42		41	6		9	3.74
Purple	10	40		37	32		29	-16		-12	5.83
Yellow green	11	76		75	-24		-23	32		29	3.32
Orange yellow	12	75		74	5		8	35		32	4.36
Blue	13	31		30	28		28	-41		-40	1.41
Green	14	58		56	-28		-23	17		12	7.35
Red	15	52		51	54		51	12		20	8.60
Yellow	16	84		83	-4		-3	36		37	1.73
Magenta	17	59		58	48		47	-5		-3	2.45
Cyan	18	53		52	-3		0	-22		-23	3.32
White	19	89		89	0		0	0		0	0.00
Neutral 8	20	82		82	0		0	0		0	0.00
Neutral 6.5	21	67		66	-1		1	1		-1	3.00
Neutral 5	22	52		50	-1		3	0		-3	5.39
Neutral 3.5	23	36		35	1		4	-1		-4	4.36
Black	24	19		18	5		7	-4		-8	4.58

Table 37

ISO 400 & ISO 640

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP4008 L*	AP6408 L*	AP4008 a*	AP6408 a*	AP4008 b*	AP6408 b*	ΔE
Dark Skin	1	56	50	22	16	-13	0	15.52
Light skin	2	82	81	20	16	-6	8	14.59
Blue sky	3	59	59	3	1	-15	-17	2.83
Foliage	4	59	55	5	-5	-7	5	16.12
Blue flower	5	70	69	18	15	-19	-15	5.10
Bluish green	6	82	83	-13	-19	-4	-2	6.40
Orange	7	78	75	24	22	5	27	22.29
Purplish blue	8	59	51	26	21	-36	-34	9.64
Moderate Red	9	71	67	41	43	-9	8	17.58
Purple	10	61	48	39	32	-32	-19	19.67
Yellow green	11	83	83	-15	-25	17	32	18.03
Orange yello	12	83	82	11	8	14	33	19.26
Blue	13	48	39	31	29	-41	-44	9.70
Green	14	68	65	-14	-27	2	14	17.94
Red	15	69	61	52	57	-14	10	25.79
Yellow	16	88	87	2	-4	18	37	19.95
Magenta	17	74	69	48	50	-19	-5	15.00
Cyan	18	64	62	6	-2	-26	-24	8.49
White	19	92	93	0	-1	0	1	1.73
Neutral 8	20	86	87	0	-1	0	1	1.73
Neutral 6.5	21	75	75	2	-1	-2	2	5.00
Neutral 5	22	60	58	4	1	-5	-2	4.69
Neutral 3.5	23	45	42	8	4	-10	-4	7.81
Black	24	30	25	13	8	-14	-8	9.27

Table 38

ISO 400 & ISO 800

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP4008 L*	AP8008 L*	AP4008 a*	AP8008 a*	AP4008 b*	AP8008 b*	ΔE
Dark Skin	1	56	68	22	24	-13	-18	13.15
Light skin	2	82	86	20	20	-6	-10	5.66
Blue sky	3	59	64	3	8	-15	-16	7.14
Foliage	4	59	69	5	14	-7	-14	15.17
Blue flower	5	70	75	18	18	-19	-18	5.10
Bluish green	6	82	82	-13	-5	-4	-7	8.54
Orange	7	78	83	24	22	5	-4	10.49
Purplish blue	8	59	72	26	25	-36	-31	13.96
Moderate Red	9	71	80	41	36	-9	-17	13.04
Purple	10	61	78	39	36	-32	-32	17.26
Yellow green	11	83	84	-15	-3	17	3	18.47
Orange yellov	12	83	84	11	15	14	-1	15.56
Blue	13	48	62	31	27	-41	-34	16.16
Green	14	68	75	-14	-2	2	-7	16.55
Red	15	69	80	52	43	-14	-20	15.43
Yellow	16	88	89	2	6	18	5	13.64
Magenta	17	74	82	48	40	-19	-23	12.00
Cyan	18	64	70	6	12	-26	-25	8.54
White	19	92	93	0	0	0	0	1.00
Neutral 8	20	86	87	0	2	0	-2	3.00
Neutral 6.5	21	75	78	2	4	-2	-4	4.12
Neutral 5	22	60	64	4	9	-5	-10	8.12
Neutral 3.5	23	45	51	8	12	-10	-14	8.25
Black	24	30	40	13	16	-14	-17	10.86

Table 39

ISO 400 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

	AP4008 L*	AP10008 L*	AP4008 a*	AP10008 a*	AP4008 b*	AP10008 b*	ΔE
Dark Skin	1	56	47	22	19	-13	-10	9.95
Light skin	2	82	75	20	18	-6	1	10.10
Blue sky	3	59	53	3	2	-15	-16	6.16
Foliage	4	59	50	5	2	-7	-4	9.95
Blue flower	5	70	63	18	16	-19	-17	7.55
Bluish green	6	82	76	-13	-15	-4	-4	6.32
Orange	7	78	69	24	22	5	12	11.58
Purplish blue	8	59	49	26	23	-36	-34	10.63
Moderate Red	9	71	62	41	40	-9	-2	11.45
Purple	10	61	48	39	32	-32	-25	16.34
Yellow green	11	83	78	-15	-19	17	21	7.55
Orange yello\	12	83	78	11	8	14	22	9.90
Blue	13	48	38	31	29	-41	-41	10.20
Green	14	68	60	-14	-17	2	3	8.60
Red	15	69	58	52	50	-14	-4	15.00
Yellow	16	88	84	2	-1	18	25	8.60
Magenta	17	74	64	48	47	-19	-13	11.70
Cyan	18	64	56	6	4	-26	-26	8.25
White	19	92	89	0	-1	0	0	3.16
Neutral 8	20	86	83	0	-1	0	0	3.16
Neutral 6.5	21	75	67	2	1	-2	-2	8.06
Neutral 5	22	60	52	4	4	-5	-6	8.06
Neutral 3.5	23	45	38	8	7	-10	-9	7.14
Black	24	30	23	13	11	-14	-12	7.55

Table 40

ISO 400 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP4008 L*	AP12508 L*	AP4008 a*	AP12508 a*	AP4008 b*	AP12508 b*	ΔE
Dark Skin	1	56	52	22	19	-13	-9	6.40
Light skin	2	82	81	20	18	-6	1	7.35
Blue sky	3	59	58	3	3	-15	-17	2.24
Foliage	4	59	55	5	1	-7	-3	6.93
Blue flower	5	70	68	18	17	-19	-17	3.00
Bluish green	6	82	82	-13	-17	-4	-2	4.47
Orange	7	78	75	24	24	5	14	9.49
Purplish blue	8	59	54	26	23	-36	-35	5.92
Moderate Red	9	71	67	41	42	-9	-3	7.28
Purple	10	61	52	39	35	-32	-27	11.05
Yellow green	11	83	82	-15	-20	17	22	7.14
Orange yellov	12	83	82	11	9	14	23	9.27
Blue	13	48	43	31	30	-41	-43	5.48
Green	14	68	65	-14	-16	2	2	3.61
Red	15	69	64	52	54	-14	-2	13.15
Yellow	16	88	87	2	-1	18	27	9.54
Magenta	17	74	70	48	48	-19	-12	8.06
Cyan	18	64	61	6	4	-26	-27	3.74
White	19	92	92	0	0	0	0	0.00
Neutral 8	20	86	86	0	-1	0	1	1.41
Neutral 6.5	21	75	73	2	2	-2	-4	2.83
Neutral 5	22	60	58	4	4	-5	-6	2.24
Neutral 3.5	23	45	42	8	7	-10	-10	3.16
Black	24	30	27	13	10	-14	-10	5.83

Table 41

ISO 400 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP4008 L*	AP16008 L*	AP4008 a*	AP16008 a*	AP4008 b*	AP16008 b*	ΔE
Dark Skin	1	56	51	22	20	-13	-9	6.71
Light skin	2	82	80	20	20	-6	0	6.32
Blue sky	3	59	56	3	3	-15	-15	3.00
Foliage	4	59	53	5	3	-7	-3	7.48
Blue flower	5	70	67	18	17	-19	-16	4.36
Bluish green	6	82	80	-13	-14	-4	-5	2.45
Orange	7	78	74	24	26	5	11	7.48
Purplish blue	8	59	53	26	26	-36	-35	6.08
Moderate Red	9	71	66	41	42	-9	-4	7.14
Purple	10	61	53	39	36	-32	-27	9.90
Yellow green	11	83	82	-15	-16	17	20	3.32
Orange yello\	12	83	82	11	12	14	21	7.14
Blue	13	48	42	31	31	-41	-42	6.08
Green	14	68	64	-14	-15	2	2	4.12
Red	15	69	64	52	54	-14	-7	8.83
Yellow	16	88	87	2	1	18	24	6.16
Magenta	17	74	69	48	50	-19	-14	7.35
Cyan	18	64	60	6	6	-26	-27	4.12
White	19	92	91	0	1	0	1	1.73
Neutral 8	20	86	85	0	0	0	1	1.41
Neutral 6.5	21	75	72	2	3	-2	-2	3.16
Neutral 5	22	60	56	4	5	-5	-5	4.12
Neutral 3.5	23	45	41	8	8	-10	-7	5.00
Black	24	30	25	13	11	-14	-9	7.35

AP NC2000e ISO640 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 640 f/8 without the hot mirror filter in Figure 5 is smaller than the gamut of the test image photographed with the hot mirror filter. The reduction in gamut is most significant in the yellow, green and red region of the gamut. The blue and cyan portion of the gamut shares a border for both test images. The non-hot mirror test image gamut border reflects an accentuation in the magenta region.

At ISO 640, Figure 5, the test image taken with a hot mirror filter has the largest color gamut of all the ISO's examined thus far. At ISO 640 the gamut of the hot mirror image and the non-hot mirror image are the most similar of all ISO hot mirror comparisons.

Table 42 and 43 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror filter. Tables 42 and 43 illustrate the fact that a reproduction varies in color from an original.

Table 44 illustrates the ΔE^* for ISO 640 shot with and without a hot mirror. There is only one acceptable ΔE^* on Table 44, white ($2.32\Delta E^*$). All ΔE^* value fall beyond the range of $4\text{-}6\Delta E^*$ which would depict a "noticeable color difference."

Tables 45-48 illustrate the color difference between different ISO's while using a hot mirror filter. Tables 49-52 illustrate the color difference between different ISO's without using a hot mirror. Figure 2 and 3 show the trend of color difference between ISO's illustrated in ΔE^* values in Tables 45-52. All gamuts regardless of ISO are different with and or without a hot mirror filter.

ISO 640 and ISO 800 comparison illustrated on Table 45 photogrpahed with a hot mirror filter have the greatest ΔE^* values compared to the other ISO's. Table 49, ISO 640 and ISO 800 comparison without hot mirror filter also has the greatest ΔE^* values compared to the other ISO's. Table 45 has three wedges with ΔE^* less than five, three ΔE^* values between five and nine and sixteen ΔE^* values greater than nine. Table 49 has two ΔE^* values less than five, three less than 9 and nineteen ΔE^* values between 9 and $38.17\Delta E^*$. The large ΔE^* values illustrate the great color difference between ISO 640 and ISO 800. Of all the ISOs ISO 640 has the greatest gamut and ISO 800 has the smallest gamut.

Figure 5

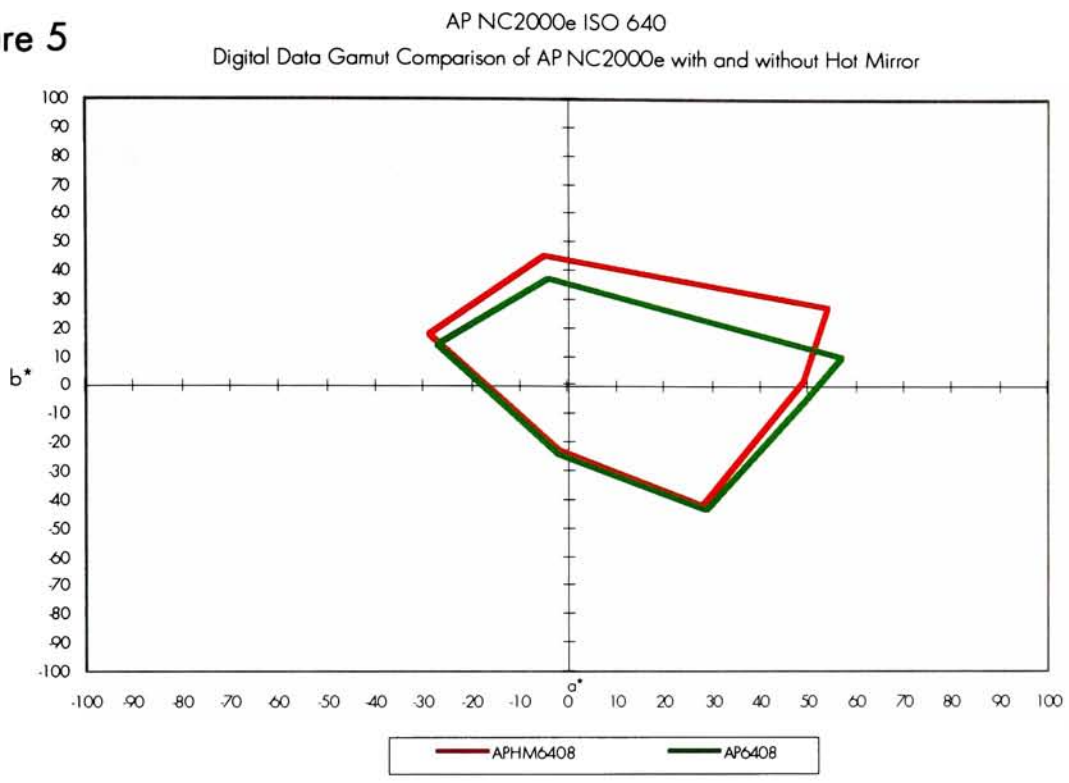

AP NC2000e ISO 640
Digital Data Gamut Comparison of AP NC2000e with and without Hot Mirror
b*
a*
APHM6408
AP6408

Table 42

ISO 640

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

	Orig Mac		AP6408		Orig Mac		AP6408			
	L*		L*		a*		a*		b*		b*		ΔE	
Dark Skin	1	37.86	50	13.84	16	14.83	0	19.29
Light skin	2	65.57	81	16.91	16	17.79	8	18.30
Blue sky	3	48.76	59	-4.86	1	-23.14	-17	13.30
Foliage	4	43.1	55	-14.2	-5	20.01	5	21.25
Blue flower	5	54.48	69	8.97	15	-25.04	-15	18.65
Bluish green	6	69.85	83	-32.49	-19	-1.04	-2	18.86
Orange	7	62.1	75	34.86	22	63	27	40.35
Purplish blue	8	38.97	51	9.75	21	-43.64	-34	19.08
Moderate Red	9	50.32	67	48.78	43	16.89	8	19.77
Purple	10	29.92	48	22.71	32	-21.7	-19	20.51
Yellow green	11	71.67	83	-24.09	-25	59.42	32	29.68
Orange yello\	12	71.66	82	20.07	8	68.48	33	38.88
Blue	13	28.15	39	20.92	29	-56.17	-44	18.20
Green	14	54.11	65	-40.49	-27	33.08	14	25.78
Red	15	41.5	61	58.17	57	29.8	10	27.81
Yellow	16	81.82	87	3.7	-4	80.35	37	44.33
Magenta	17	51.35	69	49.87	50	-14.01	-5	19.82
Cyan	18	48.9	62	-29.14	-2	-30.58	-24	30.85
White	19	94.89	93	-0.34	-1	-0.18	1	2.32
Neutral 8	20	80.36	87	-0.11	-1	-0.39	1	6.84
Neutral 6.5	21	64.48	75	-0.01	-1	-0.24	2	10.80
Neutral 5	22	49.48	58	-0.4	1	-0.51	-2	8.76
Neutral 3.5	23	35.11	42	0.02	4	-0.43	-4	8.72
Black	24	20.56	25	0.46	8	-0.18	-8	11.74

Table 43

ISO 640

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM6408 L*	Orig Mac a*	APHM6408 a*	Orig Mac b*	APHM6408 b*	ΔE
Dark Skin	1	37.86	43	13.84	12	14.83	9	7.99
Light skin	2	65.57	74	16.91	14	17.79	13	10.12
Blue sky	3	48.76	54	-4.86	1	-23.14	-15	11.32
Foliage	4	43.1	48	-14.2	-9	20.01	12	10.73
Blue flower	5	54.48	63	8.97	15	-25.04	-15	14.48
Bluish green	6	69.85	78	-32.49	-19	-1.04	-2	15.79
Orange	7	62.1	68	34.86	19	63	37	31.02
Purplish blue	8	38.97	44	9.75	18	-43.64	-30	16.72
Moderate Red	9	50.32	60	48.78	42	16.89	15	11.97
Purple	10	29.92	38	22.71	28	-21.7	-8	16.76
Yellow green	11	71.67	80	-24.09	-26	59.42	36	24.93
Orange yello\	12	71.66	78	20.07	6	68.48	41	31.52
Blue	13	28.15	31	20.92	28	-56.17	-42	16.09
Green	14	54.11	59	-40.49	-29	33.08	18	19.58
Red	15	41.5	53	58.17	54	29.8	27	12.55
Yellow	16	81.82	85	3.7	-5	80.35	45	36.54
Magenta	17	51.35	61	49.87	49	-14.01	1	17.87
Cyan	18	48.9	56	-29.14	-2	-30.58	-23	29.06
White	19	94.89	90	-0.34	0	-0.18	0	4.91
Neutral 8	20	80.36	84	-0.11	-1	-0.39	1	4.00
Neutral 6.5	21	64.48	70	-0.01	-1	-0.24	1	5.74
Neutral 5	22	49.48	53	-0.4	1	-0.51	-1	3.82
Neutral 3.5	23	35.11	37	0.02	3	-0.43	-2	3.86
Black	24	20.56	20	0.46	3	-0.18	-2	3.17

Table 44

ISO 640

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

	APHM6408 L*	AP6408 L*	APHM6408 a*	AP6408 a*	APHM6408 b*	AP6408 b*	ΔE	
Dark Skin	1	43	50	12	16	9	0	12.08
Light skin	2	74	81	14	16	13	8	8.83
Blue sky	3	54	59	1	1	-15	-17	5.39
Foliage	4	48	55	-9	-5	12	5	10.68
Blue flower	5	63	69	15	15	-15	-15	6.00
Bluish green	6	78	83	-19	-19	-2	-2	5.00
Orange	7	68	75	19	22	37	27	12.57
Purplish blue	8	44	51	18	21	-30	-34	8.60
Moderate Red	9	60	67	42	43	15	8	9.95
Purple	10	38	48	28	32	-8	-19	15.39
Yellow green	11	80	83	-26	-25	36	32	5.10
Orange yellow	12	78	82	6	8	41	33	9.17
Blue	13	31	39	28	29	-42	-44	8.31
Green	14	59	65	-29	-27	18	14	7.48
Red	15	53	61	54	57	27	10	19.03
Yellow	16	85	87	-5	-4	45	37	8.31
Magenta	17	61	69	49	50	1	-5	10.05
Cyan	18	56	62	-2	-2	-23	-24	6.08
White	19	90	93	0	-1	0	1	3.32
Neutral 8	20	84	87	-1	-1	1	1	3.00
Neutral 6.5	21	70	75	-1	-1	1	2	5.10
Neutral 5	22	53	58	1	1	-1	-2	5.10
Neutral 3.5	23	37	42	3	4	-2	-4	5.48
Black	24	20	25	3	8	-2	-8	9.27

Table 45

ISO 640 & ISO 800

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM6408 L*	APHM8008 L*	APHM6408 a*	APHM8008 a*	APHM6408 b*	APHM8008 b*	ΔE
Dark Skin	1	43	41	12	17	9	-2	12.25
Light skin	2	74	67	14	18	13	3	12.85
Blue sky	3	54	48	1	6	-15	-16	7.87
Foliage	4	48	45	-9	5	12	-1	19.34
Blue flower	5	63	53	15	19	-15	-18	11.18
Bluish green	6	78	65	-19	-13	-2	-4	14.46
Orange	7	68	62	19	20	37	19	19.00
Purplish blue	8	44	40	18	21	-30	-30	5.00
Moderate Red	9	60	54	42	42	15	-4	19.92
Purple	10	38	42	28	36	-8	-22	16.61
Yellow green	11	80	68	-26	-19	36	24	18.36
Orange yellow	12	78	66	6	8	41	24	20.90
Blue	13	31	29	28	29	-42	-39	3.74
Green	14	59	53	-29	-20	18	11	12.88
Red	15	53	49	54	50	27	2	25.63
Yellow	16	85	80	-5	-2	45	30	16.09
Magenta	17	61	55	49	47	1	-12	14.46
Cyan	18	56	45	-2	2	-23	-23	11.70
White	19	90	87	0	0	0	0	3.00
Neutral 8	20	84	77	-1	0	1	-1	7.35
Neutral 6.5	21	70	60	-1	1	1	-2	10.63
Neutral 5	22	53	45	1	3	-1	-4	8.77
Neutral 3.5	23	37	31	3	4	-2	-5	6.78
Black	24	20	17	3	6	-2	-3	4.36

Table 46

ISO 640 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM6408 L*	APHM10008 L*	APHM6408 a*	APHM10008 a*	APHM6408 b*	APHM10008 b*	ΔE
Dark Skin	1	43	38	12	13	9	6	5.92
Light skin	2	74	66	14	14	13	9	8.94
Blue sky	3	54	47	1	1	-15	-15	7.00
Foliage	4	48	42	-9	-6	12	8	7.81
Blue flower	5	63	55	15	16	-15	-15	8.06
Bluish green	6	78	69	-19	-16	-2	-3	9.54
Orange	7	68	60	19	19	37	28	12.04
Purplish blue	8	44	38	18	18	-30	-29	6.08
Moderate Red	9	60	53	42	39	15	8	10.34
Purple	10	38	34	28	26	-8	-8	4.47
Yellow green	11	80	70	-26	-22	36	29	12.85
Orange yellow	12	78	69	6	6	41	33	12.04
Blue	13	31	26	28	28	-42	-40	5.39
Green	14	59	51	-29	-25	18	14	9.80
Red	15	53	47	54	49	27	19	11.18
Yellow	16	85	80	-5	-4	45	39	7.87
Magenta	17	61	54	49	45	1	-2	8.60
Cyan	18	56	48	-2	-1	-23	-22	8.12
White	19	90	86	0	0	0	0	4.00
Neutral 8	20	84	77	-1	-1	1	0	7.07
Neutral 6.5	21	70	61	-1	1	1	-2	9.70
Neutral 5	22	53	46	1	2	-1	-3	7.35
Neutral 3.5	23	37	31	3	4	-2	-3	6.16
Black	24	20	17	3	4	-2	-4	3.74

Table 47

ISO 640 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM6408 L*		APHM12508 L*	APHM6408 a*		APHM12508 a*	APHM6408 b*		APHM12508 b*	ΔE
Dark Skin	1	43	41	12	14	9	7	3.46			
Light skin	2	74	72	14	16	13	10	4.12			
Blue sky	3	54	52	1	2	-15	-16	2.45			
Foliage	4	48	47	-9	-8	12	12	1.41			
Blue flower	5	63	61	15	16	-15	-15	2.24			
Bluish green	6	78	76	-19	-18	-2	-3	2.45			
Orange	7	68	66	19	21	37	31	6.63			
Purplish blue	8	44	42	18	18	-30	-30	2.00			
Moderate Red	9	60	58	42	42	15	12	3.61			
Purple	10	38	38	28	29	-8	-9	1.41			
Yellow green	11	80	77	-26	-25	36	33	4.36			
Orange yellow	12	78	76	6	7	41	37	4.58			
Blue	13	31	30	28	29	-42	-42	1.41			
Green	14	59	57	-29	-26	18	15	4.69			
Red	15	53	52	54	52	27	26	2.45			
Yellow	16	85	84	-5	-4	45	42	3.32			
Magenta	17	61	60	49	49	1	-2	3.16			
Cyan	18	56	53	-2	-1	-23	-24	3.32			
White	19	90	89	0	0	0	0	1.00			
Neutral 8	20	84	83	-1	0	1	0	1.73			
Neutral 6.5	21	70	67	-1	1	1	-1	4.12			
Neutral 5	22	53	51	1	2	-1	-2	2.45			
Neutral 3.5	23	37	35	3	1	-2	1	4.12			
Black	24	20	18	3	6	-2	-3	3.74			

Table 48

ISO 640 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

	APHM6408 L*	APHM16008 L*	APHM6408 a*	APHM16008 a*	APHM6408 b*	APHM16008 b*	ΔE
Dark Skin	1	43	41	12	14	9	2	7.55
Light skin	2	74	70	14	16	13	7	7.48
Blue sky	3	54	50	1	1	-15	-15	4.00
Foliage	4	48	45	-9	-5	12	6	7.81
Blue flower	5	63	59	15	16	-15	-16	4.24
Bluish green	6	78	74	-19	-16	-2	-3	5.10
Orange	7	68	65	19	21	37	26	11.58
Purplish blue	8	44	42	18	19	-30	-29	2.45
Moderate Red	9	60	56	42	41	15	9	7.28
Purple	10	38	37	28	29	-8	-12	4.24
Yellow green	11	80	75	-26	-23	36	29	9.11
Orange yellow	12	78	74	6	8	41	32	10.05
Blue	13	31	30	28	28	-42	-40	2.24
Green	14	59	56	-29	-23	18	12	9.00
Red	15	53	51	54	51	27	20	7.87
Yellow	16	85	83	-5	-3	45	37	8.49
Magenta	17	61	58	49	47	1	-3	5.39
Cyan	18	56	52	-2	0	-23	-23	4.47
White	19	90	89	0	0	0	0	1.00
Neutral 8	20	84	82	-1	0	1	0	2.45
Neutral 6.5	21	70	66	-1	1	1	-1	4.90
Neutral 5	22	53	50	1	3	-1	-3	4.12
Neutral 3.5	23	37	35	3	4	-2	-4	3.00
Black	24	20	18	3	7	-2	-8	7.48

Table 49

ISO 640 & ISO 800

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP6408 L*	AP8008 L*	AP6408 a*	AP8008 a*	AP6408 b*	AP8008 b*	ΔE
Dark Skin	1	50	68	16	24	0	-18	26.68
Light skin	2	81	86	16	20	8	-10	19.10
Blue sky	3	59	64	1	8	-17	-16	8.66
Foliage	4	55	69	-5	14	5	-14	30.30
Blue flower	5	69	75	15	18	-15	-18	7.35
Bluish green	6	83	82	-19	-5	-2	-7	14.90
Orange	7	75	83	22	22	27	-4	32.02
Purplish blue	8	51	72	21	25	-34	-31	21.59
Moderate Red	9	67	80	43	36	8	-17	29.03
Purple	10	48	78	32	36	-19	-32	32.94
Yellow green	11	83	84	-25	-3	32	3	36.41
Orange yellov	12	82	84	8	15	33	-1	34.77
Blue	13	39	62	29	27	-44	-34	25.16
Green	14	65	75	-27	-2	14	-7	34.15
Red	15	61	80	57	43	10	-20	38.17
Yellow	16	87	89	-4	6	37	5	33.59
Magenta	17	69	82	50	40	-5	-23	24.35
Cyan	18	62	70	-2	12	-24	-25	16.16
White	19	93	93	-1	0	1	0	1.41
Neutral 8	20	87	87	-1	2	1	-2	4.24
Neutral 6.5	21	75	78	-1	4	2	-4	8.37
Neutral 5	22	58	64	1	9	-2	-10	12.81
Neutral 3.5	23	42	51	4	12	-4	-14	15.65
Black	24	25	40	8	16	-8	-17	19.24

Table 50

ISO 640 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP6408 L*	AP10008 L*	AP6408 a*	AP10008 a*	AP6408 b*	AP10008 b*	ΔE
Dark Skin	1	50	47	16	19	0	-10	10.86
Light skin	2	81	75	16	18	8	1	9.43
Blue sky	3	59	53	1	2	-17	-16	6.16
Foliage	4	55	50	-5	2	5	-4	12.45
Blue flower	5	69	63	15	16	-15	-17	6.40
Bluish green	6	83	76	-19	-15	-2	-4	8.31
Orange	7	75	69	22	22	27	12	16.16
Purplish blue	8	51	49	21	23	-34	-34	2.83
Moderate Red	9	67	62	43	40	8	-2	11.58
Purple	10	48	48	32	32	-19	-25	6.00
Yellow green	11	83	78	-25	-19	32	21	13.49
Orange yello	12	82	78	8	8	33	22	11.70
Blue	13	39	38	29	29	-44	-41	3.16
Green	14	65	60	-27	-17	14	3	15.68
Red	15	61	58	57	50	10	-4	15.94
Yellow	16	87	84	-4	-1	37	25	12.73
Magenta	17	69	64	50	47	-5	-13	9.90
Cyan	18	62	56	-2	4	-24	-26	8.72
White	19	93	89	-1	-1	1	0	4.12
Neutral 8	20	87	83	-1	-1	1	0	4.12
Neutral 6.5	21	75	67	-1	1	2	-2	9.17
Neutral 5	22	58	52	1	4	-2	-6	7.81
Neutral 3.5	23	42	38	4	7	-4	-9	7.07
Black	24	25	23	8	11	-8	-12	5.39

Table 51

ISO 640 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP6408 L*	AP12508 L*	AP6408 a*	AP12508 a*	AP6408 b*	AP12508 b*	ΔE
Dark Skin	1	50	52	16	19	0	-9	9.70
Light skin	2	81	81	16	18	8	1	7.28
Blue sky	3	59	58	1	3	-17	-17	2.24
Foliage	4	55	55	-5	1	5	-3	10.00
Blue flower	5	69	68	15	17	-15	-17	3.00
Bluish green	6	83	82	-19	-17	-2	-2	2.24
Orange	7	75	75	22	24	27	14	13.15
Purplish blue	8	51	54	21	23	-34	-35	3.74
Moderate Red	9	67	67	43	42	8	-3	11.05
Purple	10	48	52	32	35	-19	-27	9.43
Yellow green	11	83	82	-25	-20	32	22	11.22
Orange yellov	12	82	82	8	9	33	23	10.05
Blue	13	39	43	29	30	-44	-43	4.24
Green	14	65	65	-27	-16	14	2	16.28
Red	15	61	64	57	54	10	-2	12.73
Yellow	16	87	87	-4	-1	37	27	10.44
Magenta	17	69	70	50	48	-5	-12	7.35
Cyan	18	62	61	-2	4	-24	-27	6.78
White	19	93	92	-1	0	1	0	1.73
Neutral 8	20	87	86	-1	-1	1	1	1.00
Neutral 6.5	21	75	73	-1	2	2	-4	7.00
Neutral 5	22	58	58	1	4	-2	-6	5.00
Neutral 3.5	23	42	42	4	7	-4	-10	6.71
Black	24	25	27	8	10	-8	-10	3.46

Table 52

ISO 640 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP6408 L*	AP16008 L*	AP6408 a*	AP16008 a*	AP6408 b*	AP16008 b*	ΔE
Dark Skin	1	50	51	16	20	0	-9	9.90
Light skin	2	81	80	16	20	8	0	9.00
Blue sky	3	59	56	1	3	-17	-15	4.12
Foliage	4	55	53	-5	3	5	-3	11.49
Blue flower	5	69	67	15	17	-15	-16	3.00
Bluish green	6	83	80	-19	-14	-2	-5	6.56
Orange	7	75	74	22	26	27	11	16.52
Purplish blue	8	51	53	21	26	-34	-35	5.48
Moderate Red	9	67	66	43	42	8	-4	12.08
Purple	10	48	53	32	36	-19	-27	10.25
Yellow green	11	83	82	-25	-16	32	20	15.03
Orange yellov	12	82	82	8	12	33	21	12.65
Blue	13	39	42	29	31	-44	-42	4.12
Green	14	65	64	-27	-15	14	2	17.00
Red	15	61	64	57	54	10	-7	17.52
Yellow	16	87	87	-4	1	37	24	13.93
Magenta	17	69	69	50	50	-5	-14	9.00
Cyan	18	62	60	-2	6	-24	-27	8.77
White	19	93	91	-1	1	1	1	2.83
Neutral 8	20	87	85	-1	0	1	1	2.24
Neutral 6.5	21	75	72	-1	3	2	-2	6.40
Neutral 5	22	58	56	1	5	-2	-5	5.39
Neutral 3.5	23	42	41	4	8	-4	-7	5.10
Black	24	25	25	8	11	-8	-9	3.16

AP NC2000e ISO800 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 800 f/8 without the hot mirror filter in Figure 6 is smaller than the gamut of the test image photographed with the hot mirror filter. The reduction in gamut is most significant in the yellow, green and red regions. Unlike lower ISO gamuts ISO 800 does not share a common boundary at blue. The magenta area of the non hot mirror filter gamut at ISO 800 falls within the gamut of the the hot mirror filter test image. According to the gamut of Figure 3 there is less magenta cast found in the ISO 800 image taken without the hot mirror filter than in other ISO's photographed without the hot mirror filter.

If we examine the ΔE^* values from ISO 800 comparing hot mirror filter vs. no hot mirror filter in Table 55 we can note that all values except those dealing with neutral wedges range from 16.12ΔE^* at sky blue to 38.65ΔE^* at red. Nine color wedges have ΔE^* values greater than 30, ten swatches have values between 20 and 30 with three wedges having ΔE^* values between 16 and 20.

Table 53 and 54 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror. Tables 53 and 54 illustrate the fact that a reproduction varies in color from the original.

Tables 56-58 illustrate the color difference between different ISO's while using a hot mirror filter. Tables 59-61 illustrate the color difference between different ISO's without the use of a hot mirror. Figures 2 and 3 show the trend of color difference between ISO's illustrated in ΔE^* values in tables 56-61. All gamuts regardless of ISO and use of a hot mirror filter or not are different.

Figure 6

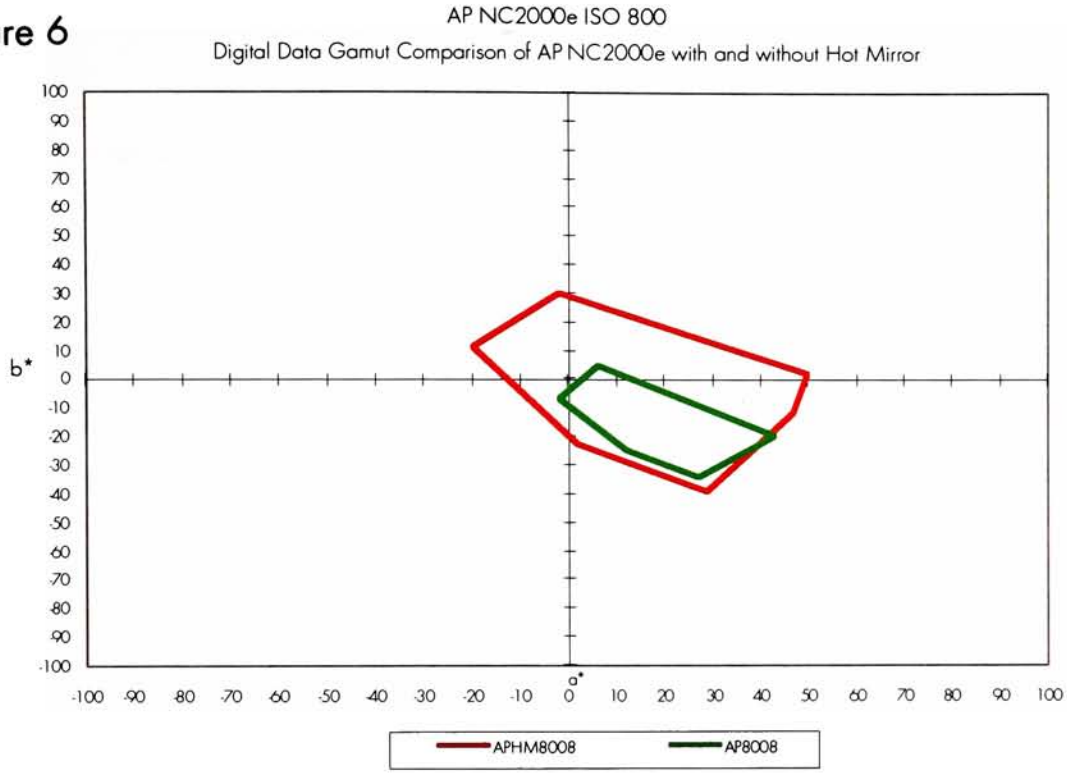

AP NC2000e ISO 800
Digital Data Gamut Comparison of AP NC2000e with and without Hot Mirror
b*
a*
APHM8008
AP8008

Table 53

ISO 800

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

		Orig Mac L*	AP8008 L*	Orig Mac a*	AP8008 a*	Orig Mac b*	AP8008 b*	ΔE
Dark Skin	1	37.86	68	13.84	24	14.83	-18	45.71
Light skin	2	65.57	86	16.91	20	17.79	-10	34.63
Blue sky	3	48.76	64	-4.86	8	-23.14	-16	21.18
Foliage	4	43.1	69	-14.2	14	20.01	-14	51.21
Blue flower	5	54.48	75	8.97	18	-25.04	-18	23.50
Bluish green	6	69.85	82	-32.49	-5	-1.04	-7	30.64
Orange	7	62.1	83	34.86	22	63	-4	71.35
Purplish blue	8	38.97	72	9.75	25	-43.64	-31	38.51
Moderate Red	9	50.32	80	48.78	36	16.89	-17	46.83
Purple	10	29.92	78	22.71	36	-21.7	-32	50.94
Yellow green	11	71.67	84	-24.09	-3	59.42	3	61.48
Orange yello\	12	71.66	84	20.07	15	68.48	-1	70.75
Blue	13	28.15	62	20.92	27	-56.17	-34	40.92
Green	14	54.11	75	-40.49	-2	33.08	-7	59.37
Red	15	41.5	80	58.17	43	29.8	-20	64.75
Yellow	16	81.82	89	3.7	6	80.35	5	75.73
Magenta	17	51.35	82	49.87	40	-14.01	-23	33.43
Cyan	18	48.9	70	-29.14	12	-30.58	-25	46.57
White	19	94.89	93	-0.34	0	-0.18	0	1.93
Neutral 8	20	80.36	87	-0.11	2	-0.39	-2	7.15
Neutral 6.5	21	64.48	78	-0.01	4	-0.24	-4	14.59
Neutral 5	22	49.48	64	-0.4	9	-0.51	-10	19.73
Neutral 3.5	23	35.11	51	0.02	12	-0.43	-14	24.09
Black	24	20.56	40	0.46	16	-0.18	-17	30.04

Table 54

ISO 800

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM8008 L*	Orig Mac a*	APHM8008 a*	Orig Mac b*	APHM8008 b*	ΔE
Dark Skin	1	37.86	41	13.84	17	14.83	-2	17.41
Light skin	2	65.57	67	16.91	18	17.79	3	14.90
Blue sky	3	48.76	48	-4.86	6	-23.14	-16	13.02
Foliage	4	43.1	45	-14.2	5	20.01	-1	28.52
Blue flower	5	54.48	53	8.97	19	-25.04	-18	12.34
Bluish green	6	69.85	65	-32.49	-13	-1.04	-4	20.30
Orange	7	62.1	62	34.86	20	63	19	46.44
Purplish blue	8	38.97	40	9.75	21	-43.64	-30	17.71
Moderate Red	9	50.32	54	48.78	42	16.89	-4	22.27
Purple	10	29.92	42	22.71	36	-21.7	-22	17.96
Yellow green	11	71.67	68	-24.09	-19	59.42	24	35.97
Orange yello\	12	71.66	66	20.07	8	68.48	24	46.43
Blue	13	28.15	29	20.92	29	-56.17	-39	19.00
Green	14	54.11	53	-40.49	-20	33.08	11	30.14
Red	15	41.5	49	58.17	50	29.8	2	29.93
Yellow	16	81.82	80	3.7	-2	80.35	30	50.70
Magenta	17	51.35	55	49.87	47	-14.01	-12	5.06
Cyan	18	48.9	45	-29.14	2	-30.58	-23	32.29
White	19	94.89	87	-0.34	0	-0.18	0	7.90
Neutral 8	20	80.36	77	-0.11	0	-0.39	-1	3.42
Neutral 6.5	21	64.48	60	-0.01	1	-0.24	-2	4.92
Neutral 5	22	49.48	45	-0.4	3	-0.51	-4	6.62
Neutral 3.5	23	35.11	31	0.02	4	-0.43	-5	7.32
Black	24	20.56	17	0.46	6	-0.18	-3	7.16

Table 55

ISO 800

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

		APHM8008 L*	AP8008 L*	APHM8008 a*	AP8008 a*	APHM8008 b*	AP8008 b*	ΔE
Dark Skin	1	41	68	17	24	-2	-18	32.16
Light skin	2	67	86	18	20	3	-10	23.11
Blue sky	3	48	64	6	8	-16	-16	16.12
Foliage	4	45	69	5	14	-1	-14	28.74
Blue flower	5	53	75	19	18	-18	-18	22.02
Bluish green	6	65	82	-13	-5	-4	-7	19.03
Orange	7	62	83	20	22	19	-4	31.21
Purplish blue	8	40	72	21	25	-30	-31	32.26
Moderate Red	9	54	80	42	36	-4	-17	29.68
Purple	10	42	78	36	36	-22	-32	37.36
Yellow green	11	68	84	-19	-3	24	3	30.87
Orange yellow	12	66	84	8	15	24	-1	31.59
Blue	13	29	62	29	27	-39	-34	33.44
Green	14	53	75	-20	-2	11	-7	33.65
Red	15	49	80	50	43	2	-20	38.65
Yellow	16	80	89	-2	6	30	5	27.75
Magenta	17	55	82	47	40	-12	-23	29.98
Cyan	18	45	70	2	12	-23	-25	27.00
White	19	87	93	0	0	0	0	6.00
Neutral 8	20	77	87	0	2	-1	-2	10.25
Neutral 6.5	21	60	78	1	4	-2	-4	18.36
Neutral 5	22	45	64	3	9	-4	-10	20.81
Neutral 3.5	23	31	51	4	12	-5	-14	23.35
Black	24	17	40	6	16	-3	-17	28.72

Table 56

ISO 800 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM8008 L*	APHM10008 L*	APHM8008 a*	APHM10008 a*	APHM8008 b*	APHM10008 b*	ΔE
Dark Skin	1	41	38	17	13	-2	6	9.43
Light skin	2	67	66	18	14	3	9	7.28
Blue sky	3	48	47	6	1	-16	-15	5.20
Foliage	4	45	42	5	-6	-1	8	14.53
Blue flower	5	53	55	19	16	-18	-15	4.69
Bluish green	6	65	69	-13	-16	-4	-3	5.10
Orange	7	62	60	20	19	19	28	9.27
Purplish blue	8	40	38	21	18	-30	-29	3.74
Moderate Red	9	54	53	42	39	-4	8	12.41
Purple	10	42	34	36	26	-22	-8	18.97
Yellow green	11	68	70	-19	-22	24	29	6.16
Orange yellow	12	66	69	8	6	24	33	9.70
Blue	13	29	26	29	28	-39	-40	3.32
Green	14	53	51	-20	-25	11	14	6.16
Red	15	49	47	50	49	2	19	17.15
Yellow	16	80	80	-2	-4	30	39	9.22
Magenta	17	55	54	47	45	-12	-2	10.25
Cyan	18	45	48	2	-1	-23	-22	4.36
White	19	87	86	0	0	0	0	1.00
Neutral 8	20	77	77	0	-1	-1	0	1.41
Neutral 6.5	21	60	61	1	1	-2	-2	1.00
Neutral 5	22	45	46	3	2	-4	-3	1.73
Neutral 3.5	23	31	31	4	4	-5	-3	2.00
Black	24	17	17	6	4	-3	-4	2.24

Table 57

ISO 800 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

	APHM8008 L*	APHM12508 L*	APHM8008 a*	APHM12508 a*	APHM8008 b*	APHM12508 b*	ΔE
Dark Skin	1	41	41	17	14	-2	7	9.49
Light skin	2	67	72	18	16	3	10	8.83
Blue sky	3	48	52	6	2	-16	-16	5.66
Foliage	4	45	47	5	-8	-1	12	18.49
Blue flower	5	53	61	19	16	-18	-15	9.06
Bluish green	6	65	76	-13	-18	-4	-3	12.12
Orange	7	62	66	20	21	19	31	12.69
Purplish blue	8	40	42	21	18	-30	-30	3.61
Moderate Red	9	54	58	42	42	-4	12	16.49
Purple	10	42	38	36	29	-22	-9	15.30
Yellow green	11	68	77	-19	-25	24	33	14.07
Orange yellow	12	66	76	8	7	24	37	16.43
Blue	13	29	30	29	29	-39	-42	3.16
Green	14	53	57	-20	-26	11	15	8.25
Red	15	49	52	50	52	2	26	24.27
Yellow	16	80	84	-2	-4	30	42	12.81
Magenta	17	55	60	47	49	-12	-2	11.36
Cyan	18	45	53	2	-1	-23	-24	8.60
White	19	87	89	0	0	0	0	2.00
Neutral 8	20	77	83	0	0	-1	0	6.08
Neutral 6.5	21	60	67	1	1	-2	-1	7.07
Neutral 5	22	45	51	3	2	-4	-2	6.40
Neutral 3.5	23	31	35	4	1	-5	1	7.81
Black	24	17	18	6	6	-3	-3	1.00

Table 58

ISO 800 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM8008 L*	APHM16008 L*	APHM8008 a*	APHM16008 a*	APHM8008 b*	APHM16008 b*	ΔE
Dark Skin	1	41	41	17	14	-2	2	5.00
Light skin	2	67	70	18	16	3	7	5.39
Blue sky	3	48	50	6	1	-16	-15	5.48
Foliage	4	45	45	5	-5	-1	6	12.21
Blue flower	5	53	59	19	16	-18	-16	7.00
Bluish green	6	65	74	-13	-16	-4	-3	9.54
Orange	7	62	65	20	21	19	26	7.68
Purplish blue	8	40	42	21	19	-30	-29	3.00
Moderate Red	9	54	56	42	41	-4	9	13.19
Purple	10	42	37	36	29	-22	-12	13.19
Yellow green	11	68	75	-19	-23	24	29	9.49
Orange yellow	12	66	74	8	8	24	32	11.31
Blue	13	29	30	29	28	-39	-40	1.73
Green	14	53	56	-20	-23	11	12	4.36
Red	15	49	51	50	51	2	20	18.14
Yellow	16	80	83	-2	-3	30	37	7.68
Magenta	17	55	58	47	47	-12	-3	9.49
Cyan	18	45	52	2	0	-23	-23	7.28
White	19	87	89	0	0	0	0	2.00
Neutral 8	20	77	82	0	0	-1	0	5.10
Neutral 6.5	21	60	66	1	1	-2	-1	6.08
Neutral 5	22	45	50	3	3	-4	-3	5.10
Neutral 3.5	23	31	35	4	4	-5	-4	4.12
Black	24	17	18	6	7	-3	-8	5.20

Table 59

ISO 800 & ISO 1000

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP8008 L*	AP10008 L*	AP8008 a*	AP10008 a*	AP8008 b*	AP10008 b*	ΔE
Dark Skin	1	68	47	24	19	-18	-10	23.02
Light skin	2	86	75	20	18	-10	1	15.68
Blue sky	3	64	53	8	2	-16	-16	12.53
Foliage	4	69	50	14	2	-14	-4	24.60
Blue flower	5	75	63	18	16	-18	-17	12.21
Bluish green	6	82	76	-5	-15	-7	-4	12.04
Orange	7	83	69	22	22	-4	12	21.26
Purplish blue	8	72	49	25	23	-31	-34	23.28
Moderate Red	9	80	62	36	40	-17	-2	23.77
Purple	10	78	48	36	32	-32	-25	31.06
Yellow green	11	84	78	-3	-19	3	21	24.82
Orange yellov	12	84	78	15	8	-1	22	24.78
Blue	13	62	38	27	29	-34	-41	25.08
Green	14	75	60	-2	-17	-7	3	23.45
Red	15	80	58	43	50	-20	-4	28.09
Yellow	16	89	84	6	-1	5	25	21.77
Magenta	17	82	64	40	47	-23	-13	21.75
Cyan	18	70	56	12	4	-25	-26	16.16
White	19	93	89	0	-1	0	0	4.12
Neutral 8	20	87	83	2	-1	-2	0	5.39
Neutral 6.5	21	78	67	4	1	-4	-2	11.58
Neutral 5	22	64	52	9	4	-10	-6	13.60
Neutral 3.5	23	51	38	12	7	-14	-9	14.80
Black	24	40	23	16	11	-17	-12	18.41

Table 60

ISO 800 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP8008 L*	AP12508 L*	AP8008 a*	AP12508 a*	APHM8008 b*	AP12508 b*	ΔE
Dark Skin	1	68	52	24	19	-2	-9	18.17
Light skin	2	86	81	20	18	3	1	5.74
Blue sky	3	64	58	8	3	-16	-17	7.87
Foliage	4	69	55	14	1	-1	-3	19.21
Blue flower	5	75	68	18	17	-18	-17	7.14
Bluish green	6	82	82	-5	-17	-4	-2	12.17
Orange	7	83	75	22	24	19	14	9.64
Purplish blue	8	72	54	25	23	-30	-35	18.79
Moderate Red	9	80	67	36	42	-4	-3	14.35
Purple	10	78	52	36	35	-22	-27	26.50
Yellow green	11	84	82	-3	-20	24	22	17.23
Orange yello\	12	84	82	15	9	24	23	6.40
Blue	13	62	43	27	30	-39	-43	19.65
Green	14	75	65	-2	-16	11	2	19.42
Red	15	80	64	43	54	2	-2	19.82
Yellow	16	89	87	6	-1	30	27	7.87
Magenta	17	82	70	40	48	-12	-12	14.42
Cyan	18	70	61	12	4	-23	-27	12.69
White	19	93	92	0	0	0	0	1.00
Neutral 8	20	87	86	2	-1	-1	1	3.74
Neutral 6.5	21	78	73	4	2	-2	-4	5.74
Neutral 5	22	64	58	9	4	-4	-6	8.06
Neutral 3.5	23	51	42	12	7	-5	-10	11.45
Black	24	40	27	16	10	-3	-10	15.94

Table 61

ISO 800 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

		AP8008 L*	AP16008 L*	AP8008 a*	AP16008 a*	APHM8008 b*	AP16008 b*	ΔE
Dark Skin	1	68	51	24	20	-2	-9	18.81
Light skin	2	86	80	20	20	3	0	6.71
Blue sky	3	64	56	8	3	-16	-15	9.49
Foliage	4	69	53	14	3	-1	-3	19.52
Blue flower	5	75	67	18	17	-18	-16	8.31
Bluish green	6	82	80	-5	-14	-4	-5	9.27
Orange	7	83	74	22	26	19	11	12.69
Purplish blue	8	72	53	25	26	-30	-35	19.67
Moderate Red	9	80	66	36	42	-4	-4	15.23
Purple	10	78	53	36	36	-22	-27	25.50
Yellow green	11	84	82	-3	-16	24	20	13.75
Orange yello\	12	84	82	15	12	24	21	4.69
Blue	13	62	42	27	31	-39	-42	20.62
Green	14	75	64	-2	-15	11	2	19.26
Red	15	80	64	43	54	2	-7	21.40
Yellow	16	89	87	6	1	30	24	8.06
Magenta	17	82	69	40	50	-12	-14	16.52
Cyan	18	70	60	12	6	-23	-27	12.33
White	19	93	91	0	1	0	1	2.45
Neutral 8	20	87	85	2	0	-1	1	3.46
Neutral 6.5	21	78	72	4	3	-2	-2	6.08
Neutral 5	22	64	56	9	5	-4	-5	9.00
Neutral 3.5	23	51	41	12	8	-5	-7	10.95
Black	24	40	25	16	11	-3	-9	16.91

AP NC2000e ISO1000 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 1000 f/8 without the hot mirror filter in Figure 7 is smaller than the gamut of the test image photographed with the hot mirror filter. The reduction in gamut is most significant in the yellow, green and red region. The blue and cyan portion of the gamut shares a border for both test images.The non-hot mirror test image gamut border reflects an accentuation in the magenta region.

Tables 62 and 63 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror. Tables 62 and 63 illustrate the fact that a reproduction varies in color from the original.

Table 64 illustrates the actual CIELAB values and the corresponding ΔE^* values between the images shot with and without a hot mirror filter at ISO 1000. All but the white wedge (3.16ΔE^*) have values that fall beyond the range of 4-6ΔE^*. Falling beyond the range of 4-6ΔE^* denotes a "noticeable color difference."

Tables 65-66 illustrate the color difference between different ISO's while using a hot mirror filter. Tables 67-68 illustrate the color difference between different ISO's without using a hot mirror. Table 2 and 3 show the trend of color difference between ISO's illustrated in the ΔE^* values in Tables 65-68. All gamuts regardless of ISO have different color gamuts regardless of the use of a hot mirror filter.

Figure 7

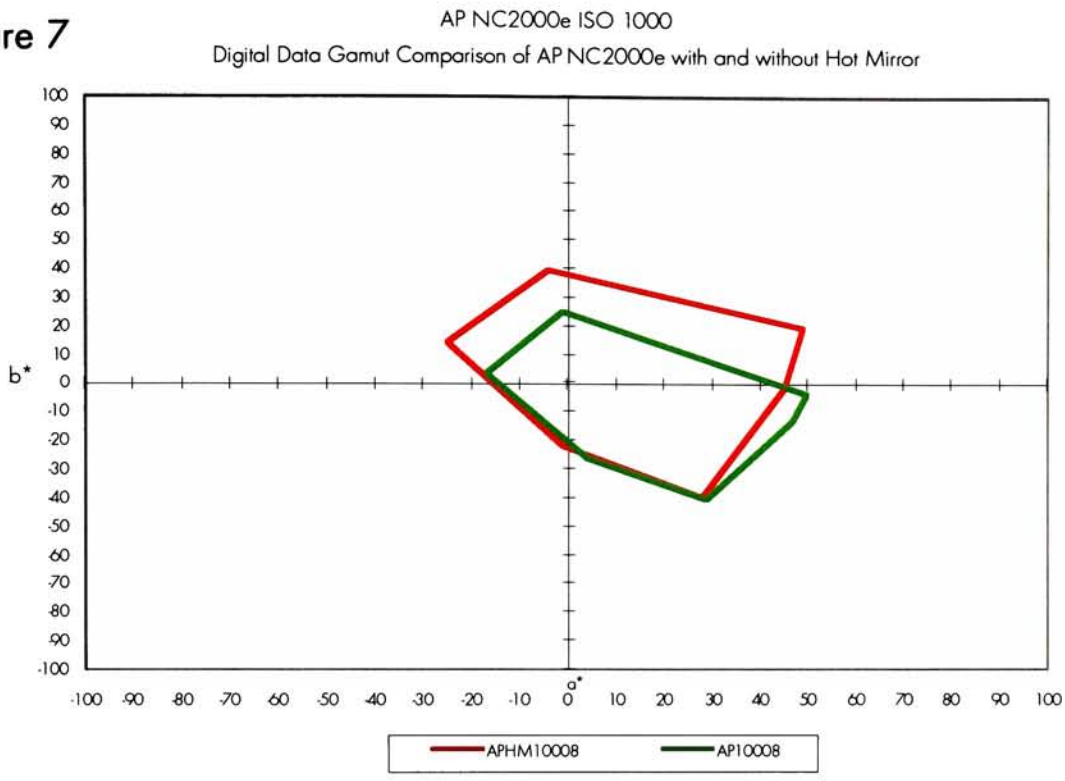

AP NC2000e ISO 1000
Digital Data Gamut Comparison of AP NC2000e with and without Hot Mirror
b*
a*
APHM10008
AP10008

Table 62

ISO 1000

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

		Orig Mac L*	AP10008 L*	Orig Mac a*	AP10008 a*	Orig Mac b*	AP10008 b*	ΔE
Dark Skin	1	37.86	47	13.84	19	14.83	-10	26.96
Light skin	2	65.57	75	16.91	18	17.79	1	19.29
Blue sky	3	48.76	53	-4.86	2	-23.14	-16	10.77
Foliage	4	43.1	50	-14.2	2	20.01	-4	29.77
Blue flower	5	54.48	63	8.97	16	-25.04	-17	13.66
Bluish green	6	69.85	76	-32.49	-15	-1.04	-4	18.77
Orange	7	62.1	69	34.86	22	63	12	53.05
Purplish blue	8	38.97	49	9.75	23	-43.64	-34	19.21
Moderate Red	9	50.32	62	48.78	40	16.89	-2	23.88
Purple	10	29.92	48	22.71	32	-21.7	-25	20.59
Yellow green	11	71.67	78	-24.09	-19	59.42	21	39.27
Orange yello\	12	71.66	78	20.07	8	68.48	22	48.44
Blue	13	28.15	38	20.92	29	-56.17	-41	19.81
Green	14	54.11	60	-40.49	-17	33.08	3	38.62
Red	15	41.5	58	58.17	50	29.8	-4	38.49
Yellow	16	81.82	84	3.7	-1	80.35	25	55.59
Magenta	17	51.35	64	49.87	47	-14.01	-13	13.01
Cyan	18	48.9	56	-29.14	4	-30.58	-26	34.20
White	19	94.89	89	-0.34	-1	-0.18	0	5.93
Neutral 8	20	80.36	83	-0.11	-1	-0.39	0	2.81
Neutral 6.5	21	64.48	67	-0.01	1	-0.24	-2	3.24
Neutral 5	22	49.48	52	-0.4	4	-0.51	-6	7.47
Neutral 3.5	23	35.11	38	0.02	7	-0.43	-9	11.42
Black	24	20.56	23	0.46	11	-0.18	-12	16.02

Table 63

ISO 1000

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM10008 L*	Orig Mac a*	APHM10008 a*	Orig Mac b*	APHM10008 b*	ΔE
Dark Skin	1	37.86	38	13.84	13	14.83	6	8.87
Light skin	2	65.57	66	16.91	14	17.79	9	9.27
Blue sky	3	48.76	47	-4.86	1	-23.14	-15	10.18
Foliage	4	43.1	42	-14.2	-6	20.01	8	14.58
Blue flower	5	54.48	55	8.97	16	-25.04	-15	12.27
Bluish green	6	69.85	69	-32.49	-16	-1.04	-3	16.63
Orange	7	62.1	60	34.86	19	63	28	38.48
Purplish blue	8	38.97	38	9.75	18	-43.64	-29	16.83
Moderate Red	9	50.32	53	48.78	39	16.89	8	13.49
Purple	10	29.92	34	22.71	26	-21.7	-8	14.67
Yellow green	11	71.67	70	-24.09	-22	59.42	29	30.54
Orange yello\	12	71.66	69	20.07	6	68.48	33	38.26
Blue	13	28.15	26	20.92	28	-56.17	-40	17.78
Green	14	54.11	51	-40.49	-25	33.08	14	24.77
Red	15	41.5	47	58.17	49	29.8	19	15.20
Yellow	16	81.82	80	3.7	-4	80.35	39	42.10
Magenta	17	51.35	54	49.87	45	-14.01	-2	13.23
Cyan	18	48.9	48	-29.14	-1	-30.58	-22	29.43
White	19	94.89	86	-0.34	0	-0.18	0	8.90
Neutral 8	20	80.36	77	-0.11	-1	-0.39	0	3.50
Neutral 6.5	21	64.48	61	-0.01	1	-0.24	-2	4.03
Neutral 5	22	49.48	46	-0.4	2	-0.51	-3	4.91
Neutral 3.5	23	35.11	31	0.02	4	-0.43	-3	6.27
Black	24	20.56	17	0.46	4	-0.18	-4	6.31

Table 64

ISO 1000

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

		APHM10008 L*	AP10008 L*	APHM10008 a*	AP10008 a*	APHM10008 b*	AP10008 b*	ΔE
Dark Skin	1	38	47	13	19	6	-10	19.31
Light skin	2	66	75	14	18	9	1	12.69
Blue sky	3	47	53	1	2	-15	-16	6.16
Foliage	4	42	50	-6	2	8	-4	16.49
Blue flower	5	55	63	16	16	-15	-17	8.25
Bluish green	6	69	76	-16	-15	-3	-4	7.14
Orange	7	60	69	19	22	28	12	18.60
Purplish blue	8	38	49	18	23	-29	-34	13.08
Moderate Red	9	53	62	39	40	8	-2	13.49
Purple	10	34	48	26	32	-8	-25	22.83
Yellow green	11	70	78	-22	-19	29	21	11.70
Orange yellow	12	69	78	6	8	33	22	14.35
Blue	13	26	38	28	29	-40	-41	12.08
Green	14	51	60	-25	-17	14	3	16.31
Red	15	47	58	49	50	19	-4	25.51
Yellow	16	80	84	-4	-1	39	25	14.87
Magenta	17	54	64	45	47	-2	-13	15.00
Cyan	18	48	56	-1	4	-22	-26	10.25
White	19	86	89	0	-1	0	0	3.16
Neutral 8	20	77	83	-1	-1	0	0	6.00
Neutral 6.5	21	61	67	1	1	-2	-2	6.00
Neutral 5	22	46	52	2	4	-3	-6	7.00
Neutral 3.5	23	31	38	4	7	-3	-9	9.70
Black	24	17	23	4	11	-4	-12	12.21

Table 65

ISO 1000 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM10008 L*	APHM12508 L*	APHM10008 a*	APHM12508 a*	APHM10008 b*	APHM12508 b*	ΔE
Dark Skin	1	38	41	13	14	6	7	3.32
Light skin	2	66	72	14	16	9	10	6.40
Blue sky	3	47	52	1	2	-15	-16	5.20
Foliage	4	42	47	-6	-8	8	12	6.71
Blue flower	5	55	61	16	16	-15	-15	6.00
Bluish green	6	69	76	-16	-18	-3	-3	7.28
Orange	7	60	66	19	21	28	31	7.00
Purplish blue	8	38	42	18	18	-29	-30	4.12
Moderate Red	9	53	58	39	42	8	12	7.07
Purple	10	34	38	26	29	-8	-9	5.10
Yellow green	11	70	77	-22	-25	29	33	8.60
Orange yellow	12	69	76	6	7	33	37	8.12
Blue	13	26	30	28	29	-40	-42	4.58
Green	14	51	57	-25	-26	14	15	6.16
Red	15	47	52	49	52	19	26	9.11
Yellow	16	80	84	-4	-4	39	42	5.00
Magenta	17	54	60	45	49	-2	-2	7.21
Cyan	18	48	53	-1	-1	-22	-24	5.39
White	19	86	89	0	0	0	0	3.00
Neutral 8	20	77	83	-1	0	0	0	6.08
Neutral 6.5	21	61	67	1	1	-2	-1	6.08
Neutral 5	22	46	51	2	2	-3	-2	5.10
Neutral 3.5	23	31	35	4	1	-3	1	6.40
Black	24	17	18	4	6	-4	-3	2.45

Table 66

ISO 1000 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM10008 L*	APHM16008 L*	APHM10008 a*	APHM16008 a*	APHM10008 b*	APHM16008 b*	ΔE
Dark Skin	1	38	41	13	14	6	2	5.10
Light skin	2	66	70	14	16	9	7	4.90
Blue sky	3	47	50	1	1	-15	-15	3.00
Foliage	4	42	45	-6	-5	8	6	3.74
Blue flower	5	55	59	16	16	-15	-16	4.12
Bluish green	6	69	74	-16	-16	-3	-3	5.00
Orange	7	60	65	19	21	28	26	5.74
Purplish blue	8	38	42	18	19	-29	-29	4.12
Moderate Red	9	53	56	39	41	8	9	3.74
Purple	10	34	37	26	29	-8	-12	5.83
Yellow green	11	70	75	-22	-23	29	29	5.10
Orange yellow	12	69	74	6	8	33	32	5.48
Blue	13	26	30	28	28	-40	-40	4.00
Green	14	51	56	-25	-23	14	12	5.74
Red	15	47	51	49	51	19	20	4.58
Yellow	16	80	83	-4	-3	39	37	3.74
Magenta	17	54	58	45	47	-2	-3	4.58
Cyan	18	48	52	-1	0	-22	-23	4.24
White	19	86	89	0	0	0	0	3.00
Neutral 8	20	77	82	-1	0	0	0	5.10
Neutral 6.5	21	61	66	1	1	-2	-1	5.10
Neutral 5	22	46	50	2	3	-3	-3	4.12
Neutral 3.5	23	31	35	4	4	-3	-4	4.12
Black	24	17	18	4	7	-4	-8	5.10

Table 67

ISO 1000 & ISO 1250

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

	AP10008 L*		AP12508 L*		AP10008 a*		AP12508 a*		AP10008 b*		AP12508 b*		ΔE
Dark Skin	1		47		52		19		19		-10		-9	5.10
Light skin	2		75		81		18		18		1		1	6.00
Blue sky	3		53		58		2		3		-16		-17	5.20
Foliage	4		50		55		2		1		-4		-3	5.20
Blue flower	5		63		68		16		17		-17		-17	5.10
Bluish green	6		76		82		-15		-17		-4		-2	6.63
Orange	7		69		75		22		24		12		14	6.63
Purplish blue	8		49		54		23		23		-34		-35	5.10
Moderate Red	9		62		67		40		42		-2		-3	5.48
Purple	10		48		52		32		35		-25		-27	5.39
Yellow green	11		78		82		-19		-20		21		22	4.24
Orange yello\	12		78		82		8		9		22		23	4.24
Blue	13		38		43		29		30		-41		-43	5.48
Green	14		60		65		-17		-16		3		2	5.20
Red	15		58		64		50		54		-4		-2	7.48
Yellow	16		84		87		-1		-1		25		27	3.61
Magenta	17		64		70		47		48		-13		-12	6.16
Cyan	18		56		61		4		4		-26		-27	5.10
White	19		89		92		-1		0		0		0	3.16
Neutral 8	20		83		86		-1		-1		0		1	3.16
Neutral 6.5	21		67		73		1		2		-2		-4	6.40
Neutral 5	22		52		58		4		4		-6		-6	6.00
Neutral 3.5	23		38		42		7		7		-9		-10	4.12
Black	24		23		27		11		10		-12		-10	4.58

Table 68

ISO 1000 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

	AP10008 L*		AP16008 L*		AP10008 a*		AP16008 a*		AP10008 b*		AP16008 b*		ΔE
Dark Skin	1		47		51		19		20		-10		-9	4.24
Light skin	2		75		80		18		20		1		0	5.48
Blue sky	3		53		56		2		3		-16		-15	3.32
Foliage	4		50		53		2		3		-4		-3	3.32
Blue flower	5		63		67		16		17		-17		-16	4.24
Bluish green	6		76		80		-15		-14		-4		-5	4.24
Orange	7		69		74		22		26		12		11	6.48
Purplish blue	8		49		53		23		26		-34		-35	5.10
Moderate Red	9		62		66		40		42		-2		-4	4.90
Purple	10		48		53		32		36		-25		-27	6.71
Yellow green	11		78		82		-19		-16		21		20	5.10
Orange yello	12		78		82		8		12		22		21	5.74
Blue	13		38		42		29		31		-41		-42	4.58
Green	14		60		64		-17		-15		3		2	4.58
Red	15		58		64		50		54		-4		-7	7.81
Yellow	16		84		87		-1		1		25		24	3.74
Magenta	17		64		69		47		50		-13		-14	5.92
Cyan	18		56		60		4		6		-26		-27	4.58
White	19		89		91		-1		1		0		1	3.00
Neutral 8	20		83		85		-1		0		0		1	2.45
Neutral 6.5	21		67		72		1		3		-2		-2	5.39
Neutral 5	22		52		56		4		5		-6		-5	4.24
Neutral 3.5	23		38		41		7		8		-9		-7	3.74
Black	24		23		25		11		11		-12		-9	3.61

AP NC2000e ISO1250 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 1250 f/8 without the hot mirror filter in Figure 8 is smaller than the gamut of the test image photographed with the hot mirror filter. The reduction in gamut is most significant in the yellow, green and red region of the gamut. The blue and cyan portion of the gamut shares a border for both test images though the non-hot mirror test image gamut border reflects an accentuation in the magenta region.

Tables 69 and 70 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror. Tables 69 and 70 illustrate the fact that a reproduction varies in color from the original.

Table 71 illustrates the CIELAB values and the corresponding ΔE^* values between the images shot with and without the hot mirror filter at ISO 1250. The white (3.00ΔE^*) and neutral 8 (3.32ΔE^*) wedges contain the only values with a ΔE^* less than four. All other wedges fall between ΔE^* of 6.16 and 30.53.

Table 72 illustrates the color difference between different ISO's while using a hot mirror filter. Tables 73 illustrates the color difference between different ISO without using a hot mirror filter. Table 2 and 3 show the trend of color difference between ISO's illustrated in the ΔE^* values of Tables 72-73. All gamuts regardless of ISO are different with and or without a hot mirror filter.

Figure 8

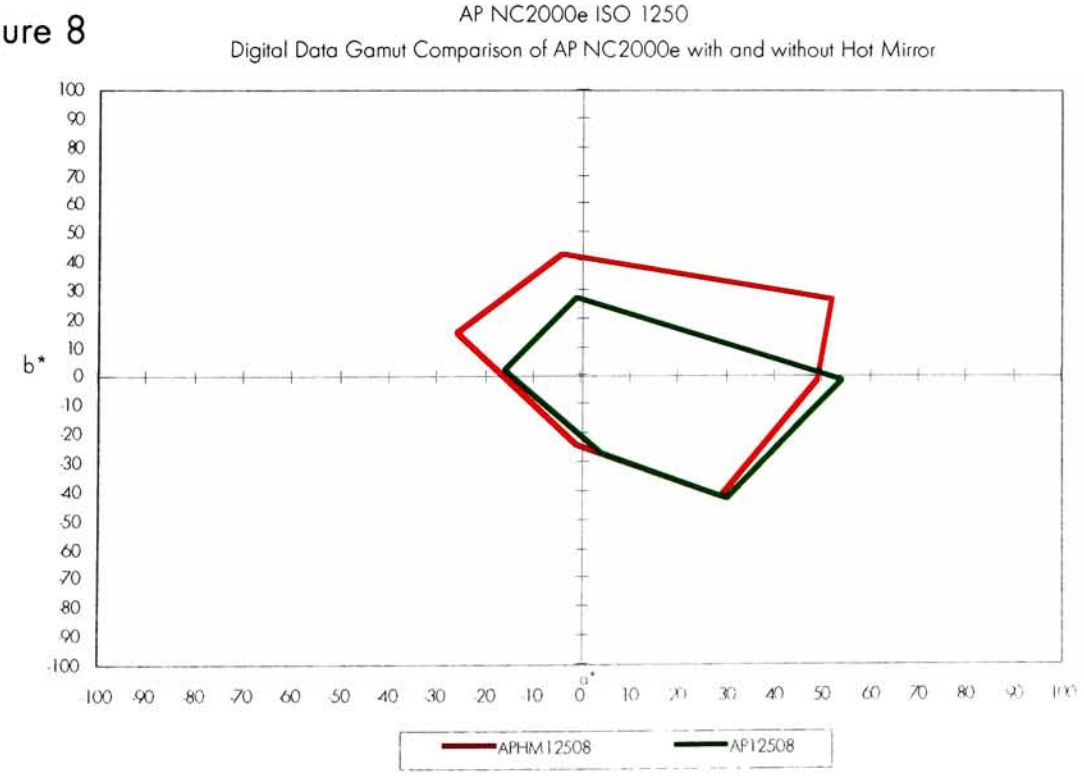


Table 69

ISO 1250

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

		Orig Mac L*	AP12508 L*	Orig Mac a*	AP12508 a*	Orig Mac b*	AP12508 b*	ΔE	
Dark Skin	1	37.86	52	13.84	19	14.83	-9	28.02
Light skin	2	65.57	81	16.91	18	17.79	1	26.71
Blue sky	3	48.76	58	-4.86	3	-23.14	-17	12.55
Foliage	4	43.1	55	-14.2	1	20.01	-3	40.55
Blue flower	5	54.48	68	8.97	17	-25.04	-17	30.36
Bluish green	6	69.85	82	-32.49	-17	-1.04	-2	57.79
Orange	7	62.1	75	34.86	24	63	14	52.04
Purplish blue	8	38.97	54	9.75	23	-43.64	-35	36.61
Moderate Red	9	50.32	67	48.78	42	16.89	-3	29.39
Purple	10	29.92	52	22.71	35	-21.7	-27	48.37
Yellow green	11	71.67	82	-24.09	-20	59.42	22	51.01
Orange yello\	12	71.66	82	20.07	9	68.48	23	47.69
Blue	13	28.15	43	20.92	30	-56.17	-43	41.92
Green	14	54.11	65	-40.49	-16	33.08	2	100.06
Red	15	41.5	64	58.17	54	29.8	-2	70.84
Yellow	16	81.82	87	3.7	-1	80.35	27	69.54
Magenta	17	51.35	70	49.87	48	-14.01	-12	49.56
Cyan	18	48.9	61	-29.14	4	-30.58	-27	31.75
White	19	94.89	92	-0.34	0	-0.18	0	2.97
Neutral 8	20	80.36	86	-0.11	-1	-0.39	1	6.18
Neutral 6.5	21	64.48	73	-0.01	2	-0.24	-4	10.14
Neutral 5	22	49.48	58	-0.4	4	-0.51	-6	12.55
Neutral 3.5	23	35.11	42	0.02	7	-0.43	-10	15.45
Black	24	20.56	27	0.46	10	-0.18	-10	11.75

Table 70

ISO 1250

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM12508 L*	Orig Mac a*	APHM12508 a*	Orig Mac b*	APHM12508 b*	ΔE
Dark Skin	1	37.86	41	13.84	14	14.83	7	8.44
Light skin	2	65.57	72	16.91	16	17.79	10	10.14
Blue sky	3	48.76	52	-4.86	2	-23.14	-16	10.42
Foliage	4	43.1	47	-14.2	-8	20.01	12	10.85
Blue flower	5	54.48	61	8.97	16	-25.04	-15	13.88
Bluish green	6	69.85	76	-32.49	-18	-1.04	-3	15.86
Orange	7	62.1	66	34.86	21	63	31	35.09
Purplish blue	8	38.97	42	9.75	18	-43.64	-30	16.23
Moderate Red	9	50.32	58	48.78	42	16.89	12	11.35
Purple	10	29.92	38	22.71	29	-21.7	-9	16.31
Yellow green	11	71.67	77	-24.09	-25	59.42	33	26.97
Orange yello	12	71.66	76	20.07	7	68.48	37	34.36
Blue	13	28.15	30	20.92	29	-56.17	-42	16.42
Green	14	54.11	57	-40.49	-26	33.08	15	23.35
Red	15	41.5	52	58.17	52	29.8	26	12.76
Yellow	16	81.82	84	3.7	-4	80.35	42	39.18
Magenta	17	51.35	60	49.87	49	-14.01	-2	14.83
Cyan	18	48.9	53	-29.14	-1	-30.58	-24	29.19
White	19	94.89	89	-0.34	0	-0.18	0	5.90
Neutral 8	20	80.36	83	-0.11	0	-0.39	0	2.67
Neutral 6.5	21	64.48	67	-0.01	1	-0.24	-1	2.82
Neutral 5	22	49.48	51	-0.4	2	-0.51	-2	3.21
Neutral 3.5	23	35.11	35	0.02	1	-0.43	1	1.74
Black	24	20.56	18	0.46	6	-0.18	-3	6.72

Table 71

ISO 1250

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

		APHM12508 L*	AP12508 L*	APHM12508 a*	AP12508 a*	APHM12508 b*	AP12508 b*	ΔE	
Dark Skin	1	41	52	14	19	7	-9		20.05
Light skin	2	72	81	16	18	10	1		12.88
Blue sky	3	52	58	2	3	-16	-17		6.16
Foliage	4	47	55	-8	1	12	-3		19.24
Blue flower	5	61	68	16	17	-15	-17		7.35
Bluish green	6	76	82	-18	-17	-3	-2		6.16
Orange	7	66	75	21	24	31	14		19.47
Purplish blue	8	42	54	18	23	-30	-35		13.93
Moderate Red	9	58	67	42	42	12	-3		17.49
Purple	10	38	52	29	35	-9	-27		23.58
Yellow green	11	77	82	-25	-20	33	22		13.08
Orange yellow	12	76	82	7	9	37	23		15.36
Blue	13	30	43	29	30	-42	-43		13.08
Green	14	57	65	-26	-16	15	2		18.25
Red	15	52	64	52	54	26	-2		30.53
Yellow	16	84	87	-4	-1	42	27		15.59
Magenta	17	60	70	49	48	-2	-12		14.18
Cyan	18	53	61	-1	4	-24	-27		9.90
White	19	89	92	0	0	0	0		3.00
Neutral 8	20	83	86	0	-1	0	1		3.32
Neutral 6.5	21	67	73	1	2	-1	-4		6.78
Neutral 5	22	51	58	2	4	-2	-6		8.31
Neutral 3.5	23	35	42	1	7	1	-10		14.35
Black	24	18	27	6	10	-3	-10		12.08

Table 72

ISO 1250 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror

		APHM12508 L*	APHM16008 L*	APHM12508 a*	APHM16008 a*	APHM12508 b*	APHM16008 b*	ΔE	
Dark Skin	1	41	41	14	14	7	2	5.00
Light skin	2	72	70	16	16	10	7	3.61
Blue sky	3	52	50	2	1	-16	-15	2.45
Foliage	4	47	45	-8	-5	12	6	7.00
Blue flower	5	61	59	16	16	-15	-16	2.24
Bluish green	6	76	74	-18	-16	-3	-3	2.83
Orange	7	66	65	21	21	31	26	5.10
Purplish blue	8	42	42	18	19	-30	-29	1.41
Moderate Red	9	58	56	42	41	12	9	3.74
Purple	10	38	37	29	29	-9	-12	3.16
Yellow green	11	77	75	-25	-23	33	29	4.90
Orange yellow	12	76	74	7	8	37	32	5.48
Blue	13	30	30	29	28	-42	-40	2.24
Green	14	57	56	-26	-23	15	12	4.36
Red	15	52	51	52	51	26	20	6.16
Yellow	16	84	83	-4	-3	42	37	5.20
Magenta	17	60	58	49	47	-2	-3	3.00
Cyan	18	53	52	-1	0	-24	-23	1.73
White	19	89	89	0	0	0	0	0.00
Neutral 8	20	83	82	0	0	0	0	1.00
Neutral 6.5	21	67	66	1	1	-1	-1	1.00
Neutral 5	22	51	50	2	3	-2	-3	1.73
Neutral 3.5	23	35	35	1	4	1	-4	5.83
Black	24	18	18	6	7	-3	-8	5.10

Table 73

ISO 1250 & ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror

	AP12508 L*		AP16008 L*		AP12508 a*		AP16008 a*		AP12508 b*		AP16008 b*		ΔE
Dark Skin	1		52		51		19		20		-9		-9	1.41
Light skin	2		81		80		18		20		1		0	2.45
Blue sky	3		58		56		3		3		-17		-15	2.83
Foliage	4		55		53		1		3		-3		-3	2.83
Blue flower	5		68		67		17		17		-17		-16	1.41
Bluish green	6		82		80		-17		-14		-2		-5	4.69
Orange	7		75		74		24		26		14		11	3.74
Purplish blue	8		54		53		23		26		-35		-35	3.16
Moderate Red	9		67		66		42		42		-3		-4	1.41
Purple	10		52		53		35		36		-27		-27	1.41
Yellow green	11		82		82		-20		-16		22		20	4.47
Orange yello\	12		82		82		9		12		23		21	3.61
Blue	13		43		42		30		31		-43		-42	1.73
Green	14		65		64		-16		-15		2		2	1.41
Red	15		64		64		54		54		-2		-7	5.00
Yellow	16		87		87		-1		1		27		24	3.61
Magenta	17		70		69		48		50		-12		-14	3.00
Cyan	18		61		60		4		6		-27		-27	2.24
White	19		92		91		0		1		0		1	1.73
Neutral 8	20		86		85		-1		0		1		1	1.41
Neutral 6.5	21		73		72		2		3		-4		-2	2.45
Neutral 5	22		58		56		4		5		-6		-5	2.45
Neutral 3.5	23		42		41		7		8		-10		-7	3.32
Black	24		27		25		10		11		-10		-9	2.45

AP NC2000e ISO1600 f/8 with and without Hot mirror filter

The color gamut of the test image photographed with the AP NC2000e at ISO 1600 f/8 without the hot mirror filter in Figure 9 is smaller than the gamut of the test image photographed with the hot mirror filter. The reduction in gamut is most significant in the yellow, green and red region of the gamut. The blue and cyan portion of the gamut shares a border for both test images. The non-hot mirror test image gamut border reflects an accentuation in the magenta region.

Tables 74 and 75 illustrate the color difference between the original MacBeth Color Checker and the AP NC2000e reproduction as photographed with and without a hot mirror filter. Tables 74 and 75 illustrate the fact that a reproduction varies in color from the original.

Table 76 shows the CIELAB values and the corresponding ΔE* values for the images shot with and without a hot mirror filter at ISO 1600. The white (2.45ΔE*) and neutral 8 (3.16ΔE*) wedges are the only values with a ΔE* less than four. All other wedges fall between ΔE* of 6.40 and 30.12. The color difference in Table 76 illustrates a color match of "fair match" to "poor match."

Figure 9

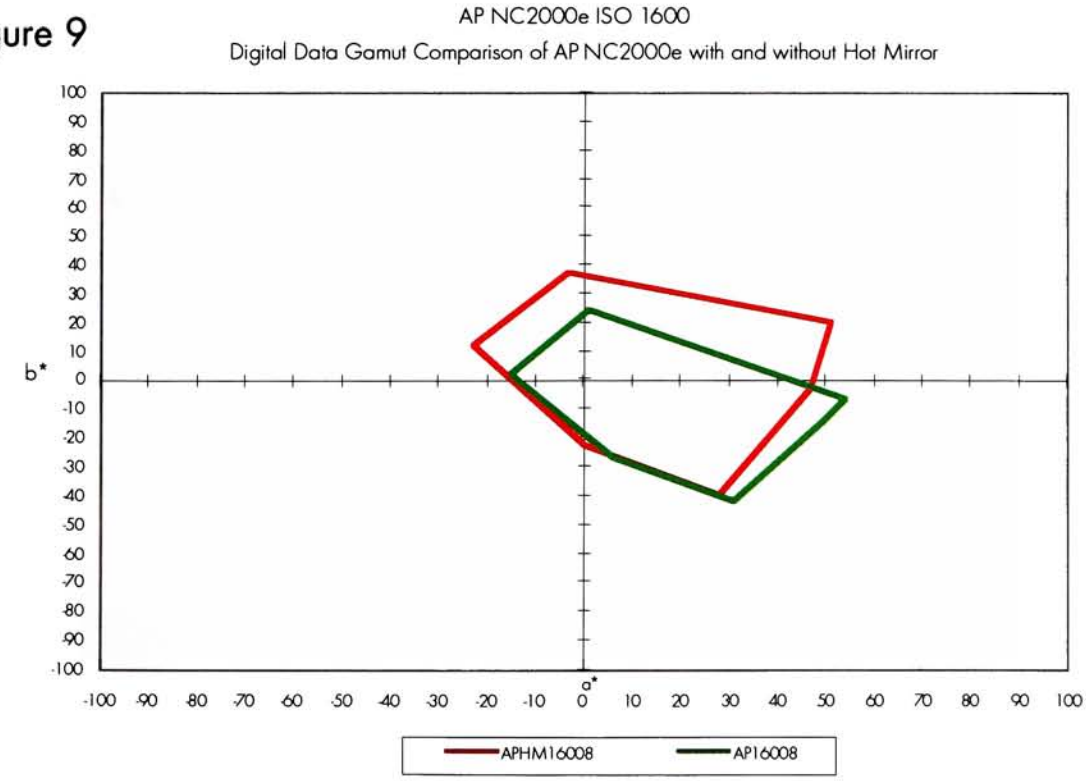


Table 74

ISO 1600

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File without Hot Mirror

	Orig Mac L*		AP16008 L*		Orig Mac a*		AP16008 a*		Orig Mac b*		AP16008 b*		ΔE
Dark Skin	1	37.86	51		13.84	20			14.83	-9			27.90
Light skin	2	65.57	80		16.91	20			17.79	0			23.11
Blue sky	3	48.76	56		-4.86	3			-23.14	-15			13.43
Foliage	4	43.1	53		-14.2	3			20.01	-3			30.39
Blue flower	5	54.48	67		8.97	17			-25.04	-16			17.41
Bluish green	6	69.85	80		-32.49	-14			-1.04	-5			21.46
Orange	7	62.1	74		34.86	26			63	11			54.08
Purplish blue	8	38.97	53		9.75	26			-43.64	-35			23.14
Moderate Red	9	50.32	66		48.78	42			16.89	-4			26.99
Purple	10	29.92	53		22.71	36			-21.7	-27			27.16
Yellow green	11	71.67	82		-24.09	-16			59.42	20			41.55
Orange yello\	12	71.66	82		20.07	12			68.48	21			49.26
Blue	13	28.15	42		20.92	31			-56.17	-42			22.23
Green	14	54.11	64		-40.49	-15			33.08	2			41.39
Red	15	41.5	64		58.17	54			29.8	-7			43.33
Yellow	16	81.82	87		3.7	1			80.35	24			56.65
Magenta	17	51.35	69		49.87	50			-14.01	-14			17.65
Cyan	18	48.9	60		-29.14	6			-30.58	-27			37.02
White	19	94.89	91		-0.34	1			-0.18	1			4.28
Neutral 8	20	80.36	85		-0.11	0			-0.39	1			4.84
Neutral 6.5	21	64.48	72		-0.01	3			-0.24	-2			8.29
Neutral 5	22	49.48	56		-0.4	5			-0.51	-5			9.58
Neutral 3.5	23	35.11	41		0.02	8			-0.43	-7			11.90
Black	24	20.56	25		0.46	11			-0.18	-9			14.44

Table 75

ISO 1600

ΔE* Comparison of Original MacBeth Color Target to AP NC2000e Digital File with Hot Mirror

		Orig Mac L*	APHM16008 L*	Orig Mac a*	APHM16008 a*	Orig Mac b*	APHM16008 b*	ΔE
Dark Skin	1	37.86	41	13.84	14	14.83	2	13.21
Light skin	2	65.57	70	16.91	16	17.79	7	11.70
Blue sky	3	48.76	50	-4.86	1	-23.14	-15	10.11
Foliage	4	43.1	45	-14.2	-5	20.01	6	16.87
Blue flower	5	54.48	59	8.97	16	-25.04	-16	12.31
Bluish green	6	69.85	74	-32.49	-16	-1.04	-3	17.12
Orange	7	62.1	65	34.86	21	63	26	39.62
Purplish blue	8	38.97	42	9.75	19	-43.64	-29	17.58
Moderate Red	9	50.32	56	48.78	41	16.89	9	12.45
Purple	10	29.92	37	22.71	29	-21.7	-12	13.56
Yellow green	11	71.67	75	-24.09	-23	59.42	29	30.62
Orange yello	12	71.66	74	20.07	8	68.48	32	38.50
Blue	13	28.15	30	20.92	28	-56.17	-40	17.75
Green	14	54.11	56	-40.49	-23	33.08	12	27.46
Red	15	41.5	51	58.17	51	29.8	20	15.42
Yellow	16	81.82	83	3.7	-3	80.35	37	43.88
Magenta	17	51.35	58	49.87	47	-14.01	-3	13.18
Cyan	18	48.9	52	-29.14	0	-30.58	-23	30.27
White	19	94.89	89	-0.34	0	-0.18	0	5.90
Neutral 8	20	80.36	82	-0.11	0	-0.39	0	1.69
Neutral 6.5	21	64.48	66	-0.01	1	-0.24	-1	1.98
Neutral 5	22	49.48	50	-0.4	3	-0.51	-3	4.25
Neutral 3.5	23	35.11	35	0.02	4	-0.43	-4	5.35
Black	24	20.56	18	0.46	7	-0.18	-8	10.51

Table 76

ISO 1600

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and with Hot Mirror

	APHM16008 L*	AP16008 L*	APHM16008 a*	AP16008 a*	APHM16008 b*	AP16008 b*	ΔE	
Dark Skin	1	41	51	14	20	2	-9	16.03
Light skin	2	70	80	16	20	7	0	12.85
Blue sky	3	50	56	1	3	-15	-15	6.32
Foliage	4	45	53	-5	3	6	-3	14.46
Blue flower	5	59	67	16	17	-16	-16	8.06
Bluish green	6	74	80	-16	-14	-3	-5	6.63
Orange	7	65	74	21	26	26	11	18.19
Purplish blue	8	42	53	19	26	-29	-35	14.35
Moderate Red	9	56	66	41	42	9	-4	16.43
Purple	10	37	53	29	36	-12	-27	23.02
Yellow green	11	75	82	-23	-16	29	20	13.38
Orange yellow	12	74	82	8	12	32	21	14.18
Blue	13	30	42	28	31	-40	-42	12.53
Green	14	56	64	-23	-15	12	2	15.10
Red	15	51	64	51	54	20	-7	30.12
Yellow	16	83	87	-3	1	37	24	14.18
Magenta	17	58	69	47	50	-3	-14	15.84
Cyan	18	52	60	0	6	-23	-27	10.77
White	19	89	91	0	1	0	1	2.45
Neutral 8	20	82	85	0	0	0	1	3.16
Neutral 6.5	21	66	72	1	3	-1	-2	6.40
Neutral 5	22	50	56	3	5	-3	-5	6.63
Neutral 3.5	23	35	41	4	8	-4	-7	7.81
Black	24	18	25	7	11	-8	-9	8.12

Fuji ISO 800, Minolta ISO 800, AP NC2000e ISO 800

Figure 10 compares the color gamut of the Fuji camera at ISO 800 and ISO 3200. ISO 800 has a slightly larger color gamut then at ISO 3200.

Figure 11 compares the color gamut of all three cameras at ISO 800. The color gamut of the Minolta camera at ISO 800 is larger than the other camera gamuts. The Minolta gamut is larger in the yellow-green and red-yellow region of the gamut. The gamuts of the AP NC2000e camera (with and without hot mirror filter) and the Fuji camera have a more expanded gamut in the magenta region. The overall gamut of the Fuji and Minolta camera are shifted toward yellow-green. The Fuji camera has a much smaller red gamut then the Minolta camera but the Fuji's red portion of the gamut is still larger than the AP NC2000e gamut. Although the Fuji has a larger gamut in the red blue region its gamut is still significantly smaller then the AP NC2000e camera with or without use of a hot mirror filter.

Figure 10

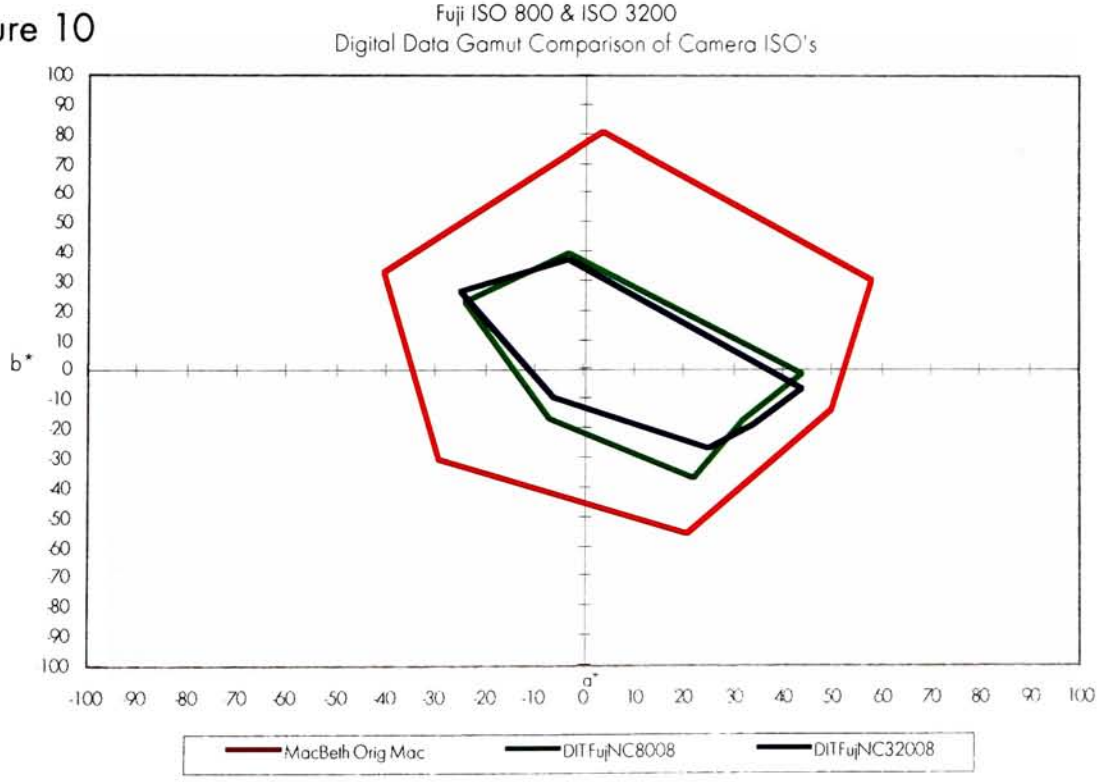
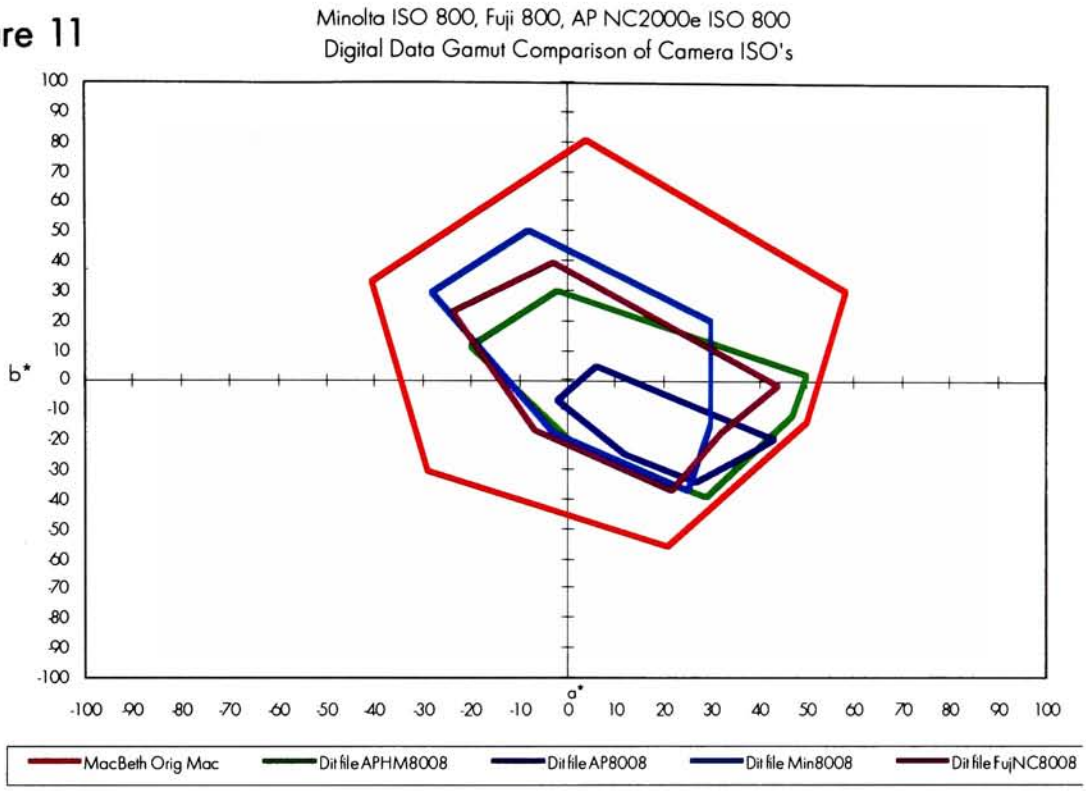


Figure 11


Minolta ISO 800, Fuji 800, AP NC2000e ISO 800
Digital Data Gamut Comparison of Camera ISO's
b*
a*
MacBeth Orig Mac
Dit file APHM8008
Dit file AP8008
Dit file Min8008
Dit file FujNC8008

Density comparison

There are two types of charts that illustrate the digital camera's image density. Figure 12 and 13 plot out the density of the grayscale against the percent dot area as measured in Adobe Photoshop's "info box" densitometer at 3x3 pixel radius. Figure 14-25 plots out all the color swatches against the *L (luminance) value as read in Adobe Photoshop's "info box" densitometer at 3x3 pixel radius. In Figures 12 and 13 we can see the luminance differences at identical color swatches for each ISO photographed with and with out hot mirror filter.

In Figure 11, ISO 1000 with no hot mirror filter has the darkest luminance value while ISO 800 has the brightest luminance value. All values of luminance for the images photographed, Figures 12 and 13, with a hot mirror filter fall below the darkest luminance value of the images photographed without a hot mirror filter.

Figures 14-25 plot the percent dot density, as read in Adobe Photoshop's "info box" densitometer, against the density of the original grayscale. Densities of the images photographed without a hot mirror filter are significantly lower then the densities of the images photographed with a hot mirror filter. Figure 16 comparing ISO 640 illustrates the least density difference when comparing the same ISO photographed with and without a hot mirror filter. Figure 17, comparing ISO 800 with and without a hot mirror filter illustrates the greatest change in density.

Figure 22 illustrates all AP NC2000e camera ISO's photographed without a hot mirror filter plotted against each other. Figure 23 shows all AP NC2000e camera ISO's photographed with a hot mirror filter plotted against each other. Figure 22 and 23 illustrate that no two ISO's share the same density reproduction.

The purpose of the hot mirror filter is to reflect infrared light away from the camera sensor When the filter is absent the infrared light, which is not accounted for with traditional metering techniques, reaches the imager. Figures 12-25 illustrate the overexposure caused by the unreflected infrared light which strikes the AP NC2000e imager.

Figure 25 illustrates the dramatic difference between the tone reproduction of the same scene by three different cameras. The Minolta camera had the greatest overall density. The density of the original at step 0.7 represents a 50% midtone. If you examine where the Fuj8008 image and the APHM8008 image intersect this point it is very near the 50% margin. Therefore the AP NC2000e imager used with the hot mirror filter and the Fuji imagers reproduced similarly.

Figure 12

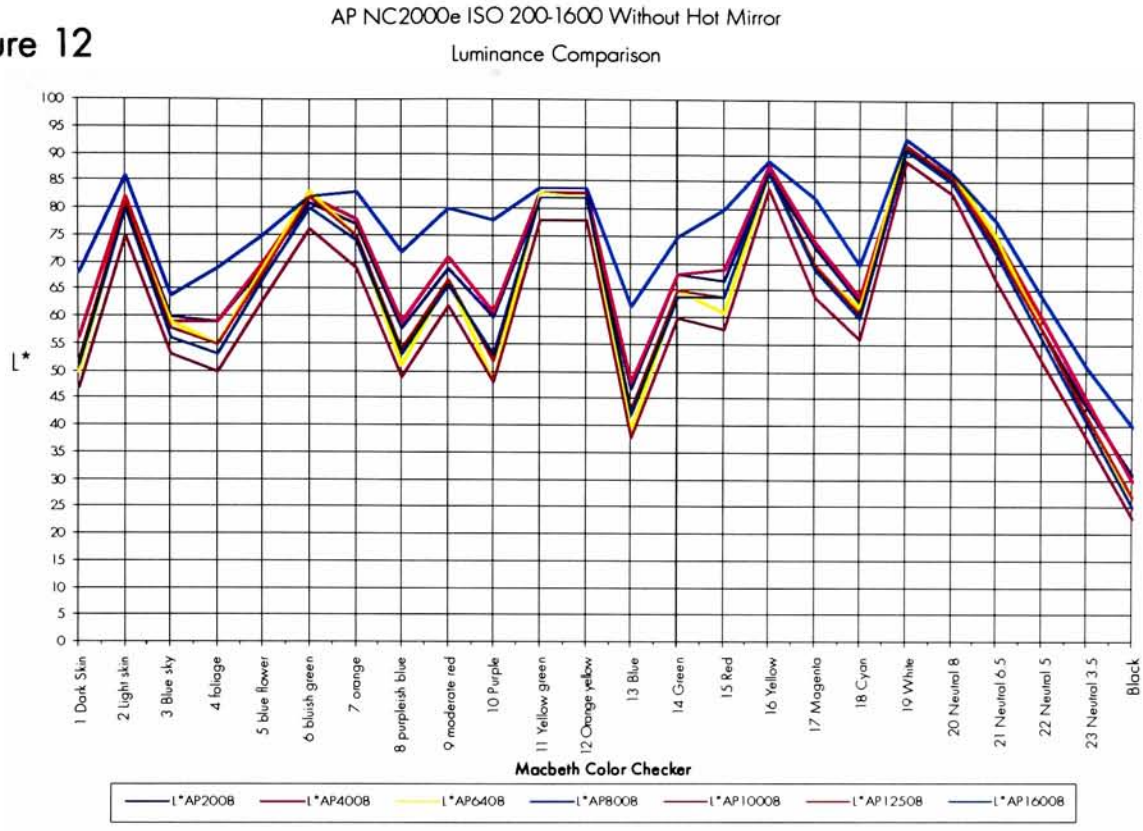


Figure 13

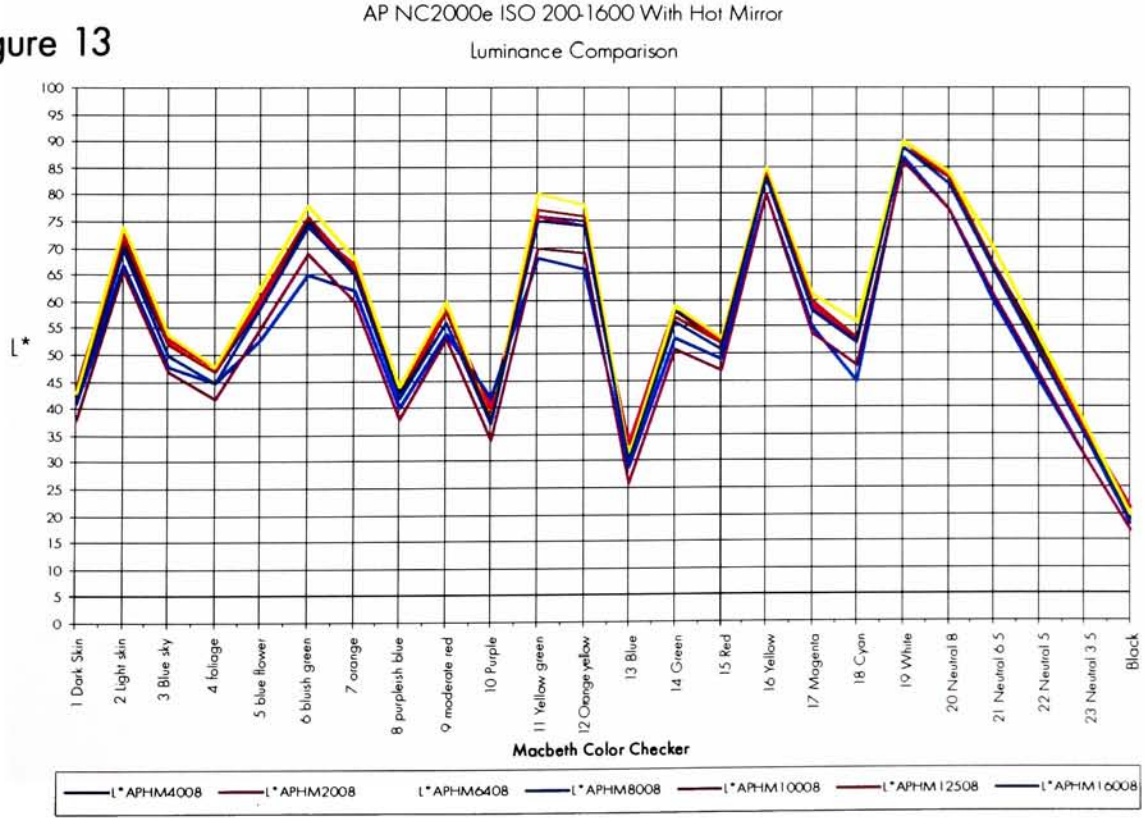


Figure 14

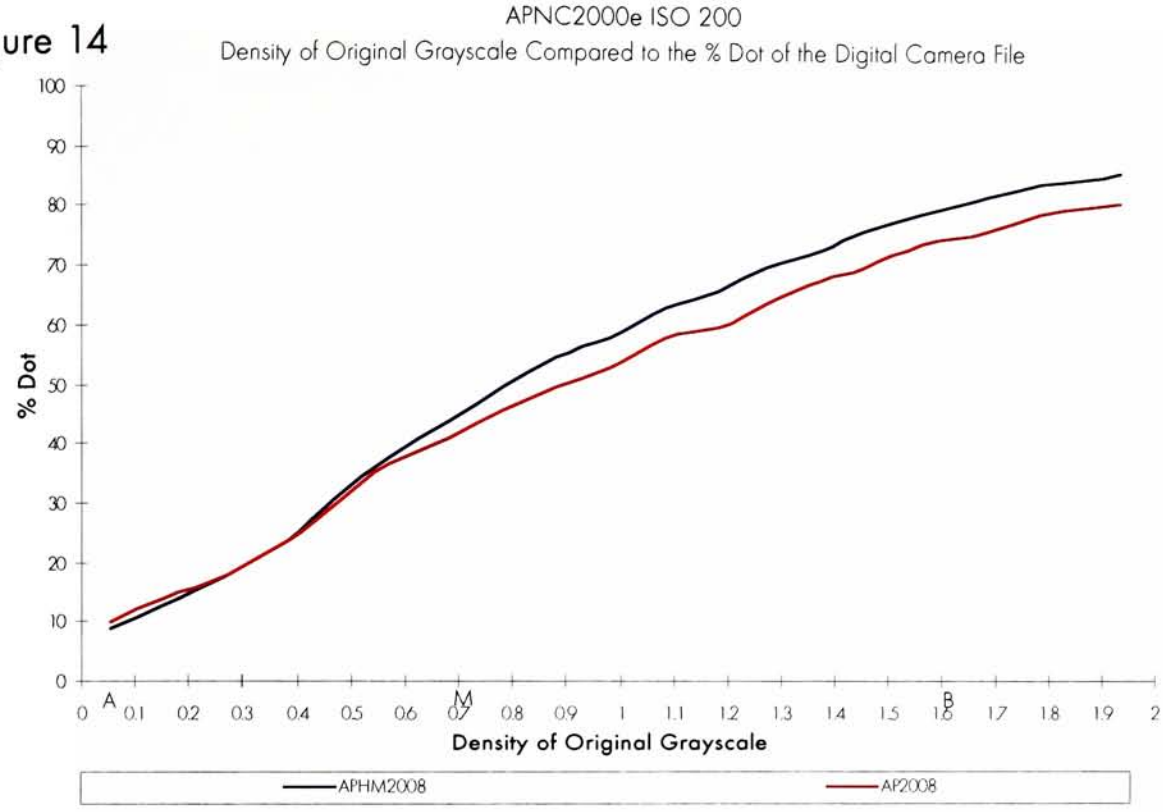


Figure 15

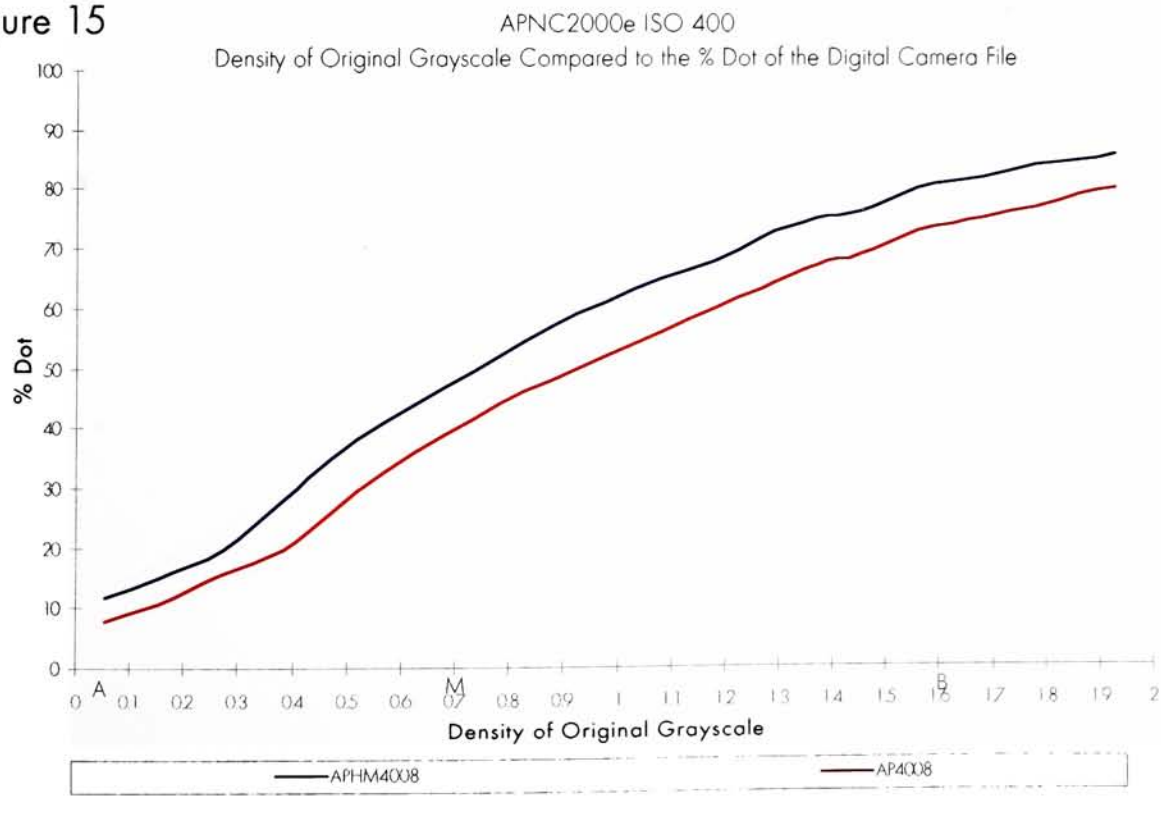


Figure 16

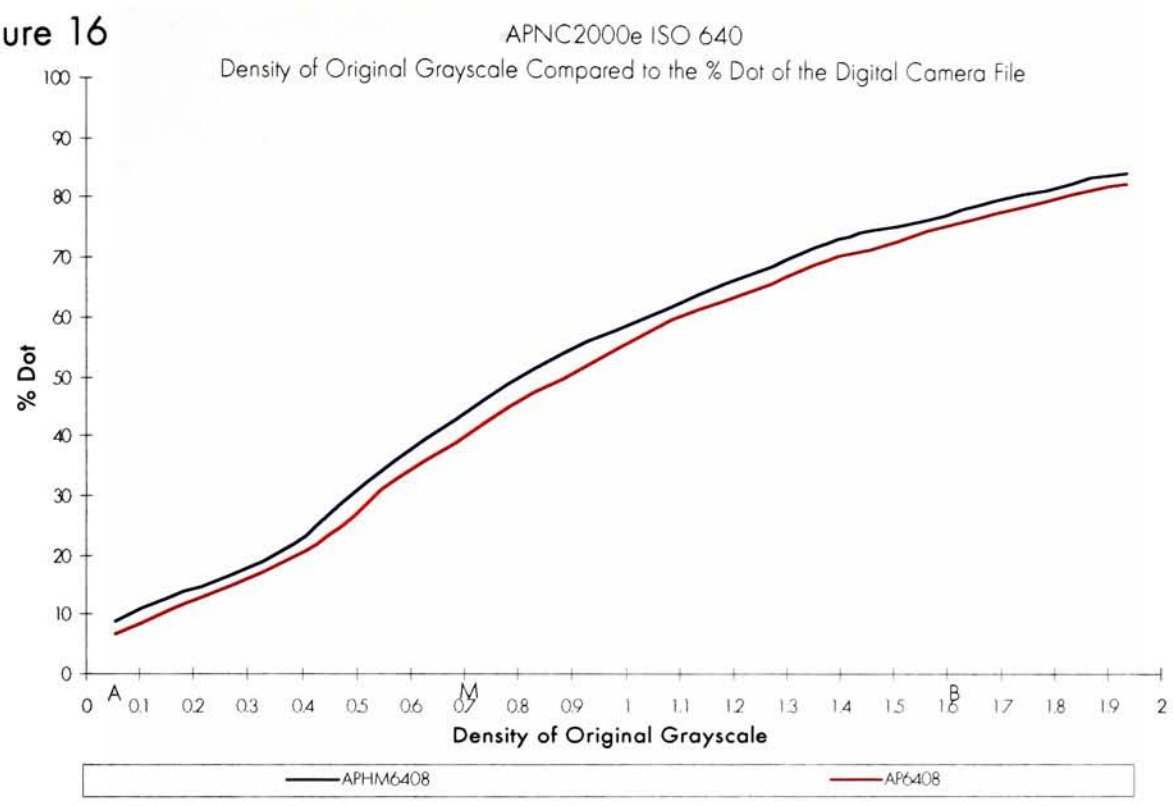


Figure 17

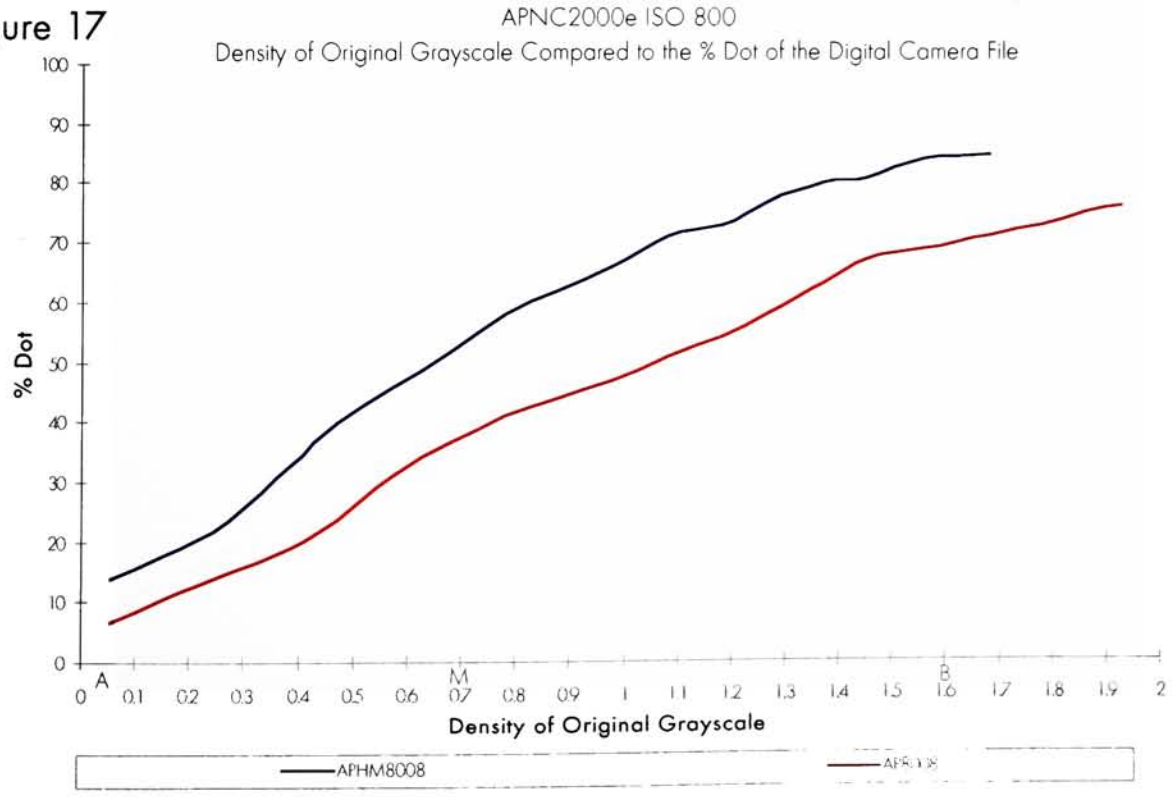


Figure 18

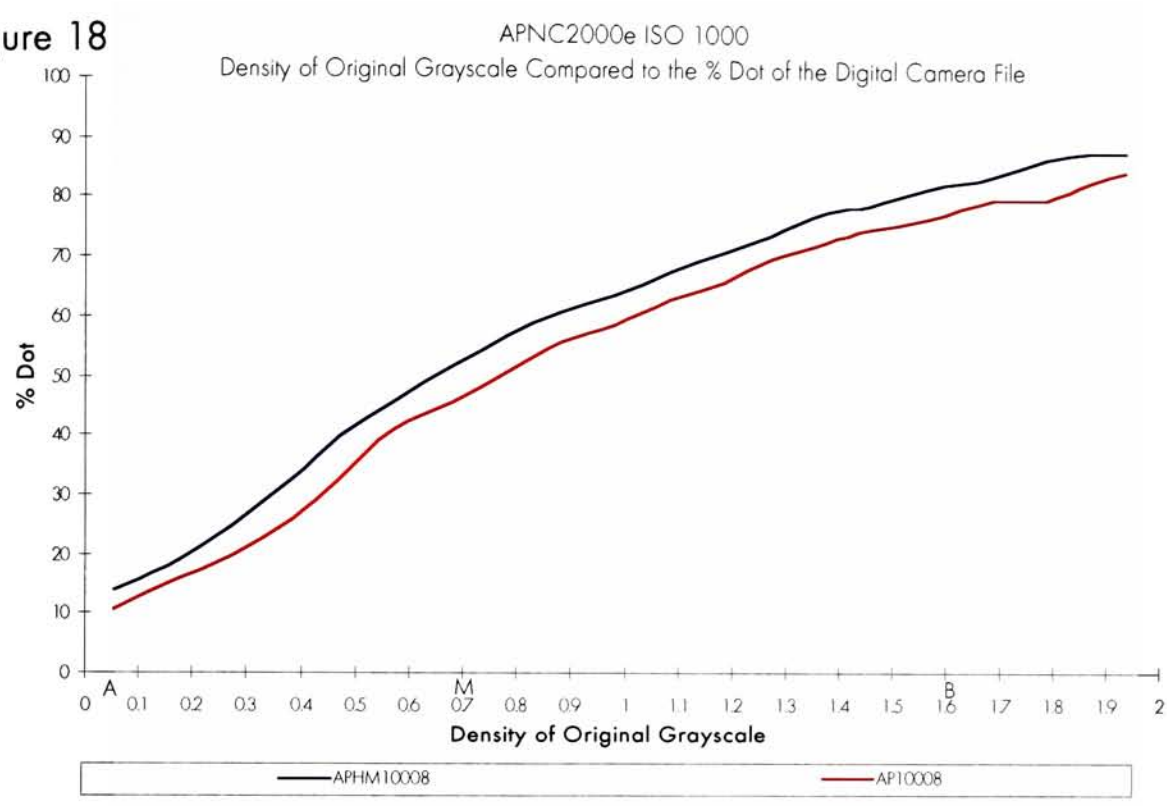


Figure 19

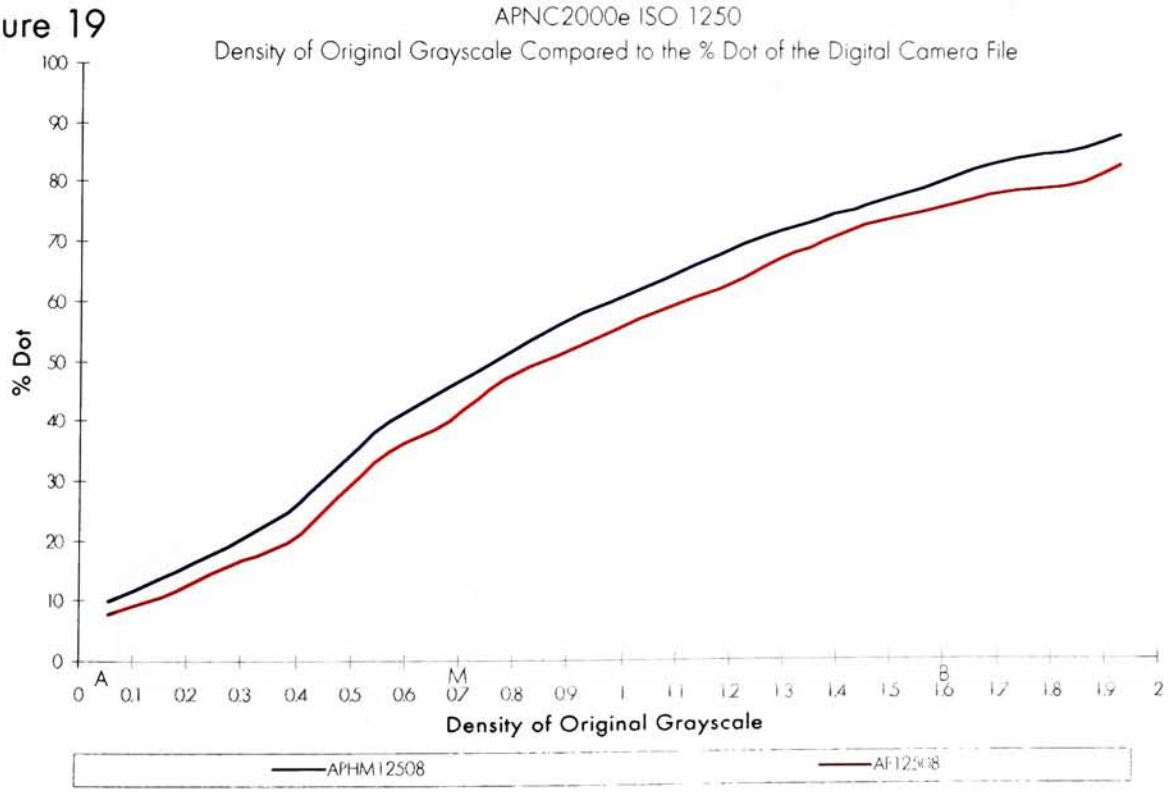


Figure 20

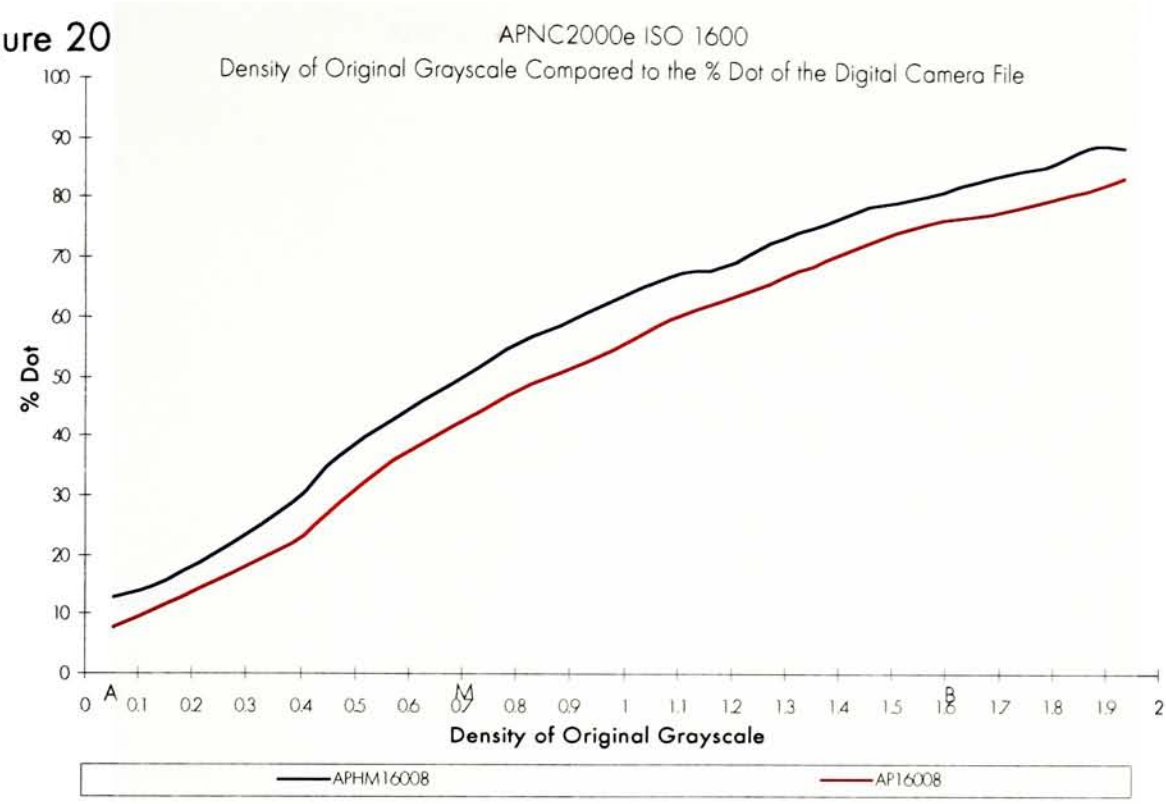


Figure 21

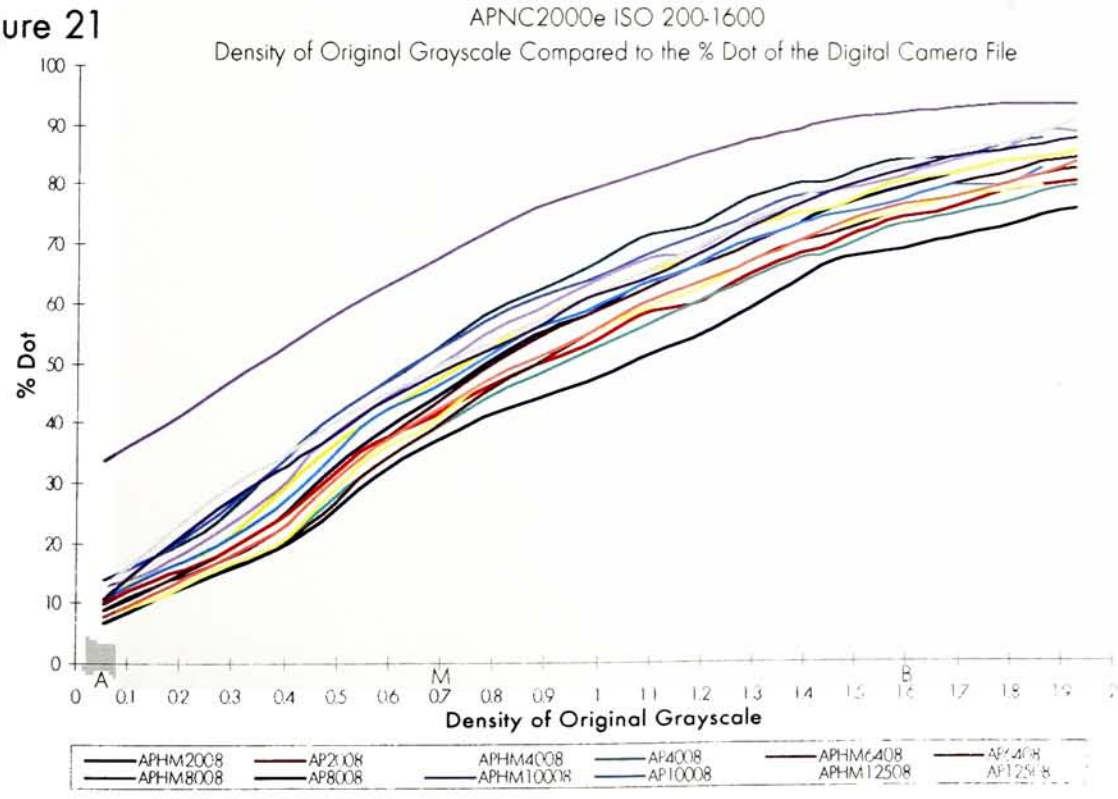


Figure 22

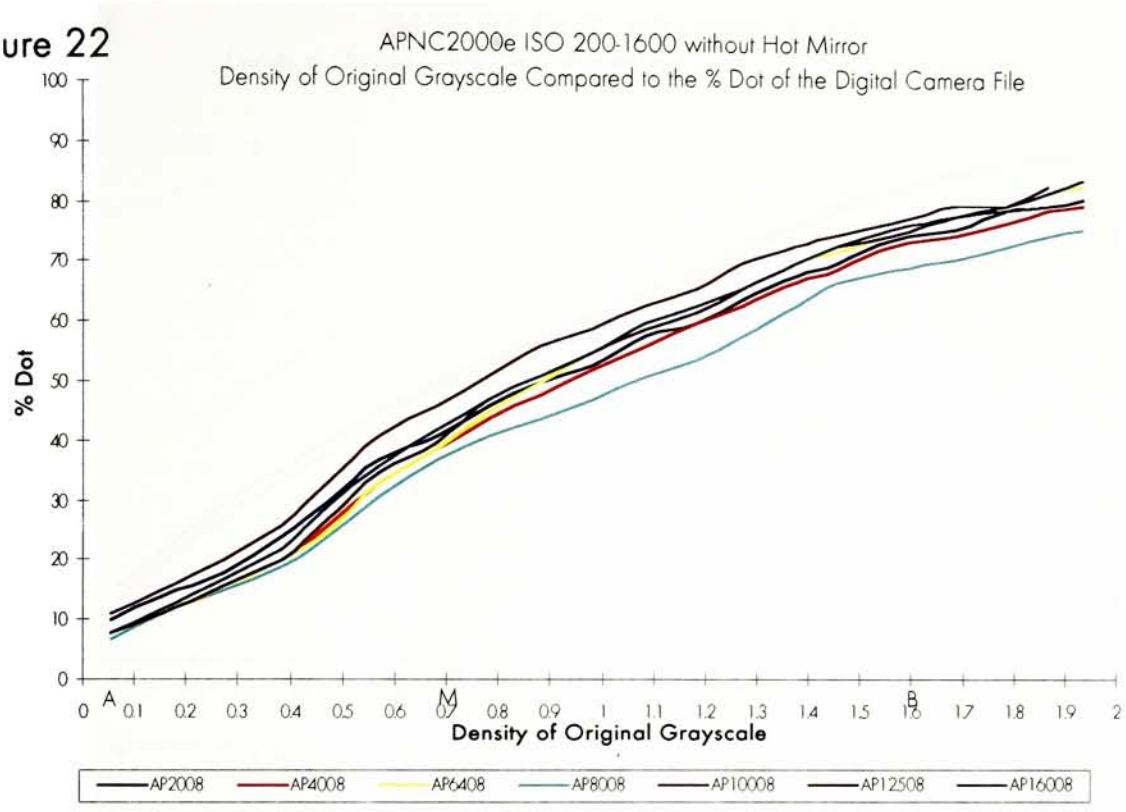


Figure 23

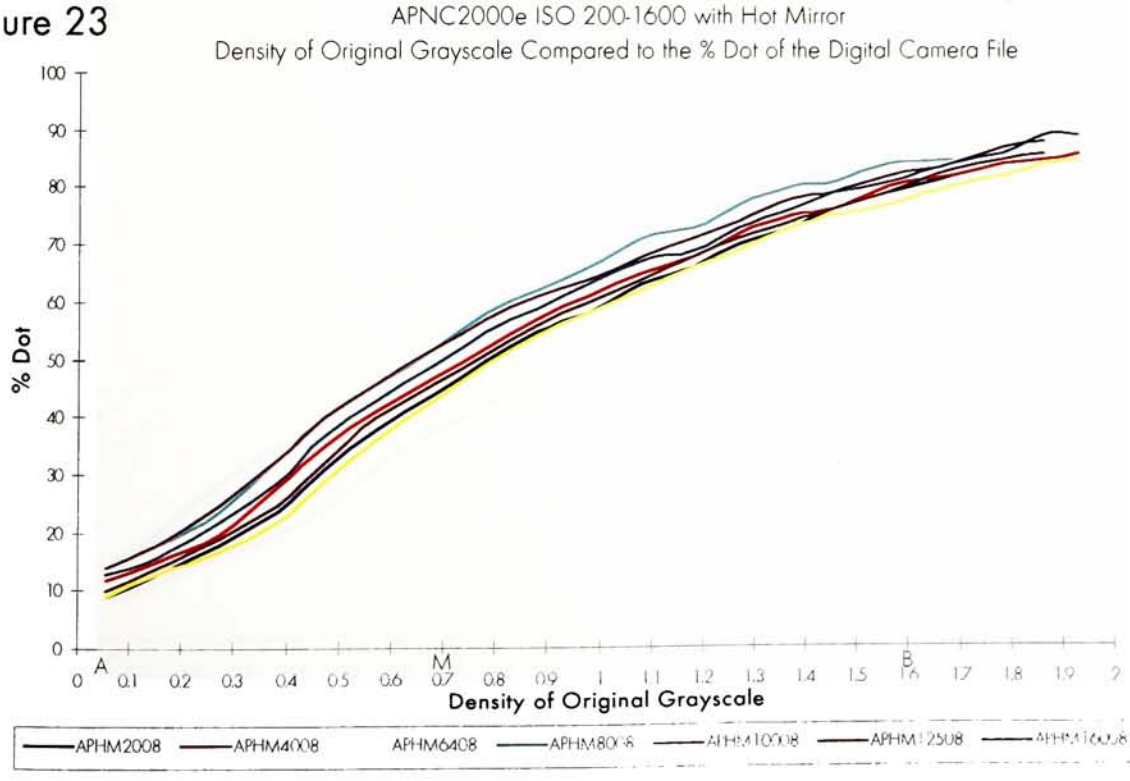


Figure 24

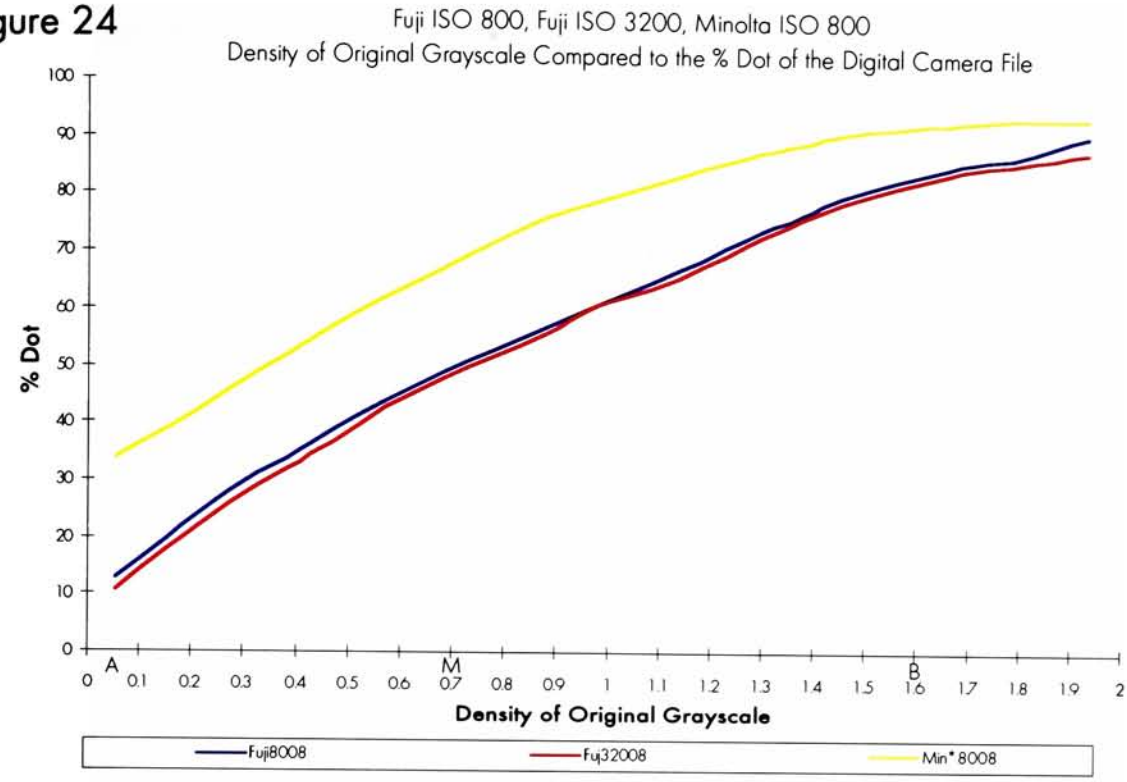
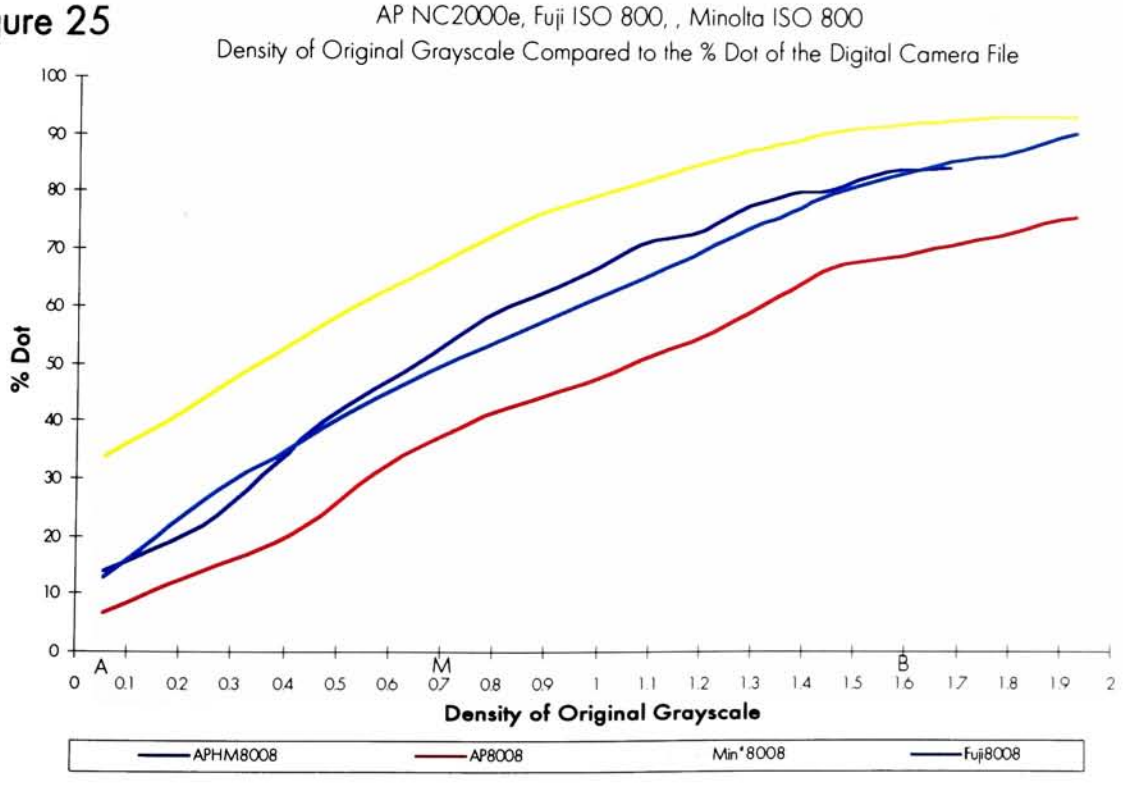


Figure 25



Dynamic Range and Noise

The dynamic range and noise observations stem from a visual and numerical analysis of a 21-step Kodak gray scale. Figures 26-42 do not depict accurate color reproduction or tonality. Figures 26-42 are intended to give a general illustration of the image noise diameter. To evaluate the images more accurately please refer to the accompanying CD which contains all the original figure digital files.

The Kodak gray scale contains 21 steps with 0.10 increments set against an 18% gray background. Each 0.10 step increment represents one-third of a stop. The highlight is identified by the letter "A." The midtone is represented by the letter "M." The shadow is represented by the letter "B."

The digital image values are outlined above each figure along with a number of usable stops identified by viewing the digital file on a computer monitor. Available stops denotes the number of stops visibly usable and containing detail. Noise factors into the determination of the available stops. When a step along the gray scale appears to contain detail because of noise frequency and diameter that step is eliminated in regards to usefulness. In this section the word detail denotes the apparent line visible between steps of varying density.

Figure 26 and 27 ISO 200 contains very little noise and the largest range of useable stops of all the cameras. As the AP NC2000e cameras ISO increase the frequency and diameter size of noise increases. At ISO 800 Figure 32 noise infiltrates the midtones. Between ISO 800 and 1600 for the AP NC2000e camera the noise frequency and diameter steadily increases.

The Fuji camera at ISO 800 Figure 40 illustrates noise frequency and diameter similar to ISO 640, Figure 30, for the AP NC2000e but the noise evident in the shadow is smoother in nature. At ISO 3200, Figure 41, the noise is significantly larger in diameter then the noise contained in Figures 26-38. Figure 41, contains a similar frequency and diameter of noise as seen in figure 38, APHM16008.

The Minolta image in Figure 42 is smooth and appears lacking in noise. It is difficult to see if there is any noise in the dark shadow region because the image is so dark. The Minolta camera has far less noise then the Fuji and AP NC2000e camera at the same ISO. The Fuji camera has more available stops of information (5 $^{1/3}$ stops) at ISO 800 then the Minolta camera (5 stops) and the AP NC2000e (4$^{1/3}$ stops).

Grayscale:

1. Compare tonal value of the reflection of the original with the tonal value of reproduced image.
2. Photograph under controlled lighting situation.

Grayscale

20 steps at 0.10 increments

Background is 18% gray.

Normal white 0.05

Black 1.95

0.10 = 1/3 stop

A 0.0 highlight

M 0.70 midtone

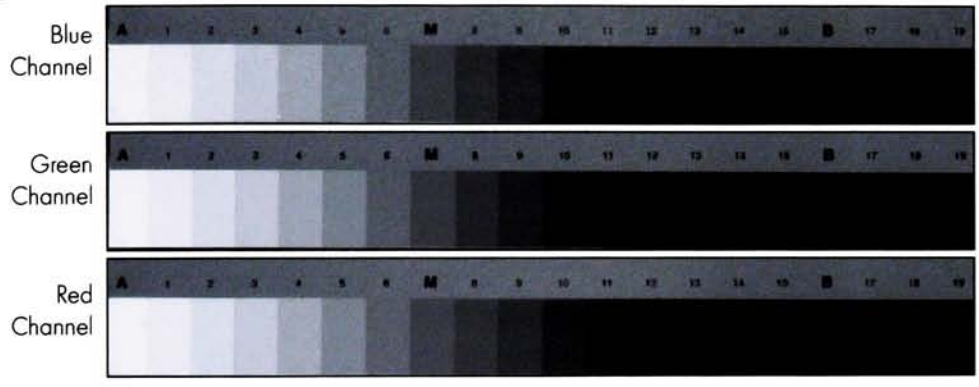
B 1.60 shadow

APHM2008

Step	Digital image % dot	Available stops 6 2/3
A	13%	
M	60%	
19	93%	

In channel b* noise is evident in steps 18 and 19. The size of the noise evident in step 18 and 19 is small. The noise seen in step 18 and 19 does not cause a loss of tonality differentiation.

Figure 26 Dynamic Range Noise Evaluation APHM2008

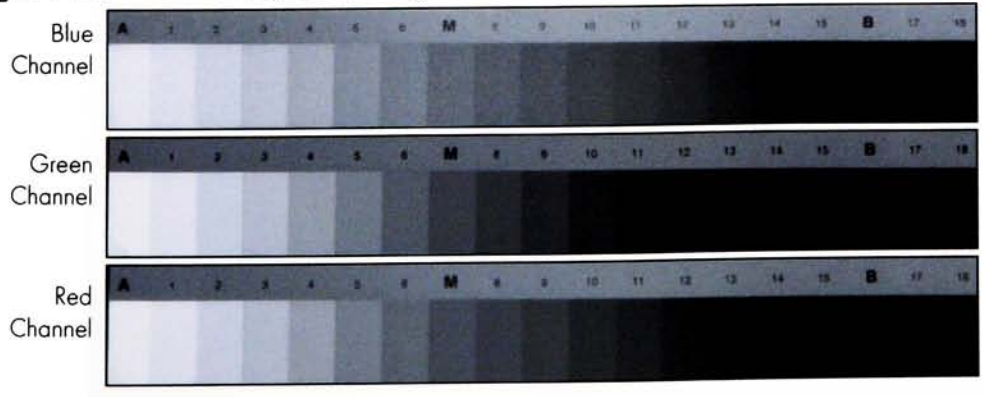


AP2008

Step	Digital image % dot	Available stops 6 1/3
A	13%	
M	56%	
19	89%	

Loss of tone differentiation is evident in the border of steps 17 and 18 with respective dot percentage being 87% and 88%. Noise is evident in channel b* at step 19 but the noise does not cause a lack in detail.

Figure 27 Dynamic Range Noise Evaluation AP2008

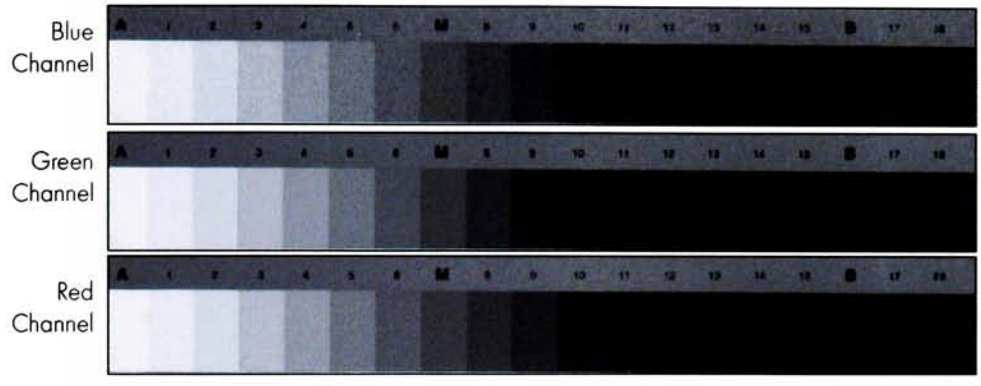


APHM4008

Step	Digital image % dot	Available stops 6
A	15%	
M	62%	
19	90%	

Loss of step border detail after step 17. Noise diameter is significantly enlarged at step 18 and 19.

Figure 28 Dynamic Range Noise Evaluation APHM4008

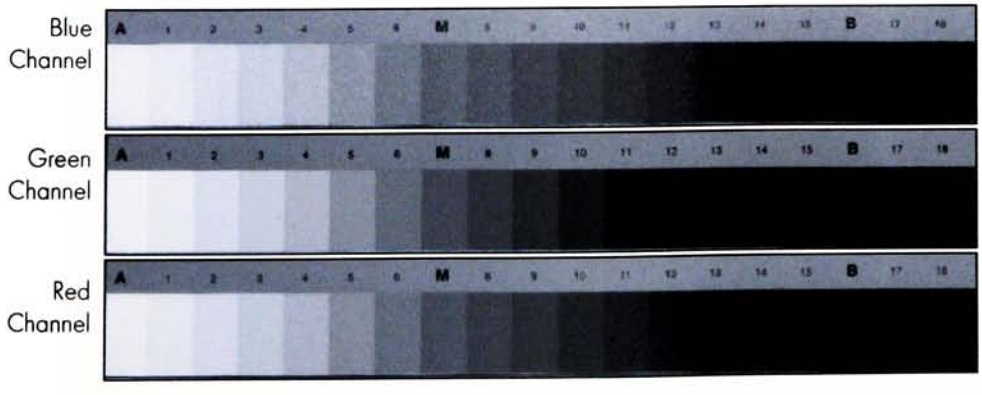


AP4008

Step	Digital image % dot	Available stops 6
A	11%	
M	54%	
19	84%	

Overall magenta cast. Noise diameter becomes problematic, large causing detail loss, at step 19. Density values change after step "B" by 1% per step beginning at step 17.

Figure 29 Dynamic Range Noise Evaluation AP4008

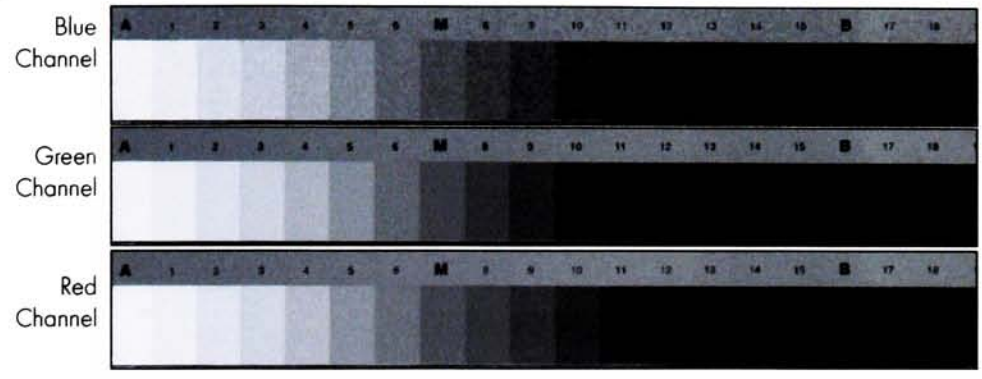


APHM640

Step	Digital image % dot	Available stops 5 2/3
A	11%	
M	59%	
19	88%	

At step 13 noise diameter becomes so large it causes step border density differentiation detail to be completely lost. Steps 17, 18 and 19 are indistinguishable due to noise diameter.

Figure 30 Dynamic Range Noise Evaluation APHM6408

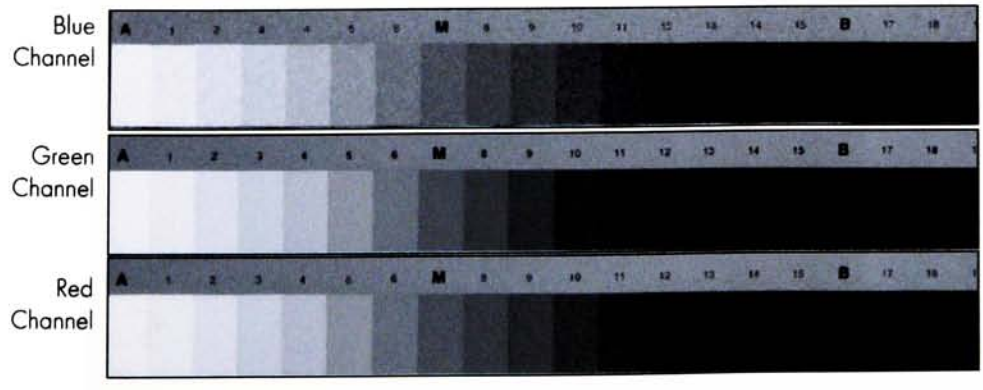


AP6408

Step	Digital image % dot	Available stops 5 2/3
A	9%	
M	55%	
19	86%	

Magenta cast in midtones. At step 13 noise diameter becomes so large it causes step border density differentiation detail to be completely loss. Steps 17, 18 and 19 are indistinguishable due to noise diameter.

Figure 31 Dynamic Range Noise Evaluation AP6408

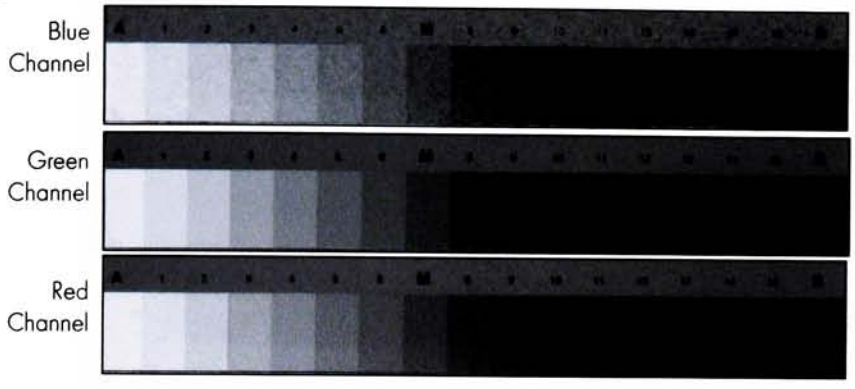


APHM8008

Step	Digital image % dot	Available stops 4 1/3
A	18%	
M	67%	
19		

After step 12 noise is so great it is difficult to distinguish steps. Step 13 and 14 contain enough large diameter noise to appear as it it were one large step. Steps 15 thru B contain such large diameter of yellow and blue noise it appears to look like detail.

Figure 32 Dynamic Range Noise Evaluation APHM8008

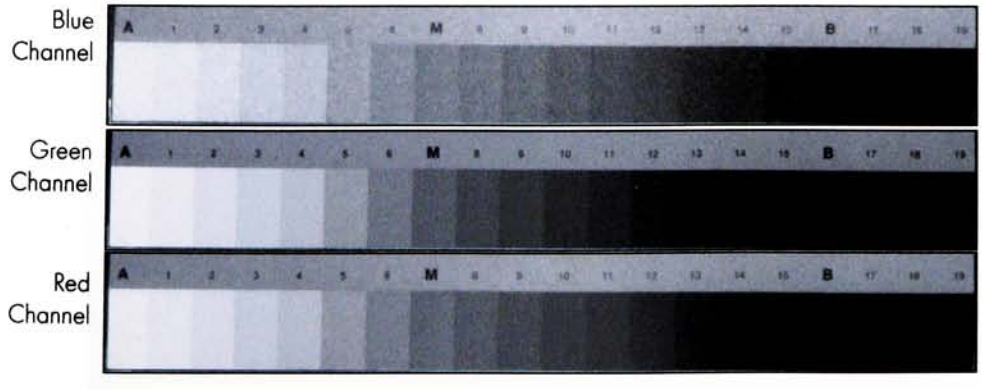


AP8008

Step	Digital image % dot	Available stops 4 2/3
A	9%	
M	50%	
19	73%	

Overall magenta cast. Step 13 and 14 contain enough large diameter noise to appear as it it were one large step. At step 17 there appears to be no tone differentiating detail between steps.

Figure 33 Dynamic Range Noise Evaluation AP8008

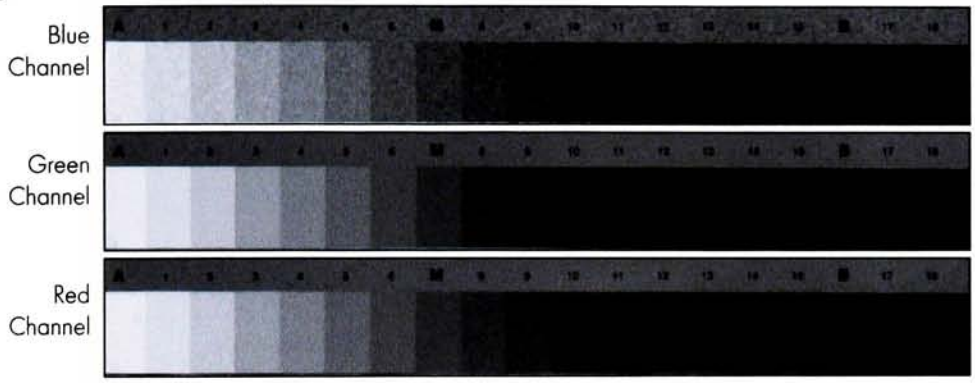


APHM10008

Step	Digital image	% dot	Available stops 4 2/3
	A	18%	
	M	67%	
	19	92%	

Noise begins at step 10. Noise diameter becomes large at step 13 causing detail loss at step B.

Figure 34 Dynamic Range Noise Evaluation APHM10008

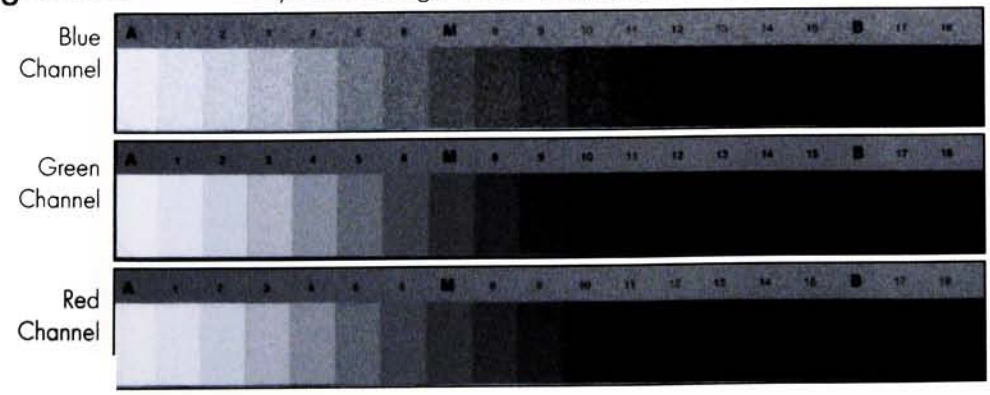


AP10008

Step	Digital image	% dot	Available stops 4 2/3
	A	14%	
	M	62%	
	19	88%	

Noise starts at step 13. Noise frequency becomes a problem at step B. Tonality differentiation border detail is non-existent at step B, 17, 18 and 19. Noise diameter is significantly large at step B.

Figure 35 Dynamic Range Noise Evaluation AP10008

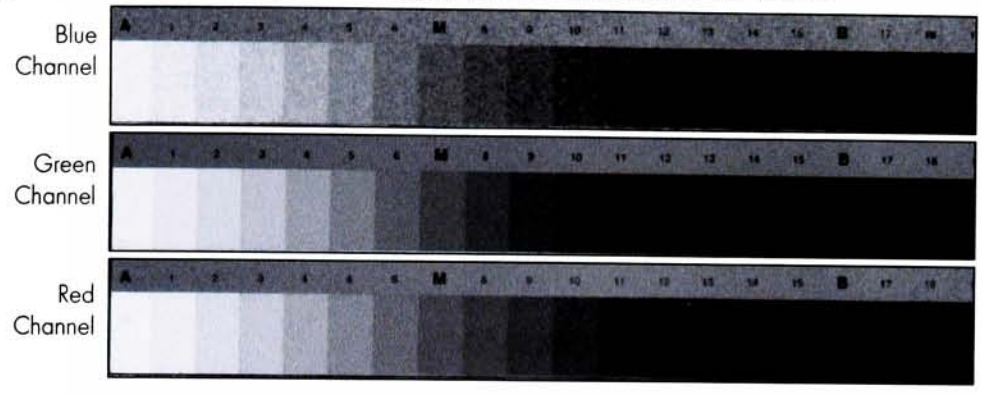


APHM12508

Step	Digital image % dot	Available stops 5 1/3
A	13%	
M	61%	
19	90%	

After step B noise diameter is so significant detail is loss at tonality differentiation border and color noise appears to look like detail.

Figure 36 Dynamic Range Noise Evaluation APHM12508

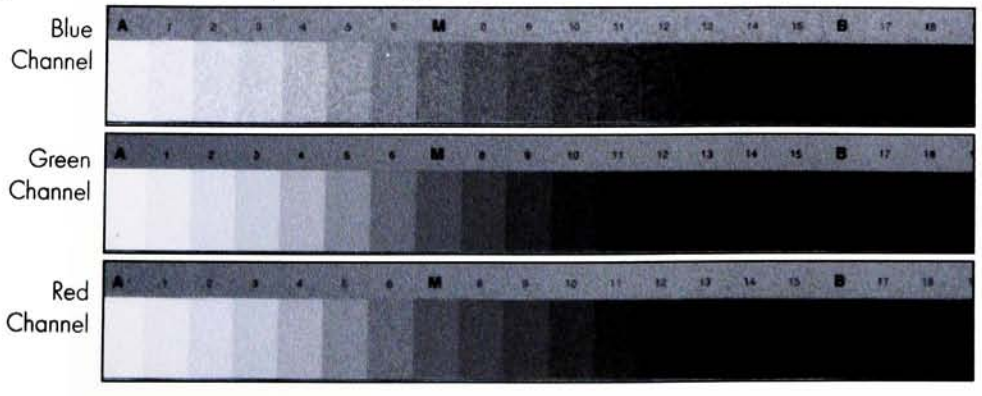


AP12508

Step	Digital image % dot	Available stops 5 1/3
A	10%	
M	56%	
19	85%	

After step B noise diameter is so significant detail is loss at tonality differentiation border and color noise appears to look like detail.

Figure 37 Dynamic Range Noise Evaluation AP12508

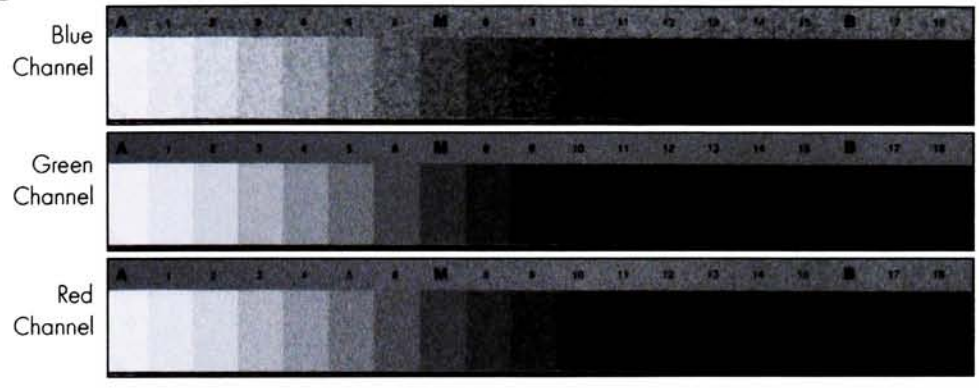


APHM16008

Step	Digital image	% dot	Available stops 4 2/3
	A	16%	
	M	65%	
	19	85%	

After step 13 noise diameter is so large detail is loss at the border of the steps. Noise is first evident at step 8.

Figure 38 Dynamic Range Noise Evaluation APHM16008

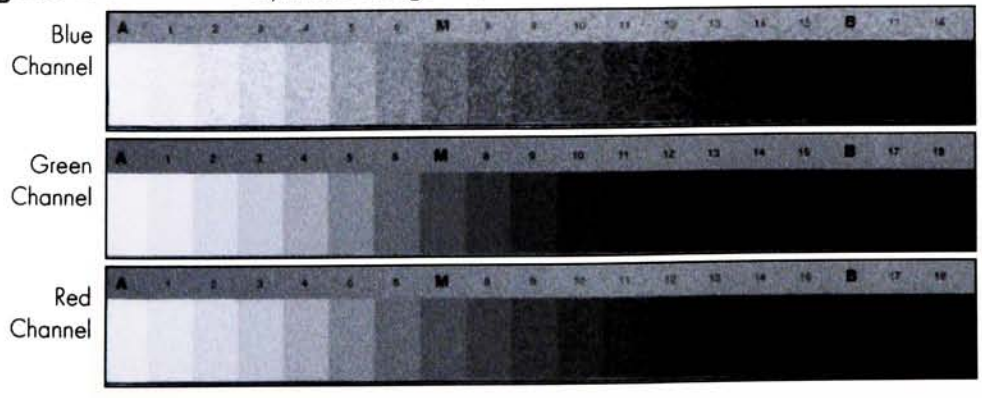


AP16008

Step	Digital image	% dot	Available stops 4 2/3
	A	11%	
	M	57%	
	19	80%	

Magenta cast is evident over entire gray scale. After step 13 noise diameter is so large detail is lost at the border of the steps. Noise is first evident at step 8.

Figure 39 Dynamic Range Noise Evaluation AP16008

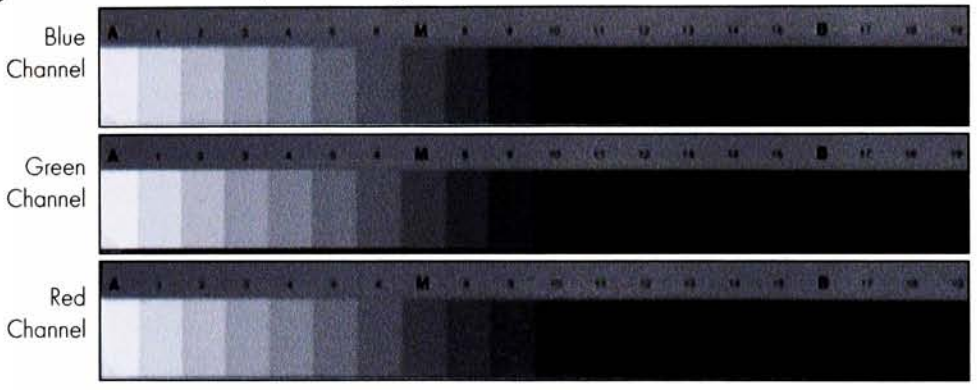


Fuj8008 No Compression

Step	Digital image	% dot	Available stops 5 1/3
	A	11%	
	M	49%	
	19	89%	

Small amount of noise evident at step 11. At step 13 noise diameter increases with a greater frequency of extraneous color aliasing. Noise diameter remains the same in size from step 13 on but appears smooth. Frequency of noise increases slightly with density.

Figure 40 Dynamic Range Noise Evaluation FUJ8008NC

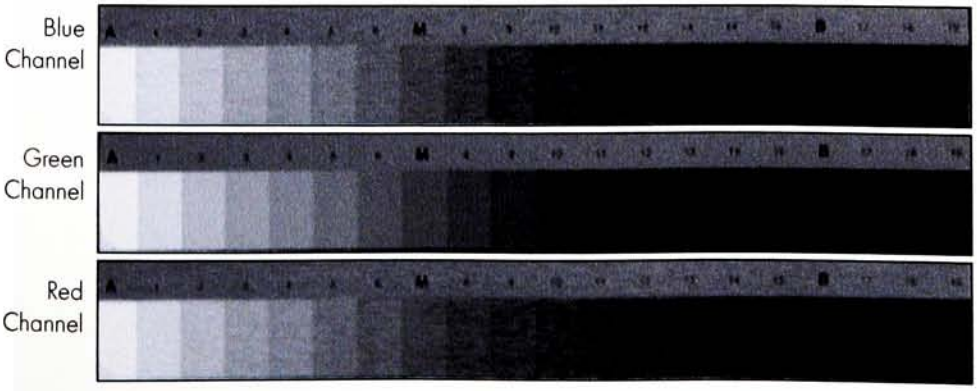


Fuj32008 No Compression

Step	Digital image	% dot	Available stops 4
	A	10%	
	M	48%	
	19	86%	

Noise is first evident at step 11. Step 13, 14 and 15 appear like one large step the detail in the tonality differentiation border is non-existent in steps 13, 14 and 15. Steps B, 17, 18 and 19 also appear like one large step with the detail in the tonality differentiation border being non-existent. The noise diameter at step 11 is so large it appears to look like detail.

Figure 41 Dynamic Range Noise Evaluation FUJ32008NC

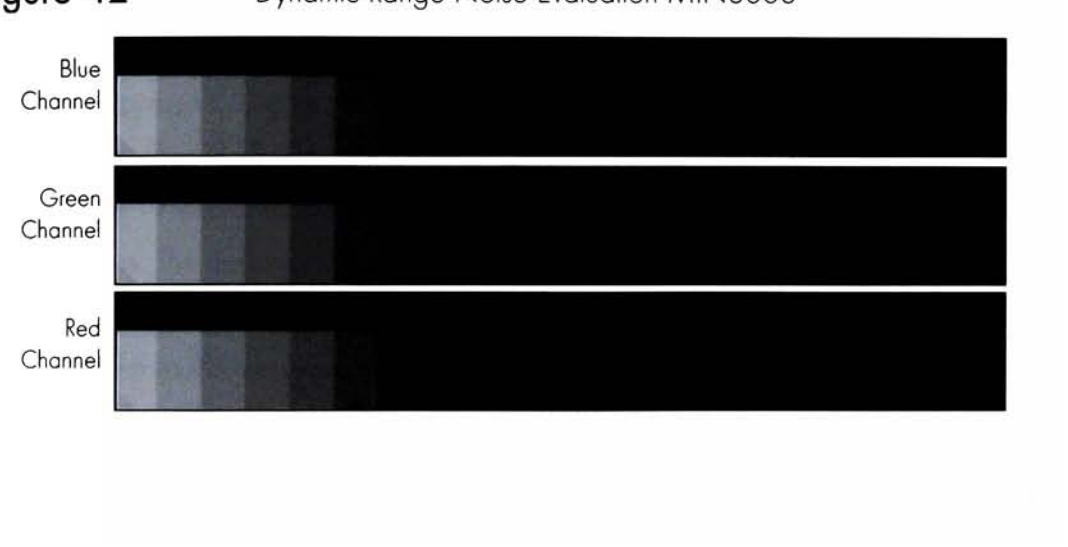


MIN8008

Step	Digital image	% dot	Available stops 5
	A	31%	
	M	66%	
	19	94%	

Last tonality difference detail is evident at step B. In the red channel noise is evident at step 8 but the exhibited noise is smooth without jagged edges. In the blue channel step M the frequency of smooth noise increase. Diameter remains same.

Figure 42 Dynamic Range Noise Evaluation MIN8008



Newspaper Sample Results

In the newspaper sample three areas were evaluated: color reproduction, visual resolution, and noise. Plates 17-29 illustrate digital camera color reproduction, tonal reproduction and noise. Plates 17-29 show the digital camera data in its rawest form. In Plates 17-29 the only toning done to the images was for neutrality. Neutrality was set using the white wedge.

Plates 17-20 compare the raw images of each camera at ISO 800. We can see the significant color and density difference between Plate 17, AP NC2000e at ISO 800 shot with a hot mirror filter, and Plate 18, AP NC2000e at ISO 800 shot without a hot mirror filter. Plate 18 has an overall magenta hazy cast throughout the image. The magenta hazy cast is a result of infrared over exposure which occurs when the hot mirror filter is not used.

Plate 19 illustrating the Minolta camera file at ISO 800 is the darkest reproduced image of all three cameras. The darkness in Plate 19 mimics the graphical density reproduction results in figure 23 and 24. The Fuji image in Plate 20 also is dark but less so than the Minolta file in Plate 19.

Based on the unadjusted images it can be concluded that the AP NC2000e camera using the hot mirror filter exhibited the best overall uncorrected color and tone reproduction of the three cameras photographed using ISO 800.

Plate 21 and 22 compare ISO 200 with a hot mirror filter but using two different cameras, AP NC2000e and the EOS DCS3, with the same type of CCD imager. Plate 21, AP NC2000e, is brighter than Plate 22, EOS DCS3. The color for Plates 21 and 22 appear slightly different. The color difference can be attributed the fact that the imagers are unique devices and may vary slightly in the production process.

Plate 23 and 24 compare ISO 1600 with a hot mirror filter using two different cameras, AP NC2000e and the EOS DCS3, with the same type of CCD imager. Plate 23, AP NC2000e, is brighter than Plate 24, EOS DCS3. Color for Plates 23 and 24 appear slightly different.

The tone reproduction and color difference results from Plates 23 and 24 mimic the results in Plate 21 and 22. It can be concluded that the CCD imager in the EOS DCS3 has a slightly darker tone reproduction then the CCD imager in the AP NC2000e camera.

In Plate 25 and 26, images photographed with the Fuji camera at ISO 3200, we compare compression. Plate 26 has a 1:1 compression ratio while Plate 25 has no compression. There appears to be not noticeable difference between Plate 26 with compression and Plate 25 without compression.

Plates 27-29 illustrate the digital camera files with adjustments made in Adobe Photoshop. The adjustments made to the three images included setting neutrality using the MacBeth Color Checker white wedge for highlight placement and the black wedge for shadow placement. Noise reduction procedures as outlined in the Plates was performed.

The adjusted image in Plate 27 looks brighter, cleaner and more saturated then its equivalent APHM8008 raw image in Plate 17. Plate 28 also is brighter, more saturated and cleaner then its equivalent MIN8008 raw image in Plate 19. Plate 29 also is brighter, more saturated and cleaner then its equivalent Fuj8008 raw image in figure 20.

In evaluating Plates 27-29 for color, Plate 28, MIN8008, exhibited the best saturation and memory color accuracy to the original MacBeth Color Checker. Plate 28, MIN8008, was most vivid and true in appearance in the reds and yellow. In Plate 27, APHM8008, the reds and yellows are muted and have a hue shift toward magenta.

Of Plates 27-29 Plate 27, APHM8008, exhibits the best "light skin" tone (top row second wedge from left). The "light skin" wedge in Plate 28, MIN8008, appears muddy and brown. The "light skin" wedge in Plate 29, FUJ8008, is lacking in red but appears more accurate than in Plate 28.

The adjusted digital files in Plates 27-29 illustrate a tremendous increase in apparent image quality with only the bare minimum of adjustments.

Plate 17

APHM8008

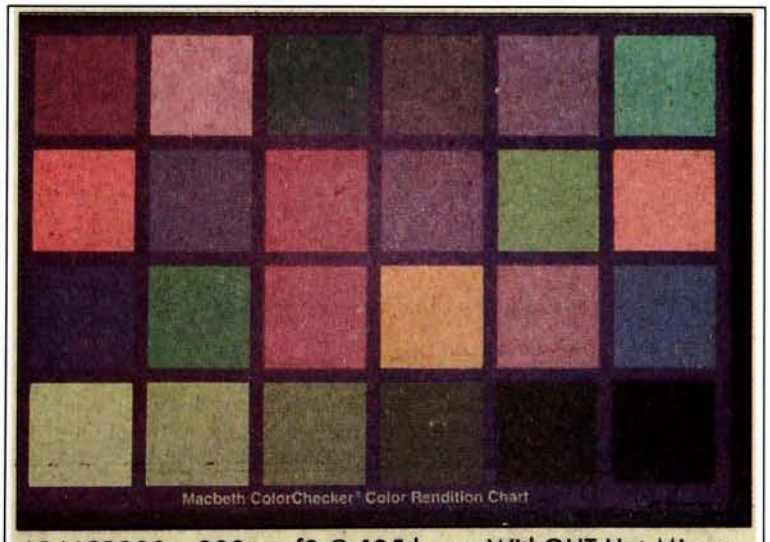
Newspaper Raw Color Reproduction

AP NC2000e, 800asa f8 @ 125th sec, With Hot Mirror

Plate 18

AP8008

Newspaper Raw Color Reproduction

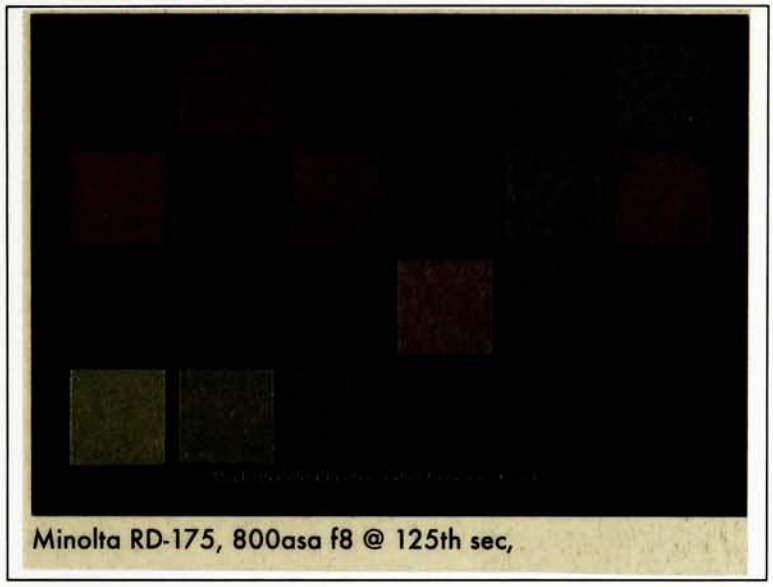


AP NC2000e, 800asa f8 @ 125th sec, WithOUT Hot Mirror

Plate 19

MIN8008

Newspaper Raw Color Reproduction



Minolta RD-175, 800asa f8 @ 125th sec,

Plate 20

FUJ8008

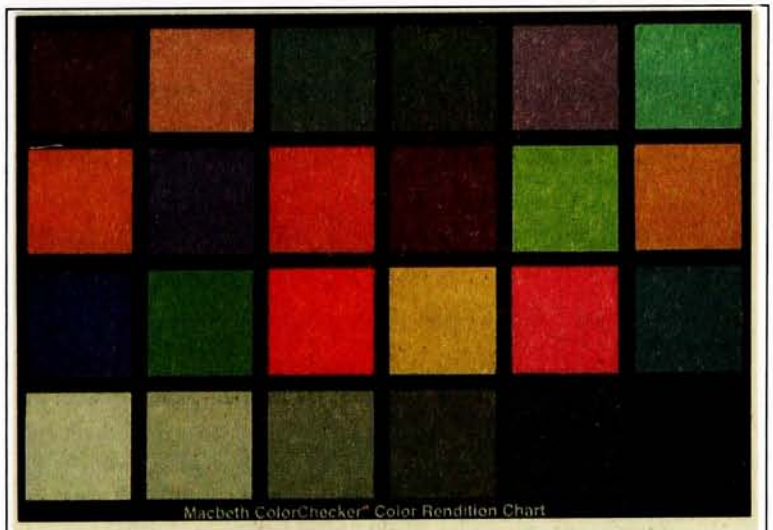
Newspaper Raw Color Reproduction

Fuji 505a, 800asa f8 @ 125th sec, No compression

Plate 21

APHM2008

Newspaper Raw Color Reproduction

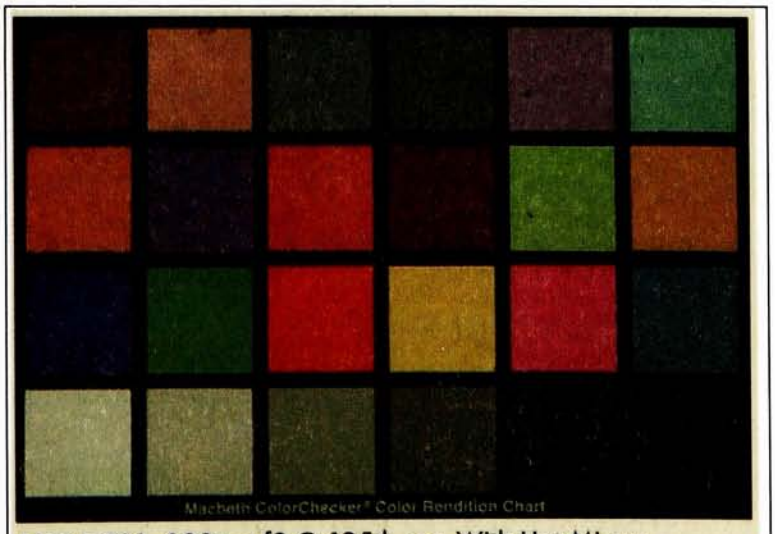


AP NC2000e, 200asa f8 @ 125th sec, With Hot Mirror

Plate 22

EOSHM2008

Newspaper Raw Color Reproduction

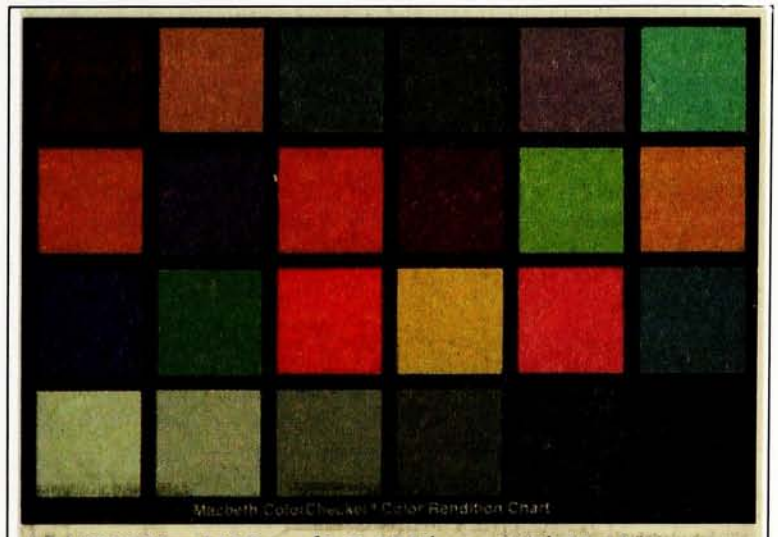


EOS DCS3, 200asa f8 @ 125th sec, With Hot Mirror

Plate 23

APHM16008

Newspaper Raw Color Reproduction

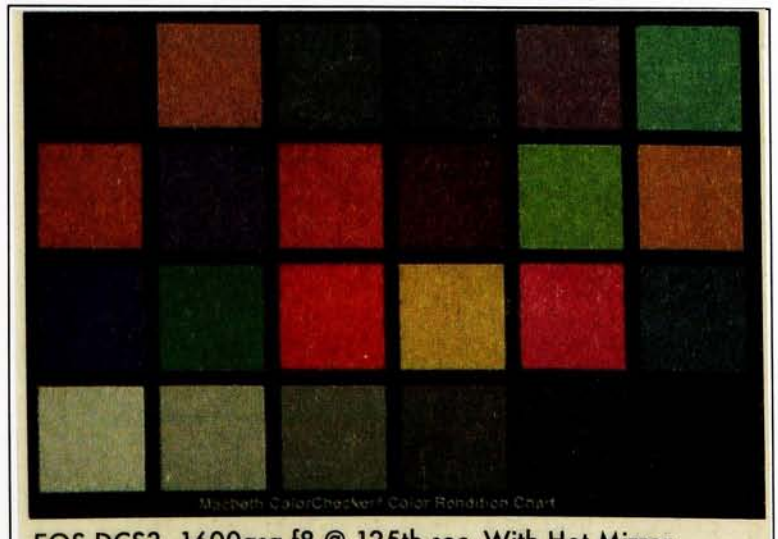


AP NC2000e, 1600asa f8 @ 125th sec, With Hot Mirror

Plate 24

EOSHM16008

Newspaper Raw Color Reproduction

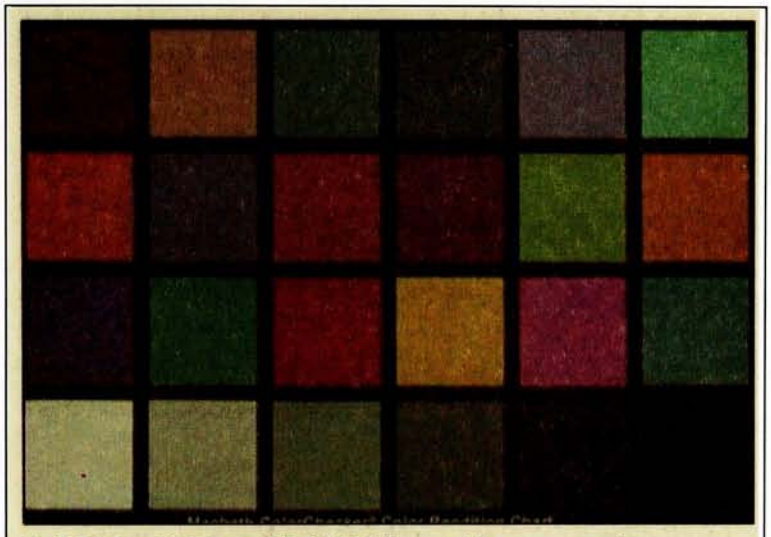


EOS DCS3, 1600asa f8 @ 125th sec, With Hot Mirror

Plate 25

FUJ32008 No Compression

Newspaper Raw Color Reproduction

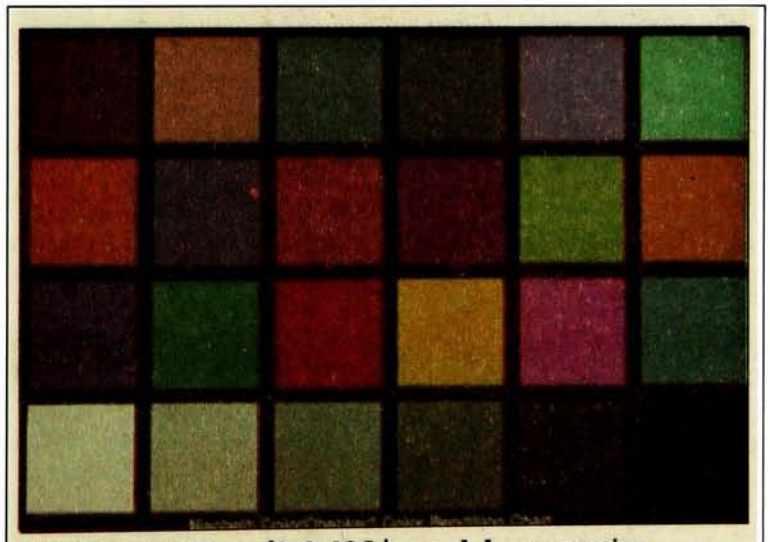


Fuji 505a, 3200asa f8 @ 125th sec, No compression

Plate 26

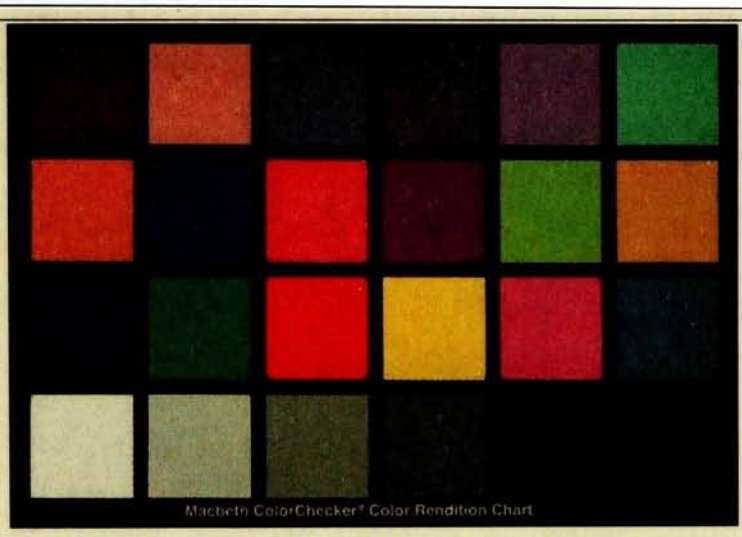
FUJ32008 1:1 Compression

Newspaper Raw Color Reproduction



Fuji 505a, 3200asa f8 @ 125th sec, 1:1 compression

Image Adjustment Newspaper Color Reproduction



AP NC2000e, 800asa f8 @ 125th sec, With Hot Mirror

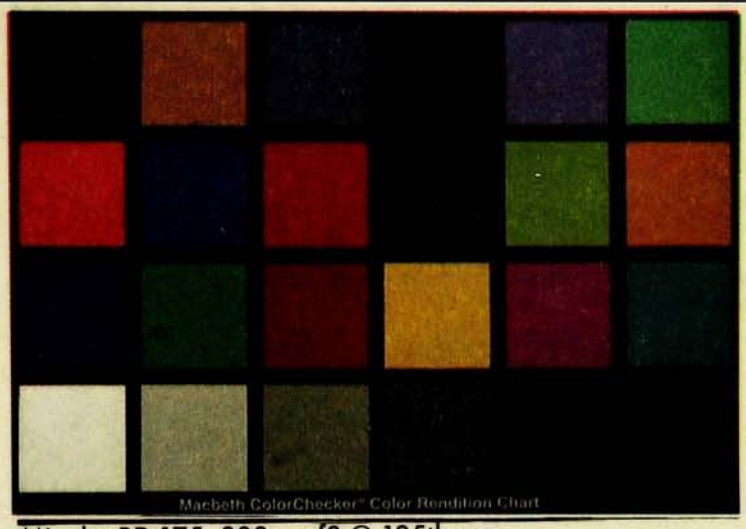
ADOBE PHOTOSHOP PROCEDURES:

Acquire: 12 bits per channel
Color balance: CLICK (use white patch of Color Checker)
Curves:

Eyedropper settings:
Highlight: C 3% M 2% Y1% K 0%
Shadow: C 80% M75% Y 75% K 70%

Convert to Lab:

- Dust and Scratches: Channel "B" = 10 & 3
- Dust and Scratches: Channel "A" = 8 & 3
- Unsharp masking of:
  "Lightness" channel = 100% 1 pixel, 7 radius



Minolta RD-175, 800asa f8 @ 125th sec

ADOBE PHOTOSHOP PROCEDURES:

Acquire: 12 bits per channel
Color balance: CLICK (use white patch of Color Checker)
Curves:

Eyedropper settings:
Highlight: C 3% M 2% Y1% K 0%
Shadow: C 80% M75% Y 75% K 70%

Convert to Lab:

- Dust and Scratches: Channel "B" = 8 & 0
- Dust and Scratches: Channel "A" = 6 & 0
- Despeckle "Lightness" Channel

Unsharp masking of:

"Lightness" channel = 100% 1 pixel, 10 radius

Plate 29

FUJ8008 No Compression

Image Adjustment Newspaper Color Reproduction

Fuji 505a, 800asa f8 @ 125th sec, No Compression

ADOBE PHOTOSHOP PROCEDURES:

Acquire: 12 bits per channel

Color balance: CLICK (use white patch of Color Checker)

Curves:

Eyedropper settings:

Highlight: C 3% M 2% Y1% K 0%

Shadow: C 80% M75% Y 75% K 70%

Convert to Lab:

- Dust and Scratches: Channel "B" = 8 & 3
- Dust and Scratches: Channel "A" = 8 & 3
- Despeckle "Lightness" Channel

Unsharp masking of:

"Lightness" channel = 100% 1.5 pixel, 6 radius

AUTHOR BIOGRAPHY

Victoria Arocho: Electronic Publishing Graduate Student and Photojournalist

GRADUATE THESIS LOOKS AT DIGITAL NEWS PHOTO AND PREPRESS

Victoria Arocho a photojournalist with an undergraduate BA from Rochester Institute of Technology in photography, examines digital photography in the newsroom to complete her graduate degree in the School of Printing at Rochester Institute of Technology.

DIGITA PHOTO

Prepress Issues and Di

Digital Camera Created Images and their Preparation for Newspaper Lithographic Reproduction

By: Victoria Arocho

The role photojournalist's have played, historically, has been to "preserve forever a finite fraction of the infinite time of the universe," according to Howard Chapnick, Truth Needs No Ally, always being asked to do so quicker, more efficiently and under the watchful cost effective guise of money management. Digital photography is one of the newest tools for allowing the establishment of "truth of events that seem inconceivable," Howard Chapnick Truth Needs No Ally, while enabling for the most timely distribution of photographs worldwide.

THESIS

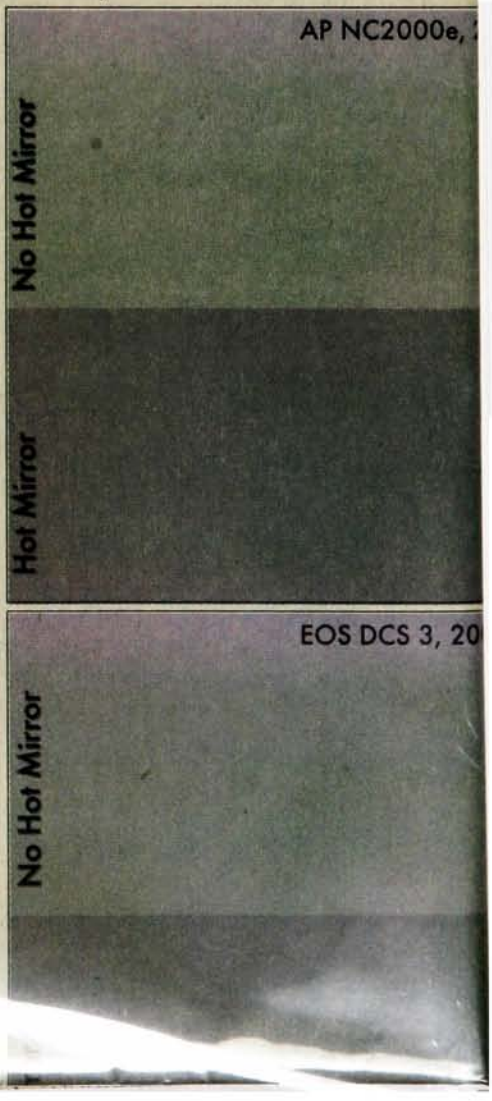
With the special demands placed on photojournalist, constantly pushing digital technology to it absolute limits, how can newspapers reproduce the highest image quality from digital images which have inherent technological limitations?

Looking at the shoes which digital [illegible] performed under [illegible] hypothesis [illegible] altered in role and placement of responsibility. The "color scanner chosen" now becomes the digital camera chosen. The "proper scanner or desktop computer setup for the printing parameters and the originals image and emulsion characteristics" now become subject to the photographers exposure control and compression ratio. "The scanner operators image adjustment for a good visual reproduction" is now complicated by camera tendencies due to technological limitations (artifacting, blue noise) and is often placed in the hand of photographers who are poorly trained in prepress issues or prepress professionals that are unfamiliar with camera limitations.

With the redefinition of color reproduction issues and the loss of control over image acquisition by the prepress professional it is important to identify digital image tendencies and possible solutions [illegible] these tendencies. This thesis being [illegible]

EFFECTS OF HO

A single tone evenly lit large sheet of pape tographed at the same exposure with a Tiff Hot Mirror filter. Images were viewed in A neutrality.



Chapter 7
Summary and Conclusion

This thesis project shows that digital camera CCD solid state devices are affected with changes in color, density, resolution and range, depending on the selected ISO. These ISO induced changes form camera/ISO specific characteristics. The camera/ISO specific characteristics are similar in nature among CCD imagers of the same type but are not identical. Identified camera/ISO specific characteristics can then be correlated with color correction and prepress methods which will help optimize the characteristic deficiencies.

The correlation between camera/ISO "specific characteristics" is based on prepress principles and Adobe Photoshop image editing techniques. For example, if a camera exhibits a particular color shift its complimentary color can be determined. In Adobe Photoshop the best tool to address needed color alteration is identified and the degree of the alteration is determined by the printing model and the prepress procedures used within workflow.

During the evaluation of the visual resolution, color gamut, tone reproduction and imager consistency tests the following summary of results were determined.

Imager Consistency

Imager consistency and image exposure affects resolution and color. Variations in imager consistency are prevalent in the AP NC2000e and EOS DCS3, as illustrated in Plates 5-10. The Minolta RD-175 and the Fuji 505a did not exhibit imager consistency problems.

The imager consistency problems prevalent in the AP NC2000e and the EOS DCS3 cameras at ISO 200-1600 were excentuated by not using a hot mirror filter. Plates 1-4 illustrate the density difference between a Kodak camera image taken with a hot mirror filter and Kodak camera derived image taken without a hot mirror filter.

The hot mirror filter and the imager consistency problems were only observed in the AP NC2000e and the EOS DCS3 Kodak made cameras. The Minolta and Fuji cameras did not need to use a hot mirror filter because of the different nature of their CCD's. The imager consistency variations did occur at each ISO, recorded with and without a hot mirror filter. The imager consistency test only yielded results identifying that there were imager variations present. It could be theorized, that the variations which occurred in two different camera systems with similar SLR bodies and the same type of

CCD imager are CCD type related or affected by some characteristic of the SLR components.

Hot mirror filters aid in the near elimination of the infrared light received by the CCD. Uncompensated infrared light causes overexposure. Since overexposure destroys needed highlight information it is imperative that the hot mirror filter be used when taking photographs. Though not recommended, if it is necessary to photograph without a hot mirror filter, it is important to account for infrared overexposure when determining exposure. This can be done by decreasing the overall image exposure. The best method to determine what exposure compensation is needed, at each ISO, is to photograph a gray scale at various exposure compensations and using the "info box" in Adobe Photoshop to determine which compensation gives the most accurate reproduction.

Imager consistency issues explain bands of discoloration which are common when shooting at high ISO's. Plate 8 and10 of ISO 800 for the AP NC2000e and the EOS DCS3, respectively, with the use of a hot mirror filter illustrate a greater level of imager inconsistencies. These inconsistencies are reflected by the center, top and bottom portion of the image appearing lighter with a magenta cast.

One method of minimizing this would be to make a selection of the area affected and add its complimentary color. When making the selection it is important to try several high feather ratios. The feathering ratios will alleviate any hard lines indicating a correction. The complimentary color can be added in curves until a visually satisfactory result is achieved. Once assimilation is achieved between the area affected by a color shift and the unaffected area the two image portions can be toned as one. Though this procedure is highly impractical in a daily newspaper workflow, it is important to recognize it as an option in cases where extreme imager inconsistencies are present. This type of selection correction is risky but often necessary.

All images shot without a hot mirror filter have an inherently expanded magenta region within the color gamut that the prepress technician can remove using the "hue/saturation" tool. It also can be noted, by looking at the NC2000e color gamuts without the hot mirror filter, that the image's gamuts are truncated in the red, yellow and green region therefore foreshadowing the need to excentuate these colors. This excentuation can also be achieved by reassigning the digital image's color values using the "hue/saturation" command in Adobe Photoshop.

Noise

Noise is a part of digital photography. Noise is caused by increasing the signal amplification of CCD's which only have one ideal sensitivity that addresses both dynamic range and color quality. For the sake of versatility, the CCD's must be able to record in various light conditions and various ISO's. Noise visi-

ble in the shadow region of an image during viewing on a computer monitor will not always appear as intense on the actual newspaper reproduction. Plate 23 of the AP NC2000e camera shot at ISO 1600 with a hot mirror filter does not illustrate half as much noise as was visible in the digital image displayed on the monitor. The reduction of noise in an image can be correlated to the spreading of the ink dot during dot gain due to the porous nature of the substrate used in the SNAP model. Plate 23 appears to retain the print quality of an image with a lower ISO and noise count. It must be noted that because the test targets reproduced were solid tones the effects of noise on detail were unobservable.

Using the lowest ISO possible decreases the overall amount of noise within a digital image. In Figure 30 AP NC2000e, using ISO 640 with a hot mirror filter, we see the last ISO available where the noise frequency and diameter has not infiltrate the midtones. At ISO's greater then 640 we see noise in the midtones as in Figure 31in the blue channel.

Color Gamut

The AP NC2000e exhibits a unique color gamut for each ISO. No two ISO's have exactly the same color gamut. The digital file of ISO 640 exhibits the greatest color gamut, as illustrated in Figures 2 and 3, with ISO 400 having the second largest color gamut and ISO 200 having the third largest gamut. All though ISO 640 exhibits a greater color gamut then ISO's 200 and 400 it is important not to select an ISO based on color gamut size alone. The ISO best for each shooting situation must be determined by considering noise, range and resolution. Despite ISO 640 in the AP NC2000e having the largest color gamut, we know that it contains more noise then ISO 200 and 400.

Acknowledging ISO 800 has the smallest color gamut and renders noise in the shadows and some midtones, we can eliminate it from use for output to a SNAP workflow. All ISO's greater than 800, though containing larger color gamuts than ISO 800, have far greater levels of noise than ISO 800 thus eliminating ISO 1000, 1250 and 1600 from use within a SNAP workflow because noise levels are too high. The reproduction of excessive noise in the shadow regions of an image reproduced within a SNAP workflow would increase the "blocking up" of the shadows. The blocking up of the shadow further reduces the ability to reproduce detail in these regions.

Use of ISO 640, when ISO 800 is called for, can be achieved by three methods. The first of these methods involves choosing a lens that offers an additional 1/3 stop of light. The second method would include adding a 1/3 stop of light to the scene and the third method involves reassigning the tone reproduction of an image in Adobe Photoshop. Using tone manipulation techniques available in Adobe Photoshop, the midtone portion of the graph representing the image would decreases. By using

ISO 640 we now have obtained the greatest color gamut affordable with the least amount of noise. This ISO/color relationship is invaluable to the prepress technician. When a prepress technician receives the highest color quality and least noise containing image he has more image data to map the workflow to.

Gamut size is increased significantly with the use of a hot mirror filter. Without the presence of of a hot mirror filter the infrared light passes through to the CCD causing infrared over-exposure which decreases density and the size of the color gamut.

It is important to choose the camera and the individual camera's ISO with the greatest color gamut since during the printing process we lose so much of the original available gamut. If we start with a small digital image color gamut, the gamut will shrink in relative proportion to the original based on the capabilities of the inks, paper and press. Because of this, it is important to use Adobe Photoshop to reassign the values that exhibit color gamut deficiencies, decreasing the digital camera color shifts in an effort to produce the best tone and color reproduction. In Appendix E, Figures 47-51, we can see the difference between the digital data color gamut and the gamut of the same file reproduced on newspaper. The exaggerated portion of the raw digital image color gamuts are reproduced in similar proportion to the smaller newspaper reproduction gamuts. Imager color shifts would be reproduced to the SNAP workflow.

The gamut deficiencies and color shifts can be adjusted by reassigning the color values using Adobe Photoshop techniques including the "hue/saturation" command and the "selective color" command. "Hue/saturation" works by reassigning the images' color values to represent colors with more saturation or a different hue. "Selective color" is similar to techniques used in "high-end scanners and separation programs to increase and decrease the amount of the process colors in each of the additive and subtractive primary color components in an image."[1] "The selective color command enables you to correct imbalances in the color as well as adjust colors to suit your preferences,"[2] or in the case of the digital files, expand your gamut.

The selective color command must be used with discretion as not to affect the SNAP ink balance during printing. An increase or decrease in a selective color value can cause an image to appear great on screen but will cause a degradation of the images' reproduction quality.

Density

The density range of an image is determined by the concentration of tones within the image. Each digital camera has the ability to reproduce a specific range of density differences. When the range of an image is changed with exposure, the results will alter the reproduction of the original scene. The selection of an exposure will determine where the center of an images' range falls. Moving the center of the range up or down the scale will render a loss of detail in the highlights and/or dark shadows. Loss of highlight detail from overexposure will cause the overexposed area to appear white and devoid of detail.

Adobe Photoshop can reassign an image's density values but overexposed highlight regions most often contain no reassignable data. Increasing the density of an overexposed digital image will cause the highlight density values to become darker, in a location where no detail is present. Because Adobe Photoshop can not recreate absent information the resulting highlight region will appear gray and without detail. Attempt to use Adobe Photoshop to reassign density values in an overexposed image will also cause the image to appear contrasty and over saturated.

An overexposed image can no longer meet the demands of a SNAP printing model because there is no information located in the highlight area of the image. The highlight area is needed to help set the tonal range of the reproduction. If an overexposed image is printed, the reproduction will contain tonal values which do not match the original scene. Original shadow scene values will be printed as midtones.

Underexposure causes the range of an image to shift, darkening the highlights, shadows and midtones. Darkened shadow detail can be lightened in Adobe Photoshop without many ill effects, but regardless of ISO, underexposure renders increased blue noise in the shadows. Increased shadow area noise, because of underexposure, at lower ISO's does not effect the overall noise content of an image as would the adding of underexposure related noise at higher ISO's. Underexposing an image at a higher ISO can add enough excessive blue noise resulting in compromised detail in the shadows and increased noise in the midtones. Compromised shadow detail is a result of the noise diameter and frequency increasing so much that it appears as if the noise itself was image detail. Noise frequency changes in two forms as the ISO increases: noise increase in the amount present or frequency and increases in size or diameter. High levels of shadow noise also can cause the image reproduction to have blocked up shadows with little or no detail.

It's the job of the photographer to be as precise as possible with the exposure thus alleviating the underexposure/noise-increase relationship and overexposure loss of highlight detail. Though underexposure is considered a lesser evil then overexposure, there are certain photojournalist situations (such as shooting low key subjects at high ISO's, ie. "indoor basketball, night football") that would make underexposure accuracy even more critical. Image exposure placement is therefore critical to the success of a digital image's overall reproduction quality and success within the SNAP printing model.

Exposure determination with the use of a calibrated camera light meter is necessary. Such use of a calibrated camera light meter should be done in conjunction with knowledge concerning the subjects relative density reflectance. Density reflectance awareness refers to the fact that subjects and colors of varying densities reflect different levels of light. Because a camera light meter indiscriminately places what is presented before it at 18% gray it is important for the photographer to be aware of the

potential reflectance value of a subject because it may, often times, not always equal 18% gray. Incorrect metering will alter the placement of the image's range.

Being aware of basic principles such as those involved in the zone system will allow photographers to visually assign a memory reflectance value reference to the subject, thus, allowing more accurate metering. "In the Zone System, the subject is described in terms of subject values, which relate to different subject luminance."[3] Using the zone system as defined in *Photographic Materials and Processes*, by Leslie Stroebel, John Compton, Ira Current and Richard Zakia,certain values are assigned to objects. Use of these objects and their assigned placement within the zone system increases the accuracy of the in-camera meter.

Exposure determination with the use of a portable handheld gray card in conjunction with the camera meter eliminates the guess work involved in assigning a memory reflectance value to the content of a scene. Photographing a gray card will give the prepress technician a neutral reference point during image toning in Adobe Photoshop. Photographing a gray scale performs a similar function to a prepress technician scanning a gray scale. The third method of exposure metering involves a handheld incident light meter. Both above methods of metering contain higher levels of exposure evaluation accuracy than using the camera meter pointed at a scene alone. The luminance of a scene will change depending on the nature of the scene. A high key image such as a polar bear in snow will reflect more light then a low key image such as black panther on black velvet cloth.

Spatial Resolution

Camera spatial resolution is affected by, the type of CCD, the size of the CCD and its pixels, manufacture acquiring functions and ISO. The use of a hot mirror filter can not affect imager resolution. As the ISO increased the horizontal and vertical visual spatial resolution of the AP NC2000e, Tables 10-13, decreased. The newspaper reproduction workflow also reduces the visual spatial resolution for all the printed digital images. The main aspect reducing the image resolution in a newspaper workflow is the nature of the substrate used and the printing processes. The porous nature of the newsprint causes ink spread to be more evident then on a coated substrate. Ink spread can render fine detail unsharp.

The AP NC2000e camera exhibited the greatest visual spatial resolution of all three cameras tested. The Minolta RD-175 contained the second greatest level of visual spatial resolution with the Fuji 505a having the least resolution of all the cameras.

The factor that identified the highest level of visual spatial resolution in the AP NC2000e was the point when color aliasing and extraneous pixel artifacts became evident. The factor that identified

the highest level of visual spatial resolution for the Minolta and Fuji cameras was the point where you could not distinguish the target lines. There was no visible aliasing in the Minolta camera but there was some visible aliasing in the Fuji camera in the form of color bands.

Color bands are a form of aliasing which can run horizontally, vertically or diagonally. The bands are most often evident in color pairs of magenta-green and blue-yellow. The width of the color bands increases with an increase in the spatial frequency of the target detail. Plates 13 and 14 at step 10 along the horizontal and vertical stepbars illustrate what color bands appear like.

Conclusion

The default situation that all prepress technicians must try to accomplish is to reproduce on press the image they are presented with. Digital cameras images add to the duties of the prepress technician because of the cameras limited capabilities regarding range, resolution, color and artifacting. The job of the prepress technician now is to try to reproduce what the original scene looked like. If a digital camera records a magenta dress on a women but the dress was truly red we need to use the prepress skills and Adobe Photoshop together to render the dress red. It is important to try to reassign the digital recorded colors and tones of a digital camera file to reflect the original scene.

If we can identify what the cameras' response will be at a particular ISO we can create a macro within Adobe Photoshop that can accommodate the camera tendencies. A macro would perform all the general functions needed, as predefined in an assigned order with assigned values. The macros created should be designed based on the specific needs of different ISOs.

We can correlate that the lower the ISO the higher the level of quality the digital image will retain. At lower ISO's the color gamut is larger, the visual resolution is larger, the image density relative to a calibrated metered exposure has less variability with the use of a hot mirror filter and the usable range for rendering tonal detail is larger, between 6 1/3 - 5 2/3 stops for ISO's 200 -640 respectively.

It can be concluded that while important to begin with the highest resolution camera for the job, the resolution of the digital images produced with each digital camera are subject to decrease depending on the methodology used in the prepress process along with the actual prepress and press equipment limitations. The visual and quantitative resolutions of a digital camera need to be considered carefully because although a camera may boast a tremendous quantitative resolution the visual resolution is effected by each individual prepress workflow and therefore of significant consequence.

To counteract some of the decrease in resolution caused by the SNAP printing model the "unsharp mask" command in Adobe Photoshop may be used. "Unsharp mask" may enhance the

appearance of image sharpness "by increasing the contrast in the narrow area of transition between light and dark areas in the original"[4]

In the case of the Associated Press, the images reproduced exist in a semi-virtual world with the only method of evaluation being the visual analysis of an image on a computer monitor. The image departs from its virtual world entering a hard copy world only after it has been selected by a newspaper for reproduction.

It is important that evaluation and image toning performed by photographers and photo editors at this point be done using the RGB mode. "Performing corrections in the RGB mode ensures device-independence: that is, the corrections you make to the image are preserved regardless of the monitor, computer, or output device you use."[5] Knowing that evaluation of our digital images is device-independent we have a starting point. In conjunction with using RGB as our mode for image toning prior to prepress procedures being performed, all image toning should be done aiming for three reference points. The three reference points are, minimum useable highlight point, the maximum placeable shadow point and image neutrality. The image should be toned free of unwanted color cast.

In the case of Associated Press photographers or any photographer where the destination of the image and the final output characteristics are unknown, the image's three reference points should be capable of accommodating any combination of reproduction characteristics. This includes leaving enough highlight information so that the final prepress technician has ample information to work with. A minimum highlight dot of 5-7% and a maximum shadow dot of 80% would allow a prepress technician enough information to adjust the highlights and shadows. The image should also be presented without any unwanted color casts. If any changes are to be made to hue/saturation or selective color they must be performed sparingly and only one time. Repeated changes of hue/saturation and or selective color are highly damaging to the integrity of the digital image and not recommended.

The most prevalent problem with image toning performed by untrained prepress technicians is their lack in knowledge concerning prepress principles. A prepress technician knows that an image will never reproduce as it is seen on screen and why. The the prepress technician knows the color gamut of an image reproduced by transmitted light on a monitor is unmatchable by any printing process. Knowing this a prepress technician can make the necessary adjustments in Adobe Photoshop, on the monitor and mentally to accommodate the for the visual discrepancy of the monitor and the final reproduction. Prepress technicians also are aided with the color values provided in the "info box" in Adobe Photoshop. The "info box" displays the numeric color and brightness values of an image. Despite what the technician sees on the screen the "info box" values will display the actual color values of the image.

In the same manner the density tendencies of each camera can be identified and altered in

Adobe Photoshop. Density tendencies is a factor of the actual density recorded by the digital camera as opposed to the true density associated with a meter reading. As with the Minolta Rd-175 we see that it acquires images significantly darker than expected. This discrepancy between the recorded density and the density that the particular exposure should render can be alleviated by the photographer altering the image exposure or the prepress technician altering the density of the image using the "curves" and/or "levels" command in Adobe Photoshop. All adjustments made in Adobe Photoshop will result in the loss of image information. It is highly recommended that foreseeable imager-density related issues be compensated for prior to prepress. When imager-density related issues are compensated during the exposure determination process valuable data otherwise thrown away during the prepress alteration process is left untouched.

Optimum use of the limited digital camera dynamic range is an issue which falls solely on the photographer. It is up to the photographer to select the exposure that will ensure the best use of the entire camera's range. If the subject and scene permit a photographer to choose an ISO with a larger range of useable tones, the prepress technician has much more information to work with. The photographer takes the place of a scanner technician. The exposure controls available to the photographer are equivalent to the scanner controls used by a scanner technician and upmost care must be taken to retain the maximum image quality. The bottom line simply stated is "garbage in garbage out."

The key to a successful digital image newspaper reproduction is consistent, precise, properly exposed photographic images, which, through proper selection of ISO, retain as much information available to the camera/ISO combination. Precise purposeful image manipulation prepress procedures which are directly related to the SNAP printing model and the particular newspapers press and workflow are also instrumental in a successful digital image newspaper reproduction. All unnecessary image manipulations done in Adobe Photoshop decrease the limited quality the digital cameras have to offer. Many manipulations performed, which are unrelated to the prepress needs of a SNAP model, do more harm then good.

A prepress technician working within a fixed workflow can enhance his prepress image preparation abilities by working with photographers in categorizing each camera and its tendencies. General Adobe Photoshop macros can then be created to alleviate some of the camera issues which are evident in every camera. Image color. Density and sharpness fine tuning can then be performed on an image by image basis. It would also be of great benefit to train photographers in the intricacies of prepress preparation and the damaging effects of unnecessary image manipulations.

When a prepress technician is presented with a digital image they should attempt eliminate

any color shifts still evident in the image and also adjust overall color towards neutrality. When we map the uncorrected digital image we are mapping the original camera color tendencies to the press' gamut, but proportionately to the original. Figures 47-51 in Appendix E illustrate how the newspaper gamut falls in relative proportion to the original digital image file. The conversion to CMYK should be performed with all necessary Photoshop preferences set to account for the SNAP model and the technicians particular workflow. Any further hue/saturation changes in Adobe Photoshop will fall within the capabilities of the printing press workflow and ink limitations. In Figure 47, APHM8008, digital file gamut compared to newspaper file gamut exemplifies the relative proportional shrinkage which occurs in the newspaper gamut.

Figures 43-45 illustrate the effects of reassigning the color and density values of a digital image in Adobe Photoshop upon color gamut. The Figures show three versions of the three digital camera files tested. "Dit file" represents the raw image data where no corrections of any kind were performed. File "high mid" represents the first version of the corrected image where a click white was performed on the white color checker wedge, a highlight value of cyan 3%, magenta 2%, yellow 1%, black 0% and a shadow value of cyan 80%, magenta 75%, yellow 75%, black 70%. File, "hue/saturation," represents the gamut of an image with the before mentioned highlight and shadow placement and with adjusted hue/saturation and or selective color values.

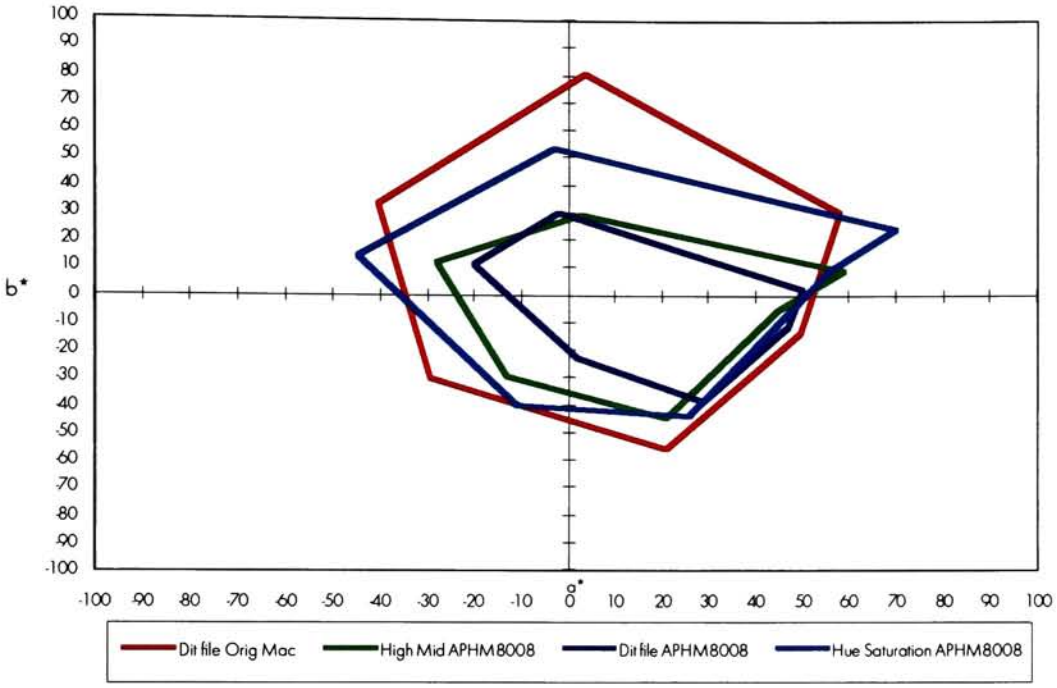
We can clearly see where the digital image gamut was expanded because of value reassignment. The most important factor illustrated is that the image gamuts were altered in shape closer to the original MacBeth Color Checker™. The magenta cast was de-emphasized and the yellow-red deficiency was decreased to better match the proportion of the original gamut. Despite a newspaper workflow from being incapable of reproducing such large gamuts we are left with a more pleasing color gamut proportion.

This hypothesis, being that issues specific to the three different types of digital cameras tested will help in identifying methods to optimize these images for print production using SNAP specifications as the model, has been concluded valid. Some of the theories that were believed prior to the start of testing rendered true while new conclusions shed light on information that further promoted the original theory.

Each camera tested yielded its own set of plus and minuses. The Kodak AP NC2000e and the EOS DCS3 yielded the highest overall marks as related to the needs of photojournalist and a newspaper workflow. The Minolta camera rendered a remarkable level of acceptable memory colors and could best be utilized rendering product photographs. The Minolta camera also received excellent

Figure 43

APHM8008 Color Gamut Comparison of Digital Camera
Corrected and Raw Digital Files



Dit File APHM8008:

Raw File. No corrections made.

High Mid APHM8008

Selective Color Adjustments:

Yellow = +100^{Yellow}

Red = -24^{Magenta}

Red = +100^{Yellow}

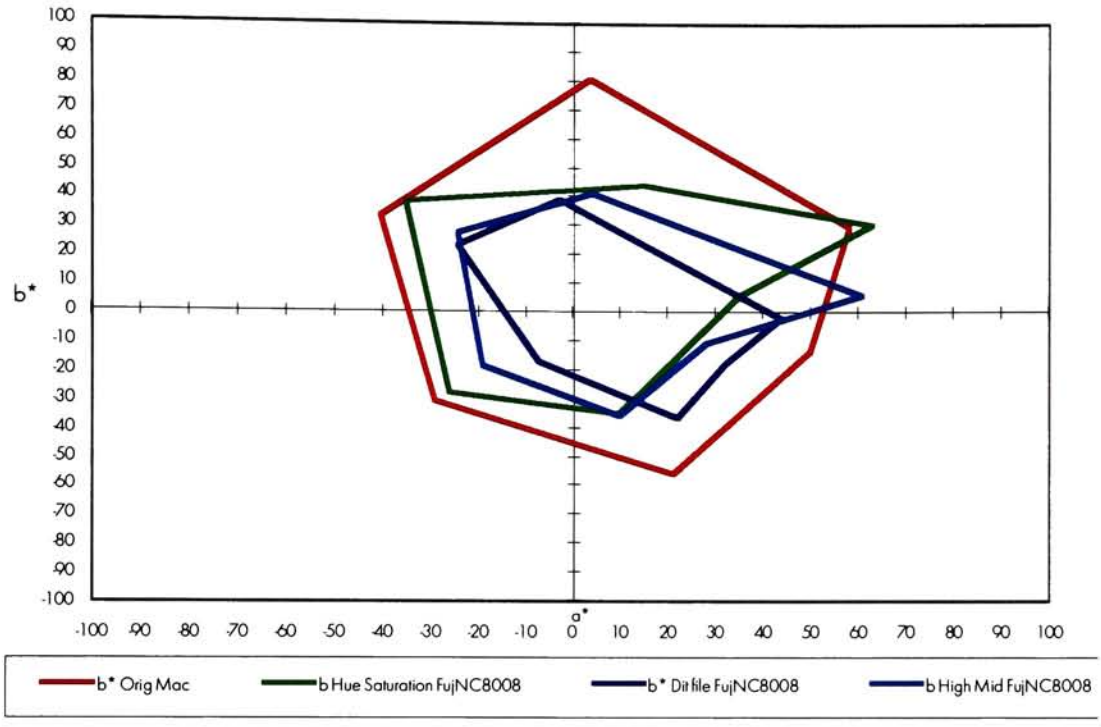
Magenta = +30^{Magenta}

High Mid APHM8008
Hue/Saturation Adjustments:

Master =	Hue +7	Saturation +23	Lightness 0
Red =	Hue +1	Saturation +18	Lightness -32
Yellow =	Hue 0	Saturation +11	Lightness -13
Green =	Hue -4	Saturation +20	Lightness -4
Magenta=	Hue +17	Saturation 0	Lightness 0

Figure 44

FUJ8008 Color Gamut Comparison of Digital Camera
Corrected and Raw Digital Files



Dit File FUJ8008:

Raw File. No corrections made.

High Mid MIN8008

Selective Color Adjustments:

No corrections made.

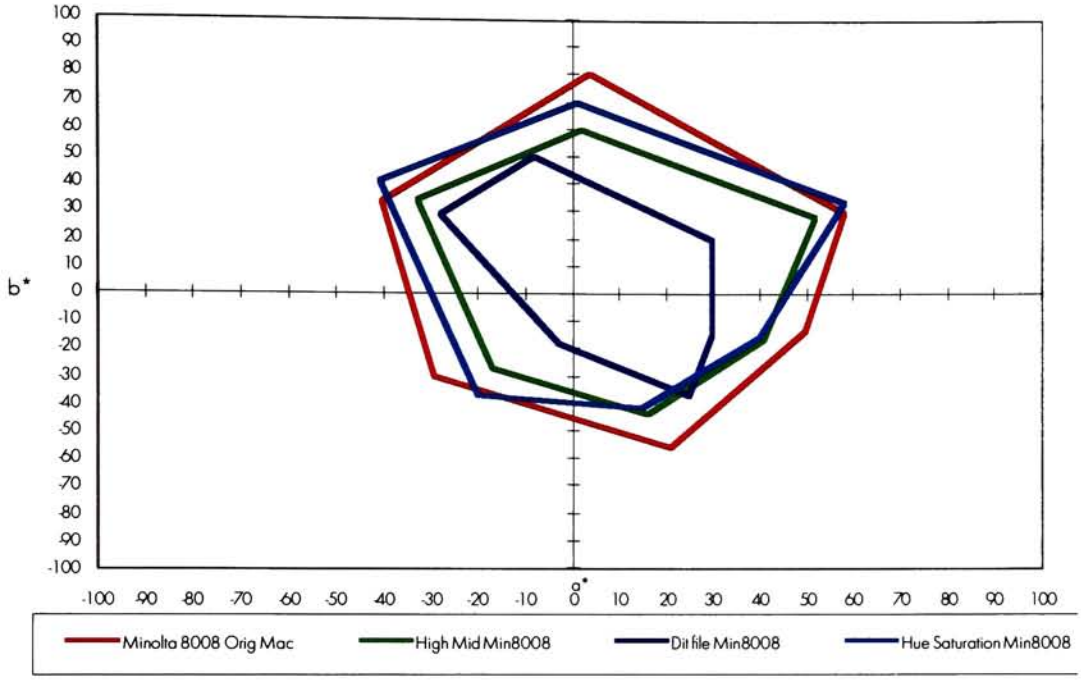
Hue Saturation MIN8008

Hue/Saturation Adjustments:

Master =	Hue 0	Saturation +32	Lightness 0
Red =	Hue -60	Saturation +30	Lightness 0
Yellow =	Hue 0	Saturation +49	Lightness 0
Magenta =	Hue 60	Saturation +32	Lightness 0

Figure 45

Min8008 Color Gamut Comparison of Digital Camera
Corrected and Raw Digital Files



Dit File MIN8008:

Raw File. No corrections made.

High Mid MIN8008

Selective Color Adjustments:

No corrections made.

Hue Saturation MIN8008

Hue/Saturation Adjustments:

Master = Hue 0 Saturation +28 Lightness 9

marks for its limited display of aliasing which would benefit any need for photographing objects with high spatial frequencies. The Fuji camera yielded the poorest overall results. It contained a low resolution, poor color and high degrees of noise.

Since the inception of this project technology has changed. New digital cameras have been developed, color technology has been improved but one constant remains, the CCD. The cameras of today will exhibit similar tendencies as long as the basic CCD technology remains the same.

In one of the newer digital cameras designed for photojournalistic applications the Kodak Nikon 620, we see how Kodak has attempted to alleviate some of the tendencies. The hot mirror filter as opposed to being a lens optional piece and has been integrated into the camera body. The acquire function allows for a two-stop density adjustment, thus allowing a greater over and underexposure latitude.

Old camera or new, the bottom line is that digital photography is in its infancy. However, by using age old printing principles a relatively high quality image can and should be reproduced.

Areas for Future Study

With new technology constantly emerging, areas of further study could encompass:

What CCD attribute causes the change in color gamut with the change in ISO.

The relationship between the original color gamut and its reproduction to SNAP.

An educational model used to teach photographers to be more prepress cognisent.

Identifying the specific results of altering hue/saturation and selective color on printing separations.

Endnotes Chapter 7

1. Adobe Photoshop, *User Guide, Version 4.0*, 1991, 133

2. IBID

3. Leslie Stroebel, John Compton, Ira Current, Richard Zakia, *Photographic Materials and Processes*, 1986, 380

4. Graphic Arts Technical Foundation, *Tone and Color Correction* ,1991, 27

5. Adobe Photoshop, *User Guide, Version 4.0*, 1991, 111

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Appendix A

Donation/Loan Request Letter

DEAR MANUFACTURER,

I am a Electronic Publishing graduate student at Rochester Institute of Technology, with an undergraduate degree in photography. I am currently working on my thesis, which is an investigation of digital camera images as applied to print reproduction for the photojournalistic news industry.

My goal is to investigate the pros and cons of digital photography and imaging, as it pertains to photojournalism and newspaper prepress. A series of test are being designed to examine specific situations that photojournalist address everyday. Test areas will include exposure, dynamic range, tone reproduction, color space reproduction, ISO to image noise relationships, depth-of-field and print production.

As a photographer I know how disheartening it can be to see an important image reproduced poorly. A poor reproduction of a great image diminishes the quality behind the photographers craft as well as the integrity of the publication. By identifying areas that need improvement meaningful solutions can be identified. My thesis will attempt to identify areas of digital photography that need improvement and seek solutions that will address such problems. Ultimately I believe these thesis findings will have value to photojournalist and the newspaper industry.

As part of my thesis I will be characterizing current digital newsroom workflow practices. By identifying trends in today's newsrooms and analyzing reoccurring digital issues, I intend to correlate my quantitative results with the qualitative issues at hand. The method which I will be using to identify trends is via a questionnaire which addresses issues from photography to press and all those falling in between.

My request of your organization is that you take the time to complete the following questionnaire and remit it to the below address. Your participation is greatly appreciated.

My advisors for this project are: Professor Douglas Ford Rea (Technical Photographic Research Advisor), Miles Southworth (Technical Printing Research Advisor), Jere Renzel (Imagesetter Support Advisor) and Professor Frank Romano (Principle Advisor). With your support, my advisors guidance and my focus I know that this thesis project can succeed and work for the benefit of many.

Please refer to the enclosed thesis proposal for additional information or contact me via e-mail at VXA7016@RIT.EDU, by telephone at 716-475-9858 or 320 Fairwood Circle, Rochester, NY 14623.

Thank you.

Sincerely,

VICTORIA AROCHO

Appendix B

Camera Settings

NOTES:

Aperture: _____

Shutterspeed: _____

ISO: _____

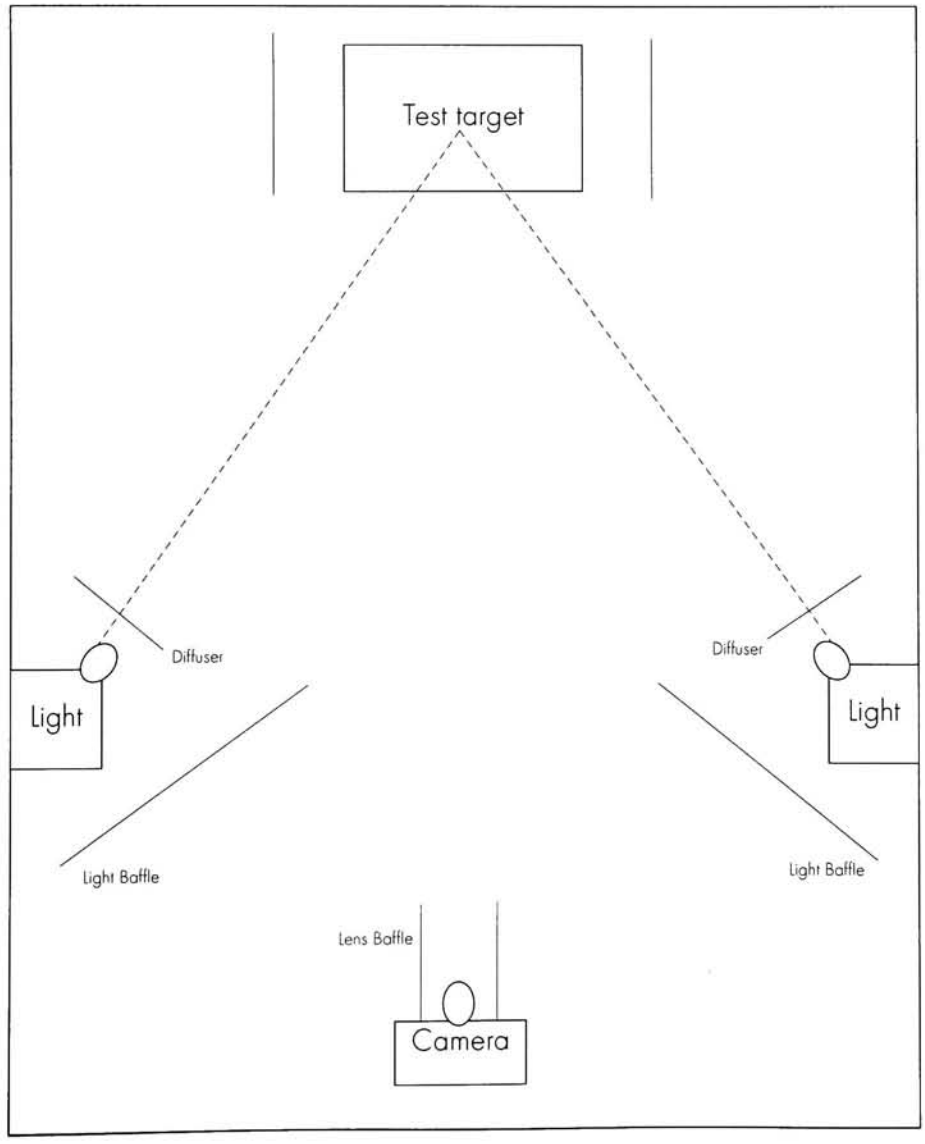
Exposure compensation: _____

Mode setting: _____

Drive: _____

Focus: _____

Diagram



Appendix C

Camera Specification Comparison Chart

Camera	AP NC2000e EOS DCS3	Nikon E2s Fujix DS505/515	Minolta RD-175
Resolution APNC200e EOSDCS3	1280 x 1024 1268 x 1012	1280 x 1000	1528x1146
Useable ISO	200-1600	800/3200	800
Lens focal length magnification	1.5	1.0	2.5
Type of Sensor	area array	area array	Tri-CCD area array
Imager Dimensions	20.5 x 16.4mm	16.9 x 13.20mm	16.5 x 12.4mm

Appendix D

Newspaper Run Reading Evaluation

The press run was run in the newspaper lab supervised by Professor John Eldridge. Samples were taken from different segments of the run and proper ink density was maintained via ink dot density readings. A post production color evaluation was performed with samples from the beginning and end of the test run. The test run consisted of approximately 800 copies.

On the following page in figure 56 the sensitometric readings from two samples taken at the beginning and and of the run were evaluated to determine ΔE^* values. In the readings taken from the page of the color reproduction illustration with samples at ISO800 shot at f/8 there was no higher ΔE^* value then $\Delta E^*=1.27$. The Fuji8008 test image illustrated $\Delta E^*=1.27$ at MacBeth color tile 13. The Minolta test image sample had no greater ΔE^* than $\Delta E^*=0.71$. The AP NC2000e hot mirror sample exhibited two color tiles with a ΔE^* greater than one. APHM8008 sample at color tile 5 exhibited a $\Delta E^*1.22$ and color tile 13 ΔE^* 1.13. All other color tiles for APHM8008 sample were not greater than ΔE^* of one.

AP NC2000e sample taken without a hot mirror showed the greatest number of of color tiles with ΔE^* above one but less than $\Delta E^*1.5$. Color tile 4 had a $1.46\Delta E^*$. A total of eight color tiles exhibited ΔE^*'s greater than 1 but less than ΔE^* 1.5. All other samples exhibited ΔE^* less than 1.

No ΔE^* value was greater then Just Noticeable difference value of ΔE^* 2 and therefore exhibited an overall good match spectrophotometrically. Visually both paper samples are almost indistinguishable from one another. Paper sample 2 was used for all comparative measurements.

ΔE^*	Perception	Interpretation
<1	No Difference	Excellent match
1-2	Just Noticeable difference	Good Match
4-6	Noticeable	Fair Match
>9	Strong difference	Poor Match

CIE LAB of Paper sample one and Paer sample 2 and ΔE
NC2000 with hot mirror 8008

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Paper 1 L*	46.16	58.13	48.81	46.88	51.95	54.74	54.39	46.19	55.45	49.02	56.37	57.13	42.96	48.99	55.09	64.7	55.59	45.97	67.72	62.23	53.74	46.88	42.02	37.3
Paper 2 L*	45.56	58.23	48.6	46.6	50.95	55.18	54.92	46.24	55.09	48.1	56.42	57.11	43.86	49.3	55.21	64.76	55.29	46.54	67.84	62.67	54.13	47.26	42.48	38.03
Paper 1 a*	6.28	11.54	-2.06	-1.43	3.01	-14.3	16.73	3.61	22.73	11.23	-11.7	7.17	2.12	-12.1	26.41	2.2	23.09	-6.28	-2.24	-3.19	-2.87	-2.08	-1.61	-0.24
Paper 2 a*	6.24	12.03	-1.38	-0.64	3.65	-13.6	16.6	3.69	23.03	11.61	-11.5	7.31	2.01	-11.7	26.43	2.34	23.92	-6.07	-1.9	-2.68	-2.5	-1.97	-1.4	0.31
Paper 1 b*	9.3	12.33	-0.45	5.29	-2.91	0.23	21.26	-6.51	9.42	-3.21	12.67	15.3	-9.4	12.31	13.98	22.77	4.04	-7.19	7.73	8.41	5.93	3.45	1.4	0.92
Paper 2 b*	8.8	12.67	-0.6	5.2	-3.17	0.5	21.25	-6.52	9.56	-3.12	12.33	14.83	-10.1	12.52	14.21	22.67	3.92	-6.87	7.95	8.56	6.05	3.59	1.7	1.22
ΔE	0.782	0.605	0.727	0.843	1.215	0.878	0.546	0.095	0.489	0.999	0.398	0.491	1.127	0.578	0.26	0.182	0.891	0.687	0.422	0.69	0.551	0.42	0.588	0.962

CIE LAB of Paper sample one and Paer sample 2 and ΔE
NC2000 with OUT Hot Mirror filter 8008

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Paper 1 L*	56.36	67.51	54.51	57.11	61.62	63.91	67.6	59.03	64.6	62.67	65.57	69.09	52.79	60.22	63.35	70.87	64.6	57.9	71.95	67.31	62.1	55.09	48.96	45.54
Paper 2 L*	56.98	67.7	55.02	58	61.38	64.57	67.07	59.07	63.97	62.58	66.05	69.17	52.84	60.05	63.42	69.9	63.79	57.43	71.8	67.56	62	55.36	49.35	45.48
Paper 1 a*	11.63	8.41	-0.75	3.86	4.85	-9.37	15.79	4.97	11.96	6.13	-4.44	12.11	5.66	-5.07	11.95	6.85	8.27	-1.15	-0.28	-0.29	0.35	1.22	1.15	1.85
Paper 2 a*	12.53	9.21	-0.23	5.01	5.66	-8.86	16.42	5.87	12.92	6.69	-4.24	12.14	6.53	-4.4	12.3	7.21	9.13	-0.05	-0.07	0.28	0.66	1.49	1.45	2.23
Paper 1 b*	-2.65	0.69	-2.3	-3.12	-4.44	-1.83	4.7	-6.62	-0.3	-4.51	4.97	4.97	-9.16	2.64	-0.57	8.95	-1.24	-10.3	5.8	5.37	3.57	-0.05	-2.3	-3.38
Paper 2 b*	-3.05	0.59	-1.53	-3.06	-4.47	-1.13	4.9	-6.21	-0.49	-4.45	5.43	5.13	-8.71	2.75	-0.21	9.06	-1.57	-10	5.81	5.22	3.9	0.58	-2.02	-3.39
ΔE	1.164	0.828	1.06	1.455	0.845	1.089	0.847	0.99	1.164	0.57	0.694	0.181	0.981	0.7	0.507	1.04	1.227	1.229	0.258	0.64	0.464	0.737	0.566	0.385

CIE LAB of Paper sample one and Paer sample 2 and ΔE
Minolta 8008

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Paper 1 L*	38.15	46.7	42.58	38.36	43.86	47.07	45.21	42.56	43.07	36.46	46.16	46.31	41.12	42.92	40.25	50.19	43.02	41.63	56.13	51.19	45.46	40.6	35.66	32.88
Paper 2 L*	37.52	46.11	42.03	38.39	43.77	46.73	45.85	42.86	43.13	36.41	46.47	46.57	41.03	42.97	40.11	50.51	43.26	41.56	55.58	51.05	45.3	40.56	35.56	32.86
Paper 1 a*	3.06	4.51	-0.88	-1.81	0.06	-8.43	11.39	1.28	10.94	1.36	-6.49	5.43	1.33	-8.44	10.39	0.84	6.78	-6.13	-3.06	-2.18	-1.24	-0.99	-0.89	-0.27
Paper 2 a*	2.82	4.68	-0.82	-2.03	0.3	-8.31	11.09	1.23	11.22	1.3	-6.37	5.68	1.16	-8.98	10.14	0.89	6.79	-6.42	-2.82	-1.89	-1.43	-1	-0.96	-0.26
Paper 1 b*	8.62	12.09	-0.22	6.99	-2.8	2.52	18.47	-5.23	11.77	-0.26	11.8	13.09	-5.56	11.95	11.93	18.68	-0.75	-3.58	8.27	8.64	6.14	4.67	3.37	2.53
Paper 2 b*	8.45	12	-0.06	6.49	-2.67	2.46	18.5	-4.99	12.13	-0.2	11.92	13.31	-5.38	11.67	11.97	18.64	-0.3	-3.51	8.85	8.66	6	4.83	2.98	2.13
ΔE	0.695	0.621	0.576	0.547	0.287	0.366	0.707	0.387	0.46	0.098	0.353	0.422	0.263	0.61	0.289	0.326	0.51	0.306	0.835	0.323	0.285	0.165	0.409	0.401

CIE LAB of Paper sample one and Paer sample 2 and ΔE
Fuji 8008 no compresion

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Paper 1 L*	44.49	55.1	49.28	46.59	52.26	56.61	51.07	47.76	49.8	46.87	54.69	54.9	45.36	48.44	48.3	58.58	53.02	50.53	65.39	59.64	52.66	47.28	41.53	35.26
Paper 2 L*	44.79	54.83	49.28	46.26	52.28	57	51.53	47.48	49.95	46.2	54.34	54.38	44.58	48.09	48.27	58.29	52.18	50.22	64.78	59.35	52.52	47.33	41.43	35.22
Paper 1 a*	5.8	6.65	-5.19	-2.69	-0.87	-15.5	17.07	1.25	14.38	7.05	-7.86	9.63	3.36	-10.5	18.86	2.75	12.05	-10.5	-1.87	-2.08	-2.83	-2.48	-0.79	1.66
Paper 2 a*	5.61	6.41	-5.29	-3.29	-0.5	-15.3	16.5	1.25	14.06	6.8	-8.47	9.19	2.52	-10.9	18.89	2.37	12.36	-10.3	-1.79	-2.22	-2.38	-2.45	-0.89	1.36
Paper 1 b*	10.11	12.41	-0.83	8.63	-5.35	1.54	22.11	-6.45	8.68	-4.99	13.63	15.76	-11	14.33	9.61	22.19	-2.96	-5.05	7.4	8.11	5.41	4.3	2.82	2.9
Paper 2 b*	10.41	12.15	-0.82	8.52	-4.87	1.88	21.62	-6.23	8.73	-5.06	13.46	15.95	-11.5	14.19	9.86	22.24	-3.32	-4.98	7.41	7.95	5.71	4.47	3.13	3.07
ΔE	0.465	0.445	0.1	0.694	0.606	0.619	0.881	0.356	0.357	0.719	0.724	0.707	1.271	0.528	0.254	0.481	0.965	0.381	0.615	0.36	0.559	0.18	0.341	0.347

Appendix E

Figure 47

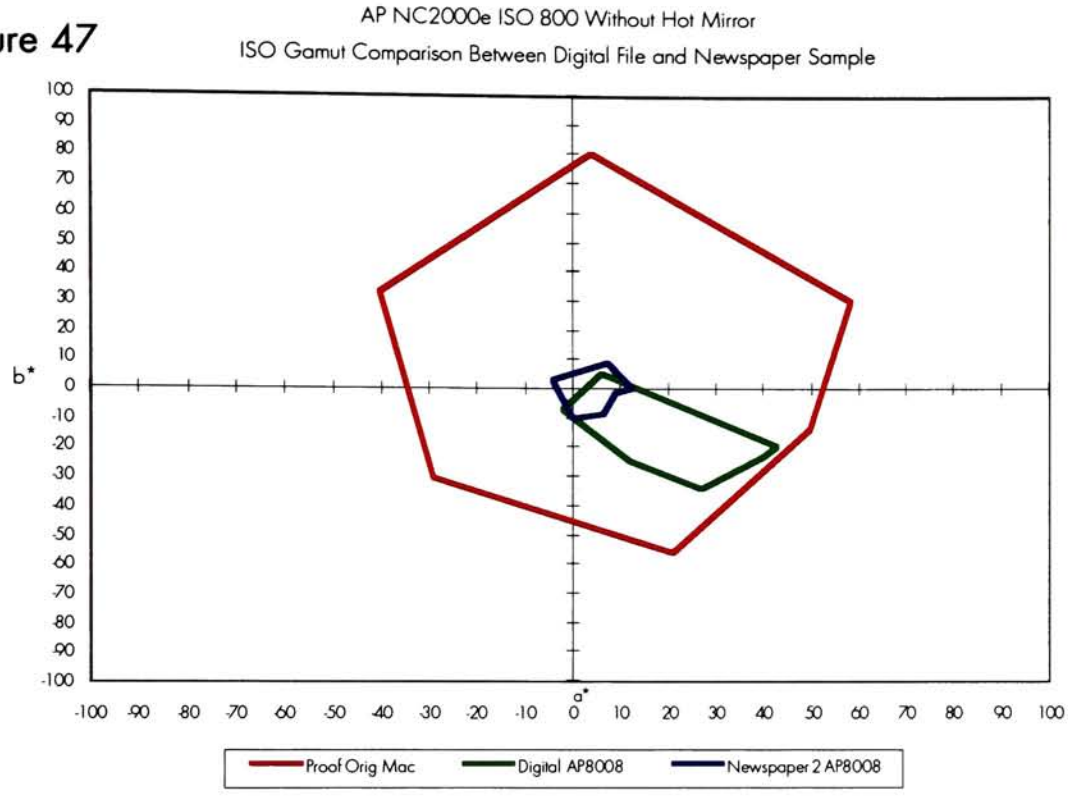


Figure 48

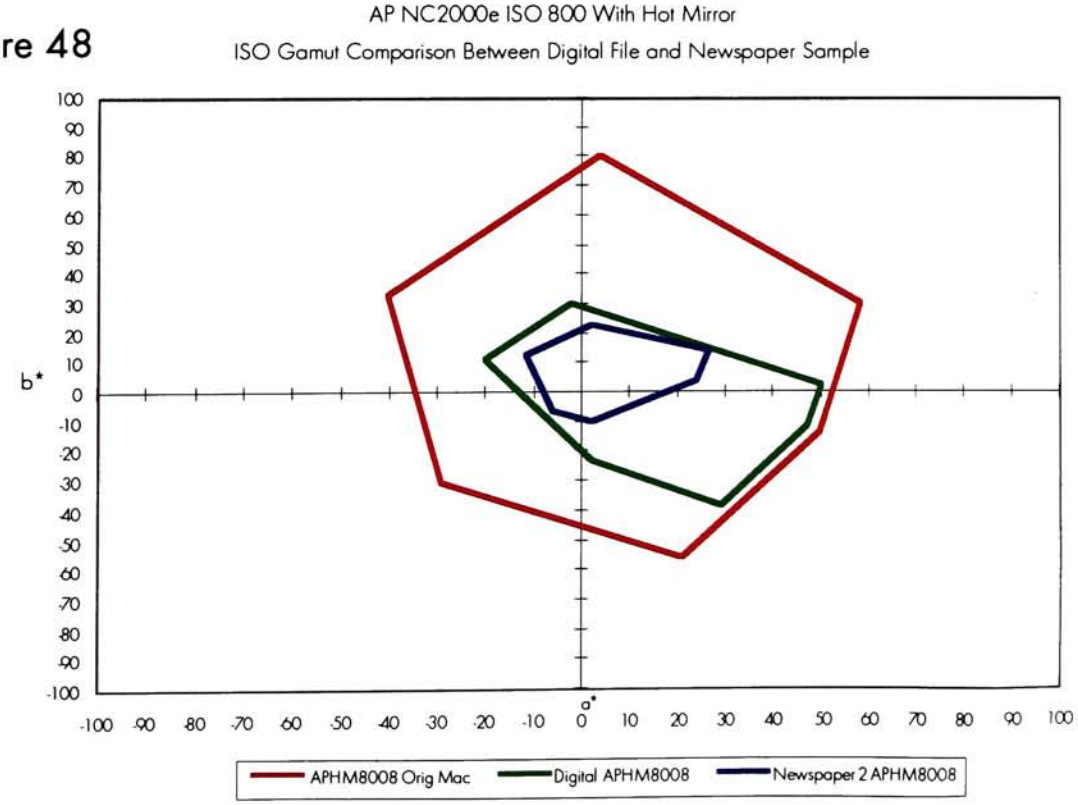


Figure 49

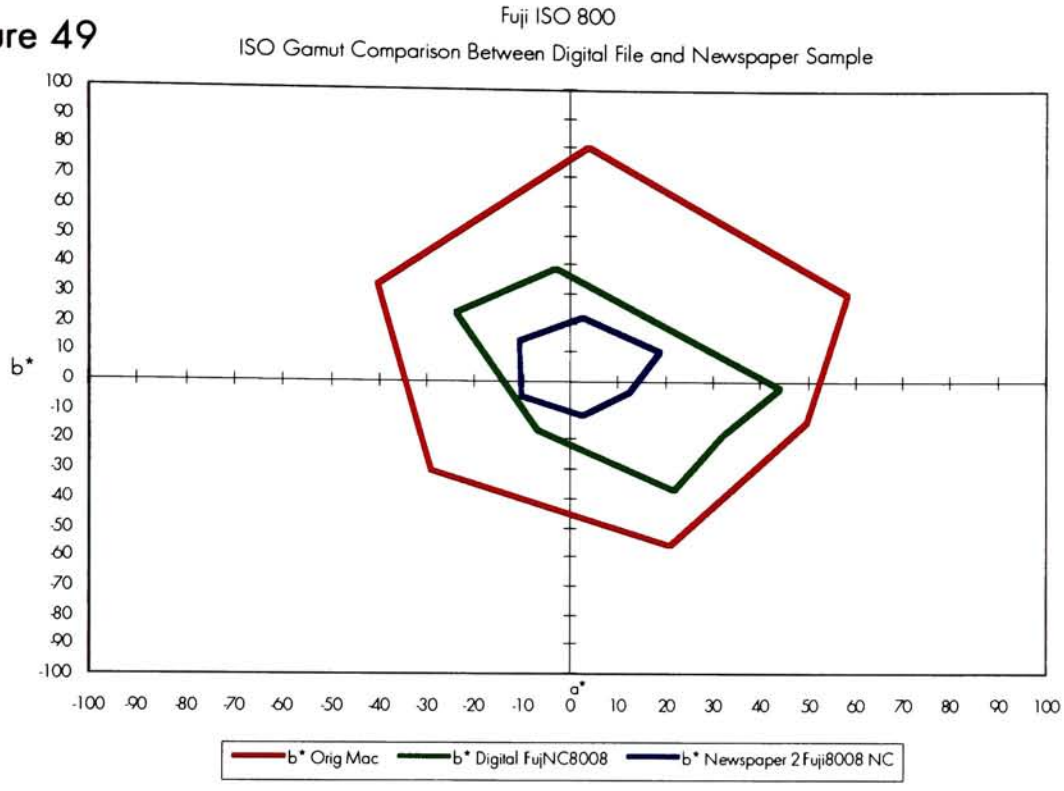


Figure 50

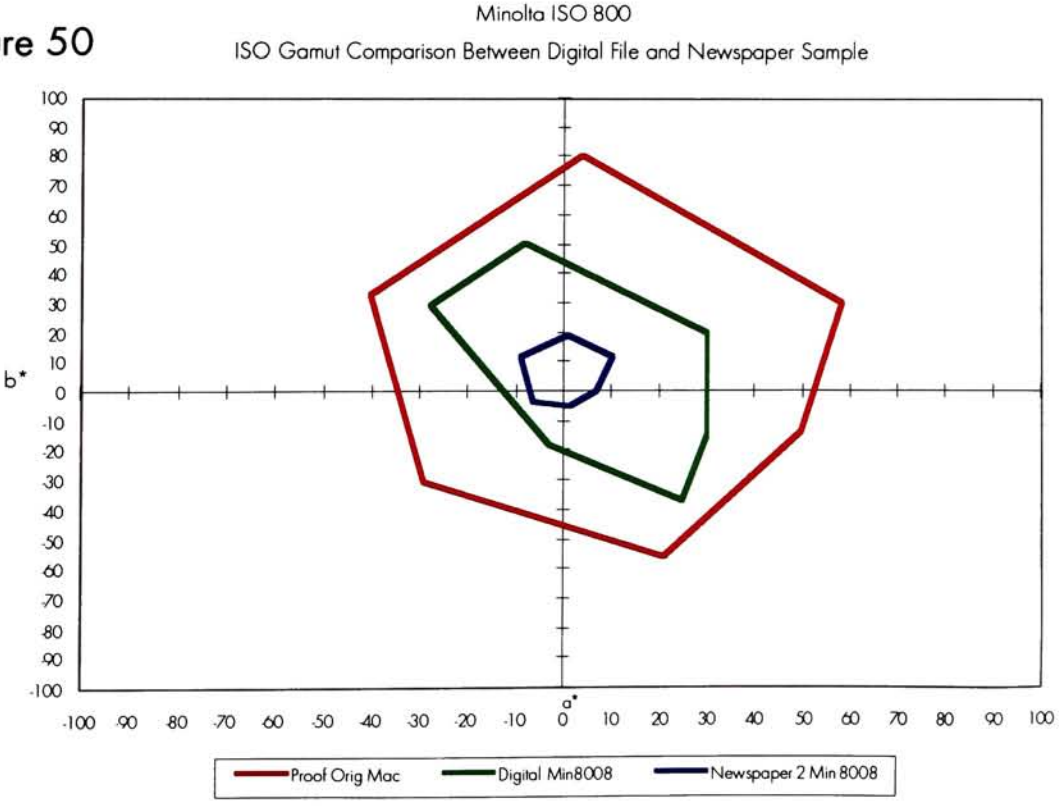
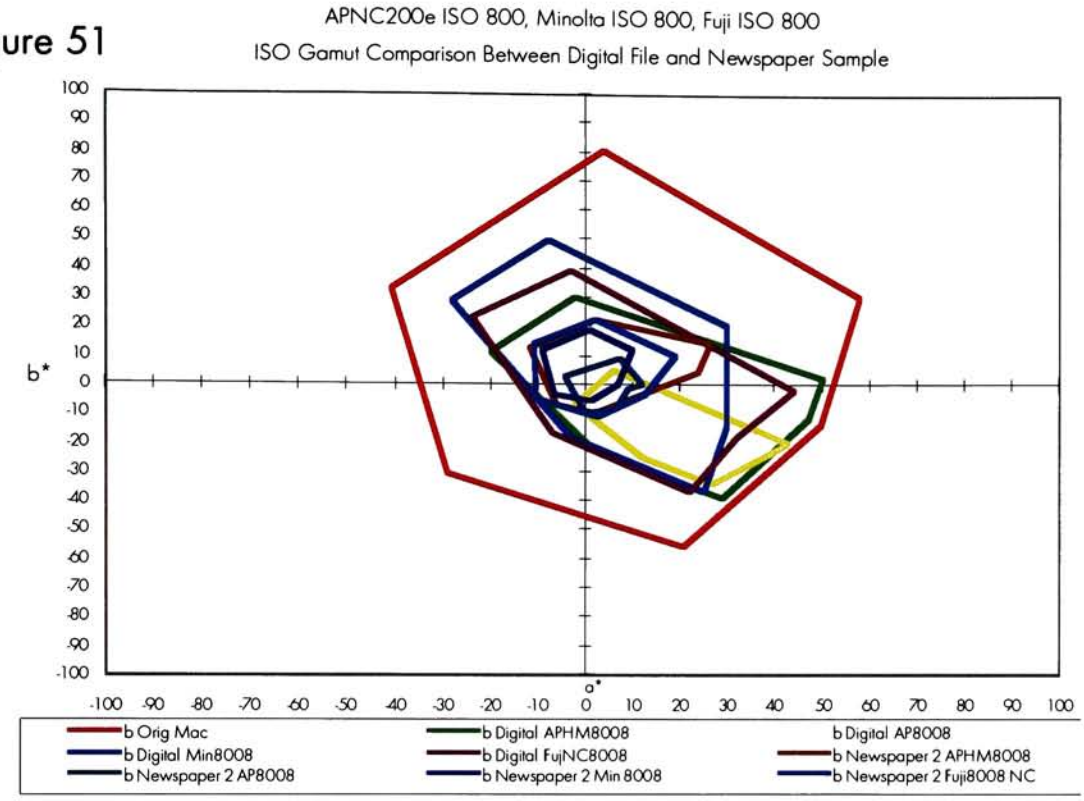


Figure 51


APNC200e ISO 800, Minolta ISO 800, Fuji ISO 800
ISO Gamut Comparison Between Digital File and Newspaper Sample
b*
a*
b Orig Mac
b Digital APHM8008
b Digital AP8008
b Digital Min8008
b Digital FujNC8008
b Newspaper 2 APHM8008
b Newspaper 2 AP8008
b Newspaper 2 Min 8008
b Newspaper 2 Fuji8008 NC

Appendix F

Table 77

ISO AP8008

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and Newspaper Sample

		Newspaper 2 AP8008 L*	Dit file AP8008 L*	Newspaper 2 AP8008 a*	Dit file AP8008 a*	Newspaper 2 AP8008 b*	Dit file AP8008 b*	ΔE
Dark Skin	1	56.98	68	12.53	24	-3.05	-18	21.83
Light skin	2	67.7	86	9.21	20	0.59	-10	23.74
Blue sky	3	55.02	64	-0.23	8	-1.53	-16	18.91
Foliage	4	58	69	5.01	14	-3.06	-14	17.93
Blue flower	5	61.38	75	5.66	18	-4.47	-18	22.82
Bluish green	6	64.57	82	-8.86	-5	-1.13	-7	18.79
Orange	7	67.07	83	16.42	22	4.9	-4	19.08
Purplish blue	8	59.07	72	5.87	25	-6.21	-31	33.88
Moderate Red	9	63.97	80	12.92	36	-0.49	-17	32.59
Purple	10	62.58	78	6.69	36	-4.45	-32	43.08
Yellow green	11	66.05	84	-4.24	-3	5.43	3	18.16
Orange yello	12	69.17	84	12.14	15	5.13	-1	16.30
Blue	13	52.84	62	6.53	27	-8.71	-34	33.80
Green	14	60.05	75	-4.4	-2	2.75	-7	18.01
Red	15	63.42	80	12.3	43	-0.21	-20	40.11
Yellow	16	69.9	89	7.21	6	9.06	5	19.56
Magenta	17	63.79	82	9.13	40	-1.57	-23	41.76
Cyan	18	57.43	70	-0.05	12	-10.02	-25	22.97
white	19	71.8	93	-0.07	0	5.81	0	21.98
Neutral 8	20	67.56	87	0.28	2	5.22	-2	20.81
Neutral 6.5	21	62	78	0.66	4	3.9	-4	18.15
Neutral 5	22	55.36	64	1.49	9	0.58	-10	15.59
Neutral 3.5	23	49.35	51	1.45	12	-2.02	-14	16.05
Black	24	45.48	40	2.23	16	-3.39	-17	20.12

Table 78

ISO APHM8008

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror and Newspaper Sample

		Newspaper 2 APHM8008 L*	Dit file APHM8008 L*	Newspaper 2 APHM8008 a*	Dit file APHM8008 a*	Newspaper 2 APHM8008 b*	Dit file APHM8008 b*	ΔE
Dark Skin	1	45.56	41	6.24	17	8.8	-2	15.91
Light skin	2	58.23	67	12.03	18	12.67	3	14.35
Blue sky	3	48.6	48	-1.38	6	-0.6	-16	17.09
Foliage	4	46.6	45	-0.64	5	5.2	-1	8.53
Blue flower	5	50.95	53	3.65	19	-3.17	-18	21.44
Bluish green	6	55.18	65	-13.58	-13	0.5	-4	10.82
Orange	7	54.92	62	16.6	20	21.25	19	8.17
Purplish blue	8	46.24	40	3.69	21	-6.52	-30	29.83
Moderate Red	9	55.09	54	23.03	42	9.56	-4	23.34
Purple	10	48.1	42	11.61	36	-3.12	-22	31.44
Yellow green	11	56.42	68	-11.53	-19	12.33	24	18.06
Orange yello\	12	57.11	66	7.31	8	14.83	24	12.79
Blue	13	43.86	29	2.01	29	-10.07	-39	42.26
Green	14	49.3	53	-11.66	-20	12.52	11	9.25
Red	15	55.21	49	26.43	50	14.21	2	27.26
Yellow	16	64.76	80	2.34	-2	22.67	30	17.46
Magenta	17	55.29	55	23.92	47	3.92	-12	28.04
Cyan	18	46.54	45	-6.07	2	-6.87	-23	18.10
white	19	67.84	87	-1.9	0	7.95	0	20.83
Neutral 8	20	62.67	77	-2.68	0	8.56	-1	17.43
Neutral 6.5	21	54.13	60	-2.5	1	6.05	-2	10.56
Neutral 5	22	47.26	45	-1.97	3	3.59	-4	9.35
Neutral 3.5	23	42.48	31	-1.4	4	1.7	-5	14.35
Black	24	38.03	17	0.31	6	1.22	-3	22.19

Table 79

ISO MIN8008

ΔE* Comparison of Minolta Digital File and Newspaper Sample

		Newspaper 2 Min 8008 L*	Dit file Min8008 L*	Newspaper 2 Min 8008 a*	Dit file Min8008 a*	Newspaper 2 Min 8008 b*	Dit file Min8008 b*	ΔE
Dark Skin	1	37.52	20	2.82	7	8.45	11	18.19
Light skin	2	46.11	45	4.68	8	12	11	3.64
Blue sky	3	42.03	34	-0.82	7	-0.06	-17	20.31
Foliage	4	38.39	24	-2.03	-10	6.49	16	19.00
Blue flower	5	43.77	38	0.3	12	-2.67	-17	19.38
Bluish green	6	46.73	47	-8.31	-12	2.46	2	3.73
Orange	7	45.85	40	11.09	15	18.5	40	22.62
Purplish blue	8	42.86	28	1.23	19	-4.99	-32	35.58
Moderate Red	9	43.13	29	11.22	30	12.13	10	23.60
Purple	10	36.41	14	1.3	15	-0.2	-18	31.73
Yellow green	11	46.47	48	-6.37	-20	11.92	42	33.06
Orange yello\	12	46.57	44	5.68	3	13.31	42	28.93
Blue	13	41.03	20	1.16	25	-5.38	-37	44.84
Green	14	42.97	36	-8.98	-28	11.67	29	26.66
Red	15	40.11	20	10.14	30	11.97	20	29.38
Yellow	16	50.51	54	0.89	-8	18.64	50	32.78
Magenta	17	43.26	30	6.79	30	-0.3	-15	30.51
Cyan	18	41.56	33	-6.42	-3	-3.51	-18	17.17
white	19	55.58	68	-2.82	0	8.85	0	15.51
Neutral 8	20	51.05	57	-1.89	0	8.66	0	10.68
Neutral 6.5	21	45.3	44	-1.43	1	6	0	6.60
Neutral 5	22	40.56	29	-1	1	4.83	0	12.69
Neutral 3.5	23	35.56	14	-0.96	1	2.98	1	21.74
Black	24	32.86	3	-0.26	1	2.13	0	29.96

Table 80

ISO FUJ8008

ΔE* Comparison of Fuji Digital File and Newspaper Sample

		Newspaper 2 Fuji8008 NC L*	Dit file FujNC8008 L*	Newspaper 2 Fuji8008 NC a*	Dit file FujNC8008 a*	Newspaper 2 Fuji8008 NC b*	Dit file FujNC8008 b*	ΔE
Dark Skin	1	44.79	41	5.61	15	10.41	3	12.55
Light skin	2	54.83	64	6.41	11	12.15	5	12.50
Blue sky	3	49.28	54	-5.29	0	-0.82	-14	14.97
Foliage	4	46.26	46	-3.29	-4	8.52	11	2.59
Blue flower	5	52.28	60	-0.5	10	-4.87	-17	17.80
Bluish green	6	57	71	-15.25	-17	1.88	2	14.11
Orange	7	51.53	55	16.5	23	21.62	27	9.12
Purplish blue	8	47.48	48	1.25	13	-6.23	-27	23.87
Moderate Red	9	49.95	48	14.06	31	8.73	-1	19.63
Purple	10	46.2	39	6.8	31	-5.06	-24	31.56
Yellow green	11	54.34	66	-8.47	-17	13.46	33	24.30
Orange yello\	12	54.38	62	9.19	10	15.95	32	17.79
Blue	13	44.58	39	2.52	22	-11.5	-37	32.57
Green	14	48.09	53	-10.85	-24	14.19	23	16.57
Red	15	48.27	40	18.89	44	9.86	-2	28.98
Yellow	16	58.29	71	2.37	-3	22.24	39	21.71
Magenta	17	52.18	53	12.36	32	-3.32	-18	24.53
Cyan	18	50.22	56	-10.27	-7	-4.98	-17	13.73
white	19	64.78	85	-1.79	0	7.41	0	21.61
Neutral 8	20	59.35	74	-2.22	0	7.95	-1	17.31
Neutral 6.5	21	52.52	60	-2.38	0	5.71	-2	11.00
¡Neutral 5	22	47.33	48	-2.45	0	4.47	-1	6.03
Neutral 3.5	23	41.43	33	-0.89	3	3.13	0	9.80
Black	24	35.22	14	1.36	7	3.07	0	22.17

Table 81

ISO AP8008

ΔE* Comparison of AP NC2000e Digital File without Hot Mirror and the Original MacBeth Chart

		Orig Mac L*	Newspaper 2 AP8008 L*	Orig Mac a*	Newspaper 2 AP8008 a*	Orig Mac b*	Newspaper 2 AP8008 b*	ΔE
Dark Skin	1	37.86	56.98	13.84	12.53	14.83	-3.05	26.21
Light skin	2	65.57	67.7	16.91	9.21	17.79	0.59	18.96
Blue sky	3	48.76	55.02	-4.86	-0.23	-23.14	-1.53	22.97
Foliage	4	43.1	58	-14.2	5.01	20.01	-3.06	33.52
Blue flower	5	54.48	61.38	8.97	5.66	-25.04	-4.47	21.95
Bluish green	6	69.85	64.57	-32.49	-8.86	-1.04	-1.13	24.21
Orange	7	62.1	67.07	34.86	16.42	63	4.9	61.16
Purplish blue	8	38.97	59.07	9.75	5.87	-43.64	-6.21	42.66
Moderate Red	9	50.32	63.97	48.78	12.92	16.89	-0.49	42.12
Purple	10	29.92	62.58	22.71	6.69	-21.7	-4.45	40.26
Yellow green	11	71.67	66.05	-24.09	-4.24	59.42	5.43	57.80
Orange yellow	12	71.66	69.17	20.07	12.14	68.48	5.13	63.89
Blue	13	28.15	52.84	20.92	6.53	-56.17	-8.71	55.40
Green	14	54.11	60.05	-40.49	-4.4	33.08	2.75	47.52
Red	15	41.5	63.42	58.17	12.3	29.8	-0.21	59.04
Yellow	16	81.82	69.9	3.7	7.21	80.35	9.06	72.36
Magenta	17	51.35	63.79	49.87	9.13	-14.01	-1.57	44.38
Cyan	18	48.9	57.43	-29.14	-0.05	-30.58	-10.02	36.63
white	19	94.89	71.8	-0.34	-0.07	-0.18	5.81	23.86
Neutral 8	20	80.36	67.56	-0.11	0.28	-0.39	5.22	13.98
Neutral 6.5	21	64.48	62	-0.01	0.66	-0.24	3.9	4.87
Neutral 5	22	49.48	55.36	-0.4	1.49	-0.51	0.58	6.27
Neutral 3.5	23	35.11	49.35	0.02	1.45	-0.43	-2.02	14.40
Black	24	20.56	45.48	0.46	2.23	-0.18	-3.39	25.19

Table 82

ISO APHM8008

ΔE* Comparison of AP NC2000e Digital File with Hot Mirror and the Original MacBeth Chart

		Orig Mac L*	Newspaper 2 APHM8008 L*	Orig Mac a*	Newspaper 2 APHM8008 a*	Orig Mac b*	Newspaper 2 APHM8008 b*	ΔE
Dark Skin	1	37.86	45.56	13.84	6.24	14.83	8.8	12.39
Light skin	2	65.57	58.23	16.91	12.03	17.79	12.67	10.19
Blue sky	3	48.76	48.6	-4.86	-1.38	-23.14	-0.6	22.81
Foliage	4	43.1	46.6	-14.2	-0.64	20.01	5.2	20.38
Blue flower	5	54.48	50.95	8.97	3.65	-25.04	-3.17	22.78
Bluish green	6	69.85	55.18	-32.49	-13.58	-1.04	0.5	23.98
Orange	7	62.1	54.92	34.86	16.6	63	21.25	46.13
Purplish blue	8	38.97	46.24	9.75	3.69	-43.64	-6.52	38.31
Moderate Red	9	50.32	55.09	48.78	23.03	16.89	9.56	27.19
Purple	10	29.92	48.1	22.71	11.61	-21.7	-3.12	28.27
Yellow green	11	71.67	56.42	-24.09	-11.53	59.42	12.33	51.07
Orange yellow	12	71.66	57.11	20.07	7.31	68.48	14.83	57.03
Blue	13	28.15	43.86	20.92	2.01	-56.17	-10.07	52.25
Green	14	54.11	49.3	-40.49	-11.66	33.08	12.52	35.74
Red	15	41.5	55.21	58.17	26.43	29.8	14.21	37.93
Yellow	16	81.82	64.76	3.7	2.34	80.35	22.67	60.17
Magenta	17	51.35	55.29	49.87	23.92	-14.01	3.92	31.79
Cyan	18	48.9	46.54	-29.14	-6.07	-30.58	-6.87	33.17
white	19	94.89	67.84	-0.34	-1.9	-0.18	7.95	28.29
Neutral 8	20	80.36	62.67	-0.11	-2.68	-0.39	8.56	19.99
Neutral 6.5	21	64.48	54.13	-0.01	-2.5	-0.24	6.05	12.36
Neutral 5	22	49.48	47.26	-0.4	-1.97	-0.51	3.59	4.92
Neutral 3.5	23	35.11	42.48	0.02	-1.4	-0.43	1.7	7.80
Black	24	20.56	38.03	0.46	0.31	-0.18	1.22	17.53

Table 83

ISO MIN8008

ΔE* Comparison of Minolta Digital File and the Original MacBeth Chart

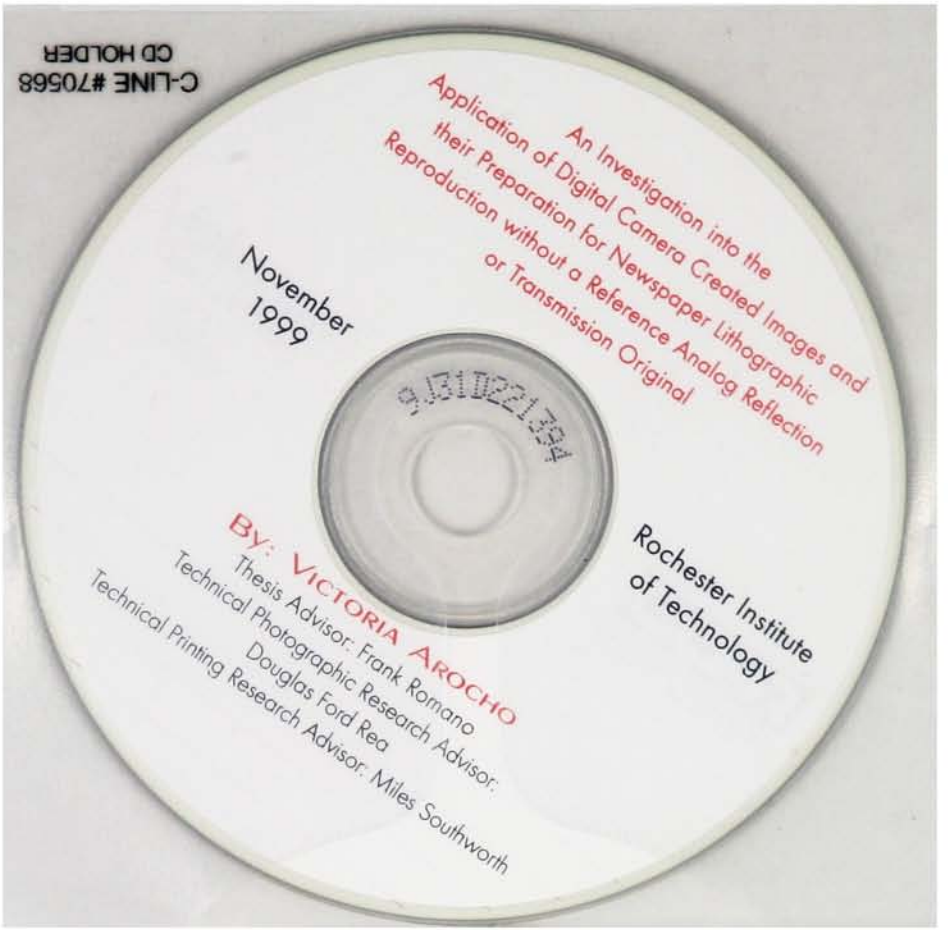
		Orig Mac L*	Newspaper 2 Min8008 L*	Orig Mac a*	Newspaper 2 Min8008 a*	Orig Mac b*	Newspaper 2 Min8008 b*	ΔE
Dark Skin	1	37.86	37.52	13.84	2.82	14.83	8.45	12.74
Light skin	2	65.57	46.11	16.91	4.68	17.79	12	23.70
Blue sky	3	48.76	42.03	-4.86	-0.82	-23.14	-0.06	24.38
Foliage	4	43.1	38.39	-14.2	-2.03	20.01	6.49	18.79
Blue flower	5	54.48	43.77	8.97	0.3	-25.04	-2.67	26.27
Bluish green	6	69.85	46.73	-32.49	-8.31	-1.04	2.46	33.64
Orange	7	62.1	45.85	34.86	11.09	63	18.5	53.00
Purplish blue	8	38.97	42.86	9.75	1.23	-43.64	-4.99	39.77
Moderate Red	9	50.32	43.13	48.78	11.22	16.89	12.13	38.54
Purple	10	29.92	36.41	22.71	1.3	-21.7	-0.2	31.03
Yellow green	11	71.67	46.47	-24.09	-6.37	59.42	11.92	56.62
Orange yellow	12	71.66	46.57	20.07	5.68	68.48	13.31	62.29
Blue	13	28.15	41.03	20.92	1.16	-56.17	-5.38	56.00
Green	14	54.11	42.97	-40.49	-8.98	33.08	11.67	39.69
Red	15	41.5	40.11	58.17	10.14	29.8	11.97	51.25
Yellow	16	81.82	50.51	3.7	0.89	80.35	18.64	69.26
Magenta	17	51.35	43.26	49.87	6.79	-14.01	-0.3	45.93
Cyan	18	48.9	41.56	-29.14	-6.42	-30.58	-3.51	36.10
white	19	94.89	55.58	-0.34	-2.82	-0.18	8.85	40.41
Neutral 8	20	80.36	51.05	-0.11	-1.89	-0.39	8.66	30.73
Neutral 6.5	21	64.48	45.3	-0.01	-1.43	-0.24	6	20.22
Neutral 5	22	49.48	40.56	-0.4	-1	-0.51	4.83	10.41
Neutral 3.5	23	35.11	35.56	0.02	-0.96	-0.43	2.98	3.58
Black	24	20.56	32.86	0.46	-0.26	-0.18	2.13	12.54

Table 84

ISO FUJ8008

ΔE* Comparison of Fuji Digital File and the Original MacBeth Chart

		Orig Mac L*	Newspaper 2 Fuji8008 NC L*	Orig Mac a*	Newspaper 2 Fuji8008 NC a*	Orig Mac b*	Newspaper 2 Fuji8008 NC b*	ΔE
Dark Skin	1	37.86	44.79	13.84	5.61	14.83	10.41	11.63
Light skin	2	65.57	54.83	16.91	6.41	17.79	12.15	16.04
Blue sky	3	48.76	49.28	-4.86	-5.29	-23.14	-0.82	22.33
Foliage	4	43.1	46.26	-14.2	-3.29	20.01	8.52	16.16
Blue flower	5	54.48	52.28	8.97	-0.5	-25.04	-4.87	22.39
Bluish green	6	69.85	57	-32.49	-15.25	-1.04	1.88	21.70
Orange	7	62.1	51.53	34.86	16.5	63	21.62	46.49
Purplish blue	8	38.97	47.48	9.75	1.25	-43.64	-6.23	39.30
Moderate Red	9	50.32	49.95	48.78	14.06	16.89	8.73	35.67
Purple	10	29.92	46.2	22.71	6.8	-21.7	-5.06	28.20
Yellow green	11	71.67	54.34	-24.09	-8.47	59.42	13.46	51.54
Orange yellow	12	71.66	54.38	20.07	9.19	68.48	15.95	56.36
Blue	13	28.15	44.58	20.92	2.52	-56.17	-11.5	51.03
Green	14	54.11	48.09	-40.49	-10.85	33.08	14.19	35.66
Red	15	41.5	48.27	58.17	18.89	29.8	9.86	44.57
Yellow	16	81.82	58.29	3.7	2.37	80.35	22.24	62.71
Magenta	17	51.35	52.18	49.87	12.36	-14.01	-3.32	39.01
Cyan	18	48.9	50.22	-29.14	-10.27	-30.58	-4.98	31.83
White	19	94.89	64.78	-0.34	-1.79	-0.18	7.41	31.09
Neutral 8	20	80.36	59.35	-0.11	-2.22	-0.39	7.95	22.70
Neutral 6.5	21	64.48	52.52	-0.01	-2.38	-0.24	5.71	13.57
Neutral 5	22	49.48	47.33	-0.4	-2.45	-0.51	4.47	5.80
Neutral 3.5	23	35.11	41.43	0.02	-0.89	-0.43	3.13	7.31
Black	24	20.56	35.22	0.46	1.36	-0.18	3.07	15.04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