A Practical Guide to Film Characteristic Curves

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How can we benefit from looking at the characteristic curve? Can't we modify the shape of the curve during scanning, with dodging and burning or other post processing? Yes, but that's not the point.

The actual shape of the curve can be interesting but the real benefit is that you can quickly determine your film speed and development without a lot of trial and error which can be subjective and misleading. With an objective film curve test you can get the answers you need in just one or two tries.

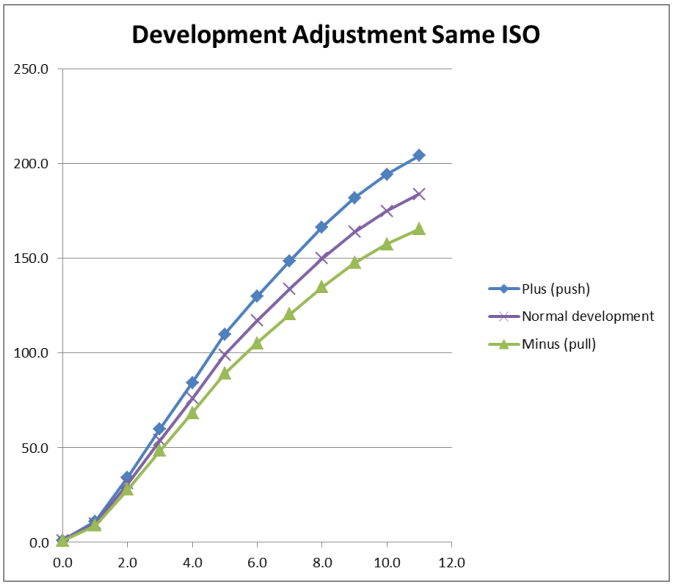
Isn't there already enough information available on the Internet? Yes, and a lot of misinformation like the common suggestion that a proper negative is one that you can place over newsprint and still be able to read through it. You can't even trust your own subjective eyes if you are basing your development on "typical" subjects and lighting conditions.

Background

Film characteristic curves are different for different formats (sizes) of the same emulsion. What might work for medium format will not render the same distribution of tonalities in 35mm and it will be a little different in large format. To understand these differences we need to look to the characteristic curves.

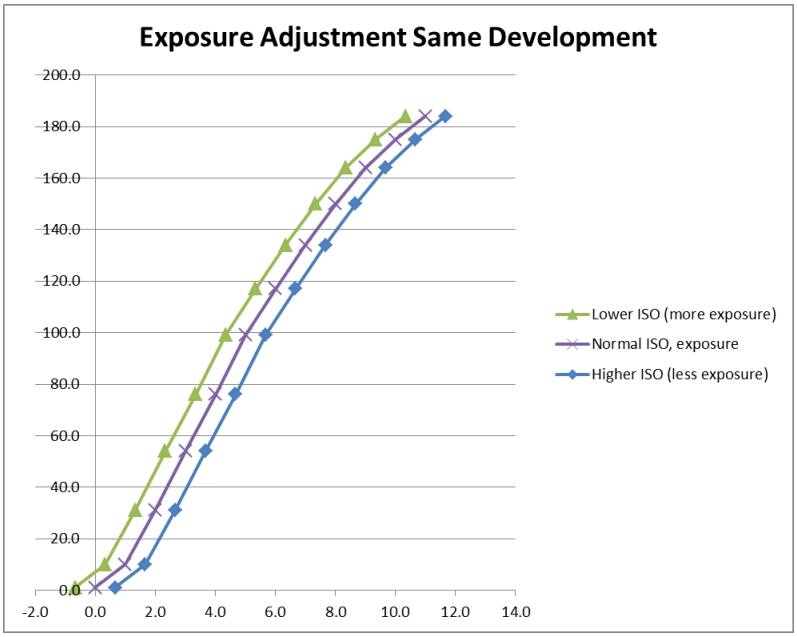
Useful information about film characteristic curves is hard to find. Kodak provides a good bit of information in their data sheets but graphed exposure is labeled as "LOG EXPOSURE (lux-seconds)". Ilford simply calls it "Relative log exposure" which is no better. For it to mean anything to us we need to convert that to exposure levels. Kodak's graphs are designed mainly to illustrate the effect of changing development time on film density. That does not help to compare one film to another. And Kodak's graphs represent *their* results using *their* processing, not yours.

Here is an example of the type of display presented by Kodak but with more meaningful scales:

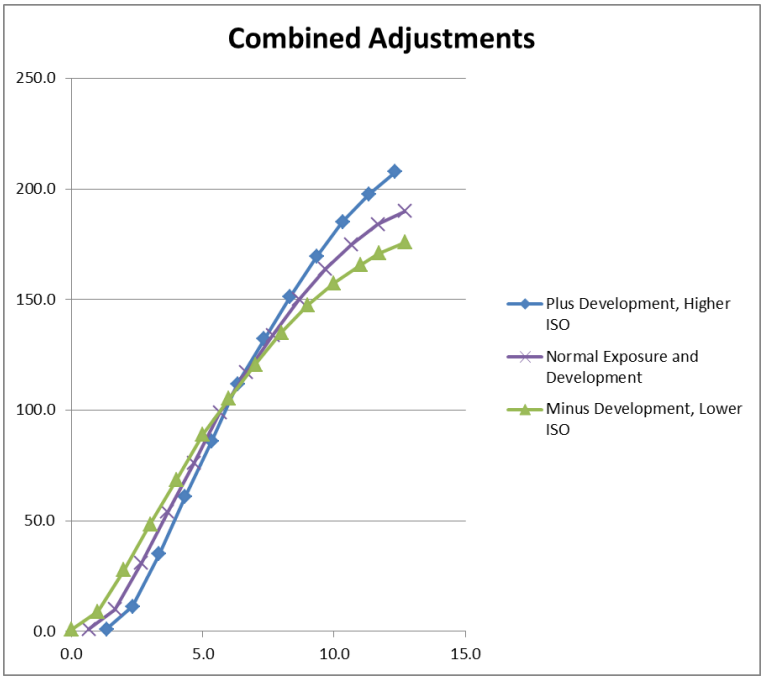


The horizontal scale has been replaced by exposure steps from 0 through 12 with 5 representing middle gray. The vertical scale ranges from 0 to 255 which is how a film scanner (like an Epson flatbed) reports film density. It is still clear that more development, however it is accomplished, affects the higher exposure values (highlights) more than the lower values. It also illustrates the concept of exposing for the shadows and developing for the highlights.

What is not obvious from the graph is the simple effect from increasing or decreasing exposure:

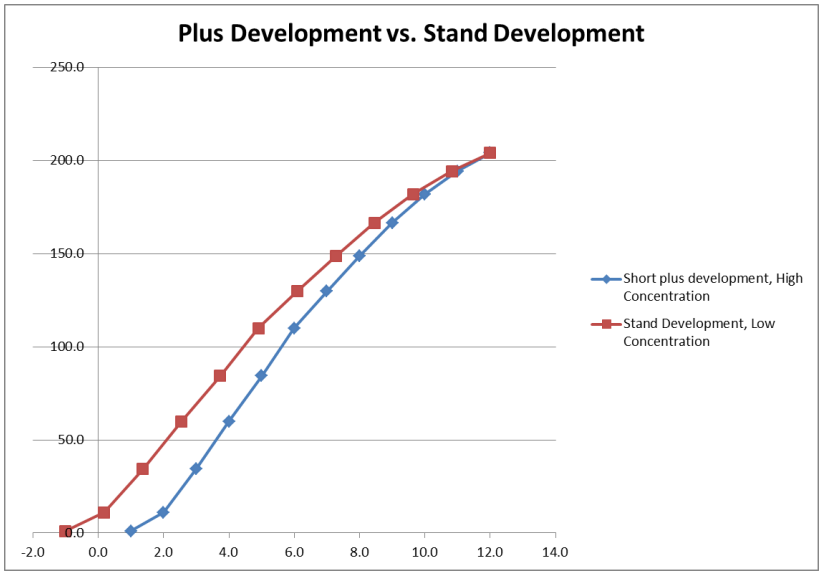


We can also change both the development and exposure while keeping the mid-tone density unchanged:



This is what can be done with push or pull processing to achieve a higher ISO or lower contrast. It may be more relevant than following the principle of exposing for the shadows and developing for the highlights since the photographer might be more interested in mid-tone exposure and contrast than in the shadows or highlights.

Then there is stand development:



It's not easy to achieve but the idea is to get the highlight development to slow down or stop while the shadows continue to develop. The benefit is that you can get additional film speed from the boosted development without the extra contrast. It requires little or no agitation, uses less developer, does not require careful timing or temperature control. The down-side is that it can take one or more hours to complete and the actual developer concentration needs to be measured carefully.

Methodology

If you don't have access to a densitometer, a film scanner will work fine so long as you can preview your scan and measure the density of the developed film. Here is the process I use.

I display a white document on my calibrated computer screen which currently measures EV 9 for ISO 100. I take twelve exposures from 5 stops under to 6 stops over the middle gray reading at the beginning of a 36 exposure roll. I expose the rest of the roll at the ISO being tested.

For an ISO 100 film I use the following manual settings on a 35mm camera with a normal lens, no filter, focused at infinity:

Frame	1	2	3	4	5	6	***7***	8	9	10	11	12
EV	3	4	5	6	7	8	***9***	10	11	12	13	14
Zone*	11	10	9	8	7	6	***5***	4	3	2	1	0
f/	2.8	2.8	2.8	2.8	2.8	2.8	***2.8***	2.8	2.8	4	5.6	8
1/sec	1s	2	4	8	15	30	***60***	125	250	250	250	250

* Exposure zones, not Zone System print zones.

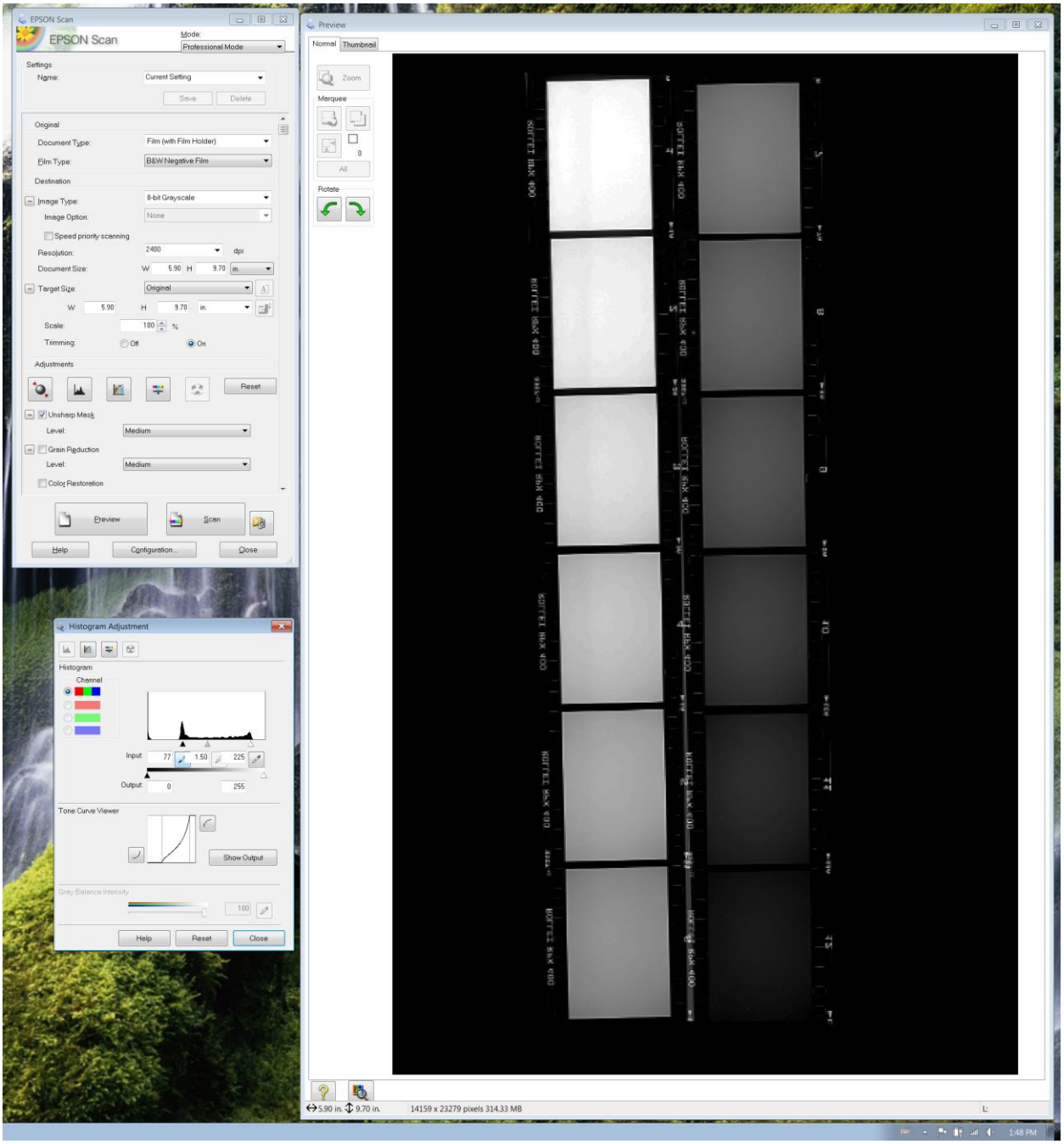
The settings are different for a different ISO and for medium or large format. For ISO 100, EV 9 corresponds to 1/60 se at f/2.8 and that is what the camera's meter or an incident meter treats as middle gray. For small format I make the brightest exposure first so that the last frame, if it is too thin to be seen, can easily be located ahead of the first regular image. For medium format at 6x6 cm the test uses up the roll. I try to avoid the largest aperture of the lens or the fastest shutter speed in case they are not accurate. I test film at even powers of ISO 100 (25, 50, 100, 200, 400, 800) and adjust the results later when I plot them.

I develop small and medium format film using stainless tanks and reels, 4x5 film two sheets at a time in trays. Everything is at room temperature, close to 75°F, about 70% as much development time as 68°F. I use the Massive Dev Chart app on my smart phone to adjust for temperature and to time the session. Agitation is continuous for the first minute and 10 seconds every minute thereafter followed by 30 seconds acid stop bath, 4 minutes Ilford rapid fixer, one minute soak in Perma Wash, 5 minutes of running water wash and 30 seconds soak in Photo Flow.

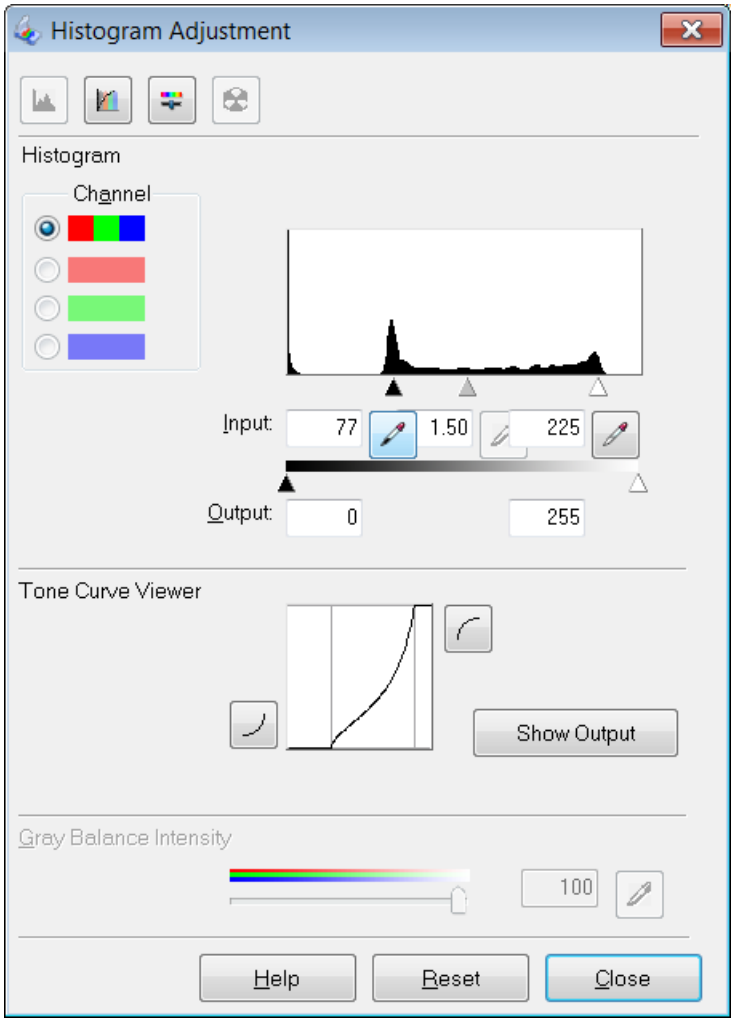
In the small tank, the film and reel are covered with 240ml of solution but the larger tank needs about 450ml. The two tanks use a different amount of concentrate for the same 80 square inches of film. For example, Xtol at 1+2 would use 80+160 in the small tank but 150+300 in the larger tank. For 4x5 films I also use 450ml in a 5x7 tray but two sheets are only about 40 square inches. For these and a number of other reasons, the same emulsion is bound to require a different development time and may result in a different ISO for each format.

Results

The exposures are measured by previewing the film on an Epson V750 and using the black or white probe to get the “density” measurement on a scale of 0-255 from the center of each frame. The FB+fog density is measured along the edge of the film between the sprockets.



The “density” measurements are read from the Histogram Adjustment dialog:

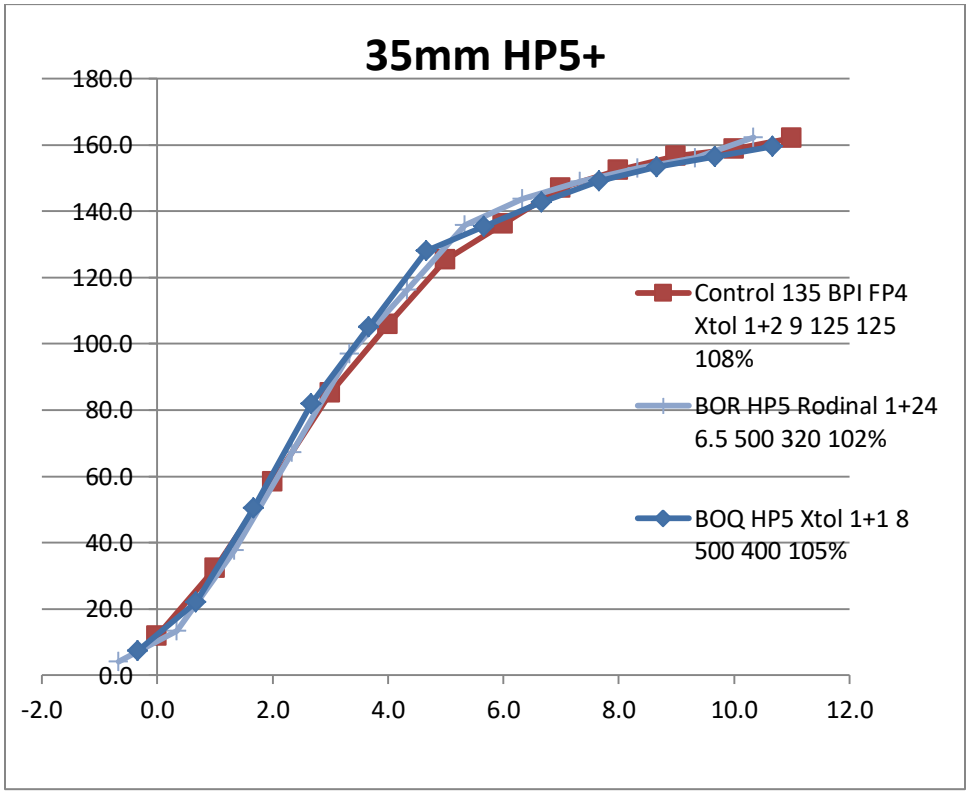


I select the white point eye dropper on the Input row and click on the center of the first frame of the preview. The "density" reading in box next to the eye dropper reads 225. I then select the black point eye dropper and click on the film edge between the sprockets of the preview. The readout is 77 for FB+fog and everything darker than that goes black. I then click on the center of each of the frames with either the black or white eye dropper and record the values in the spreadsheet. The plotting is done in Excel.

Here is a typical tabulation of three films that I tested with an earlier calibration setting of the monitor:

A	B	C	D	E	F	G	H	I	J
Format	135			135			135		
Ref	BPI			BOR			BOQ		
Film	FP4			HP5			HP5		
Developer	Xtol			Rodinal			Xtol		
Dilution	1+2			1+24			1+1		
Minutes	9			6.5			8		
Tested ISO	125			500			500		
Adjusted ISO	125			320			400		
Gain adjment	108%			102%			105%	118	
FB+fog	84			75			79		
0	95	0.0	11.9	79	-0.7	4.1	86	-0.3	7.4
1	114	1.0	32.4	88	0.3	13.3	100	0.7	22.1
2	138	2.0	58.3	112	1.3	37.7	127	1.7	50.4
3	163	3.0	85.3	141	2.3	67.3	157	2.7	81.9
4	182	4.0	105.8	170	3.3	96.9	179	3.7	105
5	200	5.0	125.3	189	4.3	116.3	201	4.7	128.1
6	210	6.0	136.1	208	5.3	135.7	208	5.7	135.5
7	220	7.0	146.9	216	6.3	143.8	215	6.7	142.8
8	225	8.0	152.3	221	7.3	148.9	221	7.7	149.1
9	229	9.0	156.6	225	8.3	153.0	225	8.7	153.3
10	231	10.0	158.8	228	9.3	156.1	228	9.7	156.5
11	234	11.0	162.0	234	10.3	162.2	231	10.7	159.6

And the plot of these three films:



The first five lines of the table are clear but here is more about the others:

Minutes – Adjusted to 75°F
Tested ISO – The above films were tested when the monitor was calibrated to a brighter value so the assumed ISO was 125 and 500 rather than 100 and 400.
Adjusted ISO – For FP4 (B) the adjusted ISO is the same as tested but HP5 (E) needed a 2/3 stop adjustment.
Gain adjustment – An adjustment to the tabulated density values in columns B and E.
FB+fog – The film base plus fog density read from the film edge or between the frames.

Column B contains the values measured for the FP4 test. The plot is based on using values from column C for the x-axis. Since the tested and adjusted ISO for FP4 are the same, the values in column C are the same as the values in column A. The values for column D are used for the y-axis and are calculated by subtracting the FB+fog value and then multiplying the result by the Gain adjustment. For row 11 (line 23 of the spreadsheet) that comes to (234-84)*1.08=162.0: =ROUND((B23-B$11)*B$10,1) where B$11is FB+fog and B$11is the Gain adjustment.

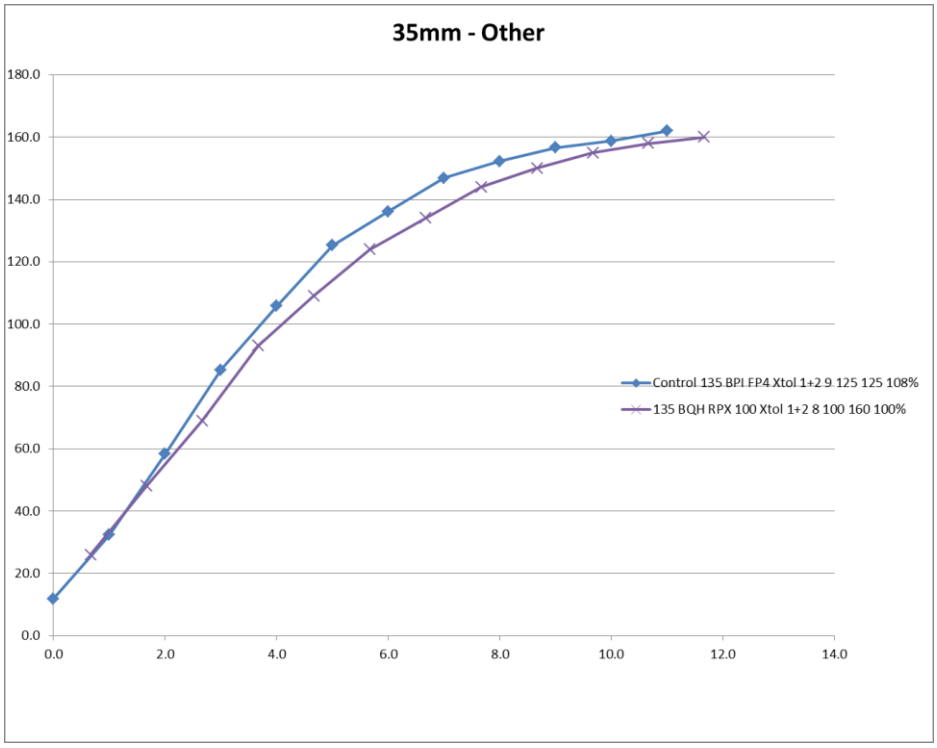
The first HP5 (in Rodinal) curve uses values from column F for the x-axis and G for the y-axis. But for HP5 there is a 2/3 stop difference between the tested and adjusted ISO so the x-axis values in column F show a 2/3 stop reduction, for example a value of 10.3 instead of 11: =$A23+ROUND(3*LOG(H$9/H$8,2),0)/3 where H$9/H$8 is the ratio of the adjusted to the tested ISO. The Y-axis values are calculated the same as the FP4 so row 11 for column G is (234-75)*1.02=162.2.

Columns H, I and J contain the results for HP5 in Xtol 1+1.

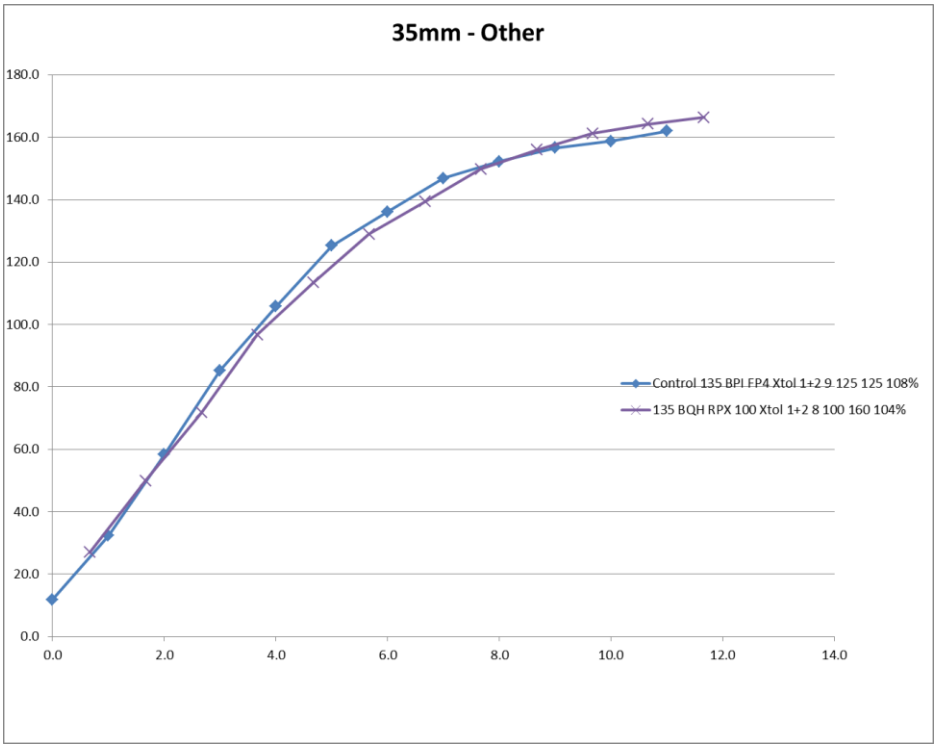
Because I was already familiar with both FP4 and HP5 the development times were already close to optimal – very little gain adjustment was needed. The most significant result was the confirmation of the ISO rating for HP5 in Xtol 1+1 (400) and Rodinal 1+24 (320).

But what about testing an unfamiliar film/ developer combination? I developed a roll of Rollei RPX 100 at ISO 100 in Xtol 1+2 using an educated guess of 8 minutes at 75°F:

The highlights look OK but the left end of the curve shows that the shadows would be overexposed. So I adjusted the ISO to 160 and got the shadows to line up:



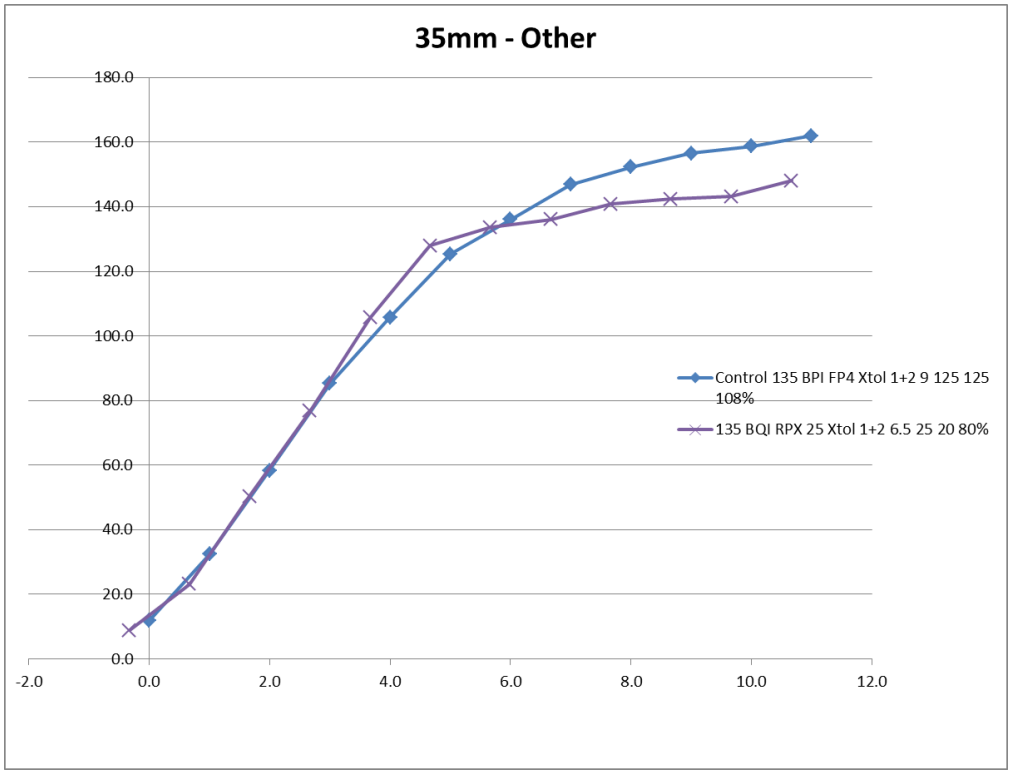
Now the highlights seem underdeveloped so I changed the gain adjustment:



It's not an exact match but it tells me what I needed to know. The film can be used at ISO 160 and developed in Xtol 1+1 for a little more than 8 minutes (8.5?) to get what I want. It took only one roll to figure out the ISO and development time.

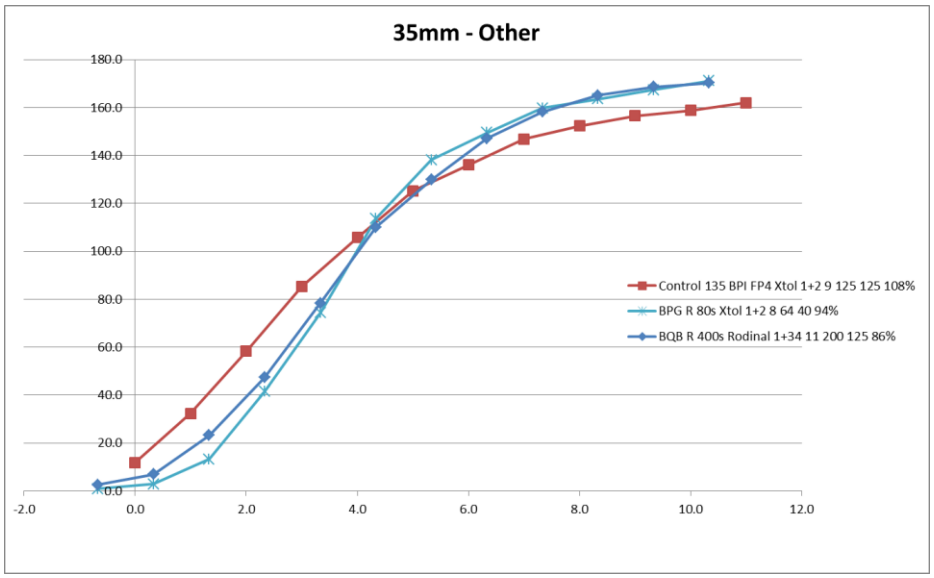
Most of the small format tests display very similar characteristic curves and made it easy to determine the working ISO and development times. I have completed more than sixty tests on other film and developer combinations. It would be overkill to detail all of them here. But there have been a couple of surprises along the way.

The first was Rollei RPX 25:



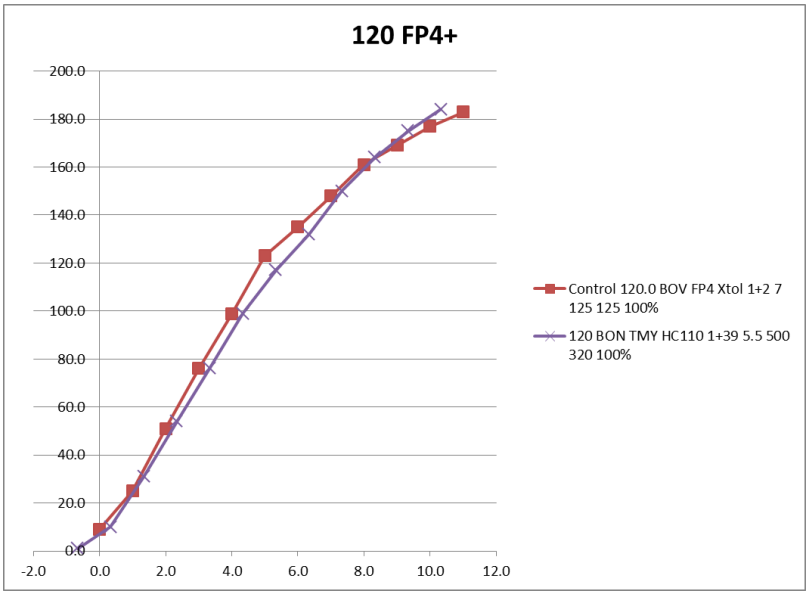
The shape of the curve is peculiar and resembles CMS 20. It looks normal up to middle gray and then the contrast drops abruptly. The same thing happens with different developers and concentrations so I know that it's a characteristic of the film. I can try to match the film to a scene where I want this to happen but the problem with both films is that they are very thin and curly – not worth the trouble.

The second surprise is Rolei Retro 80s and 400s – more promising since they open up some creative possibilities:



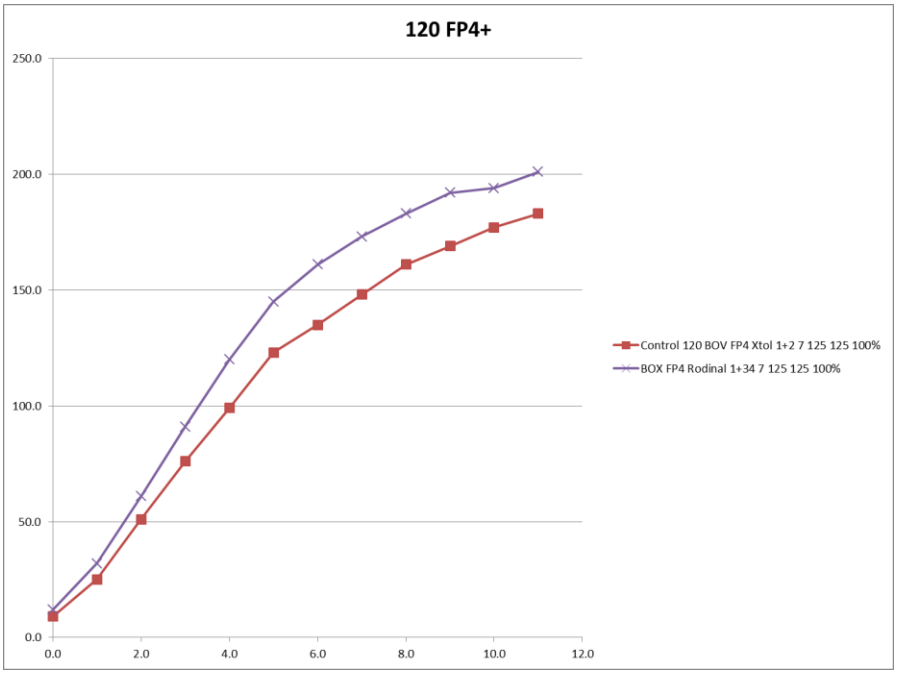
Both of these films have very low FB+fog but the curling is well controlled. They have higher contrast in the mid-tones and lower contrast in the shadows and highlights but the change is gradual and they capture most of the 11 stop range. I ended up rating them at ISO 40 and 125 and the test show that they need more exposure and less development than I gave them initially.

Because of the lower FB+fog, medium and large format films can generally be developed to a higher contrast before running into problems on the high end.

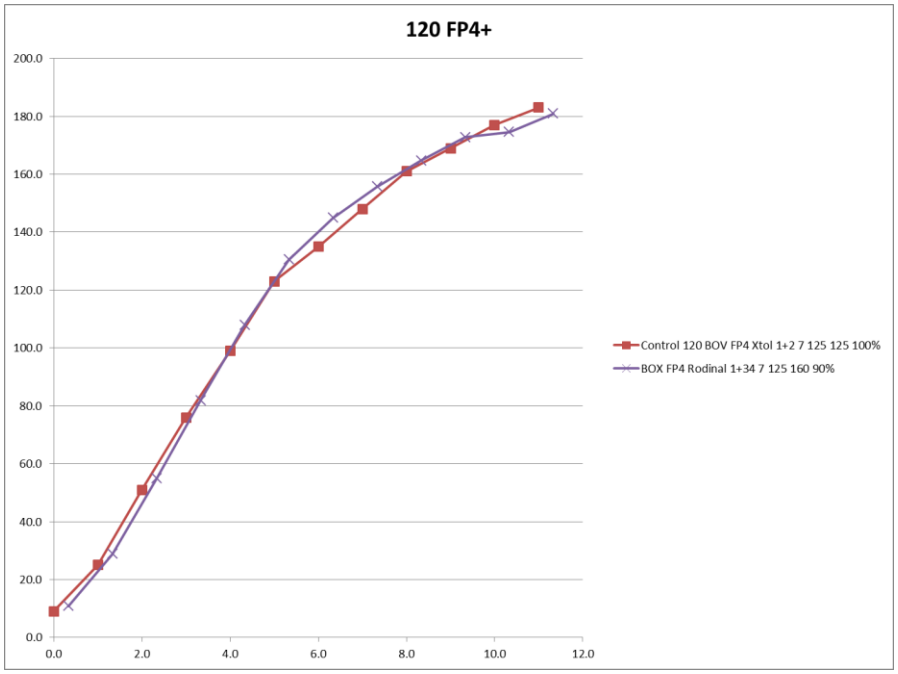


Both of these medium format films show a more linear characteristic curve than their small format versions.

I use the curve for FP4 developed in Xtol 1+1 as the standard (control) to which all other 120 film and developer combinations will be compared. For example, I developed the same film in Rodinal 1+34 and got the following result (unadjusted):



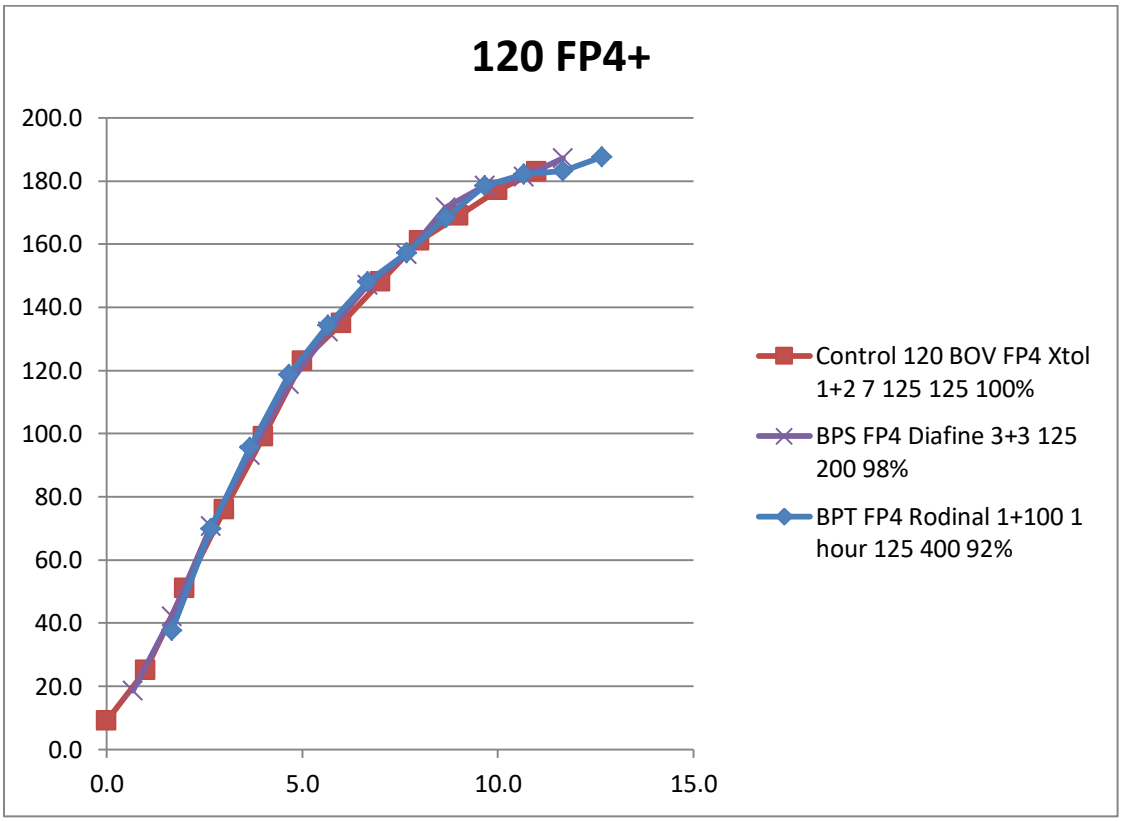
It's not that far off. But to get the same curve as the control an adjustment to both the ISO and development time is appropriate. Using ISO 160 and a gain adjustment of 90% the result looks like this:



A small gain adjustment suggests that a slight change in development time is appropriate. But if the gain adjustment is large then a change in dilution should be the next step.

Compensating or Stand Development

It seems that you cannot actually change the shape of the curve either way. Here is FP4 developed conventionally, with a popular compensating developer and with stand development.



Because of additional development in the shadows, both methods allow you to expose at higher ISO settings (lower exposures). In this case, FP4 can be used at ISO 200 in Diafine or ISO 400 with Rodinal stand development. Each approach may require a change to the scanner gain adjustment or a selection of a softer grade of paper but neither one alters the fundamental shape of the characteristic curve.

This also shows what happens with a scene whose dynamic range (DR) is not very wide, which is quite common. For example, if the DR is only about five stops, your choice of exposure will affect which portion of the curve gets used, the lower straight portion or the higher curved portion. This will change the relative contrast of the highlights and shadows and it may affect the visibility of grain but it shows why some claim that they can use these alternate methods and expose at several different ISO settings on the same roll. Remember that the higher curved portion of the curve is more pronounced in small format film than in medium format film.

Conclusions

Film base+fog is much higher for small format films (with a few exceptions) than for medium and large format film. Small format film with a normal acetate base has a minimum density of between 65 and 85 units. CMS 20 and Rollie RPX 25 measure between 8 and 20 (very clear polyester base) and Bergger Panchro 400 is around 95 to 105 (maybe I got a bad batch). Medium and large format films I tested have a minimum density around 40-50.

The round shoulder of most small format film makes the Zone System difficult to apply. Overexposing small format films pushes the exposure up into this round shoulder and you may not get enough increase in shadow detail to justify the loss of highlight contrast.

Medium and especially large format films have a longer straight line in their characteristic curves than small format. The Zone System works better because they respond more predictably to moderate adjustments to development.

Most of the films I have tested (except for the two Rollei Retro films, RPX 25 and CMS 20) can be developed to produce the same contrast within their particular format.