Softproofing in printing and publishing

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Abstract

Using soft proofing as a color communication tool from design to press has received much attention in the printing and publishing industry. This paper explores the role of proofing in printing and publishing from a technology trend point of view. Given that there are a number of softproofing technologies on the market that facilitate notable research and testing activities by industry associations and universities on soft proofing capability and performance, the soft proofing era is dawning. To commemorate the arrival of the new era, "soft proofing" or "soft-proofing" is recognized as a single word, softproofing, in this paper.

Trends in digital prepress

When the author joined School of Print Media at Rochester Institute of Technology (RIT) as a faculty member in the 1980s, the state-of-the-art technologies in the prepress area were floor model analog scanners, phototypesetting machines, light tables for manual image assembly, film-based proofing, and platemaking equipment. These were the technologies available then. Macintosh computers were not available until 1984 (Remember the Super Bowl Macintosh ad on January 24, 1984?). We, as faculty of the School, were successful in developing curriculum and in preparing college graduates for the printing/publishing industry. The author taught one course in image carriers for gravure, offset lithography, and flexographic printing to a very large group of freshmen class with repeating laboratory sessions then.

If you tour the School facilities today, you will see many Mac G5 (1.8 GHz) with OS X running with a variety of publishing software packages for graphic design, image processing, pagination, PDF, web page design, video and animation, etc. There are many peripherals, e.g., digital cameras, flatbed canners, and small- and large-format output devices. There is no phototypesetting machine, film-based proofing, manual image assembly, and film-based platemaking equipment left anymore. We, as faculty of the School, have been busy updating our curriculum so that relevant technologies and their applications are taught in the classroom.

Today, the author teaches a number of technical subjects, including color management, quality control, and tone and color analysis, to a number of small classes that is equal to the same teaching load in 1980s.

The contrast in technology change matches the contrast in teaching change. Table 1 provides a comparison in prepress imaging workflow change over a time span of 25 years. For example, a competent technologist of the 1980s might know a great deal of typesetting. He or she likely knew little about layout or color separation or presswork. As such, skills of an individual usually were bound to certain types of devices. In order to complete print production from design to press, many manual processing steps and many individuals were necessary.

Table 1: Technology comparison between 1980 and 2005

	1980s	2000s
Prepress Imaging Workflow	Many devices Analog, photomechanical Many processing steps Manual, skill intensive	Fewer devices Digital, networked Fewer processing steps Automated, integrated raw materials → finished products
Proofing Media	Hardcopy	Cross media (hardcopy & display)

If we examine a competent technologist today, he or she is capable of performing a number design and prepress tasks using the same microcomputer running with a variety of software packages. As suggested at the right-hand-side of Table 1, design and prepress activities take the shape of a funnel. The end of the funnel is a marking engine or an imaging head of any hardcopy output device. What passes underneath the imaging head is the moving substrate. Thus, a graphic art system is made up of two parts: pre-media and print media.

In the past, only hardcopy was used as proofing media. Now, both hardcopy and display are used as proofing media. In addition, a few observations are worth mentioning regarding the nature of technology change: (a) The rate of technological change becomes faster and faster; (b) Technology adoption has been an effective tool for increased quality and productivity; (c) What is new will one day become old; and (d) Survival is for the fittest.

Indeed, what happened in prepress technology is parallel to what happened in the computer industry. It is a story about the evolution of technology for increased quality and productivity. Gordon Moore, cofounder of Intel, summarized the rapid technological improvement the best with his Moore's Law in 1965, i.e., data density of the integrated circuit doubled every 18 months.

The improved performance in computing and in its peripherals, e.g., smaller and faster computer, larger and more flat monitors, eventually gave birth to softproofing. Let's discuss what a color proof is, what a certified proof is, and why softproofing is a new imaging paradigm.

Color proofing in printing and publishing

A *color proof* is a graphic medium for visual verification from design to print production. A color proof is not just a pretty picture, but is a prototype representing the look and feel of printed page. In publication printing, a *contract proof* serves as a legal binding agreement between advertisers and publishers. Printers are required to print to match contract proofs.

A *certified proof* is a contract proof that has gone through a certification process and is required to match a reference printing condition. For example, Specification Web Offset Publication (SWOP) began its certification program in 1999. Off-press proofing vendors must submit an application data sheet (ADS) and sample proofs for evaluation. To be certified, SWOP representatives will verify the submitted ADS by measuring the supplied proof. In addition, SWOP determines if there exists a visual match between the supplied proof and a SWOP certified press sheet. A SWOP certified press sheet is a press sheet, bearing the same pictorial reference images as the proof that conforms to SWOP specifications. In other words, a certified proof is required to print by numbers and a press run that conforms to SWOP specifications is also required to print by numbers. When both the proof and the press sheet conform to the same set of numbers, visual match between proof and press sheet is a natural consequence.

Hardcopy vs. softproof

It is clear that both a hardcopy digital proofer and a softproofing device take digital data as input. A question was raised if the hardcopy proof itself is digital. In other words, whether the data was rasterized and the bit map became either ink amount or toner amount on the substrate, does the hardcopy proof remain digital? Or when rasterized data is sent to a display to excite phosphors, is the softproof digital? It turned out that human visual system is analog in nature. The eye cannot see bits and bytes directly. The visual information has to be converted as light on a self-emissive device or as dots of different sizes on substrate in order for us to see. Thus, both types of digital proofer are analog.

In what way, then, does hardcopy and softproof differ from each other? Well, the imaging cycle of a hardcopy proofing system is relatively long, i.e., 10-20 minutes. It requires courier services to deliver the proof to the clients. It takes time to communicate changes back to the prepress provider. On the other hand, a display-based digital proofer works with a continuous stream of energy. Any change in the digital data immediately affects the content of the display. With broadband data communication, softproofing can be anywhere at anytime.

There is a need for a certified off-press proofing system by the publication printing market. Certified hardcopy proofs have been the norm in printing and publishing. The culture of being accustomed to using hardcopy proofs and the proliferation of non-impact digital printing technologies, e.g., dye diffusion thermo transfer (D2T2) and inkjet, prolong the hardcopy paradigm. If we examine the list of SWOP-certified off-press proofing systems today, display-based SWOP-certified proofing systems are catching up (Table 2). There are 60 certified systems by 17 vendors all together. Among the 60 certified systems, 20 of them are display-based.

In the very beginning, softproofing was a curiosity in universities. An early technology demonstration on softproofing was by Professor Roy Berns and his student in 1995 at RIT (Berns and Choh, 1995). There has been a great deal of technology development in the past decade. The first SWOP certified display-based proofing system, given to ICS Remote Director, was issued in October 2003. The International Organization for Standardization (ISO) only recently finalized the display standards for color proofing (ISO 12646, 2004). We're beginning to

Table 2: Off-press proofing system vendors

Manufacturer	Hardcopy proof	Display proof	# of certificates
ColorBurst	Epson		6
Creo	Iris; Inkjet	EIZO	3
Dalim		Apple	3
DuPont	D2T2; Epson		3
EFI	Canon; HP; Epson		7
Epson	Stylus Pro 9600		1
FujiFilm	D2T2		2
Global Graphics	Epson		1
GMG	Epson		1
HP	DesignJet		2
ICS		Apple/EIZO/LaCie	9
KPG	Approval	Matchprint Virtual	16
Latran	laser ablation		1
MediaCompass		Apple	1
Onyx	DesignJet		1
ORIS	Canon; Epson		2
Vertis	Epson		1

experience that softproofing enables the digital workflow, from digital image capturing to editing to pagination to contract proofing, seamlessly with shorter cycle time and without any solid waste.

Basics of display-to-print match

Color is a visual sensation, resulting from the integration of three variables: light source, object, and the human visual system. Within the visual system there are 3 sensors (red-, green- and blue-light sensitive cones), that each detects one-third of the visible energy and passes visual stimuli to the brain for interpretation. The process of quantifying color by integrating all visual stimuli together is also known as *tristimulus integration*. A graphical depiction of tristimulus integration is shown in Fig. 1. The diagram at left in Fig. 1 is the spectral energy distribution of the light source. The diagram in the middle is the spectral reflectance distribution of the object. The diagram on the right is the spectral sensitivities of the Standard Observer. Tristimulus values, X, Y and Z, are resulting from the tristimulus integration process (Berns, 2000).

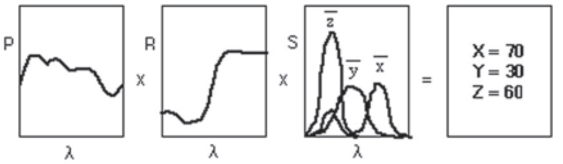

Fig. 1: Tristimulus integration

Let's examine the meaning of tristimulus integration further. First, the color sensation changes if any one of the three elements changes. For examples, the color sensation of an object changes if two different light sources, e.g., daylight and tungsten, are used to view the object side by side (color is light source dependent); the color sensation is different between two objects having different spectral energy distributions (color is object dependent); and the color sensation is different between a color-deficient and a color-normal person (color is observer dependent). This is why the international standard for process ink specifications, ISO 2846, must define the illuminant D50 and the 2-degree Standard Observer as the measurement conditions.

A more interesting phenomenon about tristimulus integration is that color matching is possible between two objects having different spectral energy distributions. This is the effect of tristimulus integration, i.e., when two objects have the same tristimulus values, they match in color. This phenomenon is called *metamerism*.

A color image can be reproduced in two ways: by subtractive color mixing and by additive color mixing. Subtractive color mixing is how hardcopy color printers work whereby cyan, magenta, yellow, and black separations/inks are printed on paper in registration. Additive color mixing is how monitors work whereby red, green, and blue lights are emitted off a display.

There are doubts in the mind of laymen that achieving display-to-print match is possible. Yet, the match between a printed color and its display is, by definition, a metameric match. Thus, color matching between proof and print does not depend on the proof being reflective (as in the hardcopy) or self emissive (as in the display).

Recent technological advancements and testing

Softproofing technology did not happen by itself. It is the synergy among a number of recent technological advancements. Display, color management, and broadband data communication are the top three technologies that we will look at with a focus on the softproofing application in the pressroom.

1. Display technology and its testing

Different display technologies may be used for softproofing applications. CRT (cathode ray tube) has been used for TV and computer display traditionally. To display an image, an electron beam strikes a phosphor coated inside a vacuum tube. CRTs are bulky and with a curved surface that reflects glare from ambient light. Burn-in, a faint image that has been displayed over a long period of time on the same location of a CRT is a problem for CRT.

LCD (liquid crystal display) is a lightweight flat-panel display device. A high-intensity light source is used. To display an image, an electric current passes through the liquid, causing the crystals to align so light can pass through them. Each pixel on the LCD has three-color cells that form red, green, and blue components of the signal. Imaging by liquid crystal does not create burn-in problems.

OLED (organic light-emitting diode) is an electronic device made by placing a series of organic thin films between two conductors. When electric current is applied, a bright light is emitted. In other words, OLED is a self-luminous display that does not require backlighting. It also has a larger brightness range with a wider viewing angle than LCD displays.

The appearance of a color display is influenced by many physical factors. Minimum display requirements for resolution, size, uniformity and convergence, according to ISO 12646 (2004), are shown in Table 3.

Table 3: Color display requirements

Parameter	Minimum requirements
Resolution	1,280 x 1,024 pixels without interpolation
Size	43 cm x 22 cm (17 inches x 8.5 inches)
Uniformity	Visually uniform when display a flat tint within 5% of luminance of the center
Convergence	Free from color fringes when display a grid pattern

The minimum size of the display, 17 inches x 8.5 inches, is close to a two-page spread for magazine publication. If we fit the 8.5 inches to the 1,280 pixels dimension, the spatial resolution of a pictorial image is 150 pixels/inch. This is considered more than adequate for softproofing applications.

In addition to the physical factors mentioned in Table 3, a dark, neutral surround is needed for display viewing. The ambient viewing conditions for softproofing application must have controlled lighting. The non-image forming or flare light at the face of the monitor should be low. At the same time, the display has to be placed near the viewing booth for reflective print viewing. In other words, pressmen have to learn how to use a softproofing system, including the viewing conditions, correctly. Else, pressmen may not have the benefit of display-to-print match. Worse yet, they may lose confidence in using the technology in the pressroom.

Researchers at RIT's Munsell Color Science Laboratory tested temporal consistency of two LCD displays and one CRT display in 2000 (Gibson and Fairchild, 2000). Each display was left on for four hours before beginning measurement. The time span for these measurements was over three hours for each display. The results showed that display devices were extremely stable ($< 0.1\ \Delta E$) over time (Table 4).

Table 4: Temporal consistency of display devices

ΔE (CIE94)	Sony CRT	SGI LCD	IBM LCD
Red	0.13	0.06	0.05
Green	0.14	0.05	0.04
Blue	0.08	0.04	0.03

Gibson and Fairchild also tested spatial uniformity of the three displays by dividing the display into 3 by 3 or nine areas. They found that there was more spatial variation (about 0.5 ΔE in CIE94 unit) than temporal consistency.

The School of Print Media performed device capability tests on an Epson SC3000 inkjet printer (Chan, Chung, and Cheung, 2000) at the same time. The testing procedure for temporal consistency was more elaborated. Also, different color difference metric, ΔE_{ab}, was used. Thirty samples of the IT8.7/3 basic data block (182 patches) were printed over a period of a month. All thirty samples were measured and analyzed. The reference was the average of L*, a*, and b* of each color patch of the thirty samples. From comparing all the thirty samples to the reference respectively, the results were thirty sets of 182 ΔE_{ab}. By averaging the 182 ΔE_{ab} of each sample, there was a result of 30 average ΔE_{ab} that represented the performance of each sample. The grand average of the thirty ΔE(ab) values was found to be 0.45 ΔE_{ab}. It was considered small in relation to the color difference between two press runs which ranges from 2~4 ΔE_{ab}.

We also conducted spatial uniformity tests for hardcopy output devices. A case in point is the paper, authored by Fred Hsu, in this issue of the Test Targets (Hsu, 2005). Hsu tested on an Epson SC4000 inkjet printer. He reported that the average color difference across the width of the paper was 0.07 ΔE_{00} and the average color difference lengthwise was 0.14 ΔE_{00}. In this paper, a different color difference metric, ΔE_{00}, was used.

Given that there were differences in the testing procedures and in color difference metrics used to assess device capabilities, a quick observation suggests that display performance in terms of temporal consistency and spatial uniformity is as good as inkjet devices tested, but better than printing presses.

2. Color management technology and its testing

Color management is a method of rendering color images from one color space to the other. It involves a source device and a destination device with known color characteristics. Using International Color Consortium (ICC) specifications, color characterization is in the form of device profiles.

As shown in Fig. 2, the image rendering from the source to destination requires the use of an application programming interface (API) with a color engine or color management module (CMM) and a selected rendering intent. Profile connection space (PCS) is a transient color space whereby the look-up table from the source profile and the look-up table from the destination profile meet.

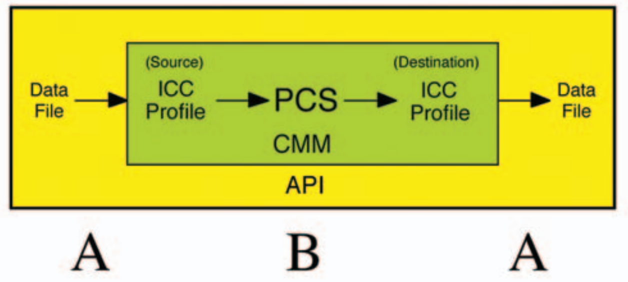

Fig. 2: Schematic of a color management system

Using publishing workflow as an example, the source is the press and the destination is the display located in the pressroom. Document or image files, with colors defined in the press CMYK space, are converted into the monitor RGB space for display. Color management performance depends on device color gamut, spatial uniformity, and temporal consistency.

The appearance match between display and print will be affected by physical factors of the display, as discussed earlier, and the accuracy of the color management system. The display-to-print match also depends on white point simulation and gamut capability of the monitor. Since most unprinted paper is not neutral, accurate profiles and a correct rendering are required for the monitor to simulate the white point of the paper.

Fig. 3 shows a comparison of color gamut between an LCD display profile (wire frame) and SWOP profile (solid).

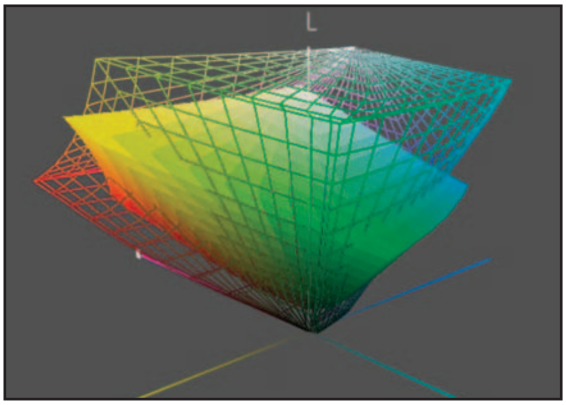

Fig. 3: Gamut comparison between a LCD display and SWOP

Notice that there are non-overlapping areas between cyan and yellow region of the two media. This means that when a SWOP certified softproofing system conforms to its SWOP application data sheet, it does not necessarily mean that a perfect display-to-print match has been achieved.

While softproofing can simulate printed color closely, it will not be able to simulate micro image structures, e.g., halftone patterns, image moiré, image gloss, etc. Unless the size of the display is very large, softproofing is also limited to display printed signature at the same size.

During the IPA Color Proofing RoundUp Conference, June 7-9, 2005 in Chicago, IL, the proof-to-print match was visually judged among 27 proofing systems with 7 systems being display-based. The results showed that judges ranked the softproofing system higher in comparison to hardcopy proofs (www.ipa.org, 2005).

3. Broadband data communication

Prepress houses traditionally made CMYK hardcopy digital proofs. They had to be delivered to advertisers for approval by courier services or via overnight FedEx. Broadband data communication, e.g., FTP and Internet, made softproofing possible at remote locations instantly with significant cost savings.

In addition, Internet browsers are used to view thumbnail displays of color-managed images. Only the images of interest are compressed and transmitted for simultaneous viewing. Annotations and comments from the reviewing party are communicated in real time. Because of the ubiquitous nature of the Internet/World Wide Web technology, it benefits not only the remote and instant nature of softproofing, but also fast adoption of the technology around the world.

Where does softproofing go from here?

Softproofing, like any new technology, provides options. But is this a "must-have" technology? Where does it go from here? Let's use the technology adoption curve to predict the softproofing trends.

The technology adoption curve is a theory that describes the rate of technology adoption over time. It starts with a slow innovation period and going through a rapid growth of early adoption, followed by significant growth in the market, and then a gradual stabilization and finally a decline (Fig. 4). The technology adoption curve distinguishes the five successive groups of adopters (Carr, 2005):

(1) *Innovators* are enthusiasts who embrace technology for its own sake.

(2) *Early adopters* are visionary users who are willing to take risks and to reap the benefits.

(3) *Early majority* are pragmatic users who are looking for proven applications and see the advantages in the vertical market.

(4) *Late majority* are pragmatic users who believe in traditional technology and are reluctant to invest in new technology and

(5) *Traditionalists or skeptics* who do not believe in new technology and speak against the claims made by the new.

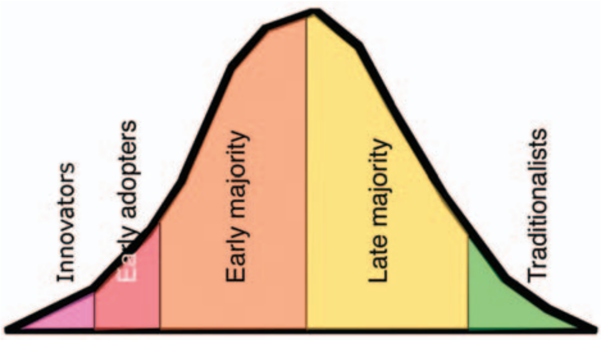

Fig. 4: Technology adoption curve

A few observations of technology adoption are worthy of mentioning in the context of softproofing. First, let us identify an early softproofing technology adopter. Time Inc. adopted the Computer-to-Plate (CTP) technology in 1997, and later, Portable Document Format (PDF) in 1999. Time Inc. is now leading the softproofing adoption in the pressroom in North America. Currently, eight printing plants in North America have each installed no fewer than two softproofing systems and with a goal of 100% softproofing-based print production workflow (Lam, 2005). When advertising agencies began embracing softproofing and were pleased with it, Time Inc. knows the risk is no longer high and the reward can only be higher since there is no competition in the field.

Ease of use and degree of comfort of the softproofing technology can make or break the path to early majority. We witnessed the reduced newspaper circulation as readers of younger generation receive news and events from watching display devices. Pressmen are accustomed to comparing press sheets to hardcopy proofs. The question is, "Will softproof be easier to use and as reliable as the hardcopy proofs in the pressroom?"

As technology matures, it eventually moves to the late majority stage. The increase in new users will be small as the technology adoption moves to the late majority stage. But the market may remain large until a new technology replaces it. A good example of a matured technology that lasted for over half a century and enjoyed a very long period of prosperity is the silver halide photography led by the Eastman Kodak Company. Of course, we all know what happened to film-based photography when digital photography came along and became very affordable to the mass.

Given that there are a number of softproofing technologies available on the market and notable research and testing activities being conducted by industry associations and universities, it is safe to recognize that the softproofing era is dawning. To commemorate the arrival of the new era, "soft proofing" or "soft-proofing" should be recognized as a single word, i.e., softproofing.

Softproofing in the pressroom

Realizing a faster rate of technology adoption is not a question of if, but when. It is a matter of focusing on user's need and overcoming barriers. The user of softproofing technology includes all parties in the publication market, i.e., publishers, advertisers, prepress, and printers. At the end of the day, everyone wants matured technologies before his/her competition in order to realize cost savings.

To gain confidence in using the softproofing technology and to lower the consequence of failure, it is strategic to provide training support to address users' needs. These include (a) the understanding the importance of the reference printing condition, e.g., TR001; (b) instill process control to achieve repeatable color in the pressroom; and (c) manage the softproofing system correctly for predictable color.

When softproofing system is used correctly, the display will predict printed color. In other words, softproof is a quality assurance tool in the pressroom. It is there to provide added confidence that things are done correctly. When pressmen love softproofing and cannot live without it, they become true believers of the technology and the technology adoption will permeate to the rest of the market.

When softproofing practices become wide spread in the printing industry, this represents a cultural change, i.e., for someone who once was a skeptic to becoming an avid user. Think about the adoption of cell phone in today's society for a moment. Many young people rely on cell phones to tell time, to send text messages, and to address their daily communication needs at any place and any time. Because of the convenience and portability of the wireless technology, they no longer need landlines. It would be interesting to see how fast and to what extent print media communities adopt softproofing.

The other cultural change is the role of the customer at the printer's plant. In the past, color proof represented the customer's intent and the printer was asked to print to match the proof. It was critical for the customer to be at the printer's plant to OK color at the time of printing. Today, we subscribe to print by numbers in proofing and in printing. Conformance to specifications replaces the need to have customer at the printer's plant.

There is a lot to do in softproofing to move the rate of the technology adoption ahead. The accomplishment will require that technology providers and technology practitioners work together to achieve the common goal, i.e., making softproofing a preferred proofing media in the new imaging era.

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Literature cited

Berns, R. S. and Choh, H. K. (1995). CRT to reflection print matching under mixed chromatic adaptation using RLAB, J. Electronic Imaging 4, pp. 347-359.

Berns, R. S., (2000). Principles of color technology, John Wiley & Sons.

Carr Jr., V.H., (2005). Technology adoption and diffusion, Retrieved October 10, 2005 from http://www.au.af.mil/au/awc/awcgate/innovation/adoptiondiffusion.htm.

Chan, J., Chung, R. and Cheung, W., (2000). Digital proofing with ICC CMS, 2000 TAGA Proceedings, pp. 143-159.

Gibson, J., & Fairchild, M., (2000). Colorimetric characterization of three computer displays (LCD and CRT), Munsell Color Science Laboratory Technical Report.

Hsu, F., (2005, December). The effect of dot gain linearization as the printer calibration criteria on color matching accuracy, Test Targets 5.0, Rochester Institute of Technology, pp.32-37.

IPA color proofing RoundUP special report (2005). Retrieved October 10, 2005 from http://www.ipa.org/proofing-05.php3.

ISO 12646 (2004). Graphic technology — Displays for colour proofing —Characteristics and viewing conditions, International Organization for Standardization.

ISO/WD 12647-7 (2005). Graphic technology — Process control —Part 7: Off-press proofing processes working directly from digital data, International Organization for Standardization.

ISO 2846-1 (2000). Graphic technology — Colour and transparency of printing ink sets for four-colour-printing — Part 1: Sheet-fed and heat-set web offset lithographic printing, International Organization for Standardization.

Lam, K., (2005). Virtual proofing case study. The soft proofing era conference, September 27, 2005, Hong Kong. Retrieved October 10, 2005 from http://www.softproofing.com.hk/.