Revised 7/04

Process Monitoring: Sensitometric Parameters

In addition to monitoring the key chemical and mechanical process parameters and processing KODAK Audit Strips, Process E-6, you should continue to use control strips for daily monitoring of sensitometric parameters.

Note: Monitor your densitometer to ensure that it is operating properly. Drifting and inaccurate readings occur most often in the higher densities. Proper densitometer performance is especially important for accurate monitoring of your process with KODAK Control Strips, Process E-6. Keep a record of all maintenance (e.g., filter changes) performed on your densitometer.

Calibrate your densitometer daily by following the manufacturer's instructions. To check densitometer consistency, read the KODAK Transmission Densitometer Check Plaque (CAT No. 170 1986) and plot the values on the *KODAK Process Record Form* (KODAK Publication No. Y-55). (The Transmission Densitometer Check Plaque consists of six highly stable glass-mounted color filters, a neutral patch, and a clear patch. It is a reference standard for checking the red, green, and blue response and photometric repeatability of electronic densitometers. We recommend that you use the check plaque to evaluate densitometer performance.)

CONTROL STRIPS

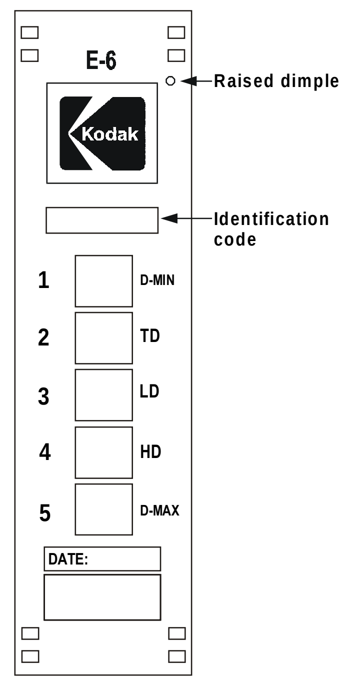
Kodak supplies control strips for monitoring processing of all KODAK PROFESSIONAL EKTACHROME Films in KODAK Chemicals, Process E-6. KODAK Control Strips, Process E-6, are precisely exposed neutral-density scales on KODAK PROFESSIONAL EKTACHROME Film E100G.

We recommend that you process at least 3 control strips per day or shift. Process a strip at the beginning of the shift (before you process customer film), another strip in the middle of the shift, and another strip at the end of the shift. We also recommend that you process a control strip with customer film at regular intervals. Handle and process control strips according to the instructions packaged with them. Use only certified Status A densitometry to read the control-strip densities.

KODAK Control Strips, Process E-6
(*Cat No.* 106 3239)

These 35 mm x 5¼-inch strips are supplied in a box of five foil packages that contain 10 strips each. Each box includes a reference strip. The ends of the strips are perforated for use with standard control-strip racks. Each strip has five neutral-density steps; a raised dimple is located on the emulsion side at the low-density end. Read and plot the following steps to monitor the sensitometric parameters of Process E-6:

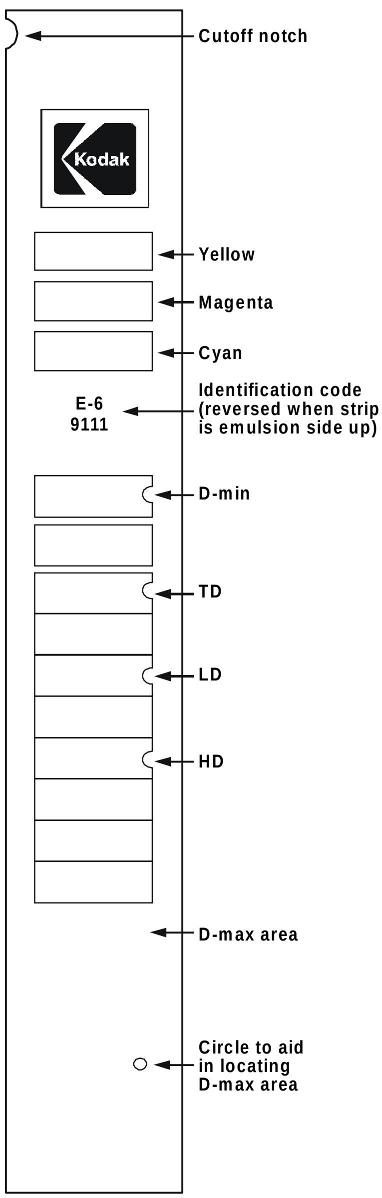
Step 1 D-min
Step 2 Toe density (TD)
Step 3 Low density (LD)
Step 4 High density (HD)
Step 5 D-max



5¼-Inch Strip

KODAK Control Strips, Process E-6
(Cat No. 173 3682)

These 35 mm control strips are supplied in 100-foot rolls of approximately 120 strips with cutoff notches at 9½-inch (24.1 cm) intervals. A reference strip is included with each roll. The roll is wound emulsion side in, with the D-min ends of the strips toward the outer end of the roll.



9½-Inch Strip from 100-Foot Roll

Each strip contains 11 equal-increment neutral-density steps and 3 color patches. Steps 1, 3, 5, and 7 are marked by a "U" in the step. Read and plot the following steps to monitor the sensitometric parameters of Process E-6:

Step 1	D-min
Step 3	Toe density (TD)
Step 5	Low density (LD)
Step 7	High density (HD)
D-max area	D-max

ESTABLISHING CONTROL-STRIP AIMS

You can use either of two methods to establish aims for a new batch of control strips.

The first method requires processing audit strips and control strips (from the new batch), using the KODAK Q-LAB Densitometer Correlation Strip to determine correlation factors for your densitometer, and applying the correlation factors to the audit-strip aims supplied by Kodak.

This procedure, described on page 5-3, *enables you to compare your process aims directly to the Process E-6 aims*. Following this procedure will help to prevent your process from drifting from the Process E-6 aim as you use different batches of control strips.

The second method of establishing aims—using the reference strip and correction factors—is the same procedure that you have routinely used. This method will provide you with aims that are similar to those determined by using Method 1. Following this procedure will also help to prevent your process from drifting from the Process E-6 aim as you use different batches of control strips, but you will not be able to compare your process aims directly to the Process E-6 aims. To use this method, follow the procedure given on page 5-6.

Important: There is one performance aim for Process E-6. Sensitometric aims for Process E-6 are reported in terms of audit-strip densities. Method 1 uses your audit-strip aims to establish control-strip aims ***directly.*** Method 2 uses the reference strip to establish your control-strip aims ***indirectly.***

Method 1 was specially developed for Q-LAB Service. It is more accurate than Method 2 because it uses additional tools (densitometer correlation strips, audit strips, etc) and data (audit-strip aims, etc). Method 2 is a simpler procedure, but because it uses an intermediate tool—the reference strip—the calculated aims *may* be less accurate than those determined with Method 1. If you carefully calculate aims by both methods to compare them, and you determine slightly different aims, *use the aims calculated with Method 1*.

Note: When you change to a new batch of control strips, aim shifts that are within the following tolerances can be attributed to small differences between batches of control strips; shifts that exceed these tolerances may indicate an error in calculating aims or a shift in your densitometer or process.

D-min	± 0.02
TD	± 0.02
LD	± 0.03
HD	± 0.04
D-max	± 0.06

Method 1

When you use Method 1, you can compare your aims for each batch of control strips *directly* to the Process E-6 aims by—

- processing audit strips and control strips from the new batch
- using the KODAK Q-LAB Densitometer Correlation Strip, Process E-6, to determine correlation factors for your densitometer
- applying the correlation factors to the audit-strip aims supplied by Kodak to determine customized audit-strip aims.
- comparing your audit-strip aims with the average densities of your processed audit strips to establish your process level
- comparing the densities of your processed audit strips with the densities of your processed control strips to establish control-strip aims.

Processing audit strips and determining customized audit-strip aims eliminates the need to use the reference strip and the correction factors supplied with the control strips.

Method 1 ties your aims directly to the Process E-6 aims.

Follow these steps (or use Worksheet 3 in Section 17) to determine aim values for D-min, TD, LD, HD, and D-max:

Step	***Why?***
1. In the same run, process 2 audit strips and 2 control strips from the ***new*** batch per day for 4 days. Process the strips when your process is in good chemical, mechanical, and sensitometric control, and at a level acceptable for processing customer film.	1. Needed to determine your process level and consistency.
2. Calibrate and zero your densitometer. *Use only certified Status A densitometry*.	2. Provides accurate and consistent readings; densitometry other than Status A may provide inaccurate readings.
3. Measure the red, green, and blue Status A densities of your Q-LAB Densitometer Correlation Strip in the center of the D-min, TD, LD, HD, and D-max steps ***twice.*** Average the readings for each step.	3. Provides average density readings of the correlation strip made with ***your*** densitometer.
4. Subtract the Status A densities given in the instructions for your correlation strip from your average densities (from step 3). Example of determining densitometer correlation factors: (see table below)	4. Provides ***densitometer correlation factors;*** these factors provide a ***direct link*** to the Process E-6 aims by telling you the difference between your densitometer and the densitometer used to establish the Process E-6 aims.
5. Compare your densitometer correlation factors (from step 4) with these tolerances. D-min ± 0.02, TD ± 0.03, LD ± 0.05, HD ± 0.12, D-max ± 0.15. If your factors are within tolerances, your densitometer is operating properly. If your factors are not within these tolerances, check or service your densitometer and repeat steps 3 and 4.	5. Ensures that there are no gross differences between your densitometer and the densitometer used to establish the Process E-6 aims.

LD Step	**Red**	**Green**	**Blue**
Your average densities for the densitometer correlation strip	1.02	1.03	1.04
Densities from the instruction sheet	– 1.03	– 1.03	–1.03
Densitometer correlation factors	– 0.01	0.00	+ 0.01

Step	Why?
6. Add your densitometer correlation factors (from step 4) to the audit-strip aims supplied by Kodak.	6. Customizes the audit-strip aims for your densitometer.

Example of determining your audit-strip aims.

LD Step	Red	Green	Blue
Densitometer correlation factors	-0.01	0.00	+0.01
Audit-strip aims from Kodak	+1.04	+1.04	+1.04
Your audit-strip aims	1.03	1.04	1.05

Step	Why?
7. Measure the red, green, and blue Status A densities of your 8 processed audit strips (from step 1) in the center of the D-min, TD, LD, HD, and D-max steps. Average the readings for each of the 5 steps.	7. Provides average density readings of your processed audit strips.
Compare the densities of each audit strip with the average of your 8 strips. The densities of each strip should be within 10 percent of the average.	Provides a tolerance for your processed audit strips.
If the density (or densities) of any single audit strip differs from the average by 10 percent or more, disregard the densities for that strip, and recalculate your average.	Ensures that data used to calculate aims are based on a stable process level.
OR	
If the density (or densities) of any pair of audit strips from the same process run differs from the average by 10 percent or more, discard the audit strips and the control strips from the same run. Process an additional pair of audit strips and control strips. Then use the readings from the new strips to recalculate your average.	

Step	***Why?***
8. Measure the red, green, and blue Status A densities of your 8 processed control strips (from step I) in the center of the D-min, TD, LD, HD, and D-max steps. Average the readings for each of the 5 steps.	8. Provides average density readings of your processed control strips.
Compare the densities of each control strip with the average of your 8 strips. The densities of each strip should be within 10 percent of the average.	Provides a tolerance for your processed control strips.
If the density (or densities) of any single control strip differs from the average by 10 percent or more, disregard the densities for that strip, and recalculate your average.	Ensures that data used to calculate aims are based on a stable process level.
OR	
If the density (or densities) of any pair of control strips from the same process run differs from the average by 10 percent or more, discard the control strips and the audit strips from the same run. Process an additional pair of control strips and audit strips. Then use the readings from the new strips to recalculate your average.	
9. Subtract your average audit-strip densities (from step 7) from your audit-strip aims (from step 6).	9. Provides ***process correction factors;*** these factors tell you the difference between your process level and the Process E-6 aim level.
Example of determining your process correction factors:	

LD Step	Red	Green	Blue
Your audit-strip aims	1.03	1.04	1.05
Average audit-strip densities	– 1.03	– 1.05	–1.04
Process correction factors	0.00	– 0.01	+ 0.01

Step	***Why?***
10. Add your process correction factors (from step 9) to your average control-strip densities (from step 8). Record these aims on Form Y-33. The aim for LD spread is always zero (0). For information on using Form Y-33, see page 5-7.	10. Provides customized control-strip aims for the new batch of control strips. Use these aims until you change to another batch of control strips.
Example of determining control-strip aims:	

LD Step	Red	Green	Blue
Process correction factors	0.00	– 0.01	+ 0.01
Average control-strip densities	+ 1.02	+ 1.02	+ 1.02
Control-strip aims	1.02	1.01	1.03

Method 2

Method 2 lets you easily determine control-strip aims by using the reference strip and the correction factors supplied with the control strips to adjust your aims to the Process E-6 aims. It does not, however, provide a thorough understanding of your process level because it uses an intermediate tool (the reference strip) to establish aims.

Follow these steps to determine aim values for D-min, TD, LD, HD, and D-max:

Step	Why?
1. Calibrate and zero your densitometer. *Use only certified Status A densitometry*.	1. Provides accurate and consistent readings; densitometry other than Status A may provide inaccurate readings.
2. Measure the red, green, and blue Status A densities of the reference strip supplied with the control strips in the center of the D-min, TD, LD, HD, and D-max steps. If you have more than one box of control strips *of the same code number,* read the reference strips from all available boxes and average the density readings.	2. Provides density readings of the reference strip(s) measured with your densitometer. The reference strips were processed in an in-control process.
3. Apply the correction factors supplied with the control strips to the density readings from step 2. These adjusted density values are the aim values for this batch of control strips. Record these aims on Form Y-33. The aim for LD spread is always zero (0). For information on using Form Y-33, see page 5-7.	3. Adjusts for the difference between the process used for the reference strips and the Process E-6 aim. Provides adjusted control-strip aims for the new batch of control strips.

KODAK PLOTTING FORM FOR PROCESS E-6

(KODAK Publication No. Y-33)

This form is similar to KODAK Publication No. Y-55, *KODAK Process Record Form,* but it includes areas for plotting two additional parameters: LD (low density) spread and TD (toe density).

LD Spread: Color balance is a critical part of image quality. LD spread provides a convenient means of monitoring color balance. This measurement is made from the LD step of the control strip because color-balance changes affect image quality most at that density level. The chart for plotting LD spread includes no space for recording aims or limits because you use it to monitor changes in the plots derived from the red, green, and blue densities of the LD step in relation to each other and to the aim line. Ideally, the R – G LD spread and the B – G LD spread will equal zero.

Toe Density: Because professional photographers are very sensitive to color shifts in the toe densities (TD) of their transparencies, it is important to maintain the control and consistency of this parameter (see page 5-10).

Use Form Y-33 to record the differences from aim of the D-min, TD, LD, HD, and D-max steps, as well as LD spread, of your control strips. Your data plots on Form Y-33 become a running record of your process.

Using Form Y-33

Use a separate form for each processor. Record the name (or identity code) of the processor in the blank labeled "Machine." Record the control-strip code number in the blank at the top of the form.

To calculate and plot your differences from aim, follow these steps:

1. Process a control strip and measure the red, green, and blue densities of D-min, TD, LD, HD, and D-max. Record the date and time on the form.
2. Subtract your control-strip aims from the control-strip readings to calculate the differences.

   Example of determining the differences between your control-strip readings and aims:

LD Step	Red	Green	Blue
Control-strip readings	1.07	1.03	1.04
Control-strip aims	– 1.05	– 1.06	–1.04
Differences	+ 0.02	– 0.03	0.00

3. Plot the differences on Form Y-33. Plot differences that are ***larger*** than the corresponding aim values (+ values) ***above*** the aim line, and those that are ***smaller*** than the aim values (– values) ***below*** the line. Use red, green, and blue pencils to plot the values for the corresponding density readings.

For LD Spread, plot the difference between the LD variations from aim by following these steps:

1. To determine the R – G LD spread by using a simple graphic method, just count the number of blocks between the LD red plot and the LD green plot on Form Y-33. If the LD red plot is ***above*** the LD green plot, plot the R – G LD spread ***above*** the aim line. If the LD red plot is ***below*** the LD green plot, plot the R – G LD spread below the aim line.

   For strip No. 1 in the illustration, the LD red plot is 2 blocks above the LD green plot. Therefore, the R – G plot is 2 blocks above the aim line. For strip No. 2, the LD red plot is 2 blocks below the LD green plot, so the R – G plot is 2 blocks below the aim line, etc.

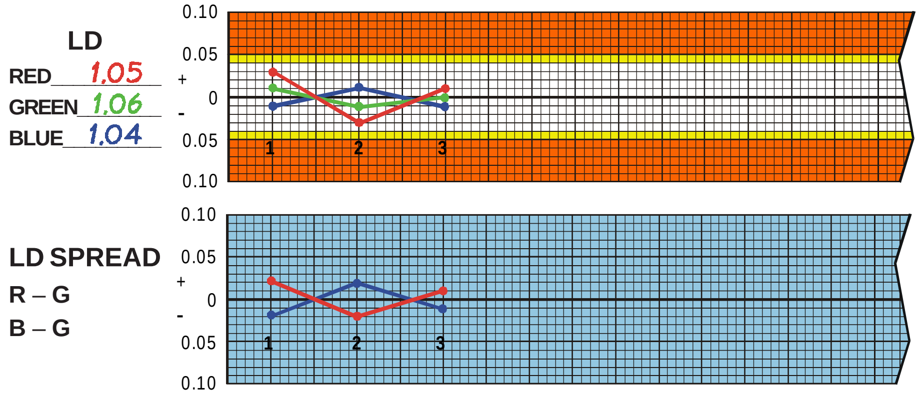
   OR

   To calculate the R – G LD spread, subtract the green difference from aim from the red difference from aim.

   Example (see strip No. 1 in the illustration above):

LD red difference from aim	0.03
LD green difference from aim	– (+ 0.01)
R – G LD spread	+ 0.02

   If the R – G LD spread is ***positive,*** plot the point ***above*** the aim (0) line; if the R – G LD spread is ***negative,*** plot the point ***below*** the line.



2. To use the graphic method to determine the B – G LD spread, count the number of blocks between the LD blue plot and the LD green plot. If the LD blue plot is ***above*** the LD green plot, plot the B – G LD spread ***above*** the aim line. If the LD blue plot is ***below*** the LD green plot, plot the B – G LD spread ***below*** the aim line.

   For strip No. 1 in the illustration above, the LD blue plot is 2 blocks below the LD green plot. Therefore, the B – G plot is 2 blocks below the aim line. For strip No. 2, the LD blue plot is 2 blocks above the LD green plot, so the B – G plot is 2 blocks above the aim line, etc.

   OR

   To calculate the B – G LD spread, subtract the green difference from aim from the blue difference from aim.

   Example (see strip No. 1 in the illustration above):

LD blue difference from aim	– 0.01
LD green difference from aim	– (+ 0.01)
B – G LD spread	– 0.02

   If the B – G LD spread is ***positive,*** plot the point ***above*** the aim (0) line; if the B – G LD spread is ***negative,*** plot the point ***below*** the line.

Using the Color Zones

Form Y-33 includes color zones similar to those on Forms Y-34, Y-35, and Y-36.

- ***White Zone***—When all the chemical and mechanical parameters are in good control, control-strip plots that are consistently in the white zone confirm that your process is in good control. Continue to monitor and plot the chemical, mechanical, and sensitometric parameters.
- ***Yellow Zone***—Plots in the yellow zone indicate a marginal control condition.

  A control strip can plot in the yellow zone even if your process is in good control. Carefully examine the plots of the chemical and mechanical parameters on Forms Y-34, Y-35, and Y-36 for any changes. Also examine your densitometer, the processor, and the control strip.
- ***Orange Zone***—Plots in the orange zone indicate an out-of-control condition. It is possible (although very unlikely) that a control strip can plot in the orange zone even if your process is in good control. Carefully examine the plots of the chemical and mechanical parameters, the densitometer, the processor, and the control strip to determine the cause of the change. You must locate the cause and take the appropriate corrective action. Then verify that the process has returned to a good state of control before processing customer film.

  Note: The cyan zone for LD spread does not indicate the control of your process. Examine the plot to determine the long-term color-balance consistency of your process.

The table below lists the variations from aim indicated by each of the color zones on Form Y-33.

Parameter	Color Zone		
	White	Yellow	Orange
D-min	0 to + 0.02 No lower limit	+ 0.02 to + 0.03	+ 0.03 to + 0.05
TD (Toe Density)	– 0.03 to + 0.03	– 0.03 to – 0.04 + 0.03 to + 0.04	– 0.04 to – 0.10 + 0.04 to + 0.10
LD (Low Density)	– 0.04 to + 0.04	– 0.04 to – 0.05 + 0.04 to + 0.05	– 0.05 to – 0.15* + 0.05 to + 0.15*
HD (High Density)	– 0.06 to + 0.06	– 0.06 to – 0.08 + 0.06 to + 0.08	– 0.08 to – 0.20* + 0.08 to + 0.20*
D-max	0 to – 0.10 No upper limit	– 0.10 to – 0.13	– 0.13 to – 0.20

* Form Y-33 does not show the whole orange zone for this step.

Evaluating Data Plots on Form Y-33

Your control-strip plots on Form Y-33 will confirm the control of your process, or provide a clear record of variations in the performance of your process. Non-random variations occur for two reasons:

1. Physical damage or improper handling of the control strips (e.g., handling that causes fogging) or variations in your densitometer (e.g., improper calibrations) can cause changes in the density readings of your control strips. Investigate and correct the cause(s) of these changes.
2. Changes in the chemical and/or mechanical parameters of the process can cause changes in the density readings of your control strips. Your plots on Forms Y-34, Y-35, and Y-36 will indicate these changes. Base your process-control decisions on the control plots for the chemical and mechanical parameters of your first developer, reversal bath, and color developer.

It is not always possible to measure all chemical and mechanical parameters that can affect image quality. (Agitation and color-developer pH are two parameters that cannot be monitored conveniently.*) Therefore, control strips are an important part of process control.

* If you routinely monitor and control all other chemical and mechanical parameters, the effects of changes in agitation or pH are more reliably detected by measuring control strip densities.

Monitoring Toe Density

The TD (toe density) step, at a density of approximately 0.35, is unique to the KODAK Q-LAB Process Monitoring. Service. We recommend that you carefully monitor this step for the following reasons:

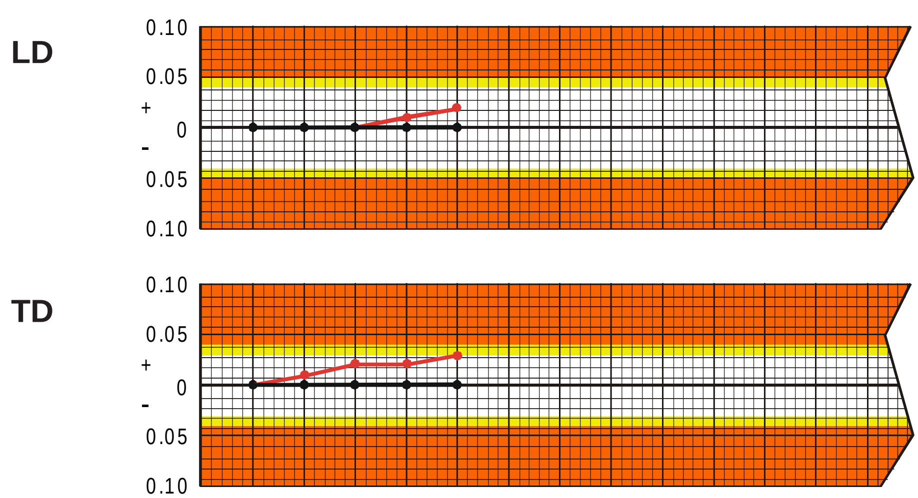
1. The toe density corresponds to the highlights of many photographic images. If your process does not maintain neutral toe densities, the highlights of customer images will show an objectionable color balance.
2. Monitoring TD lets you detect some process problems earlier than you could if you monitored only the D-min and LD steps.
3. Monitoring TD also enables you to detect multiple process problems—i.e., when two or more parameters are out of control at the same time.

Important: Before you monitor the TD step, make sure that your control-strip aims are correct. (If you have not established control-strip aims, follow the procedure for Method 1 on page 5-3. The procedure enables you to compare your process aims directly to the Process E-6 aims.)

The response of the TD step to process changes is generally the same as the response of the LD step. You will detect some process problems first by monitoring the LD step (problems that have a greater effect on upper-scale densities) and others by monitoring the TD step (problems that have a greater effect on lower-scale densities).

These examples show the effects of poor first-developer agitation on the LD and TD steps. This condition causes lower densities to increase (in the TD and D-min regions).

Therefore, you will usually detect this problem sooner at TD than at LD.

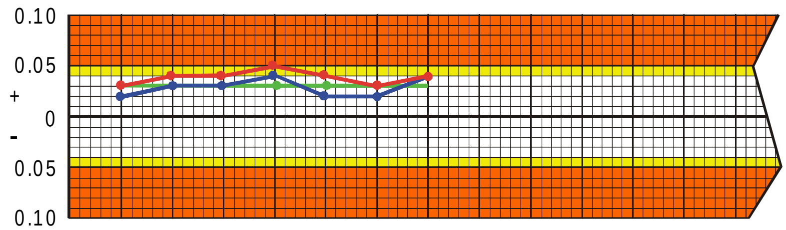


The TD and LD steps respond similarly to many process problems, so you can use the same diagnostics for TD that you use for LD. See the control-chart examples in KODAK Publication No. Z-119, or make adjustments based on your experience in monitoring the LD step. (The LD step is called the "Speed" step in the examples in Publication No. Z-119.)

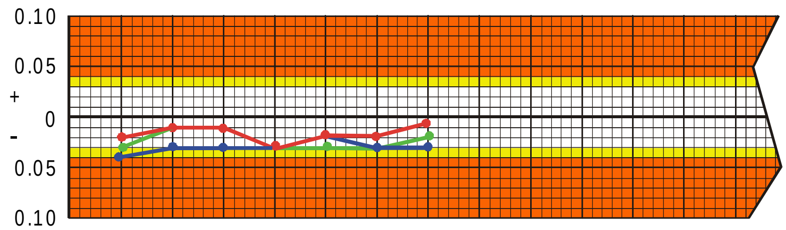
If you detect a change at the TD step without a change at the LD step, follow the diagnostics for the process problem(s) that causes the same effect at LD. If the LD and TD steps change in different directions (e.g., LD goes yellow and TD goes blue), this usually indicates that more than one chemical or mechanical parameter is out of control. In this case, measure ***all*** chemical and mechanical parameters to determine which parameters are out of control.

In this example, LD is above aim and TD is below aim. This indicates that more than one chemical or mechanical parameter is out of control. In this case, the first developer was overconcentrated and underreplenished. If the lab was to adjust the first-developer time or temperature to control LD, TD would go even lower, and then three parameters would be out of control.

LD



TD



SUMMARY

Remember that to achieve process control, you must monitor and control all chemical and mechanical parameters. Base most of your process-control decisions on the chemical and mechanical parameters, and process control strips daily to monitor your sensitometric parameters and confirm your chemical and mechanical measurements. The chart below summarizes the steps of using chemical, mechanical, and sensitometric data to monitor and control your process.