Delta X Criterion

Throughout the history of photography, differing film speed methods came into favor only to soon lose favor. Most of the methods fall into two categories of thought. One approach is the widely popular fixed density method. Speed is determined by the exposure necessary to achieve a given point of density on the film's characteristic curve. Exactly how much density depended on the specific methodology, but it generally ranged from 0.10 to 0.20 over Fb+f. The other approach is the minimum gradient method which determines speed based on the shadow gradient instead of shadow density. It theorizes quality is related less to the density of the negative than to the separation of tones in the film's toe. Film speed is the point on the toe where the lowest gradient is reached that will maintain print excellence. As with the fixed density method, there were a number of different values proposed for the minimal gradient.

Today's ISO black and white film speed method utilizes a fixed density method. At least it does by all appearances because there maybe something more clandestine at work here with fairly large ramifications? If this is the case, almost all the speed methods used by the majority of photographers come under question for any processing other than normal including the Zone System and the standard printing time method.

Background

From the mid 1930s through the mid 1940s, Lyod A. Jones and his team at Kodak conducted extensive tests to conclusively define the fundamentals of photography. Among these were for exposure and film speed. Jones began his investigation by first conducting a statistical analysis of the quality of the photographic image through psychophysical means. A group of observer's responses to the perceived quality of a series of photographs was compared to the technical parameters of the negatives and prints. Next, different film speed methods were evaluated to determine which method produced the type of print the observers considered excellent within the greatest majority of situations. Jones concluded the minimal gradient method, where the minimal gradient was 0.3 times the film's average gradient, most closely matched the results from the psychophysical tests and is therefore the most accurate film speed method (Graph 1). The new criteria, named the Fractional Gradient Method ($0.3\bar{G}$), became the first ASA film speed standard in 1943 and the BS standard in 1947.

Fractional Gradient Method

While the $0.3\bar{G}$ method effectively eliminated the plethora of speed methods in the US, it wasn't universally embraced. With the exception of Great Britain, most countries felt the drawbacks outweighed the advantages and refused to adopt it, and instead continued to use various fixed density methods. There were critics also within the US. Some claimed the method was tedious, overly complex, time consuming, and prone to technician errors. In the mid 1950s, ANSI and Kodak made a concerted effort to placate the dissenters in an attempt to create a universal standard. It failed. A few years later, the ANSI committee on film speed agreed to propose a standard using a fixed density method.

It had been over fifteen years without a reasonable challenge to the prominence of the $0.3\overline{G}$ method. In fact, from the perspective of the $0.3\overline{G}$ method, any fixed density method tends to underrate films that are processed to a lower than average contrast (overexpose) and overrate films that are processed to a higher than average contrast (underexpose). In other words, speed values change to a lesser degree from processing with the factional gradient method than with the fixed density method. Kodak went as far to suggest that if the fixed density method was adopted for normal development, people should continue to use the $0.3\overline{G}$ method for extended or contracted development conditions.

So, why would the ANSI committee members chose to compromise the quality of a proven superior method just to simplify the testing procedure in an attempt to achieve a universal standard? The answer is they really didn't compromise. As it turns out, the fixed density method has a direct relationship to the fractional gradient method when certain parameters are maintained. Consistently accurate film speeds, it appears, are possible using a fixed density method in conjunction with a computational model known as the Delta X speed criterion (ΔX) which adjusts the speed point of the fixed 0.10 density method to the more precise $0.3\overline{G}$ method.

ISO Speed Method

Since the time when the 1960 ANSI standard replaced the fractional gradient method, all the black-and-white standards have used the same fixed density approach. The film speed is determined based on the amount of exposure required to achieve a point of density 0.10 over Fb+f (H_m) where the density difference (ΔD) 1.30 log units to the right of H_m equals 0.80 (Graph 2). The value of ΔD is dependent on the processing. As the contrast increases, so does the ΔD value. Once a ΔD 0.80 is achieved, film speed is calculated, in meter candle seconds (mcs), from point H_m. For example, an ISO 125 film requires an exposure of 0.0064 mcs at H_m. This value is then plugged into the equation:

eq. 1

Equation:	Example:
$S = \dfrac{n}{H_m}$	$\dfrac{0.8}{.0064} = 125$

Where:
S = film speed
n = Constant = 0.8, The constant is not derived from ΔD 0.80
H_m = exposure in meter candle seconds

Delta X Method

It might come as a surprise to some to learn the Delta X speed criterion is actually part of the ISO speed method and is hiding in plain sight. Take a look at the development parameters. Those values are really the Delta X criterion in disguise. A value of 1.30 for the Δ log-H is too short for any kind of relevant pictorial contrast parameter. For accurate contrast determination, the log-H range should equal the approximate subject luminance range, yet the ISO value isn't long enough to represent the average subject luminance range of 2.2 or 1.80 when flare is included. It's even shorter than the fractional gradient's 1.50 log-H range. The limited log-H range also causes a few problems. Long toed films need to be processed to a higher contrast than films with more linear curves in order to fit the ΔD requirements. Any system that results in different film contrasts from different curve shapes isn't of much merit in contrast determination. So, if Δ1.30 wasn't designed for some kind of contrast control, why was it chosen? It appears that it functions as a constant that links ΔD to ΔX.

Thanks to the Δ1.30 log-H constant, there exists a definite relationship between the ΔD and the ΔX value. As ΔD increases, ΔX decreases, and as ΔD decreases, ΔX increases. After determining the value of ΔD, the ΔX value can be easily calculated (Table 1).

eq. 2

$$\Delta X = 0.83 - (0.86 \cdot \Delta D) + (0.24 \cdot \Delta D^2)$$

Example:

$$(0.83 - (0.86 \cdot 0.80)) + 0.24 \cdot 0.80^2 = 0.296$$

$$\Delta X = 0.296$$

Because ΔD and Δ1.30 log-H are fixed in the ISO standard, it isn't necessary to use the Delta X equation when adhering to the standard. The equation is implicit within the ISO properties. By obtaining ΔD 0.80, ΔX will always equal 0.296. This places the approximate fractional gradient speed point about a stop under the ISO speed point (H_m). This perfectly conforms to general exposure theory. The ISO speed point (H_m) falls 3⅓ stops (1.0 log-H units) below the meter calibration point, while the shadow exposure falls 4⅓ stops (1.30 log-H units) below (Jan/Feb 2005 *Flare and Accurate Film Speeds*). In real world use, the existence of flare will increase the shadow exposure raising it up to around the H_m point. Notice how ΔX 0.296 is also the difference between H_m in the ISO standard and the average scene's shadow placement (Graph 2). Like the ISO exposure theory, flare will bring the exposure back up to H_m. The ISO standard assumes flare conditions of 0.30 to 0.40 which will produce a slight safety factor. All of these similarities cannot be coincidental. I believe ΔD 0.80 was chosen because of its relationship between flare and exposure.

The Delta X speed criterion has managed to unite the more accurate factional gradient method with the easier to apply fixed density method. Contrary to what most think, the

$0.3\overline{G}$ method wasn't superceded by a fixed density method. The fixed density method was really subverted by the $0.3\overline{G}$ method. There was never any capitulation. One speed method is simply masquerading as another, and I believe that if this weren't the case, there would never have been international agreement on any film speed standard. But the ISO method only works for normal processing. For speeds at anything other than the ISO normal contrast parameters, a few additional steps are required.

Determining Delta X Speed

As the film contrast increases, ΔD increases while ΔX decreases (Table 1). Since the point H_{fg} is determined by subtracting ΔX from H_m, any value for ΔX that is higher than the normal 0.29 means the indicated film speed will be faster with the Delta X criterion than the fixed density method (Graph 3). Any value lower then 0.29 means the realistic film speed is slower than indicated by the fixed density method (Graph 4). Only a ΔX of 0.29 will produce identical film speeds between the two methods as it does in the ISO standard.

Determining the Delta X film speed requires only a couple of simple equations. First is the determination of the exposure (H_m) or film speed (eq. 1) using the fixed density method.

For those using relative film speeds, you will need to apply equation #1a instead to find the relative H_m. After creating a family of curves from the film testing data, select the sample that most closely fits the ISO parameters and assign a speed value. Relative speeds can then be determined in relation to this point for the other film curves in the family group.

Eq. 1a

Finding H_m from film speed value

Equation:	Example:
$H_m = \frac{n}{S}$	$\frac{0.8}{125} = 0.0064$

Once H_m is determined, the next step is the calculation of ΔX either by using equation #2 or by the look up table (Table 1). To find the exposure at point H_{fg}, take the antilog of ΔX and divide it into H_m. The value for ΔD in equation #3 is 0.80.

Eq. 3

Equation:			Example:
$H_{fg} = \frac{H_m}{\text{Antilog}(\Delta X)}$	or	$H_{fg} = \frac{H_m}{10^{\Delta X}}$	$\frac{.0064}{10^{.296}} = 0.0032$

Finally, plug H_{fg} into the Delta X speed equation.

Eq. 4

Equation:	Example:
$S_{\Delta X} = \frac{.4}{H_{fg}}$	$\frac{.4}{.0032} = 125$

Now let's take a look at why the fixed density method tends to underrate (overexpose) films that are processed to a lower than average contrast and overrate (underexpose) films that are processed to a higher than average contrast. The symbol "S" represents film speed resulting from the fixed density method.

	Lower than average ΔD		Higher than average ΔD	
	$\Delta D := .70$	$S := 108$	$\Delta D := .90$	$S := 144$
Eq. 2	$\Delta X := 0.83 - (0.86 \cdot .70) + (0.24 \cdot .70^2)$	$\Delta X = 0.346$	$\Delta X := 0.83 - (0.86 \cdot .90) + (0.24 \cdot .90^2)$	$\Delta X = 0.25$
Eq. 1a	$H_m := \frac{.8}{108}$	$H_m = 0.0074$	$H_m := \frac{.8}{144}$	$H_m = 0.0056$
Eq. 3	$H_{fg} := \frac{.0074}{10^{.346}}$	$H_{fg} = 0.0033$	$H_{fg} := \frac{.0056}{10^{.25}}$	$\frac{.0056}{10^{.25}} = 0.0031$
Eq.4	$S_{\Delta X} := \frac{.4}{.0033}$	$S_{\Delta X} = 121$	$S_{\Delta X} := \frac{.4}{.0031}$	$S_{\Delta X} = 129$

The results from Example #2 confirm a lower than normal contrast will lead to some overexpose and higher than normal contrast will lead to underexposure using the fixed density method. While these speeds range over two-thirds of a stop from EI 100 to EI 160, the surprising discovery is that all three Delta X speeds will round to 125 even though the range of processing is from an approximate contrast index of 0.54 (ΔD 0.70) to 0.69 (ΔD 0.90).

A quick review of the fractional gradient standard finds a possible explanation. The standard states the film should be processed above a minimal average gradient of 0.50; however, it doesn't state an upper limit. Why isn't the fractional gradient standard more concerned about a precise aim film contrast as is done in the current ISO speed standard? It might be because the $0.3\overline{G}$ method bases speed on the shadow gradient in relation to the overall film gradient. At lower contrasts, there is a more gradual falloff of the slope of the toe producing a greater difference between H_m and H_{fg} than at normal contrast. This effectively shores up film speeds (Graph 3). At higher contrasts, the gradient in the toe falls off much more rapidly. The shorter distance between H_m and H_{fg} retards speed increases (Graph 4). This "compensation effect" might be why the fractional gradient standard wasn't overly concerned by development variations in regard to film speed, and why today's photographers shouldn't really worry about it either.

Since the Delta X speed method isn't based on a fixed density, the placement of the film's shadow density will vary depending on the degree of development. Higher than normal processing will produce a negative with an overall higher density. It's a simple matter to just print down the overall additional density.

This might sound counter to many of the fixed density philosophies including the Zone System, and it is. The $0.3\overline{G}$ method is based on gradient and not density, and since the $0.3\overline{G}$ method is considered the most accurate method, it is only logical to question such methods as the standard printing time, the just black printing method, and the Zone System method of placing Zone I at 0.10 over fb+f with pushes and pulls. Remember, it's the shadow gradient and not density that equates to quality. Perhaps it's time to re-evaluate the validity of some of the commonly accepted speed methods.

In fact, this might be a good time to do some serious thinking about the very nature of film speed. How precise do you have to be when deciding on a film speed for a push or a pull? How definitive is film speed? How flexible is it without negatively affecting quality? If the results from Table 2 are any indication, both the chronic testers as well as the less than meticulous practitioners might just be in for a bit of a break.

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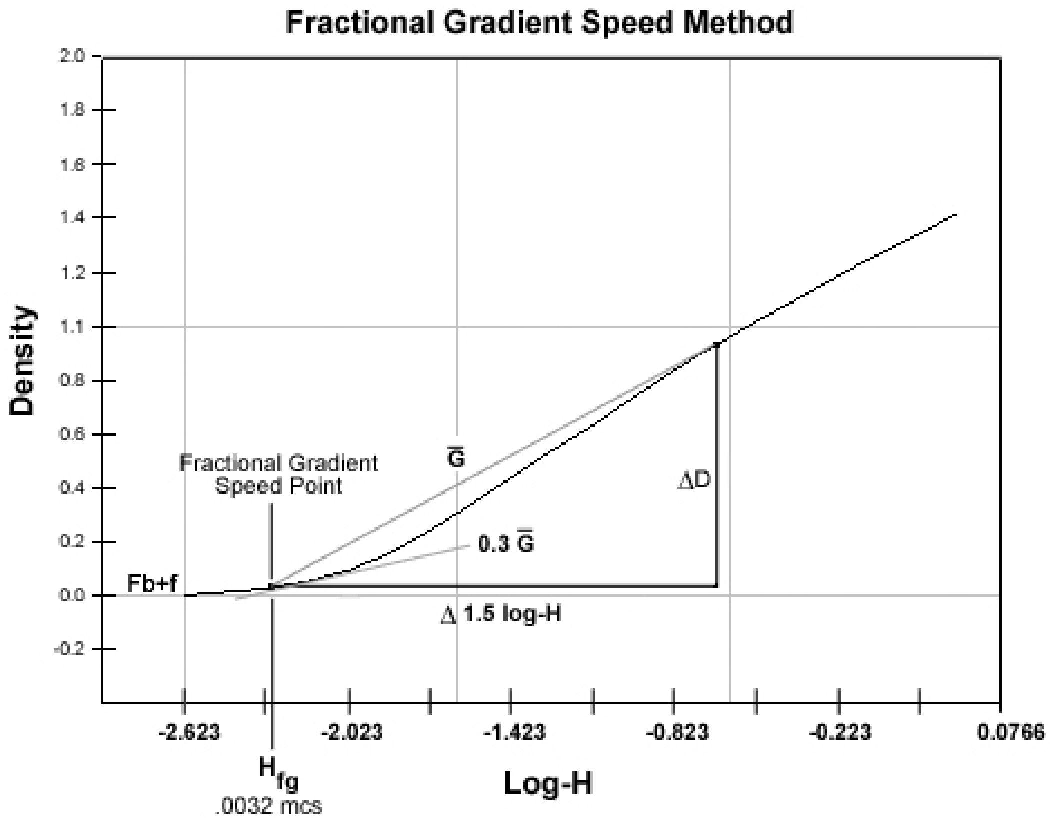
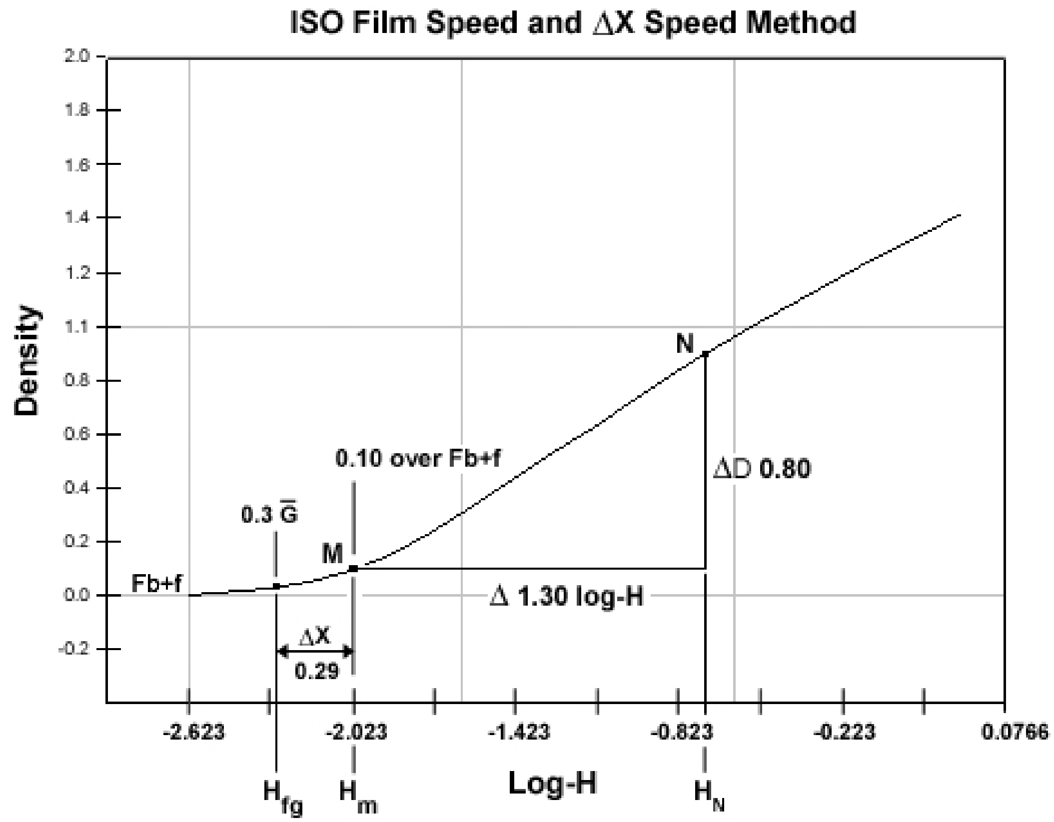
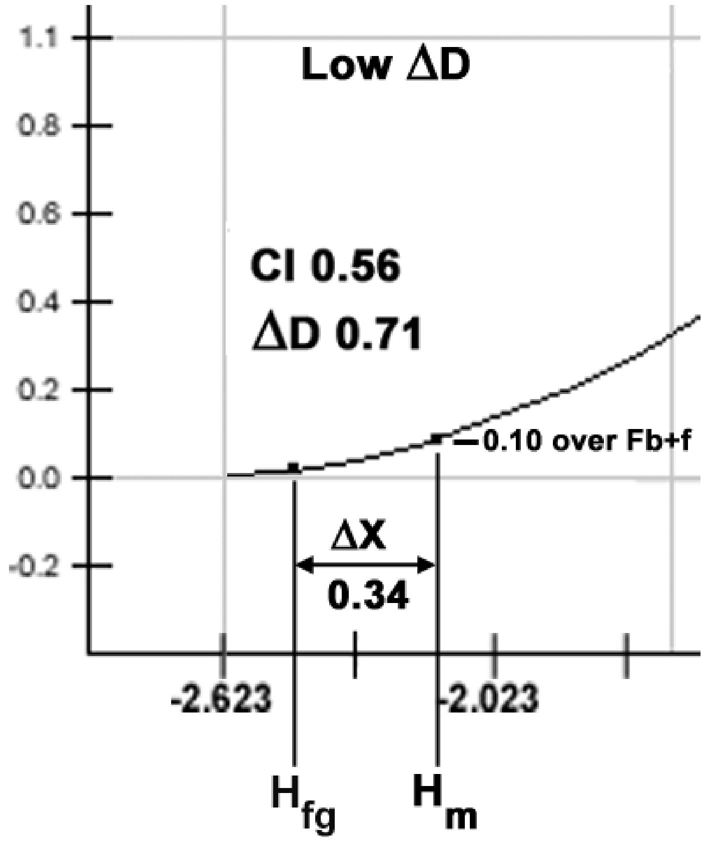


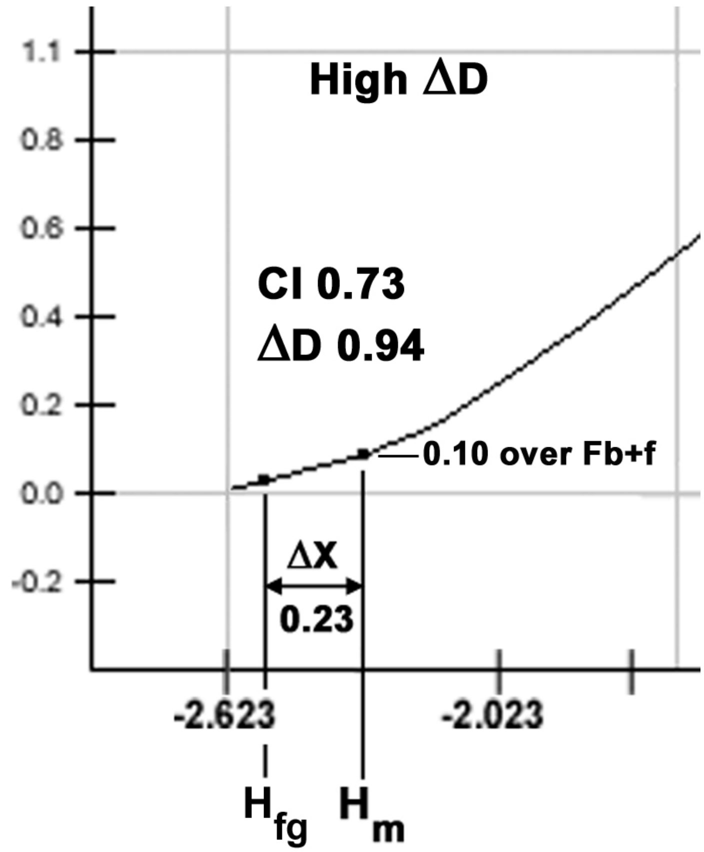
Graph 1. Fractional Gradient Speed Method.



Graph 2. The graph illustrates the ANSI and ISO black-and-white speed method and its relationship to the fractional gradient method. The ANSI / ISO contrast parameter links its fixed density method of determining film speed to the more accurate $0.3\bar{G}$ method with a consistent difference of 0.29 log-H units.



Graph 3. With films that are developed to a lower contrast index than normal, the value of ΔX increases. This means film speeds are higher when determined using the Delta X criterion at lower contrast indexes than if determined using a fixed density method.



Graph 4. The ΔX value decreased as the film is developed to a higher than normal contrast index producing lower film speeds when compared to the fixed density method. The fixed density method tends to overrate film speed under these conditions which leads to underexposure.

Table 1. Delta X Criterion Conversion Table.

Delta X Criterion Table				
ΔD	ΔX		ΔD	ΔX
0.70	0.346		0.90	0.250
0.71	0.340		0.91	0.246
0.72	0.335		0.92	0.242
0.73	0.330		0.93	0.238
0.74	0.325		0.94	0.234
0.75	0.320		0.95	0.230
0.76	0.315		0.96	0.226
0.77	0.310		0.97	0.222
0.78	0.305		0.98	0.218
0.79	0.300		0.99	0.214
0.80	0.296		1.00	0.210
0.81	0.291		1.01	0.206
0.82	0.286		1.02	0.202
0.83	0.282		1.03	0.199
0.84	0.277		1.04	0.195
0.85	0.272		1.05	0.192
0.86	0.268		1.06	0.188
0.87	0.263		1.07	0.185
0.88	0.259		1.08	0.181
0.89	0.255		1.09	0.178

Table 2

ΔD	CI	Speed Fixed Density	Rounded Speed	Speed Delta X	Rounded Speed
0.70	0.54	108	100	121	125
0.80	0.62	125	125	125	125
0.90	0.69	144	160	129	125

Table 2. This table contains the values from the three examples comparing the Delta X method with the fixed density method. While the fixed density speed values have a ⅔-stop range, the Delta X speed values determined from the same film are nearly identical.