Advances in High-Resolution Lithography

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Abstract
Recent advances in thermal lithographic plate imaging and continuous improvements in modern lithographic presses and printing materials have enabled Faust Printing, Inc. to produce a conventional lithographic print at a halftone screen ruling of 1110.80 lpi, probably the highest screen ruling yet achieved by conventional lithography. This paper describes the stages and hurdles that led Faust Printing to this achievement. This paper also provides photomicrographic comparisons of the Faust print with three other examples of high-resolution lithography. The question is framed whether an observer can perceive the improved resolution of very fine screen halftones. An experiment was conducted to compare printed reproductions at four screen rulings: 133, 175, 300, and 600 lpi. Participants ranked four sets of images in order of overall quality. The results were mixed. The images were ranked in order of their screen ruling for some pictures, but when the average rankings were examined there was no improvement in ranking for the 600-lpi prints compared to the 300-lpi ones. It seems that for some pictures observers can perceive an overall quality improvement with 600-lpi pictures, even though they cannot distinguish dot structures over about 150 lpi. No test was made to determine if the difference between 600 and 1,110 lpi would be perceived as a further quality improvement by observers.

Introduction
Through the human visual system, the brain interprets information in the form of tone, color, and detail as a vision of the world around us. Even the best graphic reproduction processes provide limited information to the observer compared to what can be seen in nature. Still, for some applications it is important to reproduce the largest gamut of colors or the greatest detail that can be obtained.

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Sheetfed offset lithography is today's dominant process for printing high-quality images on premium coated papers. Some printers in this market strive to distinguish themselves by using waterless printing, stochastic screens, high-fidelity printing, or very fine screen rulings. These methods share a common goal of presenting more visual information to the observer. Very fine screen rulings, the focus of this paper, enable more detail to be conveyed in the reproduction. The sheetfed industry as a whole prints at screen rulings of 150 to 200 lpi. Laser imagesetters, computer-to-plate systems, and improved printing presses enable today's lithographers to exceed this range, but printing at finer screen rulings is very demanding. The press has to be precisely tuned; the optimum combination of printing materials (blankets, plates, inks, fountain solution, and paper) has to be found; and stringent process control tolerances have to be met.

The quest to print at ever-higher resolutions has led Faust Printing, Inc. to produce a printed image at 1,110 lpi, probably the highest-resolution halftone yet imaged by sheetfed offset lithography. From a historical perspective, this achievement is another step in a centuries-long quest to develop graphic reproduction processes that can capture all the nuances experienced in nature. The Faust poster also begs the question of whether the resolution of the print has surpassed the observer's ability to benefit from the added information. This question gains significance because there is an inverse relationship in digital systems between resolution and gray levels, so higher screen rulings are associated with smaller color gamuts. The eye gets more detail information and less color information.

A study was conducted that showed that 600-lpi printed halftones were judged to be of better quality than 300-, 175-, or 133-lpi prints. The question is still unanswered whether 1,110-lpi prints would, in turn, be judged as better quality than 600-lpi prints.

The printing characteristics (ink density, dot gain, gray balance, trapping) of the Faust poster are not known. The platesetter that was used for the poster had been removed by the time Faust won the Printing Industries of America (PIA) 1999 *They Said It Couldn't Be Done* award, which brought their achievement to the attention of the graphic arts community. The poster was examined microscopically comparing the image structure with other high-resolution prints, including a collotype, a stochastic print, and an Advanced Continuous-Tone print.

History of High-Resolution Printing

The pursuit of high-resolution graphic images is as old as printing itself. The need to communicate and the desire to depict the world around us has led to continuous improvements in the methods of capturing and transferring imagery in the graphic arts. From the 15th to the 19th century, *relief* and *intaglio* printing were primarily used for text and images respectively. Letterpress (relief) printing with movable type was the best method for producing text, but woodblock printing, the relief process for imagery, could not depict fine detail as well as the etching (intaglio) process. From the beginning, the ability to image fine detail was often used, in methods like cross hatching, to achieve tonal effects. The best books produced prior to the 20th century bound together text pages from the letterpress process with intaglio etchings for the illustrations.

Improvements were made to both the relief and intaglio printing processes during the 17th and 18th centuries, but the intaglio process consistently set the standard for the reproduction of both tone and detail. In 1640 an intaglio process called *mezzotint* (literally meaning *halftone*) was developed by Ludwig von Siegen. In this process a roulette wheel was used to produce a random pattern to form an image structure which was then burnished to print at different tones. This was the process used by Jacob Le Blon to print the first three-color reproduction in 1704.

Stipple engraving developed in the 18th century was a refinement of the mezzotint process where the burnishing step was eliminated. The stipple pattern was applied in proportion to the tone value that was desired. This process produced a finer grain pattern than its predecessor. The appearance of the image structure in stipple engravings has been compared with the stochastic screen patterns that were developed in the last two decades of the 20th century (Pankow).

Near the end of the 18th century the *aquatint* etching process was developed setting new standards for realism in intaglio printing. A wide range of tonal effects was achieved by etching the printing plate in multiple stages with portions of the image blocked out with acid-resistant dust. The process produced a fine grain structure based on the dust particles.

The *lithographic* process, invented in 1797 by Alois Senefelder, was neither relief nor intaglio, but rather the first planographic printing method. It was immediately popular for its ability to render subtle tonal effects and to image fine detail. Soon after the invention of lithography, the photographic process was discovered. The next 150 years would see the development of photomechanical processes replacing the older mechanical processes for all printing methods. Now, in the last three decades of the 20th century, photomechanical processes have given way to electronic image processes.

Lithography set new standards for resolution that are yet to be equaled with the *collotype* process, a continuous-tone photomechanical method invented in the 1880s (Figure 1). This process used a photosensitive gelatin printing plate that was exposed to a continuous-tone negative image. A tanning development process yielded a plate that differentially absorbed water in inverse proportion to light exposure. The plate would then take ink in inverse proportion to the amount of water it absorbed, with the result that a variable ink film thickness was printed by the press. The collotype process was very demanding, and was not capable of run lengths beyond about 1500. Furthermore, the process produced a limited tonal range, making it necessary to add touch plates for many jobs.

Figure 1. Collotype print with magnified detail from 1896 *Penrose Annual.*

At the turn of the century collotype was a popular subject in technical journals as printers struggled for better control, longer pressruns, and color methods. Pousin (1920) reported on a new approach to imaging collotypes that produced lower resolution but better processing consistency. Fishenden (1920) reported on work to develop irregularly grained halftone screens for conventional offset lithography where the image structure was captured from reticulated gelatin, thus maintaining the image structure of collotype on metal printing plates. Interest in collotype fell off during the 1930s, having achieved only marginal success in developing an offset collotype process. This coincided with the successful development of the halftone process, which was compatible with offset printing and capable of very long pressruns.

There was a resurgence of interest in the collotype process in the 1950s when the government funded research in high-resolution printing methods for aerial photography. Collotype was the only printing method that could directly print a continuous-tone image. Lerner (1954) reported advances in offset collotype. He was able to produce tougher gelatin plates with the right combination of humectants and tanning agents. These plates were used for a pressrun of 25,000 impressions.

In the 1960s the pursuit of a collotype-like printing process that used metal printing plates lead to the development of *random-grain printing* (Figure 2), a method that used positive-acting photopolymer plates exposed through continuous-tone positives. An electrochemically grained aluminum plate was exposed so that the highlight of the image left a small trace of insoluble photopolymer in the bottom of the plate grain. The midtones and shadows then resulted in plate grains that were partly or completely filled with insoluble photopolymer. The plate was printed on an offset press, and run lengths in the millions were possible.

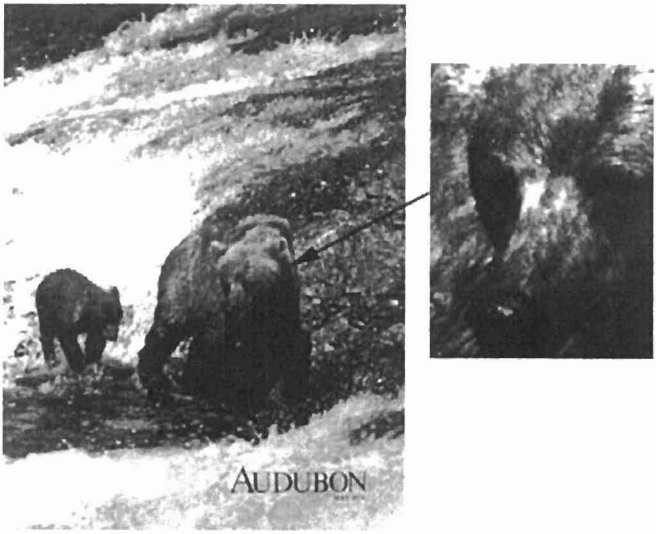

Figure 2. Random-grain lithograph with magnified detail.

The May 1975 *Audubon* magazine cover in Figure 2 was printed by Case-Hoyt , one of the few companies to offer random-grain printing on a commercial basis. The process never achieved any level of commercial success because the exposure was too critical and the tonal range was short. It was difficult to make the four plates for a color reproduction in balance with each other.

During the 1970s electronic imaging processes were rapidly replacing their photomechanical predecessors. In general, electronic systems were more predictable and faster. Furthermore, the laser light source could be used to write digital information onto photo-receptive surfaces, imaging halftone patterns without the need for contact screens. Films, and later plates, written with lasers soon surpassed the resolution limits that had been achieved with white light exposure.

Electronic imaging became commonplace during the 1980s. It offered many new possibilities that were not previously available to the industry. Images in electronic format could be transmitted, stored, manipulated, and processed in new ways. This has led to a new look in the advertising media of today. It has also led to new approaches and benchmarks for high-resolution printing.

Today's Approaches to High-Resolution Lithography

The electronic age brought a new tool to bear on the task of reproducing images at high resolutions. Frequency-modulated (FM) screens, which were developed in the early 1980s, produce halftones with random image structures rather than regularly spaced dots. The image structure is made up of microdots, which are randomly assigned within picture elements to match the tone and detail of the photograph. Several competing systems were developed based on the FM principle. The term *stochastic* was adopted to describe the whole family of screening technologies that used randomization.

CristalRaster screening from Agfa (Figure 3) was among the first successful commercial stochastic techniques. Spot sizes of 14 or 21 microns were used, depending on the application.

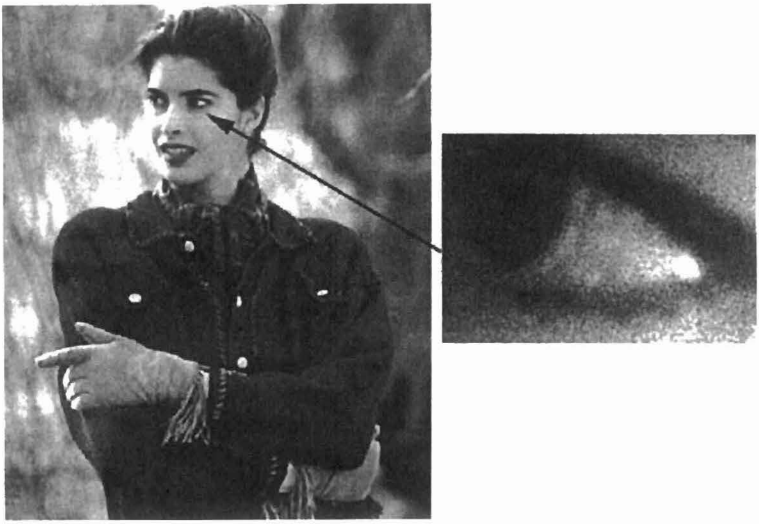

Figure 3. Agfa CristalRaster print with magnified detail.

The advantages of stochastic screens include the complete elimination of moiré patterns in the printed reproductions and improved rendition of fine details in the image. Stochastic screens can be RIPped at lower resolutions than would be required for equivalent conventional halftones. Stochastic screens have also been found to be less sensitive to color shifts on press when the process ink densities drift out of their tolerance ranges (Stanton, 1994).

Stochastic screens are ideal for avoiding moiré in *hi-fi* printing, where more than four process colors are used to increase the color gamut of the reproduction. Without stochastic screens, the printer has to chose between using ***touch plates***, solids with no halftone dots that only print in the shadows, or using the same screen angle for two different colors, a procedure which can produce good results, but requires extreme accuracy on the press.

Stochastic screens have been found to reproduce image detail more accurately than conventional halftones since the microdots can form themselves to image contours within each halftone pixel area. With so many advantages, it seems puzzling that the industry has not adopted stochastic screens in place of conventional halftones. Instead, the use of stochastic screens has remained a small niche.

One problem has been the proprietary nature of the screening algorithms preventing the widespread adoption of an independent standard technique. Another impediment has been the high levels of dot gain that are experienced with stochastic screens (about 12% higher than conventional dot gain levels). Another problem has been the lack of a good proofing system for stochastic screens. Furthermore, stochastic images sometimes have a grainy appearance in large areas of uniform tone, such as skies. This has prompted recent research into hybrid screening technologies, where the reproduction will contain both AM and FM dots in different areas depending on the localized image detail (Schrappe, 1998).

One of the highest-resolution lithographic techniques commercially available today is called Advanced Continuous-Tone (ACT) printing (Figure 4), practiced by Black Box Collotype. Interestingly, this technique is an outgrowth of the earlier random-grain lithography, and it is performed on the printing plates that were marketed for random grain printing in the 1970s. After the plates were discontinued, Black Box bought the entire remaining supply, valuing the plates for their deep random-grain pattern and their continuous-tone photographic response.

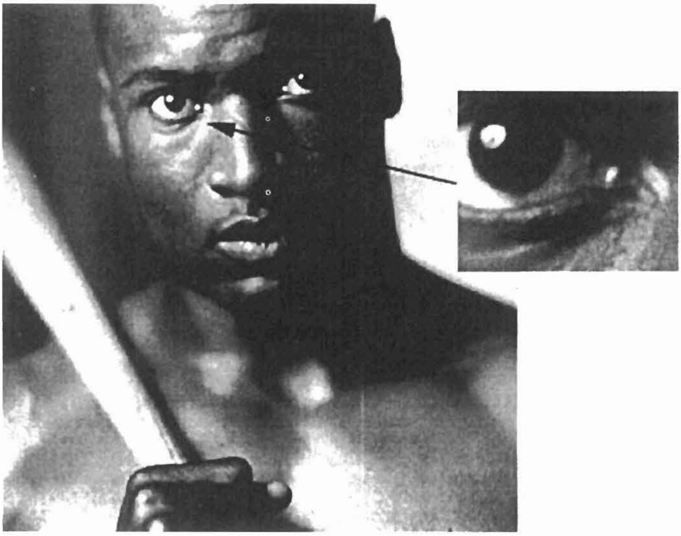

Figure 4. Advanced Continuous-Tone (ACT) print with magnified detail from *En Passant* by Dennis Manarchy.

The image in Figure 4 is taken from *En Passant*, an award-winning book printed in 1999 by Black Box (SAPPI North America Printer of the Year, gold award winner, books category). The ACT prints combine traits of stochastic screens with others from random-grain lithography. When the continuous-tone exposure required for random-grain lithography was found to be too capricious, practitioners of the art, including Black Box Collotype, pursued means to achieve the random grain structure of the print without the need for the continuous-tone exposure. Black Box commissioned a custom-made scanner from Escofot to output films with a pseudo-random-grain dot structure. When these films are printed on random-grain plates, the image structure in the printed image shows the effects of both the plate grain and the stochastic screen pattern.

Another approach to achieving high resolution in lithography is to print by the conventional halftone process, but with very high screen rulings. More detail is conveyed as smaller, more closely spaced dots are used to make up the image. The Faust 1,110-lpi lithograph sets a new record for this approach.

Faust Printing's Pursuit of High Resolution Lithography

In 1987, Faust Printing, Inc. purchased their first multicolor press, although the company was already printing four-color process work on single-color presses. To differentiate themselves from other printers, they sought to demonstrate their skills as lithographers by producing work at very high screen rulings. Working with a local color separator, they obtained separation films at 300 lpi, which was the upper limit of the Crosfield system being used. The printing was successful in that the quality was good, but the printers learned that adjustments were needed in their printing system. Specifically, plate exposure times needed to be adjusted; the fountain solution formulation was changed; and the printing inks were modified.

Still in 1987, Faust did a second test with 400-lpi separations, but the results were less successful. A wavy pattern, which could be seen in the separation films, was noticeable in the printing. Still, the Faust printers had demonstrated their ability to print the images successfully. During the printing of the 400-lpi image, the operators found that roller settings were critical for providing uniform inking for the fine screen.

In mid-1988, Faust approached Hell, Crosfield, and DS America, three scanner manufacturers, about creating a 600-lpi program for their scanners. They all declined initially, but in 1989, DS America wrote a program to produce 600-lpi screens. Faust printed these on the first attempt, but they were not totally satisfied with the results. They reexamined their printing system from top to bottom. The paper, inks, fountain solution, plates, and blankets were all put to the test. The plates and blankets that Faust had used for years would not hold or transfer the tiny dots to their liking. An exhaustive testing cycle yielded only a few lithographic plates and blankets that were deemed suitable for such high-resolution printing.

In late 1993, Faust Printing requested, and DS America wrote, a 900-lpi screen program for the DS scanner. Again, Faust was able to successfully print the fine screen, but they found that the tone curves had to be altered, particularly in magenta. During this experiment, the problem of proofing was particularly troublesome and was not resolved. At the highlight end of the scale, dots were imaged on the printed sheet that were not on the proof. At the shadow end, the press was still printing open where the proof was plugged up. The midtones were off as well.

Again, the Faust printers compared different lithographic plates and blankets. They determined that only one blanket and two printing plates were suitable for this very high-resolution printing. Also, inks and fountain solution were reformulated, and roller settings were further refined for optimum performance.

Faust's most recent experiments with ultra-high screen rulings began early in 1999. They had purchased a Creo computer-to-plate (CTP) system, consisting of a Trendsetter 3244 equipped with a 3200F thermal imaging head. The system included a DEC Alpha raster image processor (RIP). Faust had a printing job for lenticular plastic display that required a specific line screen ruling of 562.70 lpi +/-1% (568.30 through 557.07). When Faust attempted to image films at 562.70 lpi, the Creo it would default to 534.60 lpi. Faust's prepress manager, Josh Felton, worked with Creo to modify the RIP to provide films at the needed screen ruling. The 562-lpi screens were imaged on Polaroid dry film, from which photomechanical proofs were made successfully.

Next, Faust tried to image 1000-lpi screens on film, but the film would not hold such small dots. They imaged the same file on Kodak thermal plates and were surprised that the plates held the image detail. The Faust printers then decided to produce a promotional poster at the highest screen ruling their CTP system could image, which turned out to be 1,110.80 lpi. Surprisingly, each plate only took about eight minutes to RIP and image. This poster (Figure 5, left) took half of a 25x38-in. press sheet. The other half of the sheet was devoted to a comparison of four different pictures each printed at four different screen rulings, 133, 175, 300, and 600 lpi (Figure 5, right). With their Alpha RIP, each screen ruling had to be imaged separately, which meant that each plate was imaged five times in the Trendsetter. In spite of this, the register accuracy of the plates was impressive.

Figure 5. Poster at 1,110.80 lpi (left) and poster comparing different screen rulings (right).

Since their last high-resolution experiment, Faust had installed a new six-color MAN Roland 700 press. Although the press had been demonstrated to print 900-lpi screens by the manufacturer, this was its first ultra-high-resolution printing at the Faust facility. Faust applied their hard-won wisdom about inks, fountain solution, roller settings, packing thicknesses, plates, blankets, and grade of paper as they prepared the press for printing. They took the precaution, which proved unnecessary, of obtaining non-compressible blankets in case their preferred blankets were unable to hold the 1,110-lpi dots. To proof the job, films were output at 300 lpi and a photomechanical Imation Matchprint proof was made. The press match was judged to be good.

The press run went smoothly with all five screen rulings printing clean at the highlights and shadows. The 1,110-lpi screen complicated press control somewhat in that the dot pattern could not be clearly seen with most hand magnifiers. With this pressrun, Faust Printing, Inc. had reached a new level in producing ultra-high-resolution lithography. This achievement was recognized by the Printing Industries of America with their 1999 *They Said It Couldn't Be Done* Award. Through their dogged pursuit of ever-higher screen rulings, Faust has demonstrated that conventional lithography can successfully transfer and hold image elements that are nearly an order of magnitude smaller than the commercial norm of today. The 200x photomicrographs in Figure 6 show the differences in dot size between the five screen rulings printed during this pressrun.

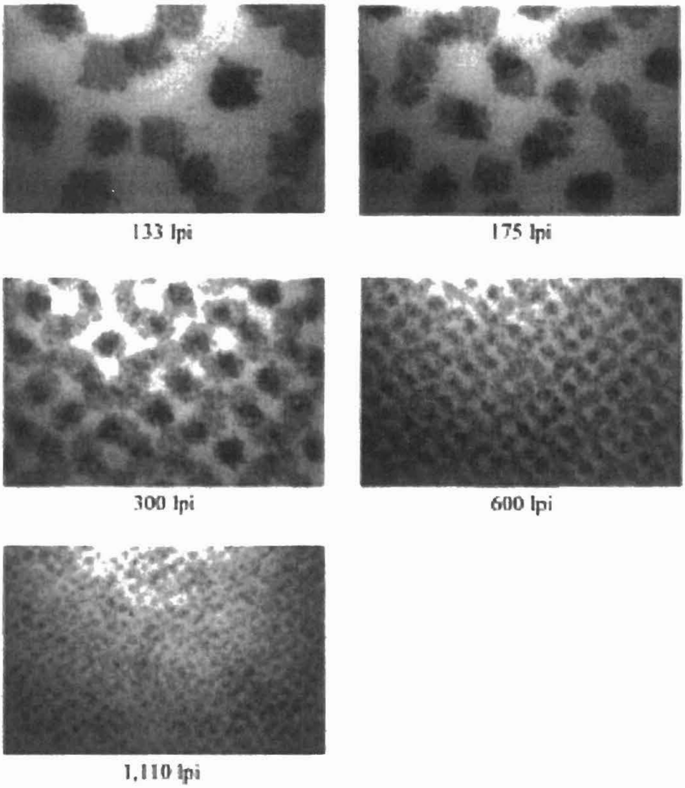

Figure 6. Photomicrographs (200x) of printed dots at five screen rulings.

The dots in the 1,110-lpi image are so small that it was difficult to distinguish them with a 40X magnifier. These images offer convincing proof of the veracity of the Faust claim of 1,110 lpi.

The detail conveyed in the Faust poster can only be fully appreciated with magnification, as seen in Figure 7.

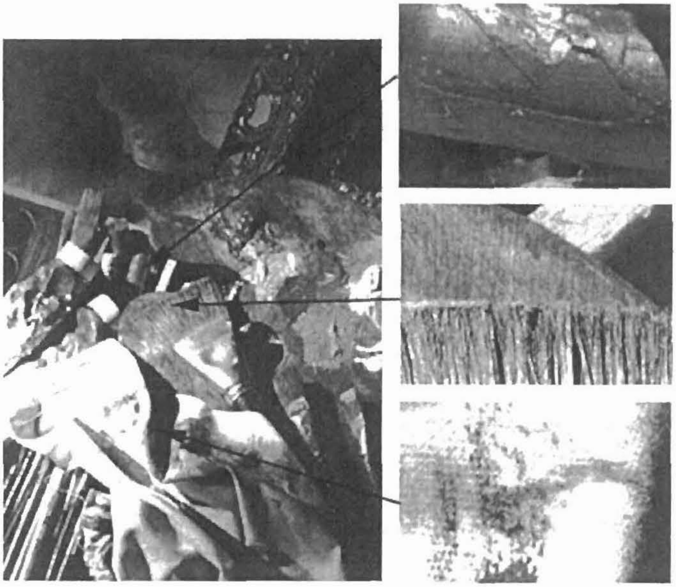

Figure 7. Magnifications from the Faust 1,110-lpi poster.

Under magnification, the wood grain and individual bristles of the paint brush are clearly reproduced. The woven pattern in the cloth is taken from an area that looks devoid of detail to the unaided eye. The chalk magnification also shows remarkable detail.

In early 2000, Faust replaced the Creo CTP system with a Scitex Lotem 800 CTP device using a Brisque RIP. This change was unrelated to Faust's pursuit of high-resolution printing. Presently, the Faust printers are working with the new system to determine the resolution limits of the new device. They intend to continue to print ultra-high screen rulings, not because they have found a ready marketplace for high-resolution lithography, but because it continues to distinguish Faust Printing, Inc. as a high-quality printer with extreme control over their press system.

Questions About the Faust 1,110-lpi Print

The award from the PIA brought the Faust print to the attention of the graphic arts community. A lively discussion ensued on the CTP Pressroom electronic forum (ctpp@ctpp.com). The reaction of professionals in the industry ranged from incredulity to admiration. The two most persistent issues raised by the skeptics were:

- The printing plates were not rated by Kodak to hold smaller than a 1% 600-lpi dot, which is equivalent to a 4.8 micron spot.

- The RIP has a maximum resolution of 3200 dpi, which would only provide about eight levels of gray if conventional screening were used.

The Faust response to the specification limit of the Kodak plate was that Kodak has underrated the resolving power of their plate, perhaps to gain manufacturing tolerance, or to limit their liability in the commercial marketplace.

The second issue was addressed in some detail by Dan Blondal from Creo in a January 14, 2000 e-mail. The RIP used for the Faust print utilized supercell rational tangent screening. In this approach, the screen is comprised of supercells, which are collections of several smaller halftone cells with slightly different shapes. The number of gray levels can be equivalent to the number of pixels in the entire supercell. If each 1,110-lpi halftone cell had eight levels and if there were 32 halftone cells in a supercell, then 257 levels of gray could be achieved ([8 x 32] + 1). This would produce a very acceptable color gamut, which the Faust print was judged to have.

Since the Creo CTP system was removed from Faust Printing, Inc., it was not possible to image and print a digital test form at 1,110-lpi. This would have enabled direct recording of the RIP settings and the measurement of various print attributes. Dot gains are of particular interest because they are known to increase as screen ruling is increased. Gray balance requirements, in turn, are dependent on the dot gain curves of the CMY inks. The authors plan to image and print a digital test form once the new Scitex CTP system has been optimized for very high screen rulings.

Comparison of Image Structure of High-Resolution Lithographs

Four different high-resolution lithographic prints were compared using photomicrographs to evaluate their image structures. These were a black-and-white collotype from 1896, a four-color Cristalraster stochastic print from 1990, an Advanced Continuous-Tone duotone print from 1999, and the Faust 1,110-lpi four-color print from 1999. The 200X photomicrographs, shown in Figure 8, are deceptive in that the stochastic print and the 1,110-lpi lithograph are black-and-white renditions of four-color pictures, resulting in lower contrast. In fact, both of these prints had high contrast and deep shadow tones.

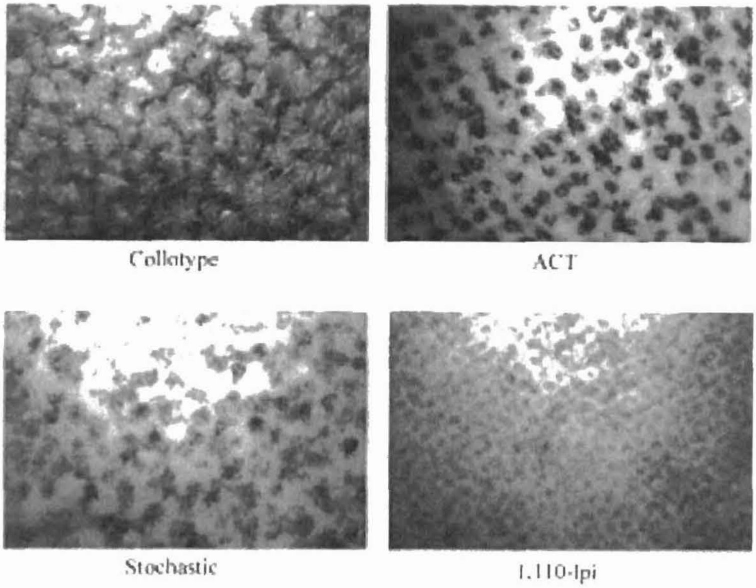

Figure 8. Photomicrographs of high-resolution lithographic prints.

The Faust 1,110-lpi print is composed of smaller image elements than the ACT print or the stochastic print. The image element size of the collotype print is difficult to evaluate because it was a continuous-tone process without a regular image structure. Microscopic evaluation of highlight areas of the collotype print showed ink particles that were smaller than those of any of the three modern printing methods.

It is difficult to appreciate the level of detail reproduced by the prints in Figure 8. A review of Figure 6 provides a comparison between the Faust 1,110-lpi print and the more typical 133 and 175-lpi lithographs.

Higher Screen Ruling and Perceived Quality

The imaging and printing of very high screen rulings are both demanding in the extreme. The question should be asked whether there is significant improvement in the perceived quality of a printed image when a higher screen ruling is used. If so, what is the limit beyond which improvements are no longer perceived? There is, after all, a resolution limit imposed by the mechanics of the human visual system. From a comfortable reading distance, the human observer cannot distinguish screen patterns higher than about 150 lpi. One might expect that screen rulings higher than 150 lpi would offer no perceived quality improvement, but empirical evidence suggests otherwise. Today, many sheetfed printing companies are routinely running 175- and 200-lpi screens to satisfy customers who are willing to pay a premium for what they perceive as a quality improvement.

The Faust poster presented a good opportunity to compare images printed at different screen rulings. Many of the variables, which can plague real world printing studies, were eliminated. For instance, all the images were printed simultaneously on the same press with the same materials, personnel, and climate conditions. All the images were processed through the same RIP and written with the same imaging device. There were, however, some drawbacks to the experiment, for instance, register and inking levels could not be optimized for each individual picture or screen ruling.

To prepare the images for visual comparison, the poster was mounted on foam core, and the individual images were cut apart, being trimmed so that no border showed around the images. Each individual picture was marked on the back with a code letter. This yielded four pictures at four different screen rulings, 133, 175, 300, and 600 lpi. The 33 participants in the study were asked to rank the four samples of each picture (see Figure 9) in order of quality. They were not told how the four pictures differed, and they were not given any other criteria on which to judge the pictures. The participants were not all professionals in color evaluation.

Figure 9. Set of mounted samples for one of the four images.

The hypothesis for the experiment was that the 300- and 600-lpi reproductions would be selected as having higher quality than the 133- and 175-lpi reproductions, but there would be no discernible quality difference between the 300- and 600-lpi reproductions. Therefore, the 300- and 600-lpi reproductions were expected to be randomly chosen as first and second in quality, and the third and fourth places would be assigned to the 175- and 133-lpi reproductions respectively.

The results of the experiment are depicted graphically in Figure 10. Each 3-D graph represents the judges' rankings for one of the four picture sets. The raw subjective scores showed that some of the judges were very erratic in their preference, while others were remarkably consistent.

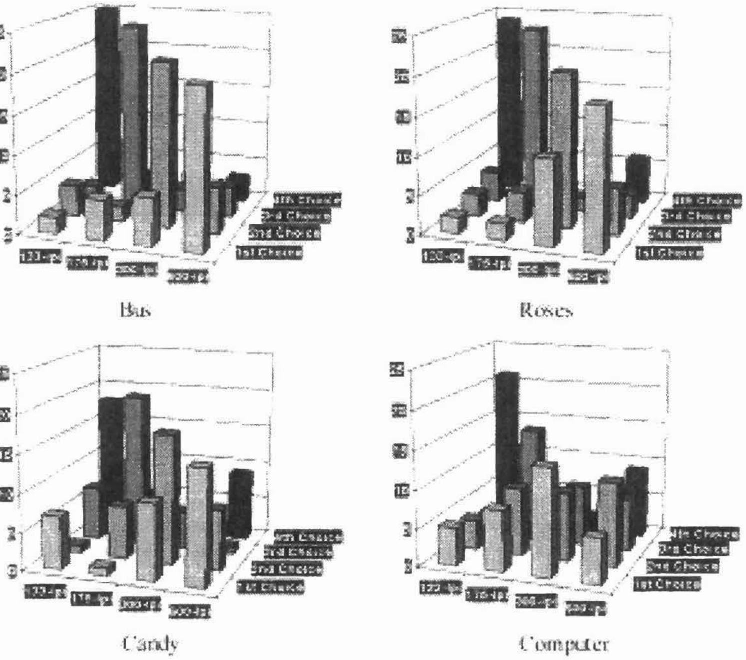

Figure 10. Judges' quality rankings for each picture.

From the graphs in Figure 10, it is clear that the rankings varied by picture as well as by screen ruling. The rankings of the computer picture were particularly inconsistent. This was not surprising because this picture has very little detail to benefit from higher screens. The subjective rankings for the bus and the roses pictures were, by contrast, strongly ordered from highest to lowest. For these images, at least, it is clear that the observers were perceiving improved quality with 600-lpi images compared to 300-lpi ones. This contradicts the hypothesis that the observer should not discern a quality improvement at these high screen frequencies.

An arbitrary point scale was developed to assign numeric values for the subjective rankings. One point was awarded for a fourth place ranking; two points for third; three points for second; and four points for first. The average subjective ranks for each screen ruling/picture combination are shown in Table 1 along with descriptive statistics for each screen ruling across all pictures.

Screen	Bus	Roses	Candy	Comp	Min.	Max.	Mean	S. Dev.
133-lpi	1.48	1.48	1.91	1.79	1.48	1.91	1.67	.2157
175-lpi	2.30	2.15	2.12	2.73	2.12	2.73	2.33	.2792
300-lpi	2.91	3.27	3.09	3.06	2.91	3.27	3.08	.1492
600-lpi	3.30	3.09	2.88	2.42	2.42	3.30	2.92	.3756

Table 1. Average quality rankings for each picture.

The results in Table 1 show that when the average subjective ranks are examined, the hypothesis is supported in that the 133-lpi image is ranked as worst, the 175-lpi image is second worst, and there is no clear difference between the 300 and 600 lpi reproductions. In fact, the 300-lpi prints had a higher composite average than did the 600-lpi prints. This finding can be explained in the higher standard deviation in the subjective ranking of the 600-lpi print compared to the 300-lpi one. Out of 132 judgments (33 judges x 4 pictures) of first and last place, the 300-lpi print was judged best 35 times and it was only judged to be worst 5 times. By contrast, the 600-lpi print was judged best 60 times, but it was judged to be worst 33 times. It seems that the 600-lpi images were more controversial with the judges. This could have be due to slight differences in the tonal rendition of the different screen rulings, or to other uncontrolled factors. It is interesting that the 300-lpi image also had a lower standard deviation than the 133- and 175-lpi screen rulings.

The findings overall indicate that the quality ranking will improve with higher screen rulings, but that there can be a point of diminishing returns, and possibly a point where increasing the screen ruling further will be counterproductive. It is interesting that with some images the observers selected the 600-lpi print consistently above the 300-lpi print, and, in total, the 600-lpi print was chosen as the best more than twice as often as the 300-lpi images. It seems that, even though observers no longer can distinguish the dot pattern, they can still appreciate quality improvements between 300 and 600 lpi. The observers may be seeing the rosette pattern formed by the four overlapping halftone dots in a color print. The rosette pattern, which is actually a moiré, may have a lower frequency than the halftone pattern itself so that the observer who can no longer distinguish the dots can still distinguish the rosette. The question still remains whether a further quality improvement would be perceived with 1,110-lpi reproductions compared to 600-lpi ones.

Summary

The Faust 1,110-lpi poster is an achievement that was out of reach in the photomechanical age. The resolution requirements are beyond the capabilities of film and chemical processes. Thermal plates have previously been found to produce higher resolution than any of the competing CTP technologies (Stanton, 1996). It has been seen that the image structure in the Faust print is finer than other high-resolution printing methods of today. The applications for very high-resolution halftone printing are as yet undetermined. There may be commercial applications in the fine arts market and in security printing. Like so many milestones in graphic communications, the Faust printers were driven by the challenge to push the limits of the process. Although immediate financial success is elusive, they have demonstrated themselves to be superior lithographers and have been justly recognized by the PIA for their achievement. Their hard-won knowledge about compatible printing materials, precision press operations, and digital prepress processes is immediately transferable to their everyday operations.

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