100% Carbon Pigment Lightfastness and Tonal Stability

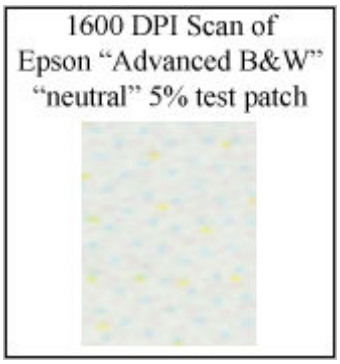
In his recent book, "Mastering Digital Black and White," Amadou Diallo writes:

> "Not all pigments are created equal. Some are inherently more light-fast than others. The undisputed leader in this regard is the carbon pigment."[1]

Carbon pigments have been used for writing and imaging for thousands of years and have an excellent history of stability.

Wilhelm Research has noted in its Epson UltraChrome "K3" (2400, 3800, etc.) testing that the black and white prints made with the "Advanced" B&W ("ABW") mode of printing show significant increases in stability due to the "highly-stable carbon pigment based black ink" replacing the color inks more than when the printer is in RGB mode.[2]

However, the Epson "Advanced B&W" prints still have significant amounts of color inks in them. See the 1600 scan of an Epson 4800 "ABW" print, below.



The goal of moving to carbon printing for B&W appears to be gaining wide acceptance. In an interview with Luminous-Landscape, Mr. Wilhelm noted with excitement the move to carbon printing for monochrome and stated, "Carbon is not affected by light."[3]

Consistent with this, Wikipedia also states with respect to carbon inks that, "The carbon particles do not fade over time even when in sunlight or bleached."[4] Although most fading is caused by oxidation, "All forms of carbon are highly stable, requiring high temperature to react even with oxygen."[5]

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[1] "Mastering Digital Black and White" at 307. To obtain this book, go to http://tinyurl.com/ysh9e7.
[2] See for example, http://www.wilhelm-research.com/epson/R2400.html at page 3, top-right box note.
[3] See http://www.luminous-landscape.com/videos/wilhelm-audio.shtml audio section 11, "Papers and Inks" at 5 minutes, 50 seconds into the interview.
[4] http://en.wikipedia.org/wiki/Ink#Carbon_Inks
[5] http://en.wikipedia.org/wiki/Carbon

In an accelerated fade test by a major inkjet pigment manufacturer, its carbon pigments showed themselves to be markedly more lightfast than its color pigments. In this test the pigments were exposed to 400 hours of strong UV-A light. The amount of fading was measured as a percentage of the original density that was retained after the exposure; the higher the percentage retained, the lower the fade rate. The carbon black pigment test sample retained more than 99% or its original density. The color pigments, however, retained from 93% to less than 50% of their original densities.[6]

While not all black inks and pigments are pure carbon, the relatively neutral MIS Associates' "Eboni" matte black is 100% carbon; there are no color pigments or dyes added.[7] Eboni, as well as Epson MK, PiezoTone Museum MK, and MIS PK and Epson K2 PK are the most lightfast pigments I've tested.[8]

The only sophisticated third-party testing of MIS Associates' "Eboni" MK carbon that I'm aware is by Aardenburg Imaging & Archives.[9] In one test of a color inkset that used Eboni MK as the black ink, at the end of this test, which was the equivalent of 41 years[10] of display, the Eboni 100% black test patch did not fade at all. In fact, it very slightly increased in density.

In an ongoing test on Hahnemuhle Photo Rag, the 1800 3-MK sample has turned in what is considered a perfect overall I* score of 100.0 after 30 MLux-Hrs (15 "Wilhelm" years) of exposure. While there was minor measurable fader, both the Eboni and the Cone Carbon Sepia PiezoTone inks did better than any of the OEM inksets or dedicated B&W inksets that used color pigments blended in with the carbon.[11]

Dilute carbon inks are warm by nature. Thus, to bring the tone back to a more neutral, modern B&W tone, inks or B&W printing workflows generally contain cool-tone color pigments to offset the warmth of the carbon. Many very good looking B&W prints are, in significant proportion, color prints. A neutralized photo black (PKN) that I designed, for example, contains 40% color inks and 60% photo black. While these color pigments are obvious in scans of Epson ABW prints, such as above, most dedicated B&W inksets have the color pigments

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[6] The chart with the results is reproduced at http://www.paulroark.com/BW-Info/Cabot-LF.jpg. The full paper is at http://nanoparticles.org/pdf/Kowalski.pdf - chart at p. 20. Note that different display conditions and environments may produce different relative fade rates among the color pigments.

[7] Note that all pigmented inks are in a fluid medium or base, and have ingredients attached to the particles or in the base to assist with dispersion and particle suspension.

[8] The dilute carbon inks from MIS have also tested as very lightfast. Note that some forms of carbon are more lightfast than others.

[9] See http://www.aardenburg-imaging.com/about.html. A modest membership fee is required to access the growing and excellent body of fade test data.

[10] Wilhelm Research equivalent years – different display lighting assumptions are used for different circumstances.

[11] See summary at http://www.paulroark.com/BW-Info/AaI-30MLuxHr.jpg (2-5-2010).

mixed into the carbon to hide them. Nonetheless, most of the color weaknesses and artifacts will still be present. Even where seemingly small amounts of color pigments are used, their high gamut gives them a disproportionate impact on image tone.[12]

Using color inks to make B&W images has introduced a number of compromises. Not only do the color inks fade faster and cause undesirable effects like metamerism, but they will also fade at different rates, causing the tones of the prints to drift with age.[13]

Often neutral digital B&W prints made with typical B&W inksets will, over time, slowly shift toward green. The magenta ink has often tested as weaker with respect to indoor lightfastness, whether it's the MIS archival color pigments[14] or the latest Epson Claria "dyes."[15] Thus many B&W inksets have suffered significant trouble with the green shift.[16]

Different display conditions, including, but not limited to, light source, paper base, and atmospheric exposure (gas fade), will cause different color pigments to fade at different rates. For example, a higher UV content of the light or the presence of certain gases or other environmental hazards may fade the cyan much faster than the magenta. An ink designer can mix and match the fade rates of color pigments to limit the tone shifts for a limited set of assumed display conditions. However, not all variables can ever be perfectly compromised. As such, the presence of more than one type of pigment makes the print more susceptible to color shifts. Making a "blended" carbon plus color ink that is stable under all circumstances is probably impossible.[17] That said, when the display conditions

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[12] In addition to the fade-related problems with color inks, there have also been inconsistencies among color ink batches and mixing, differential settling, problems of metamerism, and profiling sensitivity when high gamut color inks need to be precisely and consistently controlled.

[13] The differential fading of the color pigments is much more of a problem with respect to B&W images than color photos because the human eye is very sensitive to slight hue differences in the near-neutral zone.

[14] See http://www.paulroark.com/BW-Info/MIS-RIT.jpg (RIT test performed for MIS).

[15] See http://www.paulroark.com/BW-Info/Claria.jpg

[16] See, for example, the results of Aardenburg-Imaging fade test, compared at http://www.paulroark.com/BW-Info/Piezotone-Selenium-v-Carbon-Aardenburg-30MLuxHrs.jpg. Aardenburg Imaging is at http://www.aardenburg-imaging.com/ and does the most sophisticated, independent fade testing I know of. The bottom line of this test is that the PiezoTone Selenium shifted to green (a negative Lab A) in the equivalent of 15 Wilhelm years, which is only 3.4 years of commercial gallery level lighting. On the other hand, the Piezo Carbon Sepia was very stable.

[17] Inks sometimes contain colorants that intentionally fade in a manner that offsets the fading of other ink components. The original MIS FSN neutral inkset that I designed in 2001 used a fast-fading yellow to offset that ink's tendency to warm with time. While that inkset succeeded to a certain extent (see for example discussion at http://tech.groups.yahoo.com/group/DigitalBlackandWhiteThePrint/message/13818, fade test results also posted at http://www.paulroark.com/BW-Info/300_Fade_FS-N_FS.jpg) it turned out that different papers needed different mixes to be stable.

are within the design's parameters, the best of the blended inks can be quite stable.[18]

Note also that while some accelerated fade tests suggest specific years of display life, these are only estimates based on lighting and other conditions and assumptions.[19] Accelerated fade tests have also been criticized for exaggerating the expected lightfastness of images due to a number of technical issues.[20]

"Carbon on cotton" has been a B&W digital printing goal for some time, but in the past we've had to rely on color inks to cool off the warm carbon. That appears to have finally changed with, first, the advent of the 1.5 picoliter printers from Epson,[21] and second, the "Eboni-6" and "Carbon-6" inksets, which run on most Epson printers.[22]

With nothing but carbon pigment in the image, we should have not only the most archival inkjet print possible with today's technology but also one that should compare favorably with any B&W medium. For example, the ability to use a cotton paper base that is buffered against acids, gives the inkjet medium an advantage over traditional silver prints and other traditional processes, which were and are processed in reactive chemicals and usually do not use a cotton base.

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[18] See HP Z3100 neutral test summary at http://www.paulroark.com/BW-Info/HP-Neutral-AaI-80MLH.jpg Some of Hewlett Packard's patents disclose methods used to balance a neutral gray ink. See, for example, their 2008 patent reproduced at http://www.paulroark.com/BW-Info/HPpat7452415.pdf. Presumably these concepts are incorporated in their latest Vivera inkjet pigments. See also http://www.faqs.org/patents/app/20090025601 .

[19] See Aardenburg-Imaging light level tables, included in the individual test at http://www.aardenburg-imaging.com/ The table is also reproduced at http://www.paulroark.com/BW-Info/AaI-Light-Levels.jpg

[20] An article on the Golden Paints website notes, for example, "…reported rates of reciprocity failure suggest accelerated tests can overstate expected lightfastness results anywhere from 40% to as high as 1000% …" http://www.goldenpaints.com/justpaint/jp14article2.php

[21] See http://www.paulroark.com/BW-Info/R1800.htm for the R1800 "3-MK" workflow. The Epson 1400 also supports both concentrated and dilute Eboni inkset workflows. See, for example, http://www.paulroark.com/BW-Info/Eb1400.pdf .

[22] See http://www.paulroark.com/BW-Info/Eboni-6.pdf for Eboni-6, and http://www.paulroark.com/BW-Info/Ink-Mixing.pdf for the generic, Carbon-6 ink mixing.