Introduction to Development

Measuring, controlling and correcting film contrast

by Ralph W. Lambrecht

Film development is the final step in securing a quality negative. Unlike print processing, we rarely get the opportunity to repeat film exposure and development, if the results are below expectations. In order to prevent disappointment, we need to control film processing tightly. Otherwise, fading moments could be lost forever. Once film exposure and development is mastered, formerly unavailable manipulation possibilities allow us to control the most challenging lighting conditions in combination with the Zone System. Many photographers value the negative far higher than a print, given the fact that not just multiple copies, but in addition, multiple interpretations of the same scene are possible from just one negative. The basic chemical process is nearly identical to paper development, which was covered in some detail in 'Archival Processing', but a comprehensive understanding is important enough to warrant an additional, brief overview.

Film Processing in General

The light reaching the film during exposure has left a modified electrical charge within the light sensitive silver halides of the emulsion. This change is invisible to the human eye, and therefore, leaves only a so-called 'latent image', but it has prepared the emulsion to be responsive to developer chemicals. These chemicals convert the exposed silver halides to metallic silver, but unexposed silver halides remain unchanged. Highlight areas with elevated exposure levels develop more metallic silver than shadow areas, where exposure was low. Consequently, highlight areas have higher density than shadows, and a negative image can be made visible on the film through the action of the developer. For this negative to be of practical use, the remaining and still light sensitive silver halides must be removed without affecting the metallic silver image. This is the essential function of the fixer, which is

	time [min]	film processing	comments
Soak	3 - 5	Optional water soak at processing temperature.	A water soak prior to development brings processing tank, spiral and film to operating temperature. It also supports even development with short processing times.
Develop	4 - 16	Develop in inversion tank at constant agitation for the first minute, then give 3 - 5 inversions every 30 seconds for the first 10 minutes and once a minute thereafter. Alternatively, develop in film processor with constant agitation. Control the developer temperature within 1° C and use the developer one-time only or track developer activity for consistant development.	After filling with developer, tap tank bottom against a solid surface to dislodge any air bubbles. Development time is dictated by the negative density required for the highlights and varies with film, developer, processing temperature, rate of agitation and water quality. Supplier recomendations can serve as a starting point, but precise development times must be obtained through individual film testing. Times below 4 minutes can cause uneven development, but negative fog density increases with development time. A consistent regime is important for consistent results. Only the exposed portion of the original silver halide emulsion is reduced to metallic silver during the development of the negative. The remaining, unexposed and still insoluble portion of the silver halide impairs both the immediate usefulness of the negative and its permanence, and hence must be removed.
Stop	0.5 - 1	Use at half the supplier recommended strength for paper and agitate constantly. Relax temperature control to be within 2° C of developer temperature until wash.	The stop bath is a dilute solution of acetic or citirc acids. It neutralizes the alkaline developer quickly and brings development to a complete stop. However, the formation of unwanted gas bubbles in the emulsion is possible with some unusual film developers (carbonate). This is prevented with a preceding water rinse.
1st Fix	2 - 5	Use sodium or ammonium thiosulfate fixers without hardener at film strength. Agitate constantly or every 30 seconds in inversion tank. Use the shorter time for conventional films and rapid fixers and the longer time for modern T/grain emulsions or sodium thiosulfate fixers. Monitor silver thiosulfate levels of 1st Fix to be below 3g/l, or use fresh fixer every time. Always use fresh fixer for 2nd Fix.	In the fixing process, residual silver halide is converted to silver thiosulfate without damaging the metallic silver of the image. The first fixing bath does most of the work, but it is quickly contaminated by the now soluble silver thiosulfate and its complexes. Soon the entire chain of complex chemical reactions can not be completed sucessfully and the capacity limit of the first fixing bath is reached. A fresh second bath ensures that all silver halides and any remaining silver thiosulfate complexes are rendered soluble. Fixing time must be long enough to render all residual silver halides soluble, but extended fixing times are not as critical as with papers. The conventional test to find the appropriate time for any film/fixer combination in question is conducted with a sample piece of film, which is fixed until the film clears and the clearing time is doubled or tripled for safety.
2nd Fix	2 - 5		
Rinse	1	Wash briefly to remove excess fixer and to prolong washing aid life.	Residual fixer contaminates the washing aid and reduces its effectiveness. This step removes enough fixer to increase washing aid capacity.
Washing Aid	2	Dilute according to supplier recommendation and agitate regularly.	This process step is highly recommended for film processing. It makes residual fixer and its by-products more soluable and reduces final washing time significantly.
Wash	10	Regulate the water flow to secure a complete water exchange 4 - 6 times per minute, and relax the temperature control to be within 3° C of developer temperature. Drain entire tank every 2 1/2 minutes.	The fixed neagtive contains considerable amounts of fixer together with small, but not negligible, amounts of soluble silver thiosulfate complexes. The purpose of washing is to reduce these chemicals to miniscule archival levels and thereby significantly improve the stability of the silver image. Film longevity is inversely proportional to the residual fixer in the film. However, traces of residual fixer may actually be helpful in protecting the image. Dark storage will significantly increase longevity.
Drying Aid	1	Use a drying aid as directed or use a mixture of alcohol and distilled water (1+4).	Using distilled or deionized water will leave a clear film base without intolerable water marks. Replacing some water with more readily evaporating alcohol will speed up drying.

fig.1 Your negatives are valuable, and maximum permanence is achieved if these processing recommendations are considered.

available either as sodium or ammonium thiosulfate. The fixer converts unexposed silver halide to soluble silver thiosulfate, ensuring that it is washed from the emulsion. The metallic silver, creating the negative image, remains. Fig.1 shows our recommendation for a complete film processing sequence, which is also a reflection of our current developing technique.

Developers and Water

The variety of film developers available is bewildering, and writing about different developers with all their advantages or special applications has filled several books already, 'The Darkroom Cookbook' by Steve Anchell is full of useful recipes, and is my personal favorite. The search for a miracle potion is probably as old as photography itself, and listening to advertising claims or enthusiastic darkroom alchemists, is not about to end soon. However, I would like to pass along a piece of advice, given to me by C. J. Elfont, a creative photographer and author himself, which has served me well over the past years. 'Pick one film, one developer, one paper and work them over and over again, until you have a true feeling for how they work individually and in combination with each other.' This may sound a bit pragmatic, but it is good advice, and if it makes you feel too limited, try two each. The point is that an arsenal of too many material alternatives is often just an impatient response to disappointing initial attempts or immature and inconsistent technique. Unless you thrive on endless trial and error techniques, or enjoy experimentation with different materials in general, it is far better to improve craftsmanship and final results with repeated practice and meticulous record keeping for any given combination of proven materials, rather than blaming it possibly on the wrong material characteristics. There are no miracle potions.

Nevertheless, film developer is a most critical element in film processing. My recommendation is to begin with one of the prepackaged standard film developers like ID11, D76 or Xtol and stick to a supplier proposed dilution. This offers an appropriate compromise between sharpness, grain and film speed for standard pictorial photography. Unless you have reason to doubt your municipal water quality or consistency, you should be able to use it with any developer. However, distilled or deionized water is an alternative, providing additional consistency, especially if you develop film at different locations. Filters are available to clean tap water from physical contaminants for the remaining processing steps, but research by Gerald Levenson of Kodak as far back as 1967 and recently by Martin Reed of Silverprint suggests avoiding water softeners as they reduce washing efficiency in papers.

Characteristic Curve, Contrast and Average Gradient

Film characteristic curves were briefly introduced in 'Introduction to Sensitometry', and we use them to illustrate material and processing influences on tonal reproduction throughout the book. They are a convenient way to illustrate the relationship between exposure and developed film density, but it is also helpful to have a quantitative method to evaluate and compare characteristic curves. Over the years, many methods have been proposed, mainly for the purpose of defining and measuring film speed. Several have been found to be inadequate or not representative of modern materials and have since been abandoned. The slightly different methods used by Agfa, Ilford, Kodak, and the current ISO standard are all based on the same 'average gradient' principle explained below.

Negative contrast is defined as negative density increase per unit of exposure. Fig.2 shows how the same exposure range can differ in negative density increase according to the local shape of the characteristic curve. In this example, toe and shoulder of the curve have a relatively low increase in density signified by a gentle slope or gradient, and the gradient is steepest in the midsection of the curve. These local gradients are a direct measure of local negative contrast, but a set of multiple numbers would be required to characterize an entire curve.

The average gradient method on the other hand, identifies just two points on the characteristic curve to represent significant shadow and highlight detail, as seen in fig.3. Then a straight line, connecting these two points, is evaluated on behalf of the entire characteristic curve, while fulfilling its function of averaging all local gradients between shadows and highlights. The slope of this line is the average gradient and a direct indicator of the film's overall contrast. It can be calculated from the ratio a/b, which is the ratio of negative density range over log exposure. The average gradient method is universally accepted, but as we will see in the following chapters, the consequences of selecting the endpoints are rather

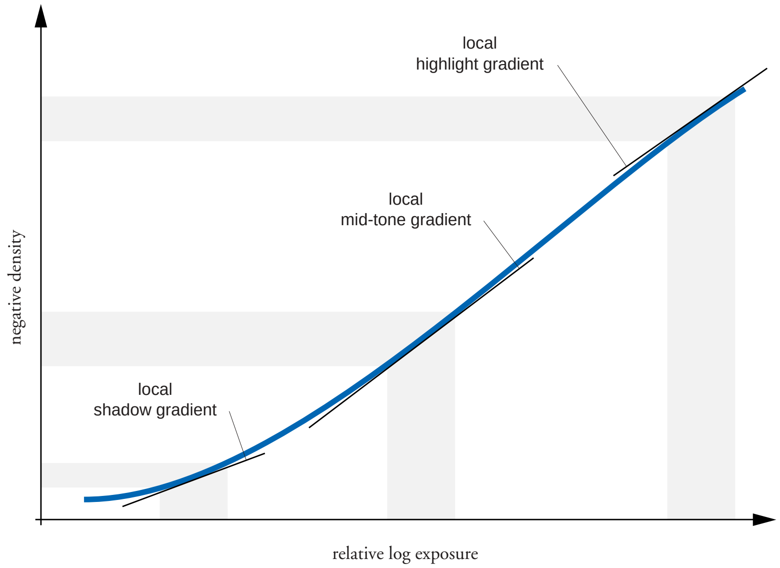

fig.2 Negative contrast is defined as negative density increase per unit of exposure. The same exposure range can differ in negative density increase according to the local shape of the characteristic curve. The local slope, or gradient, is a direct measure of local negative contrast.

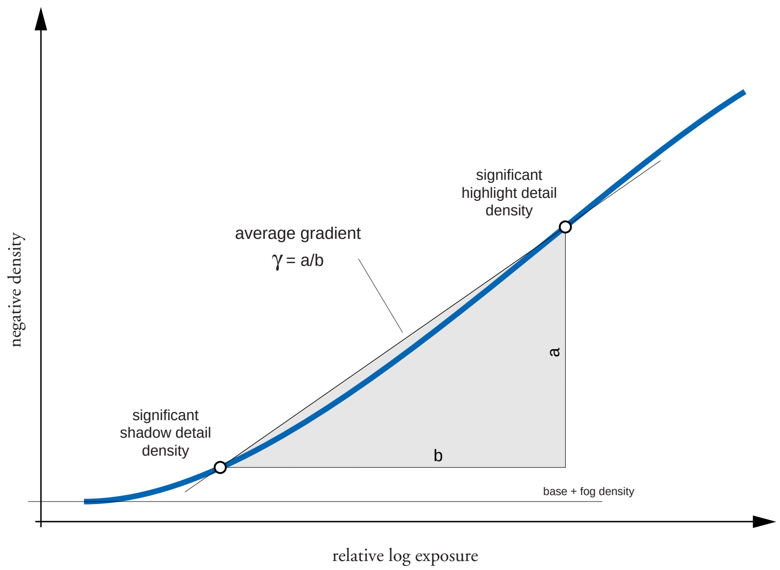

fig.3 The average gradient method identifies two points on the characteristic curve representing significant shadow and highlight detail. A straight line connecting the points is evaluated on behalf of the entire characteristic curve.

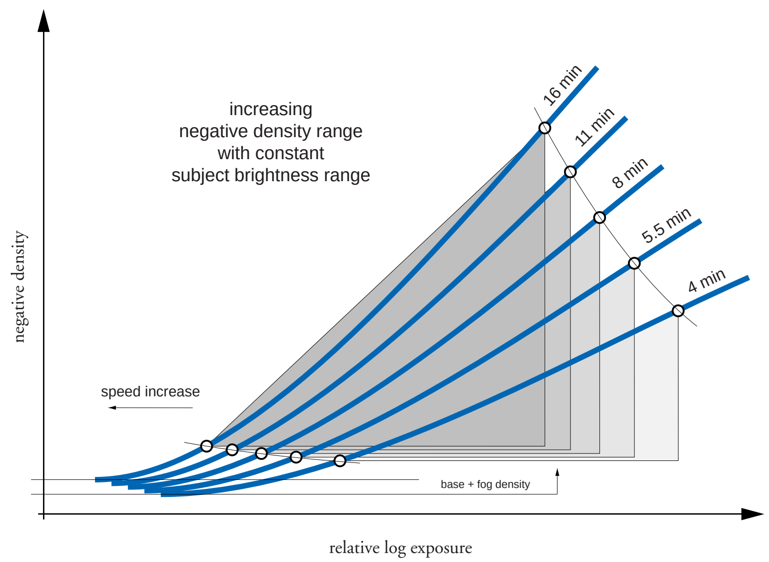

fig.4 Shadow densities change only marginally when development times are altered, but highlight densities change significantly. The average gradient and the negative density range increase with development time, when the subject brightness range is kept constant.

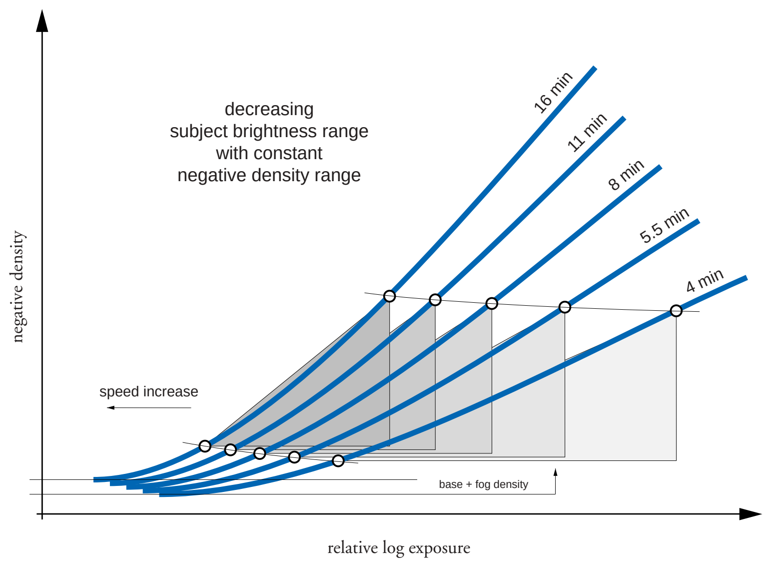

fig.5 The average gradient increases and the subject brightness range decrease with development time, when the negative density range is kept constant.

critical and different intentions have always been a source of heated discussion among manufacturers, standardization committees and practical photographers. At the end of the day, it all depends on the desired outcome and in 'Creating a Standard' we define these endpoints to our specifications in compliance with the rest of this book and a practical approach to the Zone System in mind.

Time, Temperature and Agitation

Exposure is largely responsible for negative density, but film development controls the difference between shadow and highlight density and therefore, the negative contrast. The main variables are time, temperature and agitation, and controlling development precisely requires that these variables be controlled equally well. Data sheets provide starting points for developing times and film speeds, but complete control can only be achieved through individual film testing, as described in detail through following chapters.

Fig.4 shows how the development time affects the characteristic curve when all other variables are kept constant. With increased development time, all film areas, including the unexposed base, increase in negative density, but at considerably different rates. The shadow densities increase only marginally, even when development times are quadrupled, where simultaneously, highlight densities increase significantly. This effect is most useful to the Zone System practitioner, but can be evaluated from two different aspects.

First, in fig.4 the subject brightness range is kept constant by fixing the relative log exposure difference between shadow and highlight points. We can see how the average gradient and the negative density range increase over development time. Second, in fig.5 the negative density range is kept constant by fixing the negative density difference between shadow and highlight points. This way, we can see how the average gradient increases, but the subject brightness range decreases with development time.

The last observation is the key to the Zone System's control of the subject brightness range by accordingly adjusted film development time. The negative density range is kept constant, allowing to print many lighting conditions on a single grade of paper with ease. Other paper grades are not used to compensate for difficult to print negative densities anymore, but are left for creative image interpretation.

One important side effect becomes apparent with both figures. The shadow points, having a constant density above base and fog density, require less exposure with increasing development time, or in other words, film speed increases with development. Consequently, film exposure controls shadow density and development controls highlight density, but film speed has to be adjusted, when development is altered.

The standard developing temperature for film is 20°C. Photographers living in warmer climates often find it difficult to develop film at this temperature and may choose 24°C as a viable alternative. However, development temperature is a significant process variable, and film developing tests must be repeated for different temperatures and then tightly controlled within 1°C. Do not underestimate the cooling effect of ambient darkroom temperatures in the winter or the warming effect of your own hands on the inversion tank. The temperature is less critical for any processing step after development. The above tolerance can be doubled and even tripled for the final wash, but sudden temperature changes must be avoided, otherwise reticulation, a wrinkling of the gelatin emulsion, may occur.

Agitation affects the rate of development, as it distributes the developer to all areas of the film evenly, as soon as it makes contact. While reducing the silver halides to metallic silver, the developer in immediate contact with the emulsion becomes exhausted and must be replaced through agitation. Agitation also supports the removal of bromide, a development by-product, which otherwise inhibits development locally and causes 'bromide steaks'.

A consistent agitation technique is required for uniform film development. You can use the recommendations in fig.1 as a starting point or test for proper agitation yourself. Expose an entire negative to a uniform surface placed on Zone VI and develop for the normal time, but using different agitation methods. Increased density along the edges indicates excessive agitation, and uneven or mottled negatives indicate a lack of agitation.

Normal, Contraction and Expansion Development

Normal development creates a negative of normal average gradient and contrast. A negative is considered to have normal contrast if it prints with ease on a grade 2 paper. An enlarger with a diffused light source fulfills the above condition if the negative has an average gradient of around 0.57. A condenser enlarger requires a lower average gradient to produce an identical print on the same grade of paper. We will discuss other practical average gradient targets in detail in the next two chapters, and a table with typical negative densities for all zones is given in 'Zone Reproduction'.

We saw in fig.5 how the intentional alteration of film development time and average gradient can provide control over the subject brightness range, while maintaining a constant negative density range, which keeps print making from becoming a chore. However, if the alteration is unintentional, then density control becomes a processing error. Film manufacturers have worked hard to make modern films more forgiving to these 'processing errors' and have, in turn, taken some of the tonal control away from Zone System practitioners. Nevertheless, even modern emulsions still provide enough tonal control to tolerate subject brightness ranges from 5 to 10 stops.

In a low-contrast lighting condition, the normal gradient produces a flat negative with too small of a density difference between shadows and highlights, and the average gradient must be increased to print well on normal paper. In a high-contrast lighting

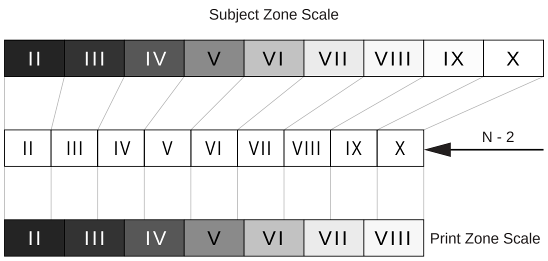

fig.6 In this example, the highlights of a high-contrast scene metered two zones above visualization. N-2 contraction development is used, limiting the highlight densities to print well on grade 2 paper.

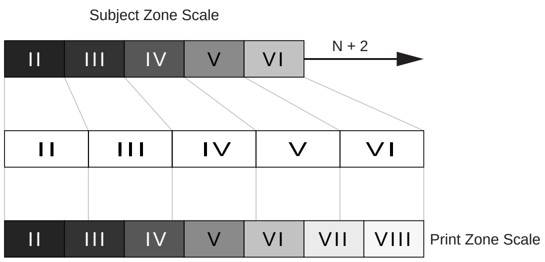

fig.7 In this example, the highlights of a low-contrast scene metered two zones below visualization. N+2 expansion development is used, elevating the highlight densities to print well on grade 2 paper.

condition, the normal gradient produces a harsh negative with a negative density range too high for normal paper, and the average gradient must be decreased. The desired average gradient can be achieved by either increasing or decreasing the development time, but the appropriate development times must be determined through careful film testing.

In regular Zone System practice, we measure the important shadow values first and then determine appropriate film exposure with that information alone, placing these shadows on the visualized zone. Then we measure the important highlight values and let them 'fall'. If they fall on the visualized highlight zone, then development is normal. If they fall two zones higher,

fig.8a (right) In this high-contrast scene, normal film development was not able to capture the entire subject brightness range and as a result some image detail is lost.

fig.8b (far right) N-2 film development extended the useful subject brightness range by two zones. This reduced negative contrast and avoided loss of image detail.

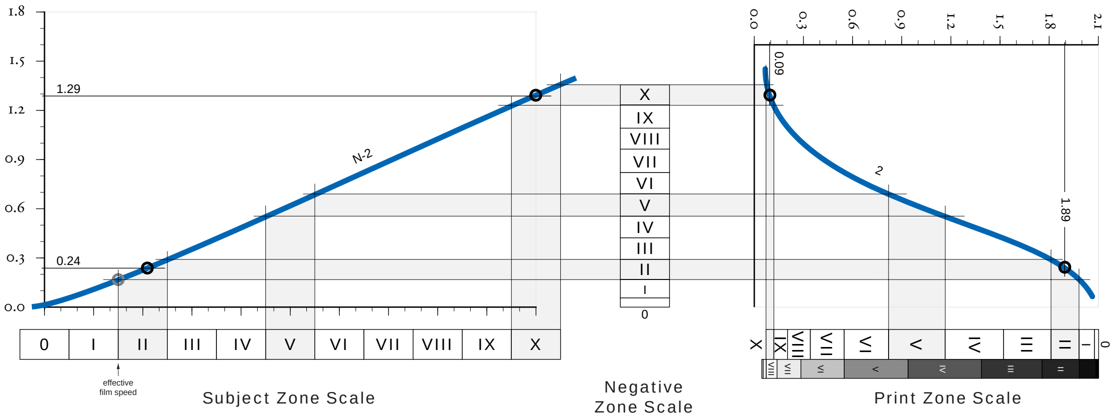

fig.8c N-2 film development is used to increase the subject brightness range captured within the normal negative density range.

then contraction development of N-2 must be used to keep the highlight from becoming to dense. On the other hand, if they fall two zones lower, then expansion development of N+2 must be used to elevate the highlight densities. Fig.6 and fig.7 illustrate how the tonal values change due to contraction and expansion development respectively.

The main message I want you to take away from the last two chapters is that we use exposure to control the shadow densities of the negative, and we use development control to achieve the appropriate highlight densities. This type of control will create a negative that is easy to print, and it also promotes print manipulation from salvaging technique to creative freedom.

fig.9a (far left) In this low-contrast scene the subject brightness range is small and normal film development will make for a dull print with normal grade paper.

fig.9b (left) N+2 film development elevated highlight densities by two zones, increasing negative and print contrast. The entire negative density range is utilized.

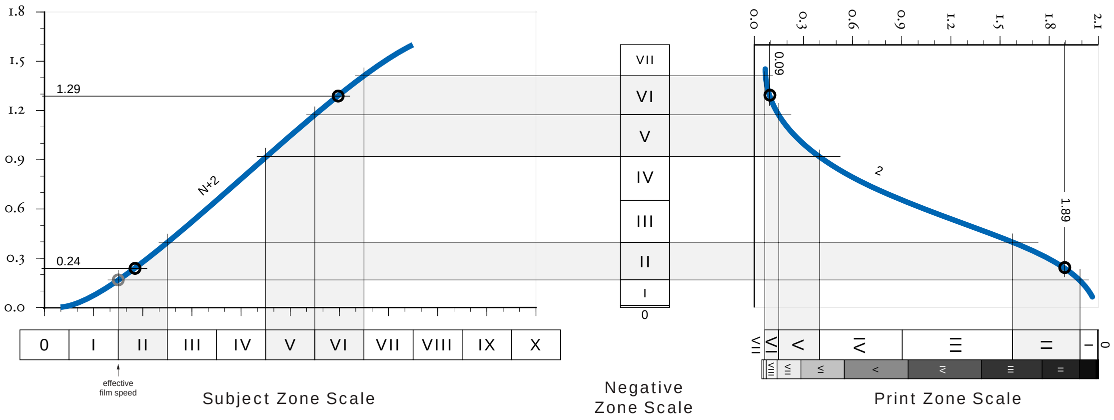

fig.9c N+2 film development is used to decrease the subject brightness range captured within the normal negative density range. Final zone densities depend on the film and paper characteristic curves, but some trends due to film development are clearly visible in fig.8c and here.