A FEW THINGS ABOUT MICROLINES THAT MOST PEOPLE DO NOT KNOW

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Abstract: The making and evaluating of an exposure series is reviewed to show how halftone dots, microlines and continuous tone steps change as a function of exposure. A history of microline test targets is presented. It is shown why optimum resolution and dot-for-dot contacting occur at an exposure where the .30 continuous tone density step in the original reproduces again as .30 density. The relationship between standard photographic resolution targets (where the line to space ratio is 1:1) and microline targets (that use line to space ratios other than 1:1) is discussed. Recommendations for practical exposure determination for film and plate making are considered.

Introduction

The term microline is relatively recent and is specific to the graphic arts. However, similar test patterns were pioneered a long time ago as resolution targets in photography. In fact, it was the astronomers who first had a need to evaluate resolution and, therefore developed tests for its measurement. *Microline targets are simply resolution targets with a different name.*

Why are we interested in finding out the resolution capability of a given system? In the graphic arts, where we use halftone rather than continuous tone images, resolution relates only indirectly to image sharpness and reproduction of fine *image* detail. Since the smallest detail of a halftone image are the dots, unsharpness, caused by a lack of resolution, affects tone reproduction rather than image sharpness. It is not only important that resolving power is adequate to

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reproduce small halftone dots but, furthermore, that these dots are reproduced without distortion. For instance, to reproduce a square dot requires more resolving power than to reproduce a round dot of the same area. *Therefore, in the case of halftone images, resolution is related to tone reproduction (dot gain) rather than sharpness of the image, and the higher the resolving power of the system, the easier it is to maintain dot-for-dot reproduction.*

Resolution or resolving power is a measure of the smallest detail that can be reproduced by a light sensitive system. Even though this definition is correct, it needs further specification in order to be practical, because we always deal with a system and not with just one part such as a film or plate. Resolution depends on the following factors:

1. Light sensitive material (grain size, coating thickness, diffusion of light within the coating, antihalation properties)
2. Exposure (point light or diffuse light, spectral distribution, vacuum between negative and film)
3. Processing after exposure (chemistry used, method of agitation)
4. Shape, contrast and sharpness of the target (lines, dots, circles, spaces)
5. Evaluation method (optics for magnification, observer, criteria for accepting or rejecting a patch)

Therefore, in order to obtain comparable results, there is a need for standardized targets and evaluation methods.

First, we need to define some terms. Microlines are normally specified in terms of microns. In the metric system, micro means 1/1000. 1 micron = 1μ = 1/1000 mm. = .00004 in. = 2 wave lengths of green light. Lines that are less than about 5 microns wide need special, high resolution optics to generate the original image. Regular light is almost too "thick" to reproduce such lines without distortion (shorter wave length energy such as ultra violet or X rays may be necessary). Also, consider that the emulsion of a high resolution film has a thickness of about 5 microns.

Positive lines are black with clear spaces. Negative lines are sometimes called gaps or slits and are clear with black spaces. Lines and spaces do not necessarily have the same dimension. Traditionally, photographic resolution targets favored designs where the lines and spaces have the same width. Such targets can be called *50% targets* since the lines cover half the area. Graphic arts targets often use a positive and negative version of the same design, where the line to space ratio is 1 to 9 or, in other words, the area covered is 10% for the positive part and 90% for the negative part. *Lines* and *dots* both can be used for constructing resolution targets. However, for a given width, they may not react the same way. Lines have the advantage of being much easier to see and find than dots. But they have the disadvantage of being directionally sensitive. A vertical line pattern may indicate a different resolution than a horizontal line pattern. For this reason, circular line patterns are often used and have the advantage of indicating directionality in a certain situation.

Theory

When a halftone image is reproduced by contacting or through an optical system, we often notice that the highlights get lighter while, at the same time, the shadows get darker. In other words, the contrast of the image increases. One could expose differently in order to improve the fidelity of highlight reproduction, but only at the price of sacrificing midtones and shadows. In other words, dot-for-dot contacting is accurate for only one dot area and can be adjusted by optimizing exposure. Why is this so?

Figure 1 helps us visualize the relationships. The original is ideal in the sense that it has very sharp edges and a high contrast. However, even in this ideal case, the light distribution behind the original is not perfectly sharp, which leads to a loss of contrast for the small dots and a loss of "hardness" of all dots. If the transmitted light is used to expose a film, then even more diffusion takes place within the light sensitive coating. In a practical situation, the degree of diffusion or unsharpness may not be significant, but it is always there and will degrade reproduction to some degree. It can be very significant in an optical system when we change the size of a halftone image on a camera (copydot). Notice that even though the film or plate is exposed with an unsharp image, the reproduction still is sharp because graphic arts materials have a very high contrast (a small exposure difference causes a large density difference). The amount of exposure that is required to just get to the threshold where the light sensitive material turns either black or clear is called *critical exposure*. By choosing exposure so that the critical exposure falls just on a given location of the unsharp fringe of the exposing light, we can determine the dot area that will be reproduced accurately.

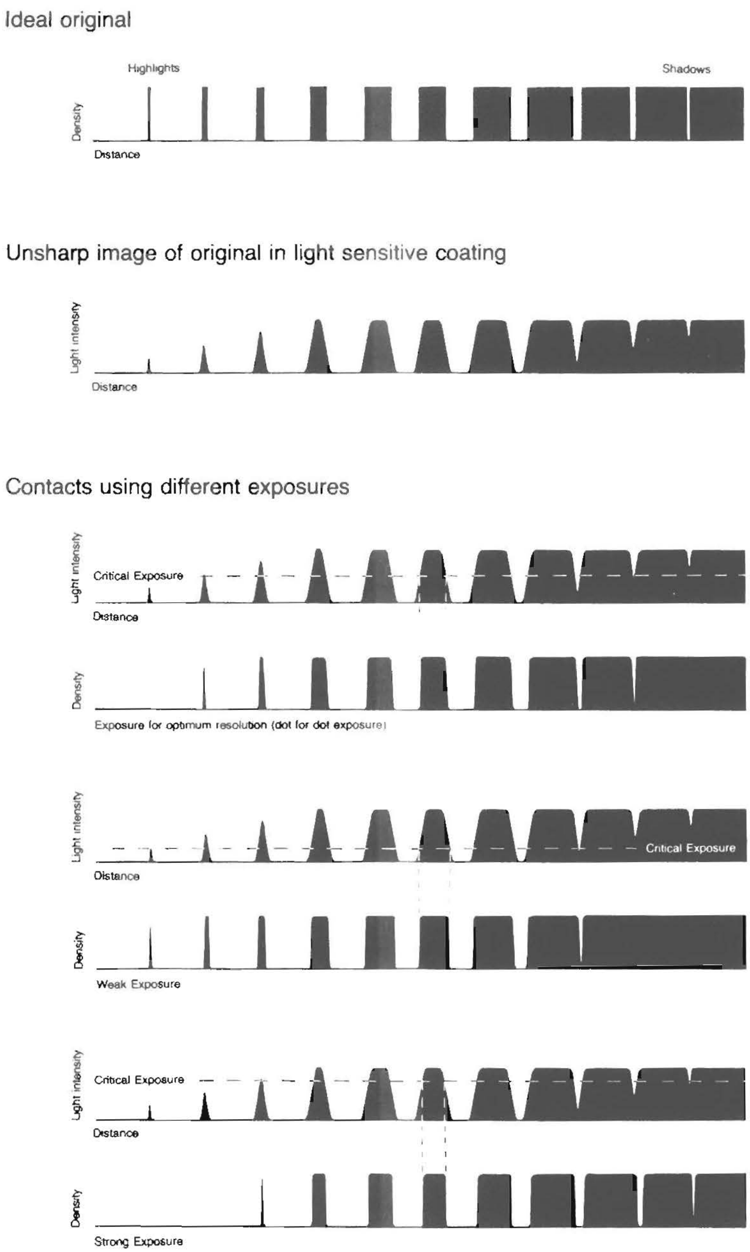


Figure 1. Schematic representation of effect of light diffusion on dot reproduction

To summarize, because resolving power is not infinite, and because of the high contrast of the light sensitive material, there is a change in dot size (tone reproduction) for every change in exposure, rather than a change in dot sharpness.

History of Graphic Arts Test Targets

In order to understand why the new targets are designed the way they are, it is helpful to review the history of resolution targets.[1] The leading research in resolution was, of course, done in the field of photography, but the same concepts also apply to any other imaging process such as those used in the graphic arts. Many different patterns for resolution targets have been investigated over the years, such as single or multiple lines, dots, crosses, circles, wedge-type "fan" targets, spokes, Siemens star or Star Target (as popularized by LTF and GATF), rings (doughnuts) and broken rings, alpha numeric block letters and others.

One of the earliest test targets used in both photography and printing is the continuous tone gray scale. At first sight it does not seem to have anything to do with resolution but, as we shall see later, there is a definite relationship between optimum resolution and the response on the gray scale.

Figure 2 shows the discussed targets. Since all the films used for this figure were designed for positive working plates, they reproduced wrong side reading in this reproduction which was produced with negative working plates.

In 1955, Warren Rhodes[2] described one of the earliest resolution targets to be used in the graphic arts. The *Calibrated Vignette* consists of small dots that gradually get smaller and smaller, in both positive and negative form. Changes in tone reproduction and resolution are indicated by a scale that marks the position of the smallest dot that just can be reproduced. Positive dots are sensitive to overexposure while the negative dots are sensitive to underexposure. Dot-for-dot exposure is obtained where both the negative and positive dots vanish at the same position. Figure 2 shows an implementation of the Vignette that was produced by the author in the late 1950s with low resolution technology.

In the late 1950s Stouffer[3] sold a *Resolution Guide* which consisted of negative and positive wedge-type lines with a scale. Optimum resolution is obtained when both the positive and negative lines vanish at the same width.

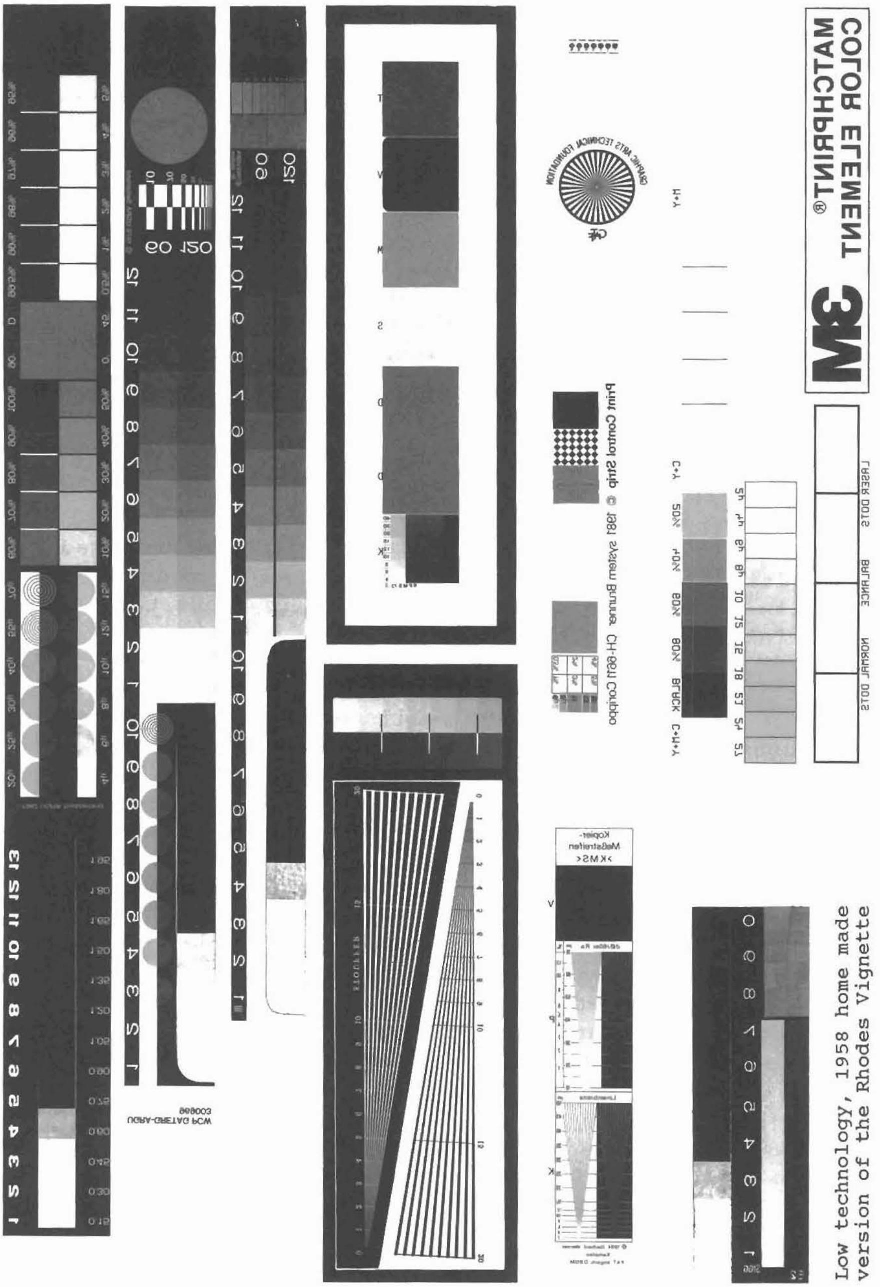


Figure 2. Various graphic arts test targets having resolution test sections

In 1961, the Lithographical Technical Foundation[4] published its *Star Target*, which is a 36-spoke Siemens star. LTF Research Progress report No. 52 describes how the Star Target can be used to measure resolution, slur and doubling. This target was originally developed to test lenses. In theory, it lends itself very nicely to test all that we need to know. In practice, however, everything takes place at the center of the target in a small area. In order to obtain quantitative data, analysis through a measuring microscope is necessary. The sensitivity of the target could be improved by increasing the number of spokes and also by making them finer, and the need for a measuring microscope could be avoided by adding a fine scale similar to the Stouffer guide or the Werner KMS.

In 1962, UGRA, a Swiss research organization for the graphic arts,[5] published its first version of the *UGRA-Wedge*. It contains a continuous tone gray scale, a 60 and a 120 lines per cm. (150 and 300 lines per in.) halftone step wedge, a parallel lines tint to measure slur and/or doubling and a parallel lines resolution target. This is a 50% target where the finest lines were 15 microns.

In 1973, Mr. Brunner[6] patented his *Supermicro-measuring-element* which contains very small negative and positive dots and crossed lines which are placed beside and within conventional round halftone dots. The finest crosses are about 3 microns wide. These small dimensions have become necessary because of the improved resolution of the then new, presensitized plates. The advantage of the design is that the patch can still be used to make integral densitometric measurements to evaluate dot gain. The price for this advantage is the fact that the resolution elements are so small that a microscope is necessary for evaluation, and several crosses or small dots need to be evaluated and averaged because a single element is subject to local variation of resolution. The Brunner control bar also contains a parallel lines microline patch where the lines cover an area of 30%.

In 1973, FOGRA, a German graphic arts research organization,[7] patented its *Precision Measuring Strip (PMS 73)*. It contains some tint patches and a so-called "K" patch which is a parallel line resolution target with both positive and negative lines. The line widths increase in nine steps from 4 to 40 microns. The spaces between the lines are nine times wider than the lines for the finest steps. For some unknown reason, the ratio is different for the higher steps.

In 1976, UGRA published an improved version of its plate control wedge. Besides the halftone tints and gray scale, it contains a resolution target using concentric circles. Half of the circular pattern is positive (20% area) and the other half is negative (80% area). The finest lines are 3 microns wide. Since the circles are relatively large (4 mm diameter), evaluation is extremely simple: One can determine the presence or absence of very fine lines with the unaided eye.

In 1982, UGRA published the presently available version of the *UGRA-Wedge* which is similar to the 1976 version except that it was redesigned to be compatible with the K patch of the FOGRA PMS in terms of spacing of the steps and area covered (10% and 90% area).

In 1983 GATF published its *Midtone Dot Gain Scale* which can be used to evaluate mechanical dot gain on a press. The test image consists of a group of nine dots spaced very closely together. The narrow gap between these dots (or negative lines) fills in with ink if there is dot gain. By varying these gaps, different amounts of mechanical dot gain on a press can be determined. There are no positive lines, since only dot gain and not dot loss is evaluated.

In 1984, 3M published its *Matchprint Color Element.* It contains microlines from 2 to 27 microns on large (1/8 x 1/4 in.) easy-to-see patches. The pattern of the microlines is octagonal rather than circular. It comes in a positive and negative version. But each version contains only positive lines, which permits exposure control on a daily basis. The target is not used to determine optimum exposure, where both positive and negative lines would be required. The line to space ratio conforms to the FOGRA PMS 73. This target and the KMS by Werner have presently the finest microlines (2 microns) of any target on the market.

In 1984, Gerhard Werner[8] published a contacting control strip *KMS* which uses essentially the same basic design as both the Rhodes vignette and the Stouffer Resolution Guide, but it is done with very fine lines and dots, using modern technology. In the vignette part, the dots vary continuously from 10 to 70 microns (corresponds to 0.4% to 13.8% and 86.2% to 99.6% dot area on a 150 l/in. (60 l/cm.) halftone). In the microline part, the wedge shaped lines vary continuously from 2 to 50 microns. The area covered by the lines is 14.3% and 85.7%. The area of interest is relatively small and normally requires a loupe for evaluation.

Use of Microline Targets

In the following, reference will be made to positive and negative lines. To avoid confusion, positive or negative will always refer to the polarity of the original and not to the polarity of the copy, which may be the same or the opposite of the original, depending on whether a positive or negative working system is used.

As with all resolution targets, it is necessary to go through an exposure series in order to evaluate a light

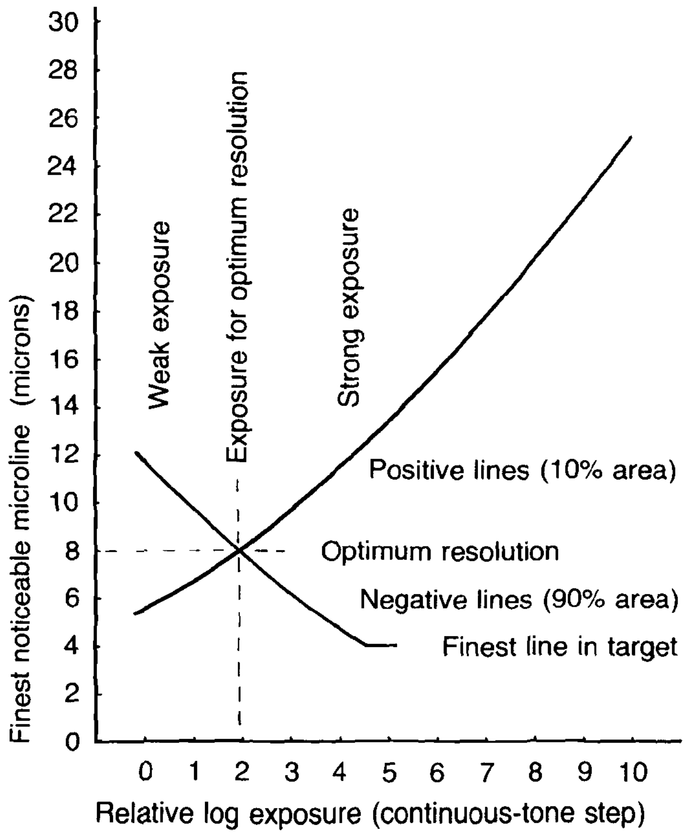


Figure 3. Microline response to exposure

sensitive system. Figure 3 shows how positive and negative microlines change as a function of exposure. At a low exposure, just enough to create an image, very fine positive lines will reproduce nicely because there is not enough light to undercut them. However, very fine negative lines will not pass enough light to create an image. Coarser negative lines, however, will reproduce. As exposure increases, the finest positive lines may get lost, while finer negative lines will now reproduce. There is a point where the thickness of the just reproducible positive and negative lines are the same. This is the point of *optimum resolution.* When exposure increases even more, more of the negative lines will reproduce (until the finest line in the target is reached), while more of the thicker positive lines are lost.

Notice that the horizontal axis in Figure 3 uses units of exposure in terms of steps of the continuous tone gray scale rather than time. This automatically makes the scale logarithmic since density is a log function. It also makes the scale *relative exposure* rather than *absolute exposure* since we plot that step which most nearly reproduced as a density of 0.30 in the copy. It may require much more light for one film than for another to obtain the same step number. Yet, using this method, we can compare the two in meaningful terms. In practice, things are made quite simple when the exposure increments chosen correspond to the steps of the gray scale. For example, in the case of the UGRA-Wedge (and most sensitivity guides), the density difference between two steps of the continuous tone gray scale is 0.15. This corresponds to an exposure factor of the square root of two, or 1.4. Therefore, if we choose an exposure series using exposure times of: .5, .7, 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32 etc., then each exposure will show one step more than the previous one on the copy. These numbers are easy to memorize since they correspond to the aperture numbers on a lens. (Notice that we do not obtain an exposure series by *adding* a constant difference to each exposure, but rather by *multiplying* each exposure by a constant factor.)

It is possible to overexpose a lot more than it is to underexpose. The exposure for optimum resolution is not necessarily the best (optimum) exposure for a given application because, by definition, at this point we are able to reproduce the finest detail, which includes all the dust and film edges. Therefore, we like to overexpose slightly for positive plates in order to get a clean image. For negative plates (where there are normally no film edges to worry about), we overexpose in order to properly harden the light sensitive coating for long plate life. Research done at Fogra[9] indicates that for positive plates, it is preferable to use only an absolute minimum of diffuse light in order to get rid of dust and film edges. It may also help to use a plate with less resolution. A paper published by R. S. Fisch and R. D. Cavin discusses the use of microlines for negative working plates.[10]

The slope of the positive line curve of Figure 3 is a measure of how fast we lose resolution as exposure increases. High resolution systems tend to have a lower slope (more exposure latitude) than low resolution systems.

Since, under normal conditions, we operate on the slight overexposure side of optimum resolution, we really need only positive lines in the original for day-to-day quality control purposes. We need both negative and positive lines only when we want to determine the optimum resolution point of a system.

The great thing about the graph in Figure 3 is that (in the case of the UGRA-Wedge) *it can be plotted without the use of a magnifier or a measuring instrument*. Furthermore, we can derive information about dot-for-dot contacting because we know from theory and practice that at optimum resolution we also obtain dot-for-dot exposure. (This may not quite be true for systems with an adjacency effect like lith or Ultratec.)

Criteria for Evaluation

When evaluating an exposure series, we are interested in those microline patches where the lines are just barely noticeable. By definition, this is a marginal image. We, therefore, need some rules about when to accept a patch and when to reject it. We could say that we will choose that patch where half the lines are still visible and half the lines are gone. So far so good, but such a patch may lie between two patches that happen to be on the test target. In other words, we need to interpolate. This is subjective: Different people may come to slightly different results. What does it mean when we say that a line is visible or gone? With a high contrast system (Ultratec or lith), there is little ambiguity. However, when we deal with a system that has a relatively low contrast (rapid access film), then the still visible lines may have quite low density or a lot of fog between them. In either case their ability to copy is a function of the exposure used. So, do we mean visible or able to copy? Able to copy on what, with what exposure? *Conclusion:* there may be reasons to choose different criteria for different applications. As long as these criteria are stated and the same for a test series, the method is quite valid. Also, there will be a small degree of uncertainty inherent in the method; may be 1, 2 or even 3 microns.

Relationship between Halftones and Microlines

To study tone reproduction (dot gain) in relation to microlines, we need to make dot area measurements so that dot gain can be calculated. In order to fully describe the effect of exposure on tone reproduction, we would need to draw a tone reproduction curve (original dot area versus dot area of the copy). However, since the largest change in dot area occurs in the midtones, it is customary to characterize dot gain by simply stating dot gain at a given midtone dot size and thereby characterizing it with a single number rather than a curve. But note that a dot gain figure for a 50% dot of a 150 line screen is not directly comparable to a dot gain figure for a different dot area or screen ruling.

Figure 4 shows how dot gain and microline response relate to one another. These are average results that were obtained from many experiments done on positive printing plates by FOGRA.[11] Since the resolving power of a plate determines the finest line can be reproduced, a different curve has to be plotted for plates with different optimum resolutions. Note that even a plate with poor resolution can reproduce a midtone dot without dot gain or loss. However, such a plate will reproduce highlights lighter and shadows darker. Dot-for-dot reproduction for all dot sizes can be obtained only when a system with very high resolving power is used.

Border zone theory is sometimes used to calculate dot gain. This theory basically says 1. that dot gain occurs at the edge (border zone) of a dot and 2. the assumption is made that the width of the border zone is the same for large or small dots or even microlines. The first part is obviously correct; the second part is not true. It takes more sophisticated mathematics to predict a change in dot size from a change in microline response.[12] Figure 4 demonstrates the inaccuracy of the border zone theory because it does not take resolving power into consideration.

FOGRA tested all those plates in order to establish a standard for plate making. It was arbitrarily decided that a standard positive plate would have a dot loss (due to slight overexposure) of 3 to 4 percent dot area at a 40% dot of a 150 lines per inch halftone. (40% happens to be the dot area of the "M" patch of the PMS 73.) The FOGRA copy tables[11] show which microline response corresponds to such standardized plates (for three classes of plates with different resolving power.)

Relationship between Continuous Tones and Microlines

Ordinarily, we tend to think that there is no fixed relationship between the response of a continuous tone gray scale and a microline scale or halftone scale. We all know that we can expose a printing plate or a film with point light or with

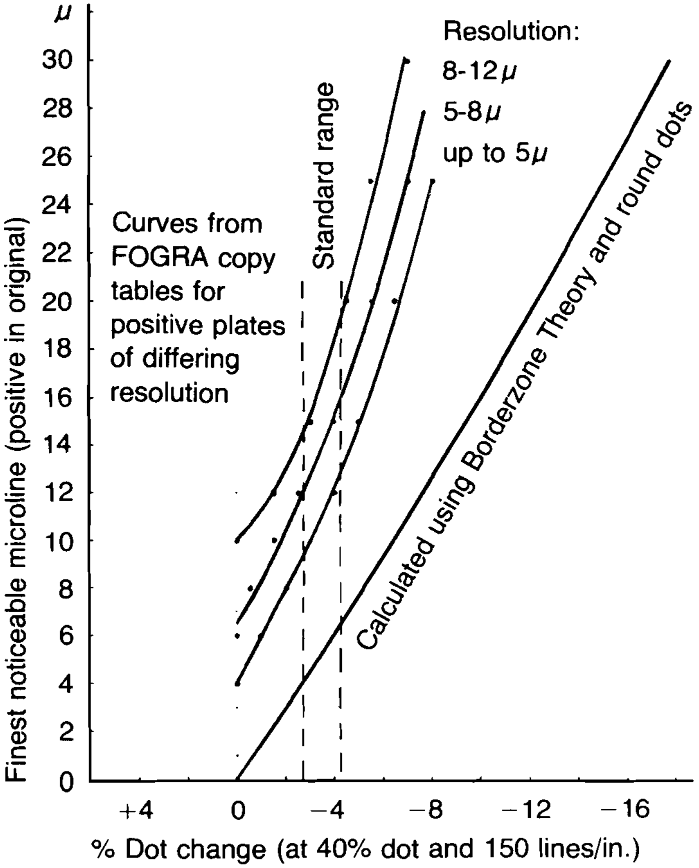


Figure 4. Relationship between microlines and dot gain

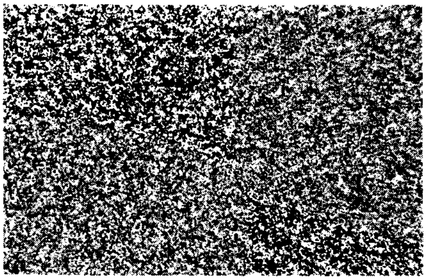
diffuse light and obtain the same continuous tone step response (possibly by adjusting exposure time) while the response to microlines and dot gain may be quite different. Therefore, we tend to believe that one cannot predict dot reproduction on the basis of a gray scale response.

While it is true that we cannot predict the resolution (and with it the tone reproduction of highlight and shadow dots) of a system from the continuous tone gray scale alone, there is a fixed relationship between the exposure for optimum resolution (which means dot-for-dot exposure for the midtones) and the response of the continuous tone step. Remember, the point of optimum resolution is defined as that condition where positive and negative microlines or small dots are just lost at the same width. This means that exposure is adjusted so that neither the shadows or highlights are favored and that the midtones are reproduced without dot gain or loss.

Now visualize the following experiment: Using the exposure for optimum resolution, we contact a special test target that includes halftone gray scales with different screen rulings and a continuous tone gray scale. For a normal screen ruling, the midtones will be reproduced dot-for-dot, while the extreme highlights and shadows may show an insignificant loss of dots (for example, 1% and 99%). As the screen ruling gets finer, the midtones will still reproduce without dot gain or loss, but since the absolute dot size is smaller in a finer screen, some higher dot percentages may be lost in the highlights and shadows (for example, 5% and 95%) and an image with higher contrast results. As the screen ruling gets even finer (this is a theoretical experiment) we eventually come to a point where the 50% dots are so small that they almost approach the limit of resolution of the imaging system. But this 50% dot will still reproduce as a 50% dot! However, the 40% and 60% dots are too small and will no longer reproduce as dots. Now comes the important end of this imaginary experiment: If we now further increase the screen ruling, we will obtain dots that are so small that they are beyond the resolving power of the system. (For normal graphic arts contacting films or plates, we are now talking of a 50% checkerboard dot pattern where each dot has a side length of about 1 micron or less.) Since these dots are so small, they look like a continuous tone patch to the light sensitive material. What density does this pseudo continuous tone original have? Exactly .30, according to the definition of density (density = $\log_{10} 1/T$, where T = transmission, which in our case is 50% or half). And what density does the reproduction have? Since we are operating at the optimum resolution point, this extremely fine

50% tint will be reproduced as a continuous tone patch that has a transmission of 50% or a density of .30. In other words, this very fine halftone behaves exactly as a continuous tone step with a density of .30. This is the reason why in Figure 3 we plot that continuous tone step which reproduces closest to a density of .30. *Therefore, even though we degrade the resolving power of a system by using diffuse rather than point light, we nevertheless can predict the dot-for-dot exposure for the midtones (optimum resolution point) from the continuous tone gray scale alone.* However, when the exposure deviates from this point, then we cannot make predictions about tone reproduction on the basis of the continuous tone gray scale alone.

In order to support this theoretical analysis, a photomicrograph was taken of the 0.30 density step of a UGRA-Wedge. What we see is a random grain structure where half of the area is covered by silver grains and the other half is transparent. In other words, rather than a regular checkerboard dot pattern, we see a random grain screen of the same "dot" area.



10μ ▮▮▮ ████ 100μ

.3 ND Orig. UGRA 50X

Figure 5. Grain structure of .30 density step on UGRA-Wedge. It covers about an area of 50%

Significance of Line to Space Ratio of a Microline Target

In the graphic arts we have become accustomed to line to space ratios of 1 to 9 (10% area) due to the predominant use of the UGRA-Wedge. *The question arises: Why this particular ratio, and how would other ratios change the results that we obtain from these targets? How would resolution determined by one of the targets used in photography (which are mostly 50% area targets) compare to the results obtained by 10% - 90% targets?* There is a small problem with the present 10%-90% targets: A 10% tint is not very dark, and sometimes it is hard to visually decide whether any lines are left on a given marginal patch or not. If we could use a 20% area (as was done for the UGRA-Wedge 76) or even 30% area, visual evaluation (without optical magnification) would be easier. But of course this is only practical if the information obtained with such a target is in agreement with the present de facto standard of 10%.

Producing a variety of such targets in order to study this question is very expensive. Therefore, an attempt was made to simulate the situation by generating a relatively coarse image with regular graphic arts equipment and then using a low resolution system for testing. It was found that truly low resolution systems are not that easy to come by. One option that was tried was electrostatic photocopying. Resolution is relatively low, but there is a characteristic effect when several generations of copies are made: 10% lines get darker and 90% lines get lighter until, after a few generations, all remaining lines are 50%! Hence, it was felt that this system does not properly represent a graphic arts film or plate. A second method of projecting an image slightly out of focus did not persuade either. It was concluded that the question could only be answered by actually producing a new target. At the same time it was possible to test a different manufacturing method. Fortunately, RIT received partial support from 3M to

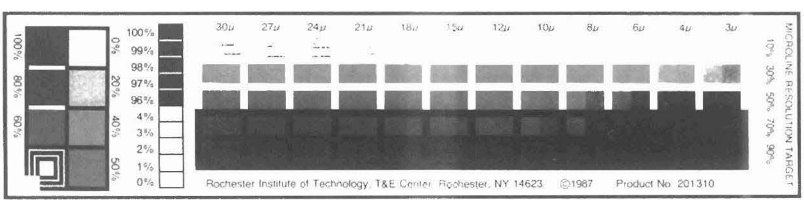


Figure 6. RIT - 3M Experimental Microline Resolution Target. (Not for sale)

pay for the production of what we called the research target. Because of the expenses involved, we decided to design it in such a way that it could be marketed if it turns out to be successful. Figure 6 shows the RIT version of the target.

Results. The first observation in using the new target was that the 50% patches tolerated much less light variation than the regular 10% - 90% patches. This suggests that it is more sensitive and, therefore, a better test target. Basically, performance of the 10% and 90% patches was comparable to the same patches of the UGRA-Wedge. But it is the microline response graphs that answer the above questions (see Figure 7). The basic distinction between the different percentages of the microlines is best shown by the Ultratec film. The 10% and 90% microlines behave in the well known manner. The 50% patch shows an interesting response: When underexposed, there is not enough light to penetrate the very small spaces (clear or negative lines) and, therefore, the whole patch acts as if it were black. *At optimum exposure, line to space ratio does not matter, all percentages will reproduce at the same line width.* With overexposure, it is because of the undercutting of the black, positive lines that patches with very fine lines are lost. Another way of describing the situation is that, with underexposure, the 50% patch shows the same response as patches with more than 50% area covered. And with overexposure, the 50% patch shows the same response as patches with less than 50% area covered.

The 30% and 70% patches both show an *inflection point* similar to the 50% patch, but at a different exposure. (And actually, so does the 90% patch.) On the overexposure side (70% and 90% patch), this simply means that the spaces (black, since it is a patch with more than 50% area) are now undercut by the light to the point where the patch is lost. For example, at the inflection point of the 90% line (exposure step 5.5), the clear lines are 3 microns wide and the black spaces are 27 microns wide. And at that same exposure the 10% or 30% lines of about 27 microns are also just lost. Similarly, at the turning point of the 70% line, the black spaces are about 18.6 microns wide which corresponds (within experimental error) to the response of the 10% or 30% lines at that same exposure.

The author has no explanation for the discrepancy between the 50% line and the 10% and 30% lines at the strong overexposure area of the graph for the Ultratec film. The graphs for the 3M Viking Plate G1 suggest that this plate has an unusually large exposure latitude. Since the 3M HSC4 film has

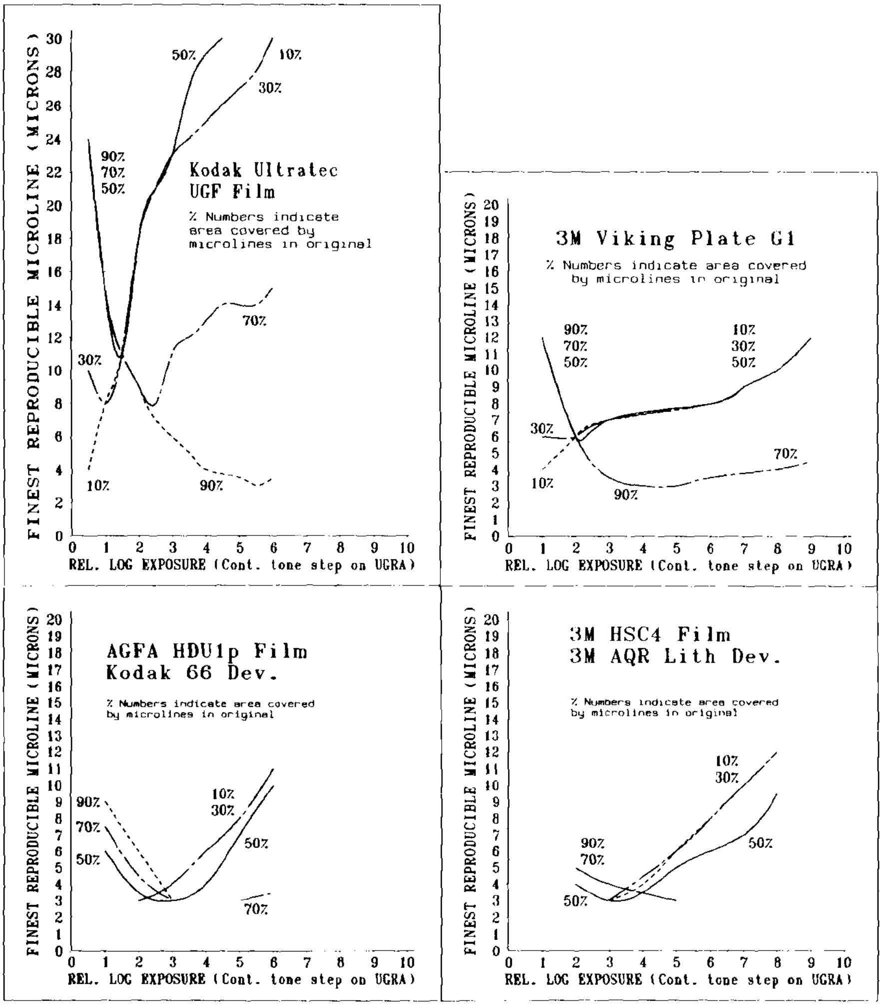


Figure 7. Microline response for different line to space ratios on different light sensitive systems

a lower contrast than a lith film, it was somewhat difficult to judge the microlines for the reasons mentioned above. The same is true for the Agfa film.

It is noteworthy that the exposure for optimum resolution is not always at the theoretically correct position of step 2 (0.30 density). Is it just coincidence that the highest contrast system (Ultratec) is farthest to the low exposure end, while the lower contrast films require higher exposure for optimum resolution? Or does the adjacency effect of Ultratec have an influence?

Conclusions from Analysis of Line to Space Ratios

The basic feature that has become standard for graphic arts resolution targets, namely the fact that there is a positive and a negative section of the same microlines, is very useful. Separating the effects of under- and over exposure to two different parts of the target is helpful and permits a clear indication whether an exact dot-for-dot exposure exists or not.

The 50% (conventional photographic) resolution target is interesting because it will never show finer lines than can be obtained at optimum resolution. It is also capable of indicating under- and overexposure: When underexposed, very fine lines of a 50% target will act as if the patch were black. When overexposed, they will act as if the patch were clear. And the finest lines shown for any exposure correspond to the coarser lines shown by either the 10% or 90% patches. And when exposed to the exact point of optimum resolution, then the patch will reproduce with a transmittance of 50% even if the screen ruling of the target is beyond the resolution of the system.

The inversion points of the 30%, 70% and 90% lines are of no consequence because 1. at optimum exposure all line to space ratios react the same and 2. at underexposure we are really only interested in the areas of more than 50% (where there are no inversion points) and 3. at overexposure we are only interested in the areas of less than 50% (where there are also no inversion points). For this reason, we could just as well use a 20% area instead of the customary 10% area, or an 80% area instead of the customary 90% area and thereby gain the advantage of better visibility of the microline patches.

Furthermore, the response of the 50% patch is interesting enough that it could (should) be used in addition to the 20% and 80% tints.

The 30% and 70% patches do not contribute to the usefulness of the present "research target." Their presence would confuse a normal user of the target.

Recommendations for Future Work

It is recommended that future designs of microline targets use a line to space ratio of 20% and 80%. A single 50% area may in practice give the same results if space is of concern. RIT is now in the process of making such a new microline target that uses circular patches of 20%, 50% and 80%.

Final Remarks

After all this is said, we need to remind ourselves that, the biggest problem in maintaining proper tone reproduction is not in film or plate making, but in printing itself. Figure 8 shows how microlines and halftones look on the original UGRA-Wedge and when printed on coated or uncoated stock. The distortions can become so large that it is difficult to determine where a halftone dot begins or ends. The edges are fuzzy and the solids are very non uniform. Our conceptual model of a halftone dot simply no longer applies (as it does for film or plate) and, therefore, simplistic theories will not do justice to the complex phenomenon of printing. For this reason it makes sense to evaluate printing as the eye does, using instrumentation that "looks" at the printed sheet in an integral way and not at the level of the halftone dots. On the other hand, this is of course no reason not to apply all the quality control tools that we know to plate and film making.

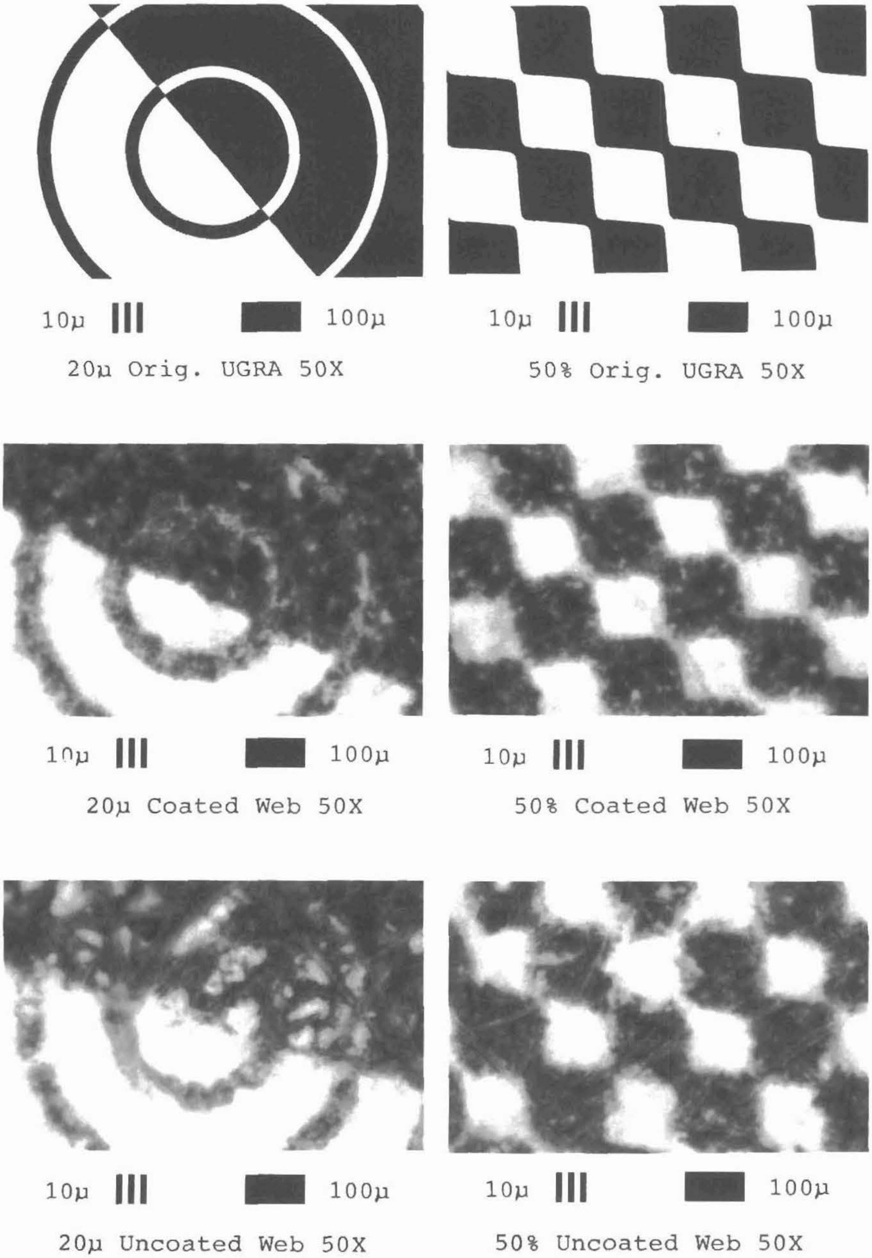


Figure 8. Enlarged halftone dots and microlines on original film and on prints

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