

Light Levels Used in Modern Flatbed Scanners

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Introduction

It has been said in some quarters that scanning is equivalent to exposing an object to a day's, or a year's worth of sunlight. This article examines that claim, and will show that not only is this not true, it may well be impossible.

Scanning an image on a flatbed scanner involves passing a sensing array (Charged Couple Device, CCD) along an object resting face down on a glass platen. The array has a light source attached. Today these sources are usually of the cold-cathode type (1) because of their color characteristics and cooler operating temperature. The method is similar to that of a photocopy machine. This has caused a misinterpretation of the scanning process. Until recently, copy machines used very strong light to produce an image on a relatively light-insensitive coated drum, which resulted in toner being deposited onto paper. The amount of light needed was dictated by the low sensitivity of the coating on the copy transfer drum. Today's CCDs have sensitivities between 0.1 and 0.001 lux. (2) This means that a CCD does not need blazingly bright light to achieve its goal. Scanner lamps have evolved for a technology with greater light sensitivity.

Measuring Light Levels

A year's worth of sunlight delivered in 1-2 minutes would vaporize most paper-based materials. A day's worth of sunlight would do serious damage. A year's worth of sunlight on the west coast of the United States is about 230 Mlx-hrs, or million lux-hours. (3) A day would be 0.63 Mlx-hrs. Based on that exposure, seven average days of full, outdoor, horizontal sunlight exposure would permanently damage an average artwork on paper (see below). The highest possible light exposure on the planet is 290 Mlx-hrs with 60,000+ Lux on a horizontal surface. (4)

A day of standard museum light exposure would range from 600 to 1200 lx-hrs (50-100 lux for 12 hours of exposure) or 0.000600 - 0.001200 Mlx-hrs. Daylight is usually excluded for the display of works on paper. Using the standard "conservation" protocol for the display of paper-based materials, an artifact is expected to have a life of approximately 4.3 Mlx-hrs. (5)

In 1992, K.M. Colby suggested a new museum display policy that was based on fading rates developed from the ISO blue wool standards. (6) She defined various categories for museum objects based on light fading to a very low 0.01 density change (Δd). (7)

Category 1 includes sensitive artworks whose members show just perceptible damage, 0.01 Δd , at an average of 1.2 Mlx-hrs (range: 0.4-3.6 Mlx-hrs). This category would include early albumen prints, most color photographs, Polaroid images, some watercolors, pastel or ink drawings, works on newsprint, and a range of other non-paper artworks.

Category 2 artworks are expected to sustain an average of 32 Mlx-hrs (range 10-100 Mlx-hrs) of exposure before showing just perceptible change due to non-UV light exposure. Category 2 contains low stability paper-based materials, B&W gelatin prints, and most color slides. I would also include black printers-ink engravings/etchings on average paper and documents printed earlier than the 1850s with carbon ink on average paper.

Category 3 materials, which include stable media on the highest quality paper, toned B&W photographs, and carbon inks, can undergo 300 Mlx-hrs of light before perceptible change.

Table 1 offers summary data on light intensity measurements for direct sunlight, exhibition conditions, and flatbed scanning, and compares those measurements to the projected light exposure levels that artwork can sustain over its lifetime.

Table 1. Light Intensity Comparison

Scanner exposure	0.0000009 to 0.0000386 Mlx-hrs
Year's worth of sunlight	115 to 290 Mlx-hrs
Day's worth of sunlight	0.3 to 0.8 Mlx-hrs
Day on a museum wall	0.000600 Mlx-hrs
Life of an artwork	4.3 to 10 Mlx-hrs

Evaluating Modern Flatbed Scanners

Seven different flatbed scanners were examined. The Umax Astra 1220S was owned by the author and was thus examined thoroughly. The other scanners were evaluated on the floor of the Seybold Seminars: Publishing 98, in San Francisco, September 1-4, 1998, with the help of several presenters and/or session leaders named in the credits below.

The data was gathered using the following equipment combined into a time-based light measurement instrument:

- Exttech B401020 lux light sensor (CIE, color and cosine corrected, size: 3 mm²)
- Pico ACD-11, 8 bit, analog to digital (A-D) converter
- Picolog Win 5.0 software
- 486/100MHz PC laptop

The measurements were made at 1-second intervals over the scan period. The sample rate was a little too coarse, but it made the data acquisition and processing manageable. Measurements made at 10 samples per second (100 ms intervals) varied by 0.1± from the slower rate, making the variation of the 1/sec measurements about ± 10%.

Table 2 shows that exposures from typical modern scanners ranged from 0.9 to 38.6 lx-hrs (lux-hours). Other scanners being sold today may vary by 10-25%, but not by an order of magnitude (100%). The average exposure was 11 lx-hrs, which is 1-2% of a daily exposure on a museum wall, or 0.000011- 0.000026% of an object's predicted life. The latter assumes that 4.3-10 Mlx-hrs are realistic estimates for an average work on paper, as noted in Table 1..

The measurement protocol used in this investigation was 600 dpi resolution, 36 bit color at the Dmax of the unit (shown in bold on Table 2). Lower resolution and bit levels were included for purposes of comparison. Color bit levels higher than 36 bit represent the lowest bit level the operator could achieve for the unit. It was incorrectly assumed that all units using the same lamp would have the same output within a line. This was found to be false only after the Microtek unit was evaluated. Unfortunately, only one Microtek unit was evaluated, mistakenly.

Table 2 Light Output During Scanning Process

Model	DPI	Bit Depth	Dynamic Range¹	Max. Lux	Exposure Time (seconds)	lux-hours
Umax Astra 1220S	300	24	2.3	1195	27	2.7
Umax Astra 1220S	600	24	2.3	1368	42	4.4
Umax Astra 1220S	300	36	2.7	1246	43	5.3
Umax Astra 1220S	600	36	2.7	1368	167	15.8
Umax Powerlook III	300	36	3.4	1664	42	4.4
Umax Powerlook III	600	36	3.4	1574	124	14.4
Umax Mirage II	600	36	3.3	2500²	114	23.8
Microtek ScanMaker 4	600	36	3.4	2270	15	2.8
Linotype Saphir Ultra 2	300	42	3.4	1157	17	0.9 ³
Linotype Saphir Ultra 2	600	42	3.4	1393	230	14.0
Heidelberg Quickstep	600	42	3.7	1302	56	4.5
Heidelberg Topaz iX	600	48	3.8	1632	218	38.6

¹ Dynamic range is the range between Dmin and Dmax. For scanners Dmin is assumed to be 0, thus

Dmax represents the dynamic range of the scanner.

² Maximum lux for this measurement is uncertain due to the A-D converter saturating. This was not noticed at the time of the scan. The actual reading could not be more than 4000 lux.

³ This is quite low and may be attributable to operator error.

The shapes of the curves created when light output (Lux) was plotted against time varied markedly for scanners within a manufacturer's line and at different scanning resolutions from the same machine. Several of the lower priced units used what appeared to be proprietary double-pass, and possibly triple-pass, scanning protocols to increase scan quality to very good effect. Several curves have steps along their slopes, some with peaks and troughs at the beginning and end of the steps.

The Heidelberg Topaz iX is possibly the best CCD flatbed scanner available, and has the highest lux-hour number. It is capable of 4.0 Dmax, 5080-7620 dpi optical resolution at 48-bit color (16 bit per channel of RGB). It costs approximately \$50,000, and takes its time making the best possible scan. Color accuracy, gamut, and sharpness were seen to be superior; the quality is also evident from the perfect Gaussian shape of the Light vs. Time curve (not shown).

UV Light Data

Data on UV (ultra violet) light was not gathered because it was too costly and not considered as significant.⁽⁸⁾ Sensitive artifacts are more vulnerable to the greater amount of visible light than to UV radiation alone. UV light represents about 3% of daylight, indoor ⁽⁹⁾. Thus, the effect of visible light is much greater than UV radiation for sensitive materials. However, UV does cause faster and greater damage to more light-stable materials. The intensity of scans is so low that even if the UV component were 5-10% of the total light energy, it would not represent a big effect.

Cold cathode lamps are a form of fluorescent illumination. Several fluorescent lamps commonly used in cultural institutions for illuminating artifacts have approximately 0.7-2.4% of their light radiation composed of UV.⁽¹⁰⁾

Conclusion

The claims made by some experts on the intensity of flatbed scans are overstated. Most scans will be from 1-15 lx-hrs, which is a minuscule fraction of the useful life of a document or artwork. Issues associated with a document's physical protection during scanning, such as damage to spine or friable paper, should be of greater concern to librarians, archivists, or curators when flatbed scanners are used for digitization. Digital cameras may be a better tool for digitizing material with high sensitivity to physical damage. Flash units would be the desired form of illumination. Normal "hot lights" used in copy stand photography can generate radiant heat that will dry and expand paper temporarily, causing pages to curl, which will distort the image during photography. Incidentally, the level of illumination using "hot lights" on the copy stand could be much greater than the intensity of a flatbed scanner. Flash illumination has a very short duration, 1/1000-1/4000 of a second; thus, the lux-hrs are very low.

[Errata](#)

Acknowledgements

This work would not have been possible without the assistance of several manufacturers' representatives:

- Umax: Steve Hendrix, Umax Applications Specialist, Umax Technologies Inc, Fremont, CA 94538 510-651-4000 (770-569-8334)
- Microtek: Brian Watt, Product Marketing Manager, Microtek Lab Inc., Redondo Beach, CA 90278-1226,310-297-5000
- Linotype: Larry Haas, Selcor Graphic Systems, Redwood City, CA 94061, 650-365-0474: representing Linotype scanners and LinoColor software from Heidelberg Color Publishing Systems, Hauppauge, NY 11788
- Heidelberg: Steven Scholl, Heidelberg Prepress Demonstrator, Heidelberg USA, Rancho Dominguez, CA 90220, 310-761-1500.

Notes

(1) For general information on cold cathode type lamps see: <http://lighting-inc.com/manufacturers/nationalcathode/whatis.html>

(2) Breitenbach, A. "Inside the Charged Coupled Device," *Digital Camera*, Vol. 1, No 1. July 1998, pp. 54-55 & 58; Dierickx, B. "The Human Eye Versus Silicon." <http://www.imec.be/bo/ccd/evs.html>, 4/6/97.

(3) Calculated for the Bay Area/Silicon Valley region, excluding foggy coastal areas, such as San Francisco and Santa Cruz. The southwest US ranges from 171-290 Mlx-hrs yearly exposure; East Coast about 171-230 Mlx-hrs; and the northern US and Canada 115-170 Mlx-hrs. Europe ranges from 115-230 Mlx-hrs yearly. See Thomson, G., *The Museum Environment*, Butterworth-Heinemann, New York & London, 1994, 2nd edition, pp. 168-174.

(4) Ibid., Thomson, p. 171.

(5) It is assumed that an artwork will have a useful life of about 500 years. Standard museum light level for works on paper is 50 lux (5 foot-candles) for 12 weeks (6-day week, 12-hour day) every 3-5 years; about 43,000 lux-hrs per exhibition. The works do not need to rest after display, the waiting period is intended to serve as a guideline for full life and reflects standard museum practice where a work is used in a exhibition every 3-5 years, or so. When the math is run, an artwork will live through about 100 exhibitions over 500 years, if displayed 12 weeks every 5 years, or about 300 years if exhibited every 3 years. The Reciprocity Law applies to light. The numbers can be pushed around at will: one could exhibit at 1 Mlx-hr and then put the artifact in the drawer for 100 years; or exhibit for only 6 weeks (21,500 lx-hrs), then the artifact would last about 1000 years.

(6) Colby, K.M. "Suggested Exhibition Policy for Works of Art on Paper," J. IIC-CG (*Journal of the International Institute for Conservation, Canadian Group*), Vol. 17, 1992 pp. 3-11; Colby, K.M. "A Suggested Exhibition/Exposure Policy for Works of Art on Paper", <http://www.webcom.com/~lightsrc/policy1.html> (1998).

(7) "Just perceptible change" seems to be a very low threshold; 0.1 d would seem a more reasonable threshold. This would reflect the reality of use and the fact that density is logarithmic. If just perceptible change is the defining limit, then collections managers will be tempted to go beyond the recommended light levels, because some fading over time (500 years) is normal and acceptable. Pegging the change at a low (0.1 d), but reasonable amount, makes stretching the light level recommendation less acceptable.

(8) Ibid., Thomson, p. 15.

(9) UV is 3% of the total light output from the sun that reaches the Earth's surface through standard window glass. UV is 4.5% of total sunlight outdoors. See Thomson, G., pp. 168-174.

(10) Ibid., Thomson, p. 168. Standard tungsten bulbs have 0.67% UV component.

This article originally appeared in RLG [DigiNews](#) October 15, 1998, Volume 2, Number 5, ISSN 1093-5371 RLG DigiNews is produced for the Research Libraries Group, Inc. (RLG) by the staff of the Department of Preservation and Conservation, Cornell University Library. Article reprinted with permission of the author, Timothy Vitale and RLG.