A Practical Approach to N-Value

William W. Pope*

Abstract–The variation of the Yule-Nielsen n-value is investigated by analyzing different inks printed on the same type of stock at a constant screen ruling. Sheets were collected at random from actual production press runs and dot area was calculated by measuring diameter with a highly accurate optical gauge. Densities of the tint screen and the accompanying solid patches were measured with a Status T densitometer through all four filters. The value of n was then derived through an iterative process. N is shown to vary substantially given these conditions.

Introduction

Most printing processes today operate on a binary system. That is, they either apply ink or they do not. This is the technique by which images are reproduced. The effect of continuous tone is possible by means of the halftone process. Ink is applied in the form of dots of varying size at a particular frequency (or screen ruling). When the frequency of the dots and/or the viewing distance is great enough, the eye can no longer resolve the halftone pattern; the dots are spatially fused together to give the perception of varying tones. Control over the size of the dots is critical in order to achieve an accurate reproduction. Therefore, it follows that dots must be measurable in order to control them. There exists a relationship between the density of a tint, density of the accompanying solid, and dot area which was first proposed by Murray in 1936.[1] This relationship has come to be known as the Murray-Davies equation.

* Rochester Institute of Technology

$$\text{Area} = \frac{1 - 10^{-Dt}}{1 - 10^{-Ds}}$$

where: Dt = Tint Density
Ds = Solid Density

Murray made the assumption, however, that the reflection of the blank paper could be disregarded by zeroing the densitometer on the paper, in effect taking the reflectance of the paper as perfect. In practice, though, this equation does not yield consistent results for measuring dot area on paper. The equation is, however, consistent and accurate for non-diffusing substrates, such as film negatives and positives. The Murray-Davies equation fails when used with paper as the substrate by not taking into account the light scattering characteristics of the paper. Yule and Nielsen pointed this out by finding that light may enter the paper through part of a dot and have many internal reflections before it emerges, through either bare paper or perhaps through part of a dot. [2] This gave way to a modification of the Murray-Davies equation to be known as the Yule-Nielsen equation.

$$\text{Area} = \frac{1 - 10^{-Dt}}{1 - 10^{-Ds}}$$

where: Dt = Tint Density
Ds = Solid Density
n = n value

The modification was the introduction of an n-value to compensate for the optical variables associated with an ink-paper interface. The area yielded by this equation is known as physical dot area whereas the area yielded by the Murray-Davies equation is called optical dot area. The big task is to determine the correct value of n for a given set of conditions. It should be noted that with n=1, the Yule-Nielsen equation reverts to the Murray-Davies equation.

Much work has been done in an attempt to determine what influences the value of n. A study by Ruckdeschel and

Hauser in 1978 showed that for low area coverages (<50%), n-value does not depend strongly on either screen frequency or area coverage. However, it does depend on these factors for shadow regions, but the Yule-Nielsen equation does not explicitly allow for this. [3] Pearson stated in a 1980 paper what the largest contributors to a correct value of n are. He found that n varied the most with changes in screen frequency. However, given a fixed screen frequency, the substrate is the largest factor affecting n. He also recommended the use of an n-value between 1.4 and 1.8 for general conditions, specifically 1.7 for practical reasons.[4]

Most of the work done, however, has had the substrate as the focal point. It is known, for instance, that a higher value for n is needed for more porous substrates (newsprint) than for less porous substrates (coated paper). Traditionally, the determination of n was done by using a non-diffusing material to carry the dots and then laminating the material to a given paper. Physical dot area was calculated prior to lamination using the Murray-Davies equation and then density of the tint and density of the solid of the laminated dots were measured and an n-value for that paper was calculated. This, however, is not typical of real printing conditions. The spreading of ink into paper is not accounted for by this method. This was also pointed out by Aronson in 1988[5]. Dot area measurement must be approached from a systems point of view with the ink and the paper comprising the system. Indeed, virtually all the evidence shows that the substrate is the chief variable affecting n, but that does not mean that the ink should be discounted as an influence on n-value. Therefore, this paper illustrates how different inks influence the value of n given the same substrate.

Experiment

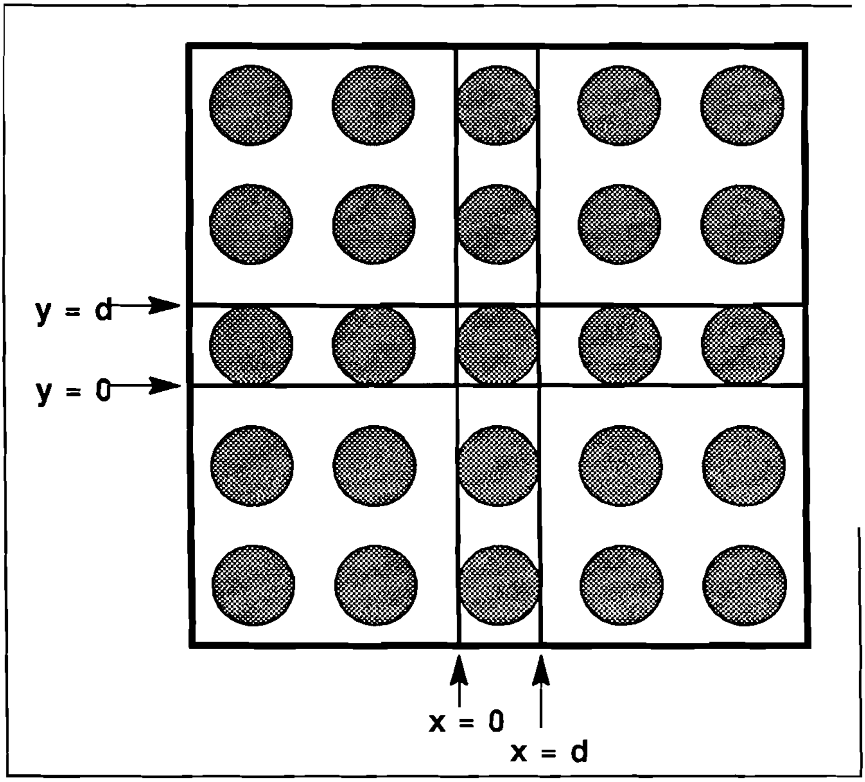

Figure 1: Drawing of measurement technique for x and y directions. Five dots were used for each best fit placement of reference line.

Sheets of the same type were chosen at random from actual production runs. Thirty-five round dot tint patches comprising eight inks were chosen for measurement. For each tint patch , the diameters of ten random dots were measured. The measurements were performed on an optical gauge which uses charge injected devices (CID's) for sensing elements and is accurate to within .00005". It operates on the basis of contrast and has a maximum magnification of 220X. As seen in figure 1, at such a magnification a matrix of 5x5 dots were within view for each measurement.

There are two reference lines controlled by joystick, one for the x-direction and one for the y-direction. For each tint patch, five measurements were made in the x-direction and five in the y-direction. For a single measurement, the reference line was be placed at one edge of a dot using the neighboring dots to place it in a best fit fashion. This was done because the dots were not of an exact uniform size. Though the variations were small, some of the perimeters of the dots within the field of view fell just outside the reference line and some fell inside. By using five dots to place the reference line, the edge of the dots could best be approximated. After the gauge was zeroed at one edge, the reference line was moved to the opposite side of the dot, again using five dots to place the line at a best fit position. This yielded the diameter and was done a total of ten times for each tint patch. The ten measurements were then averaged. Next, percent dot area was calculated by the ratio of the dot area (πr^2) to the unit area (1/screen frequency)^2. The densities of the tint and the solid were then measured and the n-value was calculated via a Pascal program written particularly for this calculation where the calculated dot area (given the density of the tint, density of the solid, and a particular starting value of n) was compared to the measured dot area and n was incremented until the calculated dot area matched the measured dot area.

Of the thirty-five tint patches, twelve were process colors and the other twenty-three were specialty colors (Pantone® colors, etc.). This raises the question of which filter to use for the density measurements. The densitometer, by default, uses the filter with the highest response for dot area calculations. This is fine for process colors since the filters are designed for them, but it may not be fine for specialty colors. Therefore, density readings were taken through each of the four filters (Red, Green, Blue, and Visual) using a Status T densitometer for all thirty-five tint patches and the n-value was calculated for each.

RESULTS

Table 1

Code	Area	D_T	D_S	n
C1	71.4	.38	.61	1.74
C2	59.9	.39	.97	1.37
C3	58.7	.39	.99	1.42
C4	67.3	.56	1.05	2.08
M1	67.4	.41	.72	1.88
M2	56.3	.35	.85	1.58
M3	65.9	.47	.86	2.12
M4	61.0	.39	.91	1.41
M5	69.0	.69	1.50	1.78
P1	61.4	.58	1.44	1.89
P2	60.8	.55	1.48	1.70
P3	71.0	.69	1.48	1.64
P4	72.0	.64	1.62	1.30
P5	69.5	.73	1.80	1.65
PB1	71.7	.65	1.42	1.47
PB2	56.6	.54	1.63	1.83
PB3	77.8	.91	1.63	1.88
PB4	72.7	.72	1.66	1.50
PB5	82.5	1.04	1.63	1.99
R1	23.2	.12	1.17	1.19
R2	32.7	.17	1.17	1.11
R3	41.4	.23	1.17	1.12
R4	48.8	.28	1.17	1.09
R5	61.6	.38	1.17	1.17
R6	74.5	.54	1.17	1.08
R7	76.4	.64	1.17	1.39
R8	83.9	.77	1.17	1.42
R9	91.6	.93	1.17	1.43
R10	61.4	.46	1.30	1.33
R11	55.5	.36	1.38	1.13
B1	78.9	.92	1.90	1.58
G1	70.8	.20	.35	0.65
K1	46.7	.35	1.15	1.82
K2	53.4	.36	1.15	1.36
K3	55.3	.40	1.29	1.37

C = Cyan **M** = Magenta **P** = 239 Purple **R** = Red
PB = Process Blue **G** = Gray **B** = 300 Blue **K** = Black

Table 1 shows, the physically measured dot area, density of the tint, density of the solid, and the calculated value of n for each of the thirty-five samples. The samples are grouped by color and listed within each group by increasing solid ink density. The values shown are those a densitometer would choose for dot area calculation (the channel with the highest response). As is seen, n is shown to vary substantially. Of particular note are the red ink samples, in particular, R1-R9. These nine patches come from the same press sheet. Note how n remained very stable for R1-R6. At R7, though, n increased substantially. This physical evidence supports Ruckdeschel and Hauser's findings that in the shadow areas n is dependent upon area coverage. For these particular tint patches R6 was a dot area of 50% on film and R7 was a dot area of 60% on film. The construction of these two tint patches is quite different as is evident in figure 2.

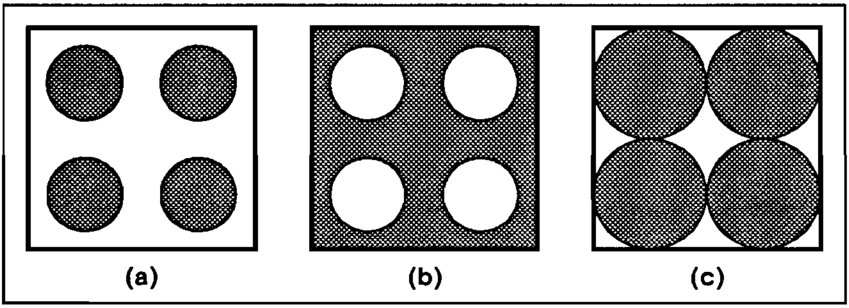

Figure 2

Figure 2a illustrates a typical round dot pattern of area less than 50%. In moving from a 50% tint to a 60% tint, the dots are not simply increased in area until 60% is achieved, as in 2c. Instead, a 40% "negative" dot is placed in an inked unit area (see 2b). The fact that the negative dot is round and not diamond shaped as in 2c made the measurement of shadow tints possible. However, if one believes in the halftone theory, it should not matter in what shape or form the dots are laid down; they are integrated into density by sampling many dots at a time.

For the non-process inks, even though a densitometer chooses the filter with the highest response for dot area calculations, the responses of one or more of the other filters may be substantially high depending on the color. For example, this particular red ink sample yields the highest density through the blue filter with the density through the green filter just a few hundredths less than that. This is because the ink contains a great deal of yellow pigmentation causing it to appear orangish in hue. As mentioned earlier, density measurements were made through each filter and n was then derived. Table 2 shows the values for n through each of the filters for each sample (including the process inks).

Table 2

Code	C	M	Y	V	Code	C	M	Y	V
C1	1.74	.80	.40	1.43	PB5	1.99	9.20	∞	4.87
C2	1.37	.80	.10	1.10	R1	.10	1.29	1.19	1.31
C3	1.42	.92	.20	1.25	R2	.20	1.20	1.11	1.26
C4	2.08	∞	.40	18.37	R3	.30	1.14	1.12	1.25
M1	∞	1.88	1.77	2.78	R4	.40	1.20	1.09	1.32
M2	.40	1.58	1.18	2.01	R5	.30	1.10	1.17	1.13
M3	.50	2.12	3.29	3.92	R6	.20	1.08	1.08	1.11
M4	.30	1.41	1.01	1.84	R7	.40	1.46	1.39	2.12
M5	.50	1.78	1.53	3.50	R8	.50	1.60	1.42	3.01
P1	1.34	1.89	3.09	3.51	R9	.70	1.56	1.43	2.74
P2	.80	1.70	1.94	2.48	R10	.20	1.34	1.33	1.63
P3	.50	1.64	1.31	2.01	R11	.30	1.17	1.13	1.11
P4	.40	1.30	.90	1.46	B1	1.58	1.11	.50	1.32
P5	.60	1.65	1.35	2.24	G1	.65	.65	.65	.65
PB1	1.47	1.00	.30	1.23	K1	1.92	1.82	1.69	1.82
PB2	1.83	1.66	.80	2.15	K2	1.42	1.29	1.21	1.36
PB3	1.88	2.79	.80	2.59	K3	1.41	1.32	1.19	1.37
PB4	1.50	.96	.40	1.18					

C = Cyan **M** = Magenta **P** = 239 Purple **R** = Red
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For samples R1 through R9, the green filter response (magenta channel) and the visual filter yielded similar relationships to the densitometer chosen blue filter (yellow channel). However, for filters where the response was very low, the value of n varied drastically, from as low as near zero up to infinity. This supports the method employed in developing densitometers to choose the filter with the highest response. The filter chosen is also most sensitive to changes in either solid ink density or dot area coverage. N-values of less than one and greater than two are theoretically impossible, but are attainable due to the fact that dots are not usually of constant microdensity.[6]

CONCLUSIONS

This study has shown that n is not easily derived. The factors that contribute to the correct derivation of n are many and not easily quantified physically. This paper was not meant to illustrate a simple way for deriving n nor to recommend a value of n. It was meant to show variance, if any, in n by attempting to vary one thing (ink type) while attempting to keep constant all other conditions. By design, different inks were chosen for evaluation. The substrate and screen ruling were kept constant with any other variations attributable to the process. But these variations are the result of actual production conditions. No special press run was conducted; the samples were most likely produced with different batches of stock, ink, fountain solution, etc., and different presses with different crews. But again, these are actual production conditions. Since this was not a controlled laboratory press run, there is no need to correlate the results to real-life situations. These are the conditions pressmen and quality control personnel must deal with on a day to day basis. That is the real worth of this experiment.

Unfortunately, not many correlations were found. This does not mean the experiment failed. It means that these variations are very real and that no one value of n can be recommended for a given set of conditions and be expected to predict the physical dot area on a consistent basis. For practical reasons, the printer should settle on an n-value that is comfortable for him and not change it. By maintaining consistency, the printing process can be monitored time after time. The important thing is for the printer to sell his product, and if he can repeat the process on a consistent basis by monitoring the process with a constant value of n, he has a good chance of repeat business. This is the practical use for n-value.

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