THE COLOR PRINTING PROCESS AS A WELL-OPTIMIZED SYSTEM

Alan J. Herbert*

Abstract: An informal target used in the development of printing plate systems has been '150 line, 3-97 percent dots.' This criterion appears to have evolved with the advance of the Printing Industry, but is, in fact, well grounded in the mechanics and economics of printing, and in the ability of the eye/brain combination to perceive tonal differences and fine detail.

The changes in screen ruling with time, are presented for a number of publications, together with information on the way color is used. The present industry average is between 145 and 150 lines per inch, 3 and 97 percent dots are being held. This, combined with press register tolerances, results in a process acceptable to the vast majority of viewers.

Introduction

For some years, members of the G.R.L. have been engaged in the Research and Development of litho printing plates and have tended to use as target minima the two criteria '150 line screen 3-97 percent dots' and 800 lines/inch resolution. While these targets are eminently practical, the author was not aware of the rationale for their use. Of particular interest was the question as to how these targets might change with time. If the basic principles underlying target selection could be established then future needs could be more readily anticipated. This paper presents a consistent model which ties together major variables and allows future needs to be projected.

Screen ruling--change with time

Twenty years ago, at this conference, Neugebauer and Bickmore[1] presented results on the limiting values for screen ruling. Their conclusion was that screen ruling

*Graphic Research Laboratory, 3M

of 150 lines/inch was likely to be adequate for the majority of applications. Bearing in mind that conventional Industry lore says that screen ruling is increasing, the question immediately arises as to how screen ruling has changed historically, and where are we now? Figure 1 shows average screen ruling as it has changed since 1940. As a word on methodology, five Journals using color printing were sampled, (Better Homes and Gardens, Vogue, National Geographic, American Dyestuff Reporter and Scientific American) at five year intervals; ten color pictures were selected at random (if present) and screen ruling measured with a SPARK gauge[2] on the cyan and magenta printers. No attempt was made to select images generated by litho printing, the results are a random sampling of all that was used at the time.

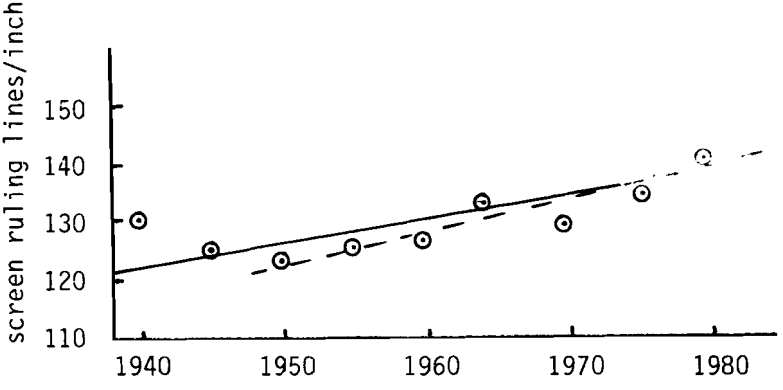

Figure 1. Average Screen Ruling vs. Time

Two linear regression fits are offered, the first for the time period 1940 to 1980, where screen ruling increase is about 0.4 line/year, and 1950 to 1980 where the increase is 0.5 line/year. I'm inclined to accept the latter value but from any viewpoint, this isn't a very significant rate of change such as might be expected if at some point in time ruling had been downright unsatisfactory.

This is broad-brush statistics however, and a more detailed look at the data shows up some interesting trends. One trend is that once color is introduced, its use increases rapidly, and through pressure from the advertisers--color printing increases. (Perhaps they should be capitalized as Advertisers--they are obviously

the force behind color printing growth, and their contribution is gratefully acknowledged.) Figure 2 shows the increase in color usage with time for American Dyestuff Reporter (whose specialist readers and advertisers are known to be critical over color rendition). In 1950 there were, on average, about two color prints/issue rising linearly to ten/issue in 1982.

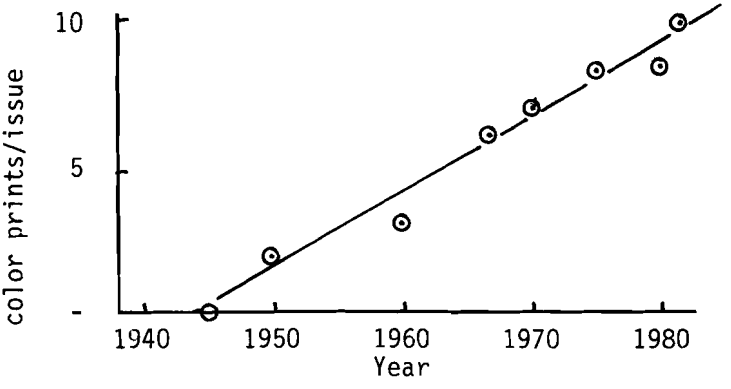

Figure 2. Color prints/issue, change with time, American Dyestuff Reporter

Figure 3 shows what happened to the screen ruling with time. In 1950 it was just below 120 lines/inch, rose rapidly to ∿143 in 1960 and stayed constant until the present. In contrast, Scientific American stayed at 120 lines/inch until 1975 (September), and between issues, jumped to about 133, staying constant. No explanations are offered for these effects except to note that the character of Scientific American changed in 1975 to become a much more advertisement-conscious publication, rather than a general-interest scientific journal. This behavior is exhibited by all the Journals sampled--black and white printing is slowly displaced until color may be used unrestrainedly and exclusively.

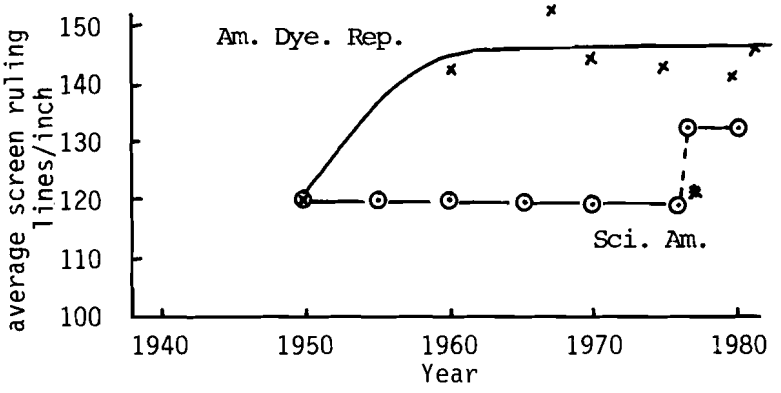

Figure 3. Change in screen ruling with time, Scientific American

*In September of 1975 this Journal changed radically--apparently deciding to become a 'glossy.' Screen ruling changed abruptly and the use of color and advertising space increased without limit.

Present Average Screen Ruling

In late 1981 a range of publications were sampled with the results given in Table 1, and calculations showed an average ruling of 145 lines/inch for color, and 127 for black and white illustrations. This is probably not a random sample; one publication (Studio Light) has a small specialist circulation, as a prestige house journal for Eastman Kodak. However one should not reject data on this type of ground, so one must accept the average of about 145 lines/inch.

This is not far short of the values suggested by Neugebauer and Bickmore--for smaller prints than we habitually now use. Agreement with their data is therefore good.

3 to 97 percent dots--why?

For a 150 line screen, a 3 percent dot (or the hole in a 97 percent tone) is about 1.3 mils in diameter. At a reasonable viewing distance--say 1-2 picture diagonals, or more, the human eye cannot resolve a 3 percent dot (between 5 and 10 mils is the limit. Individual observers may vary[3,4]). However, the density differential between an area printed with 3 percent dots and a blank area is

just distinguishable under optimum circumstances. Figure 4 plots reflection density against dot size. A 3 percent dot area has a theoretical reflection density[5] above background of 0.013 which is on, or just below, the density differential that the average observer can detect (claimed at 0.02 to 0.008 depending on who you ask).

Table 1

Screen Rulings for Various Publicaitons--1981

Publication	Screen Ruling, lines/inch
Family Circle	146
Scouting	145
High Technology--color	144 (black printer excluded)
High Technology--B&W	(121)
Contract--color	139
Contract--B&W	(133)
Modern Photography--color	138
Modern Photography--B&W	(118)
Studio Light	165
Scientific American	136
Am. Dyestuff Reporter--color	144
Am. Dyestuff Reporter--B&W	(137)
Non-weighted industry average	
color	145
B&W	127

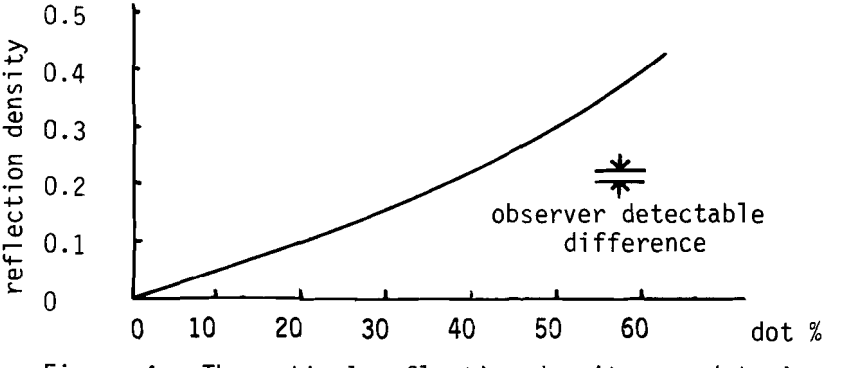

Figure 4. Theoretical reflection density vs. dot size

It seems therefore that the *purpose of the 3 percent (and 97 percent) level is to prevent the appearance of sudden 'jumps' in density* (or contouring), rather than for any resolution requirements.

Is there any other data to support this view?

Accuracy of Register

Printing Industry practice is for register to be optimized by the pressman viewing the finished color prints rather than the included register marks. This is reasonable, as the printer is being paid for the appearance of the illustrations not for the alignment of register marks. Table 2 shows the accuracy of register, sampled for a number of publications in 1981, plus giving some data on the minimum dot size observed during this survey. An average of within 6 mils is achieved, all prints being judged satisfactory in this regard (which is why I don't call this figure mis-register).

Table 2

Accuracy of Registration of Various Publications--1981

Publication	Accuracy of Register (average)	Smallest dot held
Modern Photography	within 5.5 mils	1-2 mil
National Geographic	6.2	1-2
Contract	6.2	1-2
Studio Light	3.4	1
Average	5.3	

This supports the conclusion of the previous section; as on this basis, the existence of dots 4X smaller than the registration tolerance and 4X smaller than the eye can see, makes no sense in terms of resolution. As a side note, a mis-register (genuine) of 12-15 mils is visible to the unaided eye, and Studio Light, which on account of its origin, has obviously set out to produce very high quality color printing, has a 10 mil black border around its prints. This is enough to accomodate edge register variation, and is just above the visual threshold.

Once again, the need of a 3 percent dot level is dictated by tone reproduction requirements rather than for resolution reasons.

Earlier was mentioned a target of 800 lines/inch as a resolution target. 3M labs employ the 3 bar USAF test target during development, 800 lines/inch being translated to 31.5 line pairs/mm or a 5.1 target. 1/800 inch = 1.25 mils, or about the size of a 3 percent dot. Thus the 800 lines/inch target is also an adequate and acceptable measure of the present requirements for plate materials.

Implications for the future

Average screen ruling is undoubtedly increasing, but slowly. However the use of electronic scanning is introducing in many cases, black printers ruled at 200 lines/inch (At Graph Expo 81, a four color print was observed that was screened at more than 300 lines/inch). At these higher rulings, smaller dots will be required for adequate tone reproduction. At 300 lines/inch, a 3 percent dot would be about 0.6 mils across, and while this can be achieved by the best process under optimum conditions, it doesn't seem to be normal--or perhaps even needed.

Conclusions

Color printing is moving slowly towards an average value of 150 lines per inch, and the ability to print 3 percent and 97 percent dots at this ruling in adequate register, in volume production, for fastidious customers is a sign of a well-optimized system and the Industry is to be congratulated on this feat.

Acknowledgements

I should like to thank P.K. Lee and Valdis Mikelsons of this Laboratory for their comments and arguement, and Lou Butler for his encouragement of this work.

References

1. Neugebauer, H.E.J. and Bickmore, J.T. TAGA Proceedings 14th Annual Meeting June 11-13, 1962.

2. Screen Pattern Analyzer and Rescreening Key (SPARK) G.A.R.L., Rochester, N.Y.

3. Hunt, R.W.G., "The Reproduction of Color" Wiley, New York, 3rd edition, pp. 332-337.

4. Weymouth, F.W., Am. J. Opthal. 2, 46, 102-113, (1958).

5. Yule, J.A.C., and Neilson, W.J. TAGA Proceedings 3rd Annual Meeting 1951, pp. 65-76.