DENSITOMETRY

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What is Density

- It is log of opacity

The Equation: Density = $\log_{10} 1/R$

Where R = Reflectance
Density is a function of the percentage of light reflected. The table to the right shows the relationship of percent reflectance to Density.

Why measure Density?

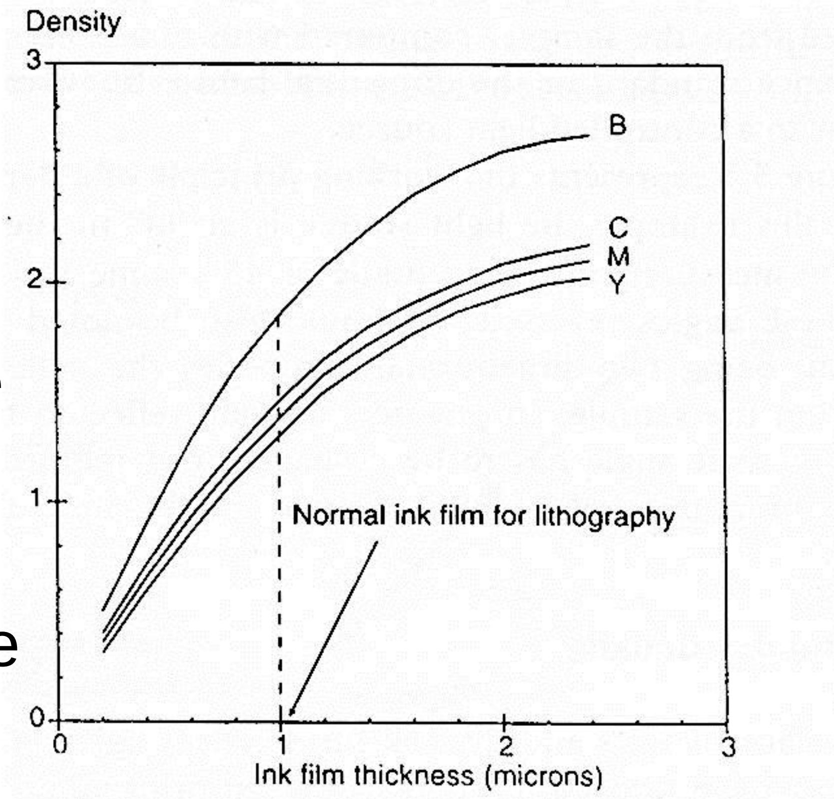
% Reflectance	DENSITY
100% = 0.0 D	
10% = 1.0 D	
1% = 2.0 D	
0.1% = 3.0 D	
0.01% = 4.0 D	

- Densitometry is not for spot colors it is only for process colors.

- For spot colors Dyestrength should be measured in integrated wavelength form

Why Density measurement

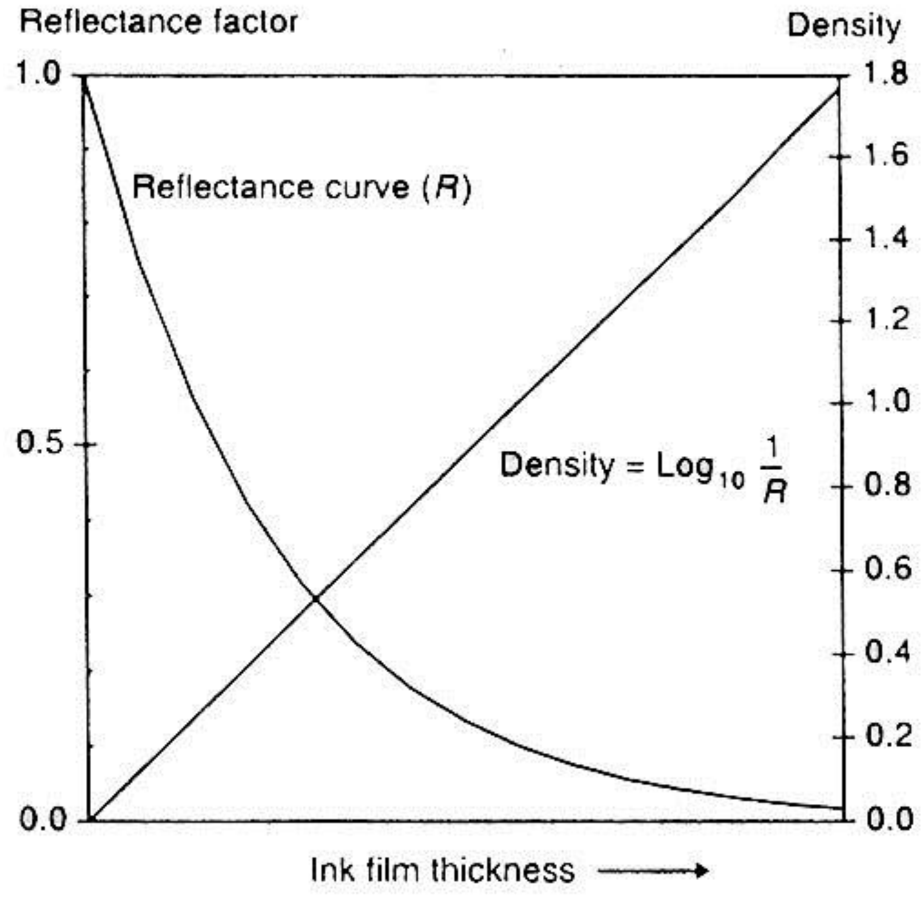
- Process colors are transparent
- Correct amount of ink quantity is required to print cast free picture.
- Picture in halftone form can not be measure, so measurement is done on patches
- As IFT increases it become opaque
- So Density help to control correct IFT which governs quality of picture



Relationship of density to ink film thickness when printed on coate

Why logarithmic Scale

- Measurement has more linear relationship to IFT
- It correlates better with visual perception of lightness difference.
- It provides increased measurement sensitivity for small reflectance difference



Type of Densities

- Optical Density- Density measurement done by filter technique
- Colorimetric Density – Conversion of tristimulus values in to densities.

Colorimetric Density

- It is conversion of tristimulus values in density
- it is used in spot color formulation when new recipe is calculated
- Dominant density is matched with recipe

$$D_x = \mathrm{Log}(X_n) - \mathrm{Log}(X)$$

$$D_y = \mathrm{Log}(Y_n) - \mathrm{Log}(Y)$$

$$D_z = \mathrm{Log}(Z_n) - \mathrm{Log}(Z)$$

Type of Densitometry

- Reflection- Reflected light from object is measured for density calculation

- Transmission – Transmitted light is measured for density calculation

Type of Instruments

- Filter instruments- Instruments those are using filter technique for measurement

- Spectral instruments – Instruments those are using diffraction grating technique & obtain reflectance data

Light Source

- For reflection ISO density the relative spectral power distribution of flux incident on specimen surface should confirmed to CIE illuminant A (corresponding to distribution temperature of 2856 K) In practice instruments, used to measure reflection ISO density, the relative spectral power distribution of the flux incident on specimen surface shall confirmed to distribution temp of 2856 K +/- 100 K

Table 1 — ISO densitometer influx spectra

Wavelength nm	Transmission densitometer influx spectrum S_H	Reflection densitometer influx spectrum S_A
340	4	4
350	5	5
360	6	6
370	8	8
380	10	10
390	12	12
400	15	15
410	18	18
420	21	21
430	25	25
440	29	29
450	33	33
460	38	38
470	43	43
480	48	48
490	54	54
500	60	60
510	66	66
520	72	72
530	79	79
540	86	86
550	93	93
560	100	100
570	107	107
580	111	114
590	115	122
600	116	129
610	119	136
620	117	144
630	113	151
[illegible]	[illegible]	[illegible]

Density calculation

$$\text{ISO standard density} = -\,LOG_{10}\left[\sum_{\lambda} \frac{W_\lambda \times R_\lambda}{100}\right]$$

where:

W_λ is the spectral weighting function at wavelength λ as defined in the file 10nmWgts.csv or 20nmWgts.csv.

R_λ is the spectral reflectance factor at wavelength λ.

The value 100 is the sum of the spectral weighting factor over the range of 340 nm to 770 nm.

Note- same formula for both transition & reflection density but different efflux spectrum

Spectral weighing functions/status

- Status T data for Filter & spectral instruments

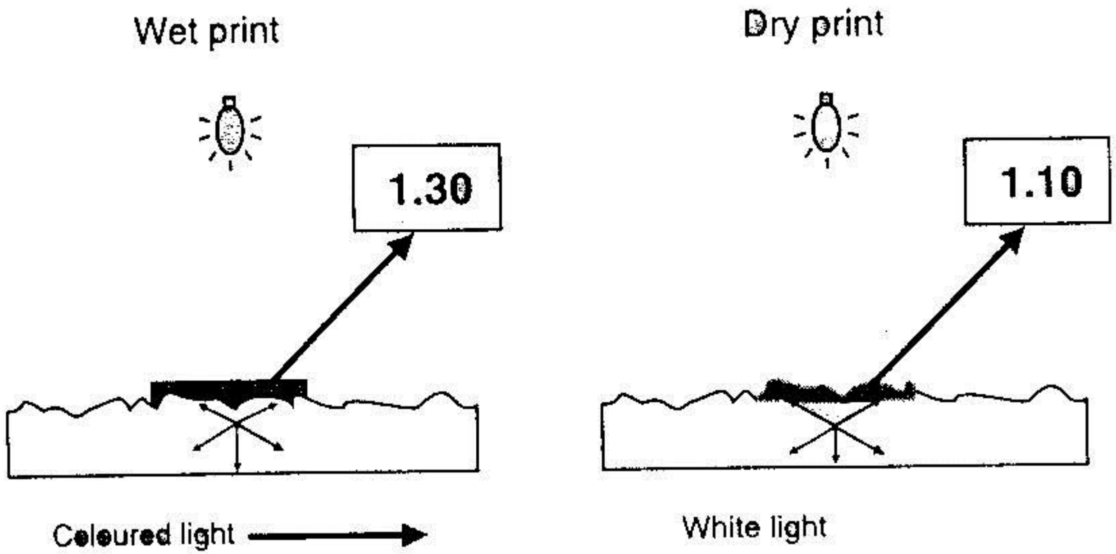
10 nm abridged weighting factors			
Wavelength nm	Blue	Green	Red
340	0,0003	0,0000	0,0000
350	0,0014	0,0000	0,0000
360	0,0028	0,0000	0,0000
370	0,0125	0,0000	0,0000
380	0,0385	0,0000	0,0000
390	0,2100	0,0000	0,0000
400	0,8323	0,0000	0,0000
410	2,4537	0,0000	0,0000
420	5,5297	0,0000	0,0000
430	8,5297	0,0000	0,0000
440	11,4476	0,0000	0,0000
450	13,2614	0,0000	0,0000
460	14,0388	-0,0013	0,0000
470	13,6479	-0,0096	0,0000
480	11,9318	0,1727	0,0000
490	9,1433	0,9640	0,0000
500	5,6020	5,4663	0,0000
510	2,5683	12,8804	0,0000
520	0,7408	17,5926	0,0000
530	0,0055	18,9941	0,0000
540	0,0001	16,7862	0,0001
550	0,0013	12,5972	0,0004
560	0,0003	8,0105	0,0027
570	0,0001	4,2078	-0,0419
580	0,0000	1,7152	-0,3728
590	0,0000	0,4815	11,4921
600	0,0000	0,1252	30,7130

Wavelength λ, nm	Blue	Green	Red
340	0.699	-6.786	-18.347
350	1.000	-6.087	-17.472
360	1.301	-5.388	-16.597
370	2.000	-4.689	-15.722
380	2.477	-3.990	-14.847
390	3.176	-3.291	-13.972
400	3.778	-2.592	-13.097
410	4.230	-1.893	-12.222
420	4.602	-1.194	-11.347
430	4.778	-0.495	-10.472
440	4.914	0.204	-9.597
450	4.973	0.903	-8.722
460	5.000	1.602	-7.847
470	4.987	2.301	-6.972
480	4.929	3.000	-6.097
490	4.813	3.699	-5.222
500	4.602	4.447	-4.347
510	4.255	4.833	-3.472
520	3.699	4.964	-2.597
530	2.301	5.000	-1.722
540	1.602	4.944	-0.847
550	0.903	4.820	0.028
560	0.204	4.623	0.903
570	-0.495	4.342	1.778
580	-1.194	3.954	2.653
590	-1.893	3.398	4.477
600	-2.592	2.845	5.000
610	-3.291	1.954	4.929
620	-3.990	1.063	4.740

Sampling condition

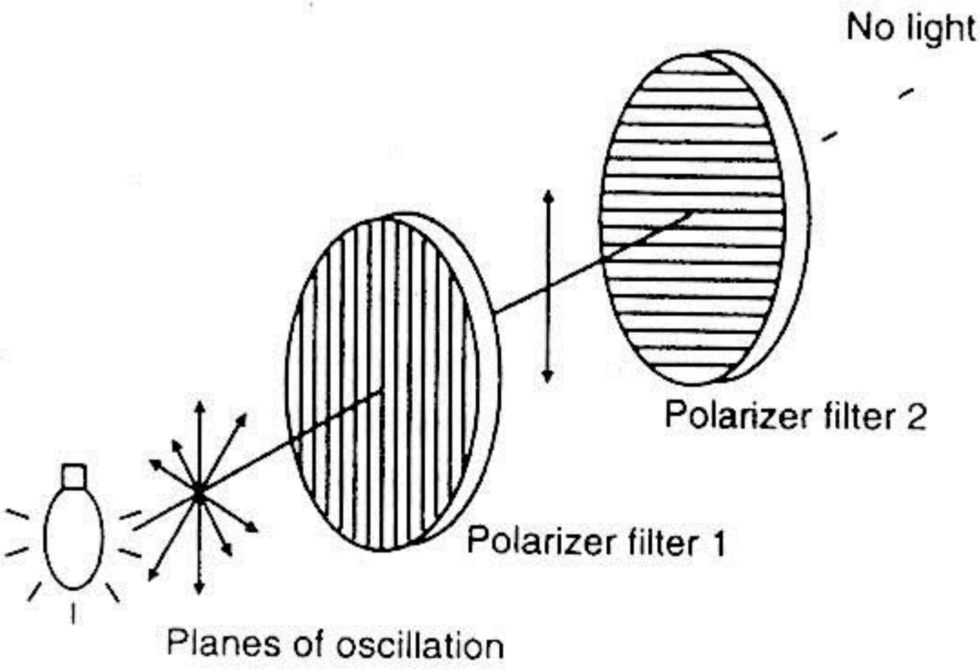
- The density of some material, changes with variation in temp. & relative humidity therefore to avoid ambiguity such materials should be at 23 +/- 2 ^{0}C & 50 +/- 5% relative humidity

Wet & dry density



- The surface of wet & dry ink film reflect light differently.
- It is found that after drying density drop down called dryback, so controlling density on press is difficult.
- Polarization filter is used to solve this dryback problem.

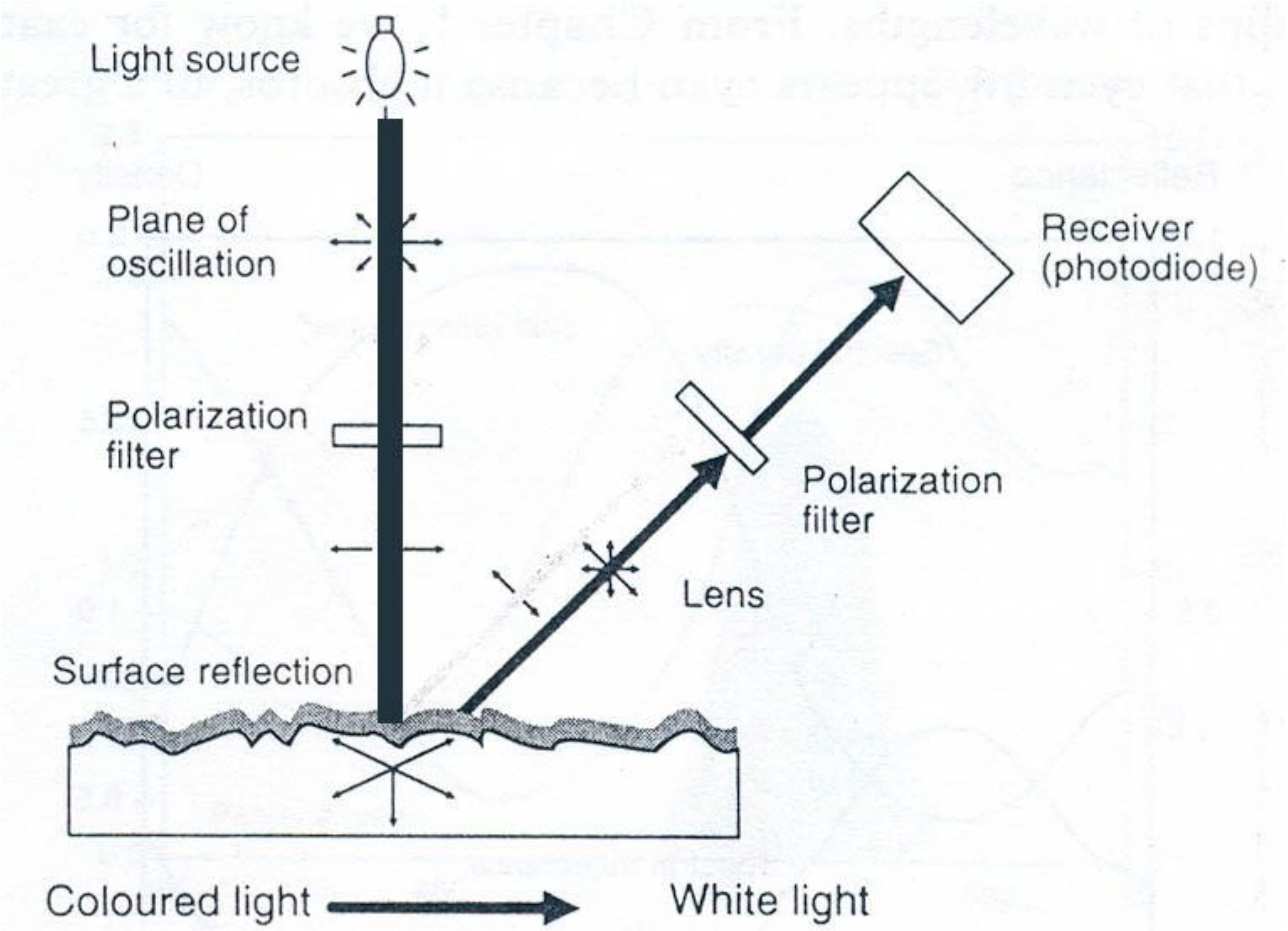
Polarization Filter



Working of pol. filter

- Emitted light passes through first pol. filter and oscillate in one plane
- Wet ink is having plane surface & when it dry it takes shape of paper surface.
- Polarized light when reflect from upper layer of ink it remains polarized but light which reflects from paper surface looses its polarization
- Nonpolarized light passes through 2nd pol filter but polarized light reflected from ink surface remains polarized and stopped by second filter.

Use of polarization



Substrate Consideration

- **Relative Density-** It is subtracting a paper while measuring density. First instrument is zeroed to paper. By zeroing on paper we more closely match the situation, when we observe a printed reproduction, where base paper is our visible reference.

  Status E & polarization filter is used

- **Absolute Density-** Paper density is not subtracted from ink density. If we are printing large area of color, which obliterates the view of paper surface , then it is particularly true if intension is to achieve similar visual appearance on different papers

  status T without pol. filter measurement is done.

Reference standards

- Absolute reference standard – The reference std. d\for determining ISO reflection density shall be an Ideal perfectly reflecting and perfectly diffusing material. Any working standard used shall not contain fluorescent additives or be intrinsically fluorescent as this fluorescence will corrupt both the scaling of reflectance and the determination of the absolute zero level of ISO density

Reference standards

- Relative density reference standards- When instrument is zeroed that time density of reference should be stated.

- Mentioning the density of paper don't represent paper completely for that whiteness, brightness, yellowness, & tint values must be mentioned along with color values, gsm & backing material

Effect of OBAs

- Optical brightening agents used in paper causes fluorescence effect in measurement, generally the effect is on cyan color. Which may cause unwanted blue or yellow cast

- Xrite iSis is only profile maker having UV filter

- Problem of OBAs can be solved either by choosing proofing paper with no OBAs or by eliminating UV light during measurement.

Densitometric Status

- ***ISO 5-3 defines various status response This concept is from selecting a set of filters for color selection***
- ***T, A, E, Ax, Tx, Ex, I HIFI, DIN, DIN NB, SPI***
- **Status T / ANSI T**: wide band color reflection densitometer response, used mainly in United States
- **Status E / DIN 16536** : wide band color reflection densitometer response, used mainly in Europe, main difference to Status T: higher values for yellow as blue blue filter is having less bandwidth.
- **Status A / ANSI A**: wide band color reflection and transmission densitometer response, used mainly in the photographic industry to measure positive prints. This response, like the Status T response, is found in both transmission and reflection densitometers.

- **Status M**: wide band color transmission densitometer response, used in the photographic industry for measurements of negatives.

- ***Status I / SPI, DIN NB***: Status I density is applicable to the evaluation of graphic arts materials such as process ink on paper. It is a special case of the narrow-band densitometry defined in ISO 5-3 with spectral bandwidth and sideband rejection as defined in that document, and peak wavelengths as follows.

- blue: 430 nm (± 5 nm)
- green: 535 nm (± 5 nm)
- red: 625 nm (± 5 nm

- ***Status Ax, Ex, Tx***: Old, classic densitometers use filters made out of glass or gelatin . The new generations of densitometers are spectrally based. This means, that modern devices measure a spectral curve and use exact mathematical filters to calculate the density. Contradictory to this the responses of classic

- densitometers have slight deviations compared to the responses defined by ANSI/DIN/ISO, because the accuracy in manufacturing glass or gelatin filters is limited. It is knows about the differences between the old and the new spectrally based . For those users, who have to use both series manufacturer provide the Ax/Ex/Tx response to get density values out of a new Series instrument, which correspond with the densities of the old Series.

Densitometric Functions

- Dot area
- Dot Gain
- Trapping
- Hue error & Grayness
- Print Contrast
- Vivacity or color contrast
- Grey balance

Why measure dot

- Most of details in halftone picture is carried in tinted area
- In process color printing, balance of dot gain between CMYK is critical for gray balance & for maintaining critical overprint colors.
- Controlling tonal values is important.

Dot Area

- Optical dot assessment- Due to scattering of light around circumference of dot, it appeare to be increased

- Physical dot assessment- Due to mechanical pressure & porosity of paper ink spreads it contribute in increase in dot area.

Murray-Davies equation

$$\text{Apparent dot area} = \frac{1-10^{-(D(t)-D(p))}}{1-10^{-(D(s)-D(p))}} \times 100$$

Apparent dot area is % of dot area, as measured & calculated with a graphic art densitometer, using Murray-Davies equation

Where:

D(s) is density of the solid
D(t) is density of the tint
D(p) is density of the paper/substrate

Yule-Nielson equation

$$\text{Apparent dot area} = \frac{1-10^{-(D(t)-D(p))/n}}{1-10^{-(D(s)-D(p))/n}} \times 100$$

Where:

D(s) is density of the solid
D(t) is density of the tint
D(p) is density of the paper/substrate
n is an empirically determined factor.

- It is modification of Murray/Davies equation where an imperially determined factor “n” is included to calculate physical dot area

“n” factor

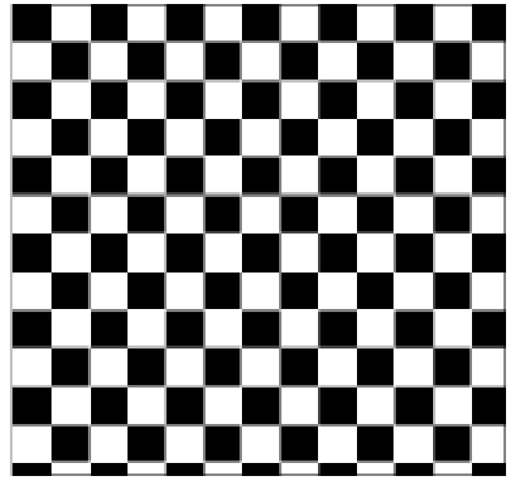
- It is not used to measure dot area on printed paper only used to measure dot area on plate, but now a days separate plate readers are available.

- 50 % Dot is selected from whole scale by microscopic measurement & n factor is added in such a way that it shows 50%

Why densitometers don't work on plate?

Densitometer - image view

DotMeter - image view



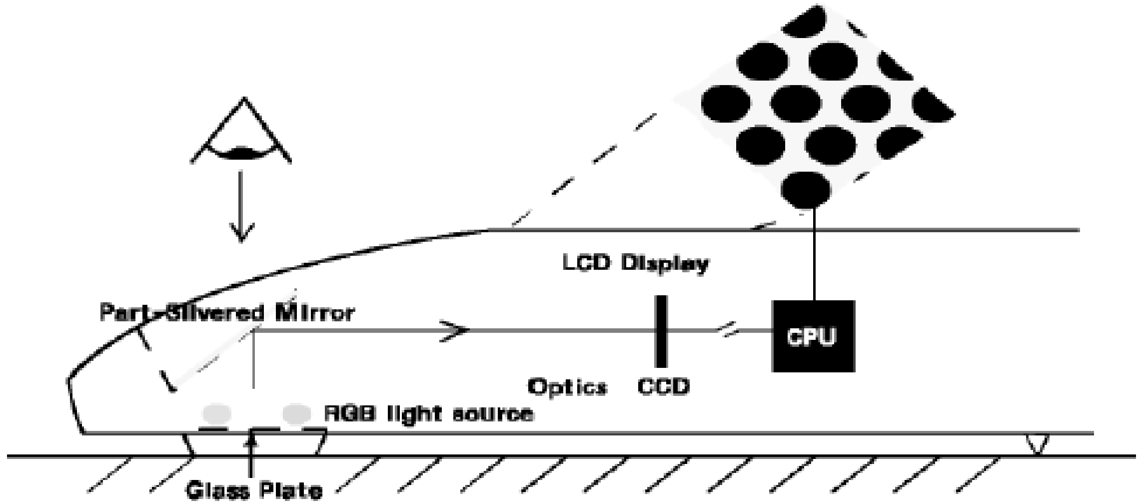
Which one is 50% ?

- Plate surface is rough then random proportion of light get in to sensor which has noise, so it is effectively impossible to obtained trustworthy results.

DotMeter

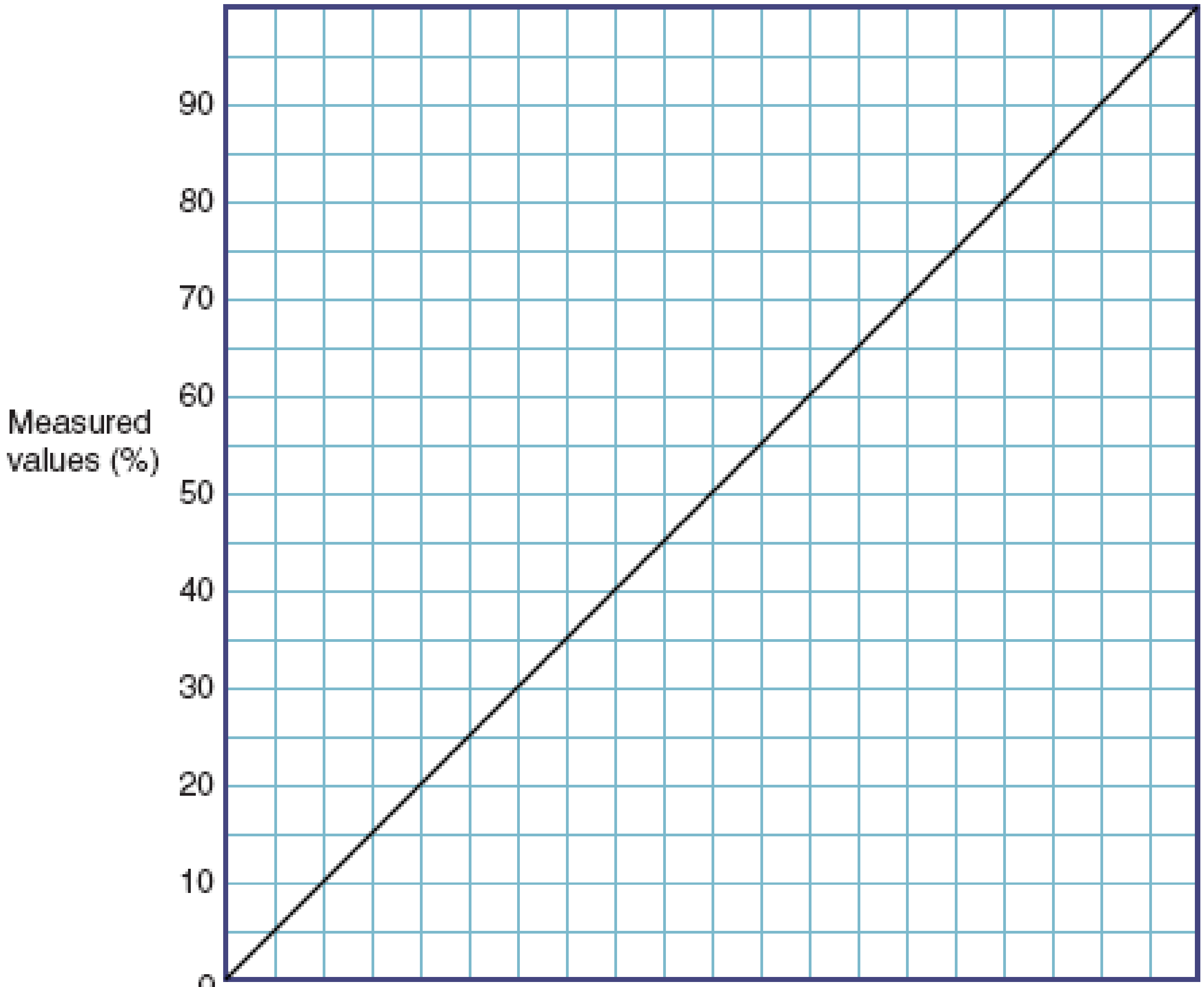
- It works on the principle of combination of CCD camera with microscope.
- Camera takes a snap shop of area being measured & counts a black & white pixels in image.
- Rather than taking a average of dot density (as like densitometer) DotMeter measure image area & provide absolute value of dot coverage.

Contraction of DotMeter



- 25 mm glass disc is used to redirect received light.
- Depth of focus is less than 0.2mm for camera.
- Exposure level is set on white & black levels.
- Can be used between 85 to 215 lpi

Dot gain chart



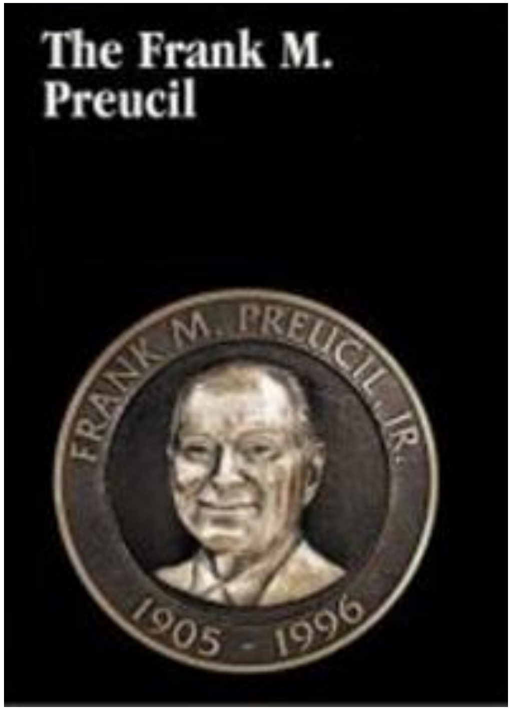
Trapping

- Trap is an indication of ability or inability of printing ink to accept the next ink printed compared to how well paper accept that ink
- Following are main equations –
- Preucil Trap- (Apparent trap)
- Bruner trap
- Newsprint trap- (Hamilton trap)

Preucil trap

$$\text{Apparent Trap (Preucil)} = \frac{\text{Dop} - \text{D1}}{\text{D2}} \times 100$$

where: (using the major filter of the second down color)
Dop is the density of overprint minus paper density
D1 is the density of first-down ink minus paper density
D2 is the density of second-down ink minus paper density



- It is ratio of difference between density of overprint and density of first down ink to density of second down ink. Where all densities are measured with complementary color filter of second down ink

Bruner trap

$$\text{Apparent Trap} = \frac{1-10^{-(Dop)}}{1-10^{-(D1+D2)}} \times 100$$

Where: (using the major filter of the second down color)

Dop is the solid density of overprint minus paper density
D1 is the solid density of first-down ink minus paper density
D2 is the solid density of second-down ink minus paper density

- Calculate trapping as apparent dot area of second color over the first as if second color were printed as a tint instead of solid

Hamilton trap

$$\text{Apparent newsprint Trap} = \frac{\text{Log}\,(1 + (\text{Dop} - \text{D1}) / (\text{Dm} - \text{Dop}))}{\text{Log}\,(1 + (\text{D2} / (\text{Dm} - \text{D2})))} \times 100$$

Where: (using the major filter of the second down color)

Dop is the density of overprint minus paper density;
D1 is the density of first-down ink minus paper density;
D2 is the density of second-down ink minus paper density;
Dm is the maximum printable density for the given substrate minus substrate density

Hamilton trap

- News print formula accounts for some of missing density arising from additivity failure of densities when overprinted.

- Here two factors contribute to additivity failure are : reduced ink trap where second down ink doesn't transfer as effectively to ink on paper as it does to paper alone, & factors like first surface reflectance & internal scattering properties of printed surface.

Hue error

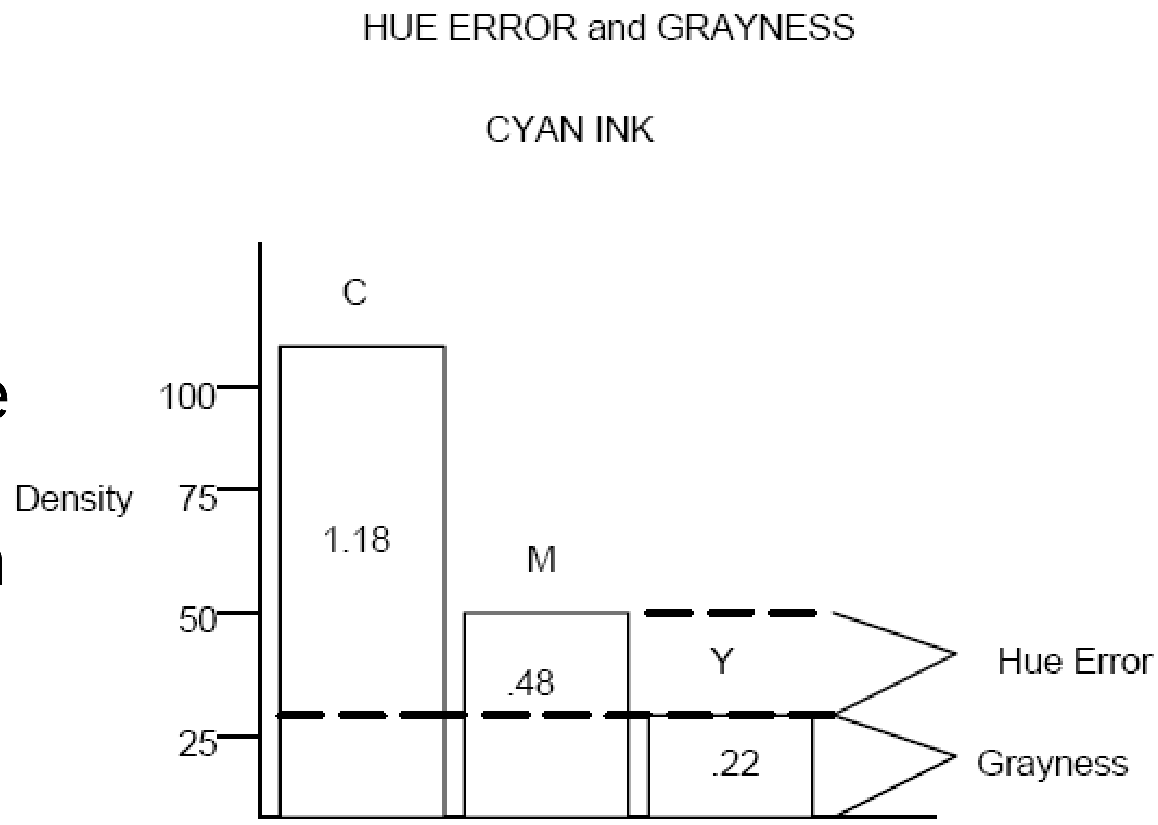
The Equations: $\% \text{ Hue Error} = \dfrac{M - L}{H - L} \times 100$

Where: L = Low density value
M = Middle density value
H = High density value

- Hue error doesn't indicate an error or problem but rather the variation from theoretically perfect or ideal cyan, magenta & yellow colors

Direction of Hue error

- Direction of error is determined by which filter gave the second lowest density, so direction is towards that color.



Grayness

$$\text{Grayness} = \frac{L}{H} \times 100$$

Where:

H is the major filter density (highest)
L is the minor-minor filter density (lowest)

- Grayness is characteristic of relative achromatic content of colorants used as process colors
- Hue doesn't changes by change in grayness indices

Print Contrast

The Equation: $\% \text{ Print Contrast} = \frac{D_s - D_t}{D_s} \times 100$

Where: D_s = Density of solid
D_t = Density of tint (typically 75%)

Print Contrast indicates the degree to which shadow detail is maintained or kept open.

- Print contrast is indication of quality in shadow details
- High print contrast required high density & sharp printing

Vivacity or color contrast

$$\text{Vivacity } (\%) = (10^{-D_l}) - (10^{-D_h}) \times 100$$

D_l – is lowest density value

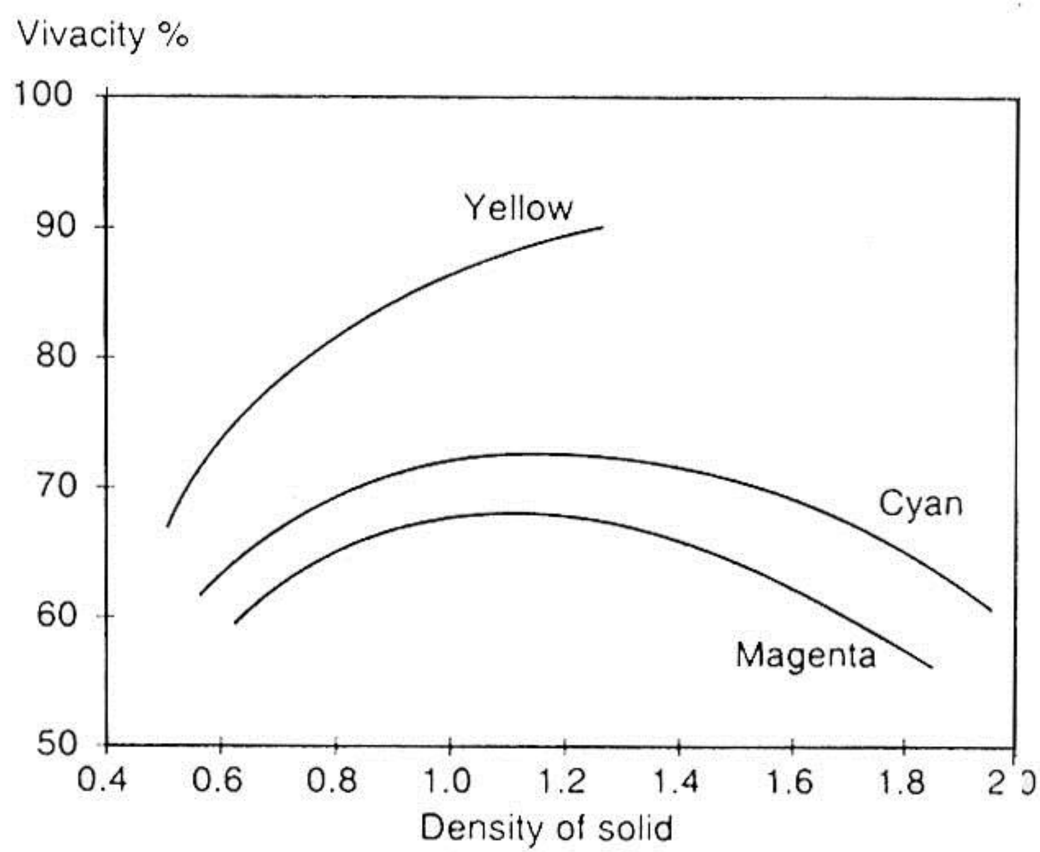
D_h- is highest density value

- It is property of process colors determined by applying formula to density measurement
- This formula can be used either to compare the relative characteristics of process color ink as a criteria to determine IFT for given ink, higher vivacity higher gamut.
- Vivacity. is poor at low IFT & increases to reach a peak before declining as IFT increases.

Use of color contrast

- With respect to graph at higher density vivacity reduces means gamut reduces, so to achieve wider gamut it is necessary to have higher vivacity

- Maximum vivacity is giving you correct density.



Backing material

- Paper is not 100% opaque.

- Some of light following on it is getting transmitted through paper & get reflected from its back material.

- That contaminated light is contributed in measurement readings.

- So readings are taken by light reflected from paper + Backing material.

Type of Backing Material

- Self Backing- Same substrate is used as backing material generally done in news paper
- White backing- White ceramic tile or plate of MgO or barium sulphate is used
- Black backing- Black matt surface sheet of density more than 1.5 is used

Aperture Size of instrument

Table F.1 — Minimum and recommended aperture size and sampling area

Nominal screen frequency		Round sampling aperture (mm)		Non-round sampling area [1] (mm^2)	
lines/inch	lines/cm	Minimum	Recommended	Minimum	Recommended
65	26	3.8	5.7	11.3	25.5
85	33	3.0	4.5	7.1	15.9
100	39	2.6	3.9	5.3	11.9
120	47	2.1	3.2	3.5	7.8
133	52	1.9	2.9	2.8	6.4
150	59	1.7	2.6	2.3	5.1
175	69	1.4	2.1	1.5	3.5
200	79	1.3	2.0	1.3	3.0

NOTE These sampling aperture sizes are valid for instruments that are not moving relative to the target and have a round aperture. For scanning instruments or instruments with apertures that are not round, the equivalent measurement area should be covered.

[1] Area can be achieved using either a single measurement, or by averaging multiple measurements in random or adjacent locations on the sample. This includes the use of scanning type instruments that make continuous measurements from a sample.

Instruments

- Manual densitome

- Auto tracking Densitometers

On Press

- Use only instruments from same model
- Use same settings always
- While mentioning density, mention settings
- Different standards are available from different institute, but derive your own
- Don’t stick to numbers, look at productivity
- All densitometric standards will get revise after 2009

Different Standards

- FIPP- Federation of Periodical Press
- UKONS- UK Offset Newspaper Specifications
- SWOP- Spe. For Web Offset Publications
- SNAP- Non-Heat Advertising Printing
- INCQC- IFRA
- PIRA- PIRA consulting
- FOGRA- The German Research Association for Printing & Reproduction.
- ISO 12647-2/3/4/5

COLOR PROBLEMS?

Solve your Color problem @

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