What is Normal?
A Developmental Model for B&W Film Processing

The idea of black and white film processing is to fit the luminance range of the subject onto the exposure range of the paper through the controlled development of the negative. Knowing the conditions under which the negative was made, and the conditions by which the negative will be printed determines how the negative is to be processed. The first step is to define the paper's log exposure range (LER) and the scene's log subject luminance range (LSLR).

Determining the Average Scene Luminance Range (LSLR)

Lyod A. Jones, a physicist at Kodak, and his team at Kodak in one of their authoritative papers defined the average luminance range of exterior scenes. Over an eighteen month period in the late 1930s, under many different conditions and within a two to three hundred mile radius of Rochester, they photographed a total of 130 scenes of which 126 were represented in the study.

The average luminance range derived from the 126 sample scenes was 1:160 (2.20 log units), with a standard deviation of 0.38 (graph 1). This means that 68% of the scenes fell within a 2½ stop luminance range of the average, while 95% fell within a 5 stop luminance range. The luminance ranges of the scenes tested were from a minimum 1:27 (1.43 log units, approx. 4⅔ stops) to a maximum 1:750 (2.88 log units, approx. 9½ stops). The idea is to make the luminance range most frequently encountered as the value for normal.

Within the camera, the scene's luminance range changes do to the influence of flare. Flare is non-image forming light created by any lens and camera system. Reflections between lens surfaces, lens-to-air surfaces, the sides of the lens (barrow), and the inside of the camera all help to create flare. Eighty percent of flare is related to the contrast and tonal distribution of the subject. What flare does is to introduce additional exposure to the film. Flare has a greater influence in the shadow exposure values than with the highlights. This effectively reduces the apparent luminance range of the subject at the film plane. The average value of flare for the statistical average luminance range is 0.40 which reduces the luminance range from 7⅓ stops (log 2.20) to a 6 stops (log 1.80) within the camera (2.20 – 0.40 = 1.80). Photographic processing is then based on the camera image of 6 stops and not the scene luminance range of 7⅓ stops. The influence of flare must always be considered when determining the luminance range when processing. (Flare is also the key reason why there isn't definitive numbers for processing.)

There are a number of beneficial aspects to flare. Film speeds would be at least a stop slower without the influence of flare, and because of the reduction of the subject luminance range caused by flare, average development times are longer than if flare didn't exist. This not only helps to reduce developmental problems associated with short development times, but the additional development time tends to increase film speeds.

Determining the Paper log Exposure Range (LER)

Now that the input conditions are defined, we need to define the aim output or negative density range (DR). Once again, Loyd Jones has done the definitive research. Jones made a large number of prints on different grades and exposures from each of around 170 different negatives (most are from the First Excellent Print Test). They were judged for quality from best to worst. The test wasn't about creating specific criteria for paper grades, but to determine the best

approach to objectively determine sensitometrically the paper grade that will consistently produce high quality prints. Jones concluded, "because of the influence of the brightness distribution and subject matter in the scenes photographed, an accurate prediction cannot always be made of the exposure scale (Log Exposure Range) of the paper which will give a first-choice print from a negative of known density scale (Density Range)… But what other course is there to follow? Either we must make the best of a somewhat imperfect relationship or face the prospect of having no criterion whatever for choosing the paper contrast grade."

The criterion of this imperfect relationship has become the ANSI/ISO standard which currently defines the useful LER of black and white continuous tone paper as the log-H difference between the points where the density falls at 0.04 above paper base-plus-fog and where the density is equal to 90% of the paper's Dmax (Graph 2). The ISO range of the paper is termed ISOR. It is simply the useful LER * 100 and rounded to the nearest 10th. So, a LER 1.10 becomes an R110.

The paper's LER is the same value as the negatives aim density range (DR). A paper R110 would require a negative with a DR of 1.10. Jones introduced the LER type of indication way back in the 1940s, and while it is now part of the current standards, paper manufacturers have never supported it enough to drop the use of grades in favor of its exclusive use. The ISOR is usually hidden away at the bottom of the paper's information sheet. It seems the idea of paper grades is too deeply engrained in our consciousness to give them up. ANSI/ISO defines a grade 2 LER as ranging from 0.95 to 1.14. An LER of 1.05 is generally used as the standard aim for contact printing and diffusion enlargers and in calculating what is considered the standard "Normal." This places the aim negative DR squarely in the middle of the range of a grade 2 paper. Even though matching the negative DR to the paper LER isn't a perfect criterion, it is good enough to produce quality images in most situations, or at least with only a slight contrast adjustment.

Determining Normal

Most methods of determining film contrast, such as Average Gradient and Contrast Index, use the determination of the slope of the film's characteristic curve. Calculating the slope of a curve uses the simple formula of rise over run or output divided by input, or in photographic terms, the LER divided by the LSLR. For a normal negative, that equals the paper's LER of 1.05 divided by the scene's luminance range of 2.20 minus 0.40 for the influence of flare.

$$\frac{Rise}{Run} \longrightarrow \frac{LER}{LSLR - Flare} \longrightarrow \frac{1.05}{2.20 - 0.40} = 0.58$$

A Contrast Index or Average Gradient of 0.58 is considered statistically normal. It was once considered to be 0.56 until the value of flare changed from 0.34 to 0.40. I believe the adjustment reflects a shift away from the use of larger format cameras to 35mm cameras with their higher proportion of lens elements creating the slightly higher average flare.

It's a simple matter to determine normal for any set of conditions. For example, the paper has a LER of 1.15, or 1.15 / 2.20 - 0.40 = 0.64. Platinum printing usually requires a LER of around 1.60, or 1.60 / 2.20 – 0.40 = 0.89.

Extended and Contracted Development

As previously discussed, normal is determined from the statistically average scene luminance range. But what about finding development for the rest of the luminance ranges? One approach is to process everything normal and use the various paper grades to adjust to the differences in scene luminance ranges. Another way is to adjust the processing. All it takes for this is to change the value of the LSLR in the above formula to determine the necessary contrast for a given push or pull. A one stop change either up or down equals a log difference of 0.30. A scene with a luminance range that is one stop shorter than average, requiring a one stop push, will have a LSLR of 2.20 – 0.30 = 1.90. A scene with a luminance range one stop greater than average, requiring a one stop pull, will have a LSLR of 2.20 + 0.30 = 2.50. Remembering to incorporate flare the required film contrasts will be:

$$\text{Plus One (+1+):} \quad \frac{1.05}{1.90 - 0.40} = 0.70$$

$$\text{Minus One (-1):} \quad \frac{1.05}{2.50 - 0.40} = 0.50$$

Creating a Developmental Model

It requires only one small step from here to produce a range of aim contrast values for a variety of shooting conditions and to plug the LSLR values into the equation for what can be called a developmental model (see also Graph 3).

Dev	- 2	- 1	N	+1	+2	+3
LSLR	2.80	2.50	2.20	1.90	1.60	1.30
CI	0.44	0.50	0.58	0.70	0.87	1.17

It would be fortunate if that was all there was to it, but alas not. What makes it near impossible for anything to be definitive in photography is flare. Flare is variable. The average value of flare changes with the luminance range of the scene. The value of flare tends to increase as with the luminance range increase. In general, the value of flare changes by one-third stop (0.10) per one stop change in the luminance range. Taking this into consideration, the following model can be called the variable flare model.

Variable Flare Model – LER 1.05						
Dev	- 2	- 1	N	+1	+2	+3
LSLR	2.80	2.50	2.20	1.90	1.60	1.30
Flare	0.60	0.50	0.40	0.30	0.20	0.10
CI	0.48	0.53	0.58	0.66	0.75	0.88

The aim contrast for normal remains the same in both models, but the aims increasingly diverge as you head outward. Between the two the fixed flare model requires greater pushes and pulls for the extreme ranges. In fact, a +3 in the variable flare model is the same as a +2 for the fixed flare model. This is a significant difference, and can be better illustrated in graph form (Graph 4).

Depending on your perspective, it is possible, with the fixed flare model, to under process negatives from scenes with a longer luminance range and over process those from shorter luminance ranges; and the variable flare model does just the opposite. So, which method works best? We must consideration consider which method most consistently represents reality, isn't unforgiving of miscalculations, too rigid, or too complex.

Knowing that eighty percent of flare originates with the subject and the level of flare can vary depending on the distribution of tones within scenes of the same luminance lays open the question of to the level of precision necessary. Can the inconsistencies of each scene's level of flare compensate for the any discrepancies in the density ranges of negatives created using either model? Will the discrepancies be small enough that a slight adjustment in the paper grade won't fix? Yes, sometimes, and this is one of the saving graces of photography. It isn't necessary to nail an exact negative density range in order to produce a quality print. Flare makes it virtually impossible anyway. Over the ranges most often encountered, both the fixed and variable flare method produce similar results well within the compensating influence of flare. It's the more extremes that are of concern, especially in the pushes.

The +2 fixed flare equals a +3 variable flare, and the aim gradient for a +3 fixed flare approximately equals a +4 for variable flare. Can flare vary enough at these shorter luminance ranges to compensate for the full stop difference between the two models? As flare cannot equal zero and the average flare value for +2 is 0.20 and +3 is 0.10, it's questionable, especially at +3. A possible solution if you opt for the fixed flare model the insurance of achieving adequate development and the resulting negative has excessive contrast, is to print the negative on a lower grade paper, but many find the loss of local contrast undesirable.

Once again, some insight and a possible solution can be found by turning to Lyod Jones. Jones found a few exceptions to the DR / LER criteria, "for the soft papers, the density scales of the negative (DR) should in most cases exceed the sensitometric exposure scale of the paper (LER), whereas, for the hard papers, the density scales of the negatives should in most cases be less than the sensitometric exposure scale of the paper (LER)." In other words, it's not only acceptable, but preferable to have a slightly flatter negative for contrasty scenes and a slightly contrastier negative for flatter scenes.

That scenario points toward the variable flare model; however, while it doesn't have the potential problem of over development in the extreme pushes, there is a question about the degree of the pulls. The -2 variable flare is very close to the fixed flare -1. Flare is much more variable with higher luminance ranges. It's possible to be stuck once again with a negative requiring a flatter paper with the accompanying loss of local contrast. There is another option.

Why not approach the problem from a Goldilocks mindset and split the difference between the two models (Graph 4)? It's a flare model that's not too hard and not too soft. It adheres to Jones conditions of Jones' criteria exceptions. It's practical.

Practical Flare Model – LER 1.05					
Dev	- 2	- 1	N	+1	+2	+3
LSLR	2.80	2.50	2.20	1.90	1.60	1.30
CI	0.46	0.51	0.58	0.68	0.81	1.02

The fixed flare model has the capability to produce extreme results, and the variable flare model, may not take the processing far enough. The practical model compensates for both of these disadvantages with a slight safety factor. While nothing is definite when flare is involved, and all three models are capable of producing quality negatives, the practical flare model has the potential to produce manageable negatives over a broad range of conditions with minimal printing adjustments.

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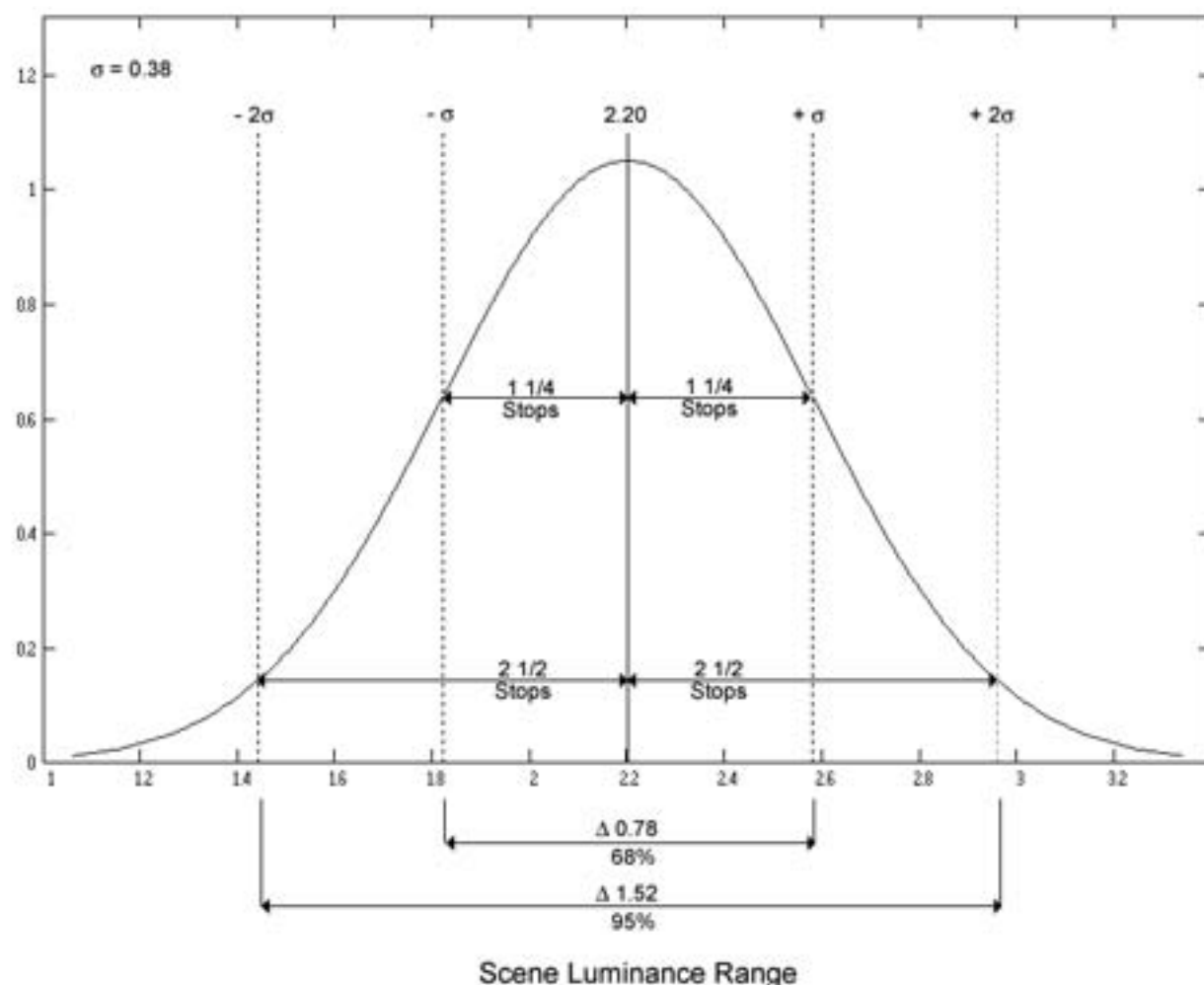
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for photography (sensitometry)- black-and-white continuous-tone papers- determination of ISO speed and range for printing, ANSI/ISO 6846 – 1983.

Developmental Model Comparison Table

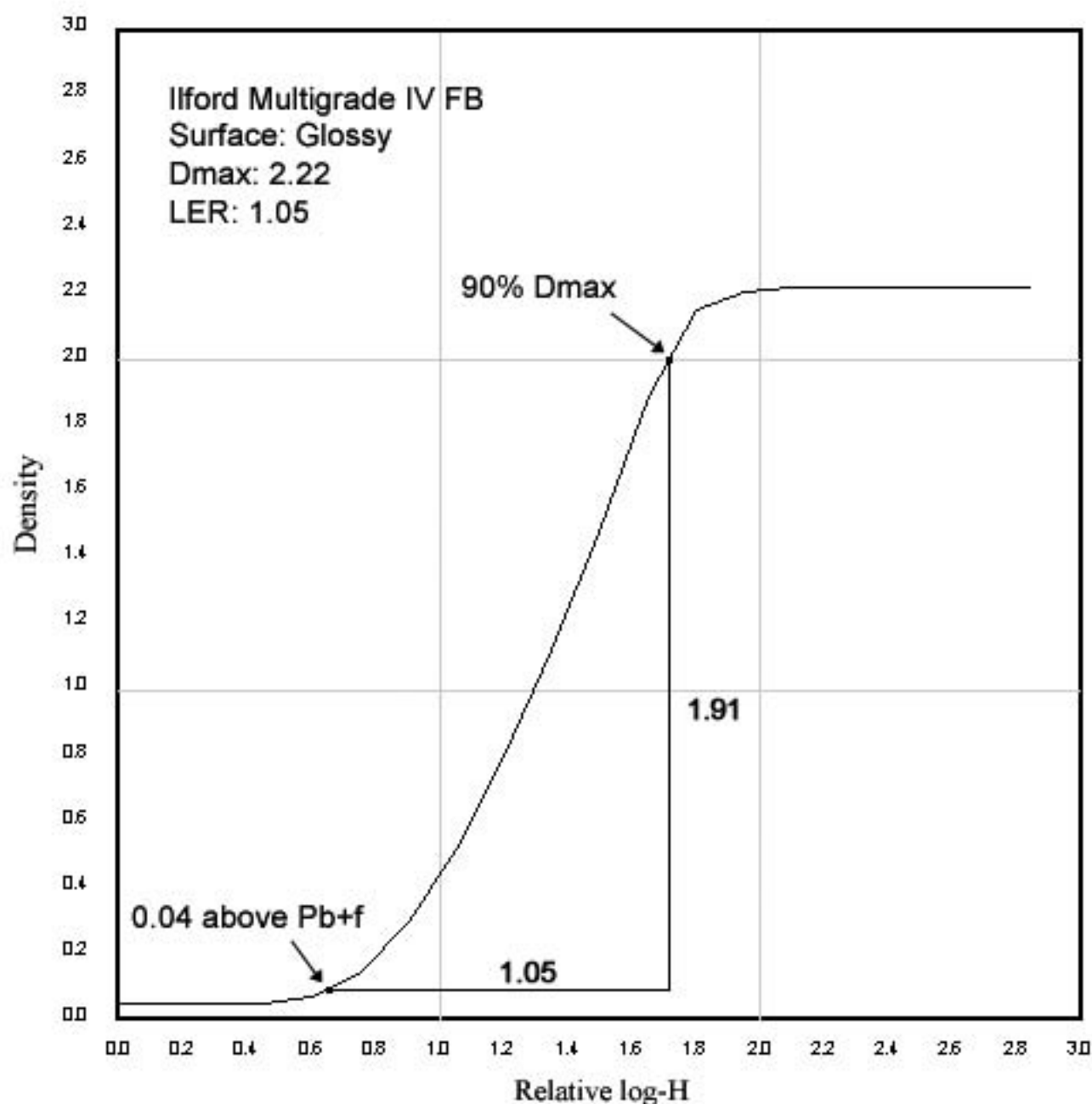| Dev	LSLR	No Flare	Fixed Flare	Variable Flare	Practical Flare Method
-2	2.80	0.38	0.44	0.48	0.46
-1	2.50	0.42	0.50	0.53	0.51
N	2.20	0.48	0.58	0.58	0.58
+1	1.90	0.55	0.70	0.66	0.68
+2	1.60	0.66	0.87	0.75	0.81
+3	1.30	0.81	1.17	0.88	1.02

Graph 1

Graph 1.
Normal distribution curve for scene luminance ranges. Loyd A. Jones found the average luminance range of exterior scenes to be 1:160 (2.2 log units) with a standard divination of 0.38. This means that 68% of the sample population (± 1σ) falls within a ± 1¼ stop luminance range from the average, while 95% falls within a ± 2½ stop range (2σ). The luminance range of the scenes tested are from a minimum 1:27 (1.43 log units) to a maximum 1:750 (2.88 log units).
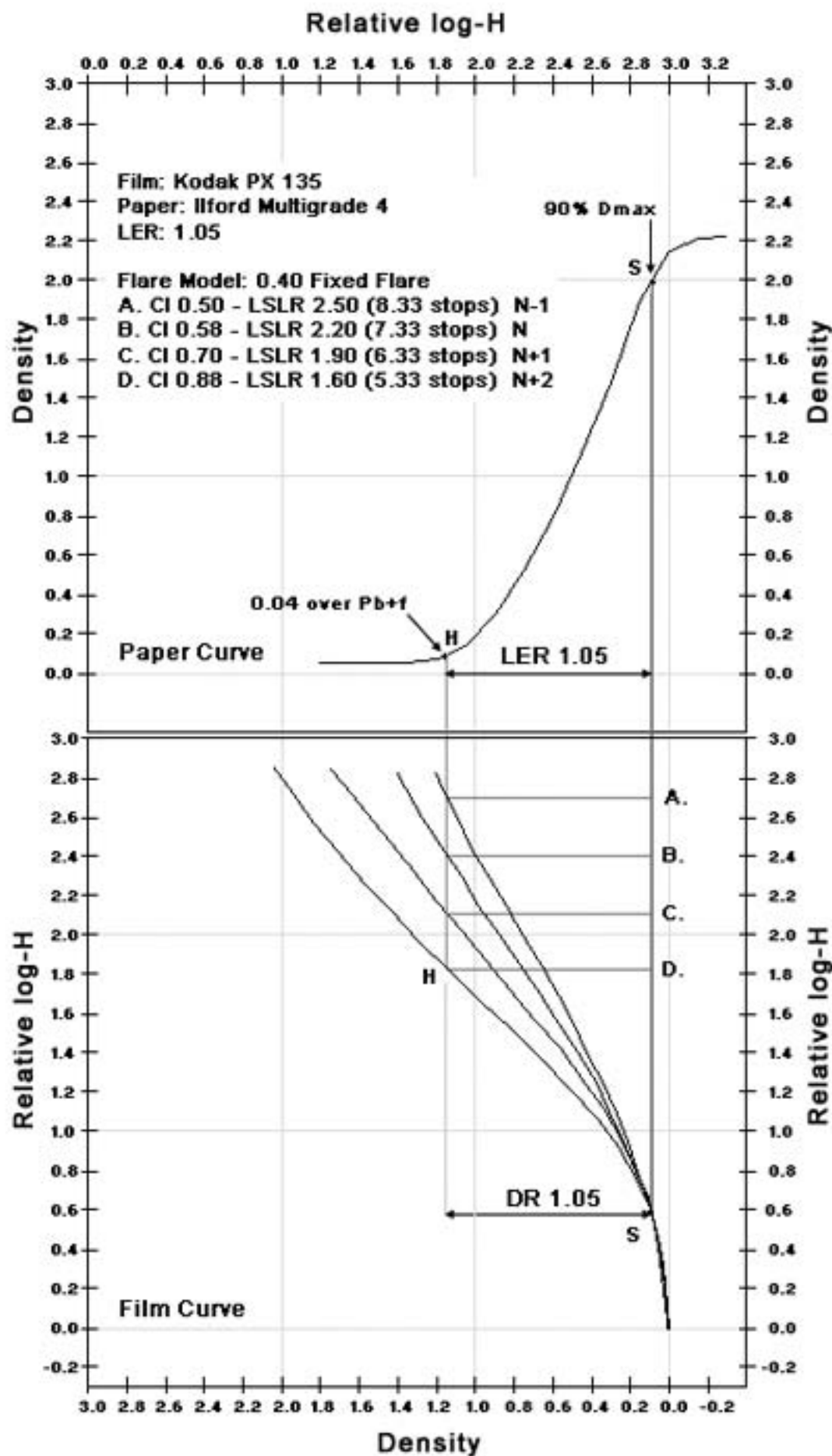
Graph 2

Graph 2.
The paper's log exposure range (LER), is the log-H difference between a point 0.04 density units over paper-base-plus-fog and a point at 90% of the papers Dmax. In the above example the paper has a LER of 1.05.

Graph 3

Relative log-H

Film: Kodak PX 135
Paper: Ilford Multigrade 4
LER: 1.05

Flare Model: 0.40 Fixed Flare
A. CI 0.50 – LSLR 2.50 (8.33 stops) N-1
B. CI 0.58 – LSLR 2.20 (7.33 stops) N
C. CI 0.70 – LSLR 1.90 (6.33 stops) N+1
D. CI 0.88 – LSLR 1.60 (5.33 stops) N+2

90% Dmax

0.04 over Pb+f

Paper Curve

LER 1.05

Density

Film Curve

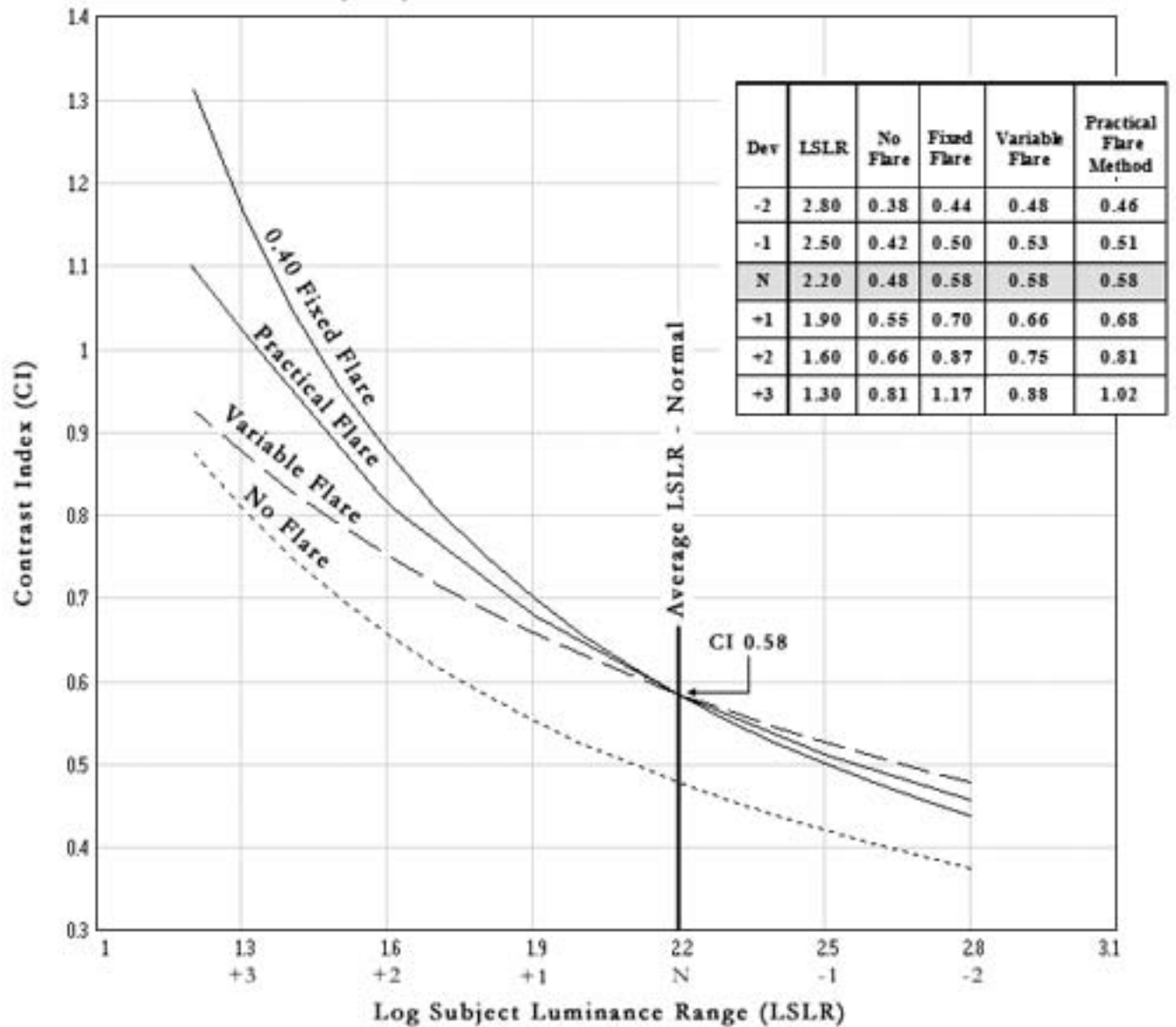DR 1.05

Relative log-H

Density

Graph 3.
This is an example using Kodak's Plus-X film and Ilford's Multigrade paper of the fixed flare model of development. Film contrast is adjusted for differences in the scene's luminance range to maintain a consistent film density range which matches the paper of choice.

Graph 4

Comparison of Flare Methods on Developmental Model
Fixed Flare (0.40), No Flare, Variable Flare, and Practicial Flare

Dev	LSLR	No Flare	Fixed Flare	Variable Flare	Practical Flare Method
-2	2.80	0.38	0.44	0.48	0.46
-1	2.50	0.42	0.50	0.53	0.51
N	2.20	0.48	0.58	0.58	0.58
+1	1.90	0.55	0.70	0.66	0.68
+2	1.60	0.66	0.87	0.75	0.81
+3	1.30	0.81	1.17	0.88	1.02

Graph 4.
Above compares three different developmental models incorporating different values for flare, and a no flare model as a base reference. All three flare models have the same CI 0.56 for normal.